SUSTAINABLE LANDSCAPE PLANTING

IN THE

NEGEV DESERT

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Abstract

The research concerns the potential for using the native plants of the Negev Desert in southern Israel in the Negev, which will help to promote more sustainable landscape development in the region. The Negev desert has a substantial resource of native plant species. To date native species are not used and most have not been considered for use. Instead exotic species are introduced and these have an impact on landscape and ecological values. Exotic plant species also require more water, in a region where water is particularly scarce and contentious.

The study combines the data collection in the field of 163 plant species located in the Negev desert and the literature review of these species. The plants' key physical, visual and aesthetic characteristics as well as their natural growing conditions are analysed. The analysis leads to an evaluation of the Negev plants in terms of suitability for particular uses in the Negev landscape. This process raises a number of important issues and questions, which are included within the literature review chapters. Major areas of discussion include the physical and historical context of the Negev, the reasons why the native Negev plants are not generally used, and an evaluation of the general landscape paradigm within which landscape architects and others define types of planting. An alternative landscape paradigm is proposed.

The conclusion reached is that the main reason for the non-use of the native plants is that they are still considered a part of the hostile desert environment. They have not as yet been 'culturalised'. Whereas, the existing landscape paradigm either treats landscape areas as nature or garden, the alternative landscape paradigm, which is considered more appropriate to desert environments separates out garden areas, which are intensive, high water use areas from the 'middle landscape', which are extensive, low water use areas. The middle landscape consists of habitat, comprising native plants. This system proves more sustainable in terms of landscape and ecological effects and water use.

The advantages/disadvantages of using the native plant species is considered for each plant using a natural/quasi-experimental method, where each of the 163 species located by the author is analysed in terms of its physical and aesthetic characteristics and potential use. Furthermore, the individual species are matched with an exotic species and evaluated according to their potential landscape and ecological effects, water use and their potentials for environmental use in natural areas, the middle landscape and garden locations. The analysis and evaluation of the native Negev species confirms that 95%-96% of the native Negev plants have the potential for environmental use in natural areas and the middle landscape and 69% have the potential for garden use.

A scientific study of the shade characteristics of 6 native Negev trees confirms that these trees provide an equal, if not better shade, compared to two control species and thus their potential for use in creating shade and altering micro-climate has been proven.

The research also proposes a series of micro-landscape solutions, taken from observations and the literature, which will help to promote plant establishment and growth in the Negev as well as other desert environments. These proposals are seen as part of the agenda for establishing more sustainable landscape development in the Negev.

The Author

Benz Kotzen is a chartered landscape architect, a member of the Landscape Institute. He has worked in private practice for over twenty years. An interest in sustainability issues in desert areas commenced when living in Israel for a period of 6 months during the mid 1990's. This interest ties in with the consultancy work in sustainable development, landscape design, landscape planning and landscape assessment which forms the most part of his work.

Benz has worked on landscape projects throughout the Middle East and has co-authored a publication on Environmental Noise Barriers and teaches landscape design and landscape assessment and design at the University of Greenwich in London.

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'Full many a flower is born to blush unseen,
And waste its sweetness on the desert air'

'Elegy Written in a Country Churchyard' by Thomas Gray (1716-71).

'It is in the Negev that the creativity and pioneer vigour of Israel shall be tested'[1]

David Ben Gurion [(1883-1973) First Prime Minister of Israel

[1] http://www.jewishvirtuallibrary.org/jsource/vie/desert.html

Table of Contents

Page

(Note: Appendix A is repeated and all other appendices are included on the CD Rom at the back of the dissertation.)

List of Appendices

(The appendices are included on a CD Rom located at the back of the dissertation. Appendix A is also printed as the last printed section of the dissertation.)

Tables

Page

Chapter 8

1. CHAPTER 1 INTRODUCTION

1.1 Evolution of the Research Topic

1.1.1 The research stems from the author's professional and academic involvement over many years in desert environments and in particular the Negev Desert in southern Israel. (Appendix A, Figures 1 and 2 [2].) The research idea originated during the authors' stay in the Negev for approximately nine months in the mid 1990's.

1.1.2 As a practicing landscape architect in the Negev, curiosity was aroused about the native plants of the Negev and it became apparent that they were not being used within local landscape projects. It thus became evident that there were numerous questions to be asked and many answers to be found regarding the plants and their suitability for use in landscape and environmental design. The topic thus evolved out of apparent discrepancies in the appreciation Israelis have for their indigenous flora and the natural landscape in general, and their apparent disregard of their own plant species for landscape purposes in the Negev Desert and the lack of understanding of the potential effects in the introduction and use of foreign plant species, which is widespread across the region.

1.2 The Hypothesis

1.2.1 The formulation of a hypothesis is not as straightforward an endeavour as it appears. In the case of this research the hypothesis followed an evolutionary process. Thus the set of assumptions, which have been provisionally accepted as the basis of reasoning, experiment and investigation for this dissertation, evolved over a period of years whilst the field and literature

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[2] All the appendices are located on a CD Rom, located on the inner side of the back cover of the dissertation. Appendix A is also printed at the back.

research was carrying on apace.[3] In the beginning, the focus of the research in the early years centred on the indigenous plants themselves, whereas later research focused on illustrating the strengths and weaknesses of the proposed hypothesis.

1.2.2 The hypothesis states:

The indigenous xerophytic and halophytic plants of the Negev are suitable for use in landscape design in the Negev Desert in Israel.

1.2.3 The above statement and indeed the crux of the research centres on the meaning relating to the word *suitable* and the principles of *suitability* with regard to landscape architecture in general and specifically to plant use.

1.2.4 The professional landscape architect is faced with choices relating to a host of design issues, which fall within his/her remit. These choices relate to the location and massing of elements, scale, choices of materials as well as the choice in the types and species of plants. It is suggested that where there is choice, there is also the concomitant issue of suitability. Ian McHarg in 'Design with Nature' creates a sieve mapping system, which relies on the issue of suitability when confronted with the choices of aligning roads or locating development. McHarg (1971, page 104), poses the question as to which areas of land are '*intrinsically suitable for conservation*' or for '*active or passive recreation*' and so forth. It is the environment, which is McHarg's focus, and the application of his method aims to reduce environmental damage and protect those parts of the landscape, which need to be conserved. Although the term 'sustainable development' is not used by McHarg, this is what he is trying to achieve.

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[3] The definition of a hypothesis as 'a set of assumptions provisionally accepted as a basis for reasoning, experiment or investigation has been taken from Funk & Wagnall's *New Practical Standard Dictionary of the English Language*, 1956.

1.2.5 The issue of sustainable development [4] is also the focus of this research and it is posited that the question of suitability with regard to plant use in the Negev is also based on choice. At the heart of the matter is the choice between using native plants versus using exotic, foreign species. Thus, in the first instance, the issue of suitability centres on whether the native species are more, or less appropriate relative to sustainability issues, i.e. ecological impacts, landscape effects and water demands, compared to the foreign species. Furthermore the focus of the research centres on whether the native species may be suitable or 'fit for purpose' with regard to specific functions within the landscape, such as hedging, windbreaks, planting in beds and shade provision. The concept of being 'fit for purpose' is used in the design and construction fields to ensure that products and methods and outcomes negate 'over-design' and 'under-design'. It is suggested that the criteria for design should consider the appropriateness to context, particularly in hot arid, 'sensitive', water poor environments. This means that functionality cannot be the prerequisite of suitability and 'fit for purpose' design should take account the environmental potentials and constraints.

1.2.6 Finally the issue of suitability focuses on whether the native plants are suitable with regard to their aesthetic characteristics, which takes account of the plants' seasonal, physical and visual characteristics with regard to shape, colour, texture, smell, etc.

1.2.7 Marcus Vitruvius Polio [5] encapsulated the principles of suitability in architecture with the 3 main principles: *commodity, firmness and delight.* These principles relate specifically to architecture in the need to be a)

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[4] It is acknowledged that the issue of sustainable development is an expansive subject. The research focuses on a small part of the area with respect to development in the Negev, namely the use of plants.

[5] Marcus Vitruvius Polio (90-20 BCE) was a Roman architect and engineer who lived during the time of Julius Caesar.

functional, b) sturdy in the sense that the construction will not fall down, as well as c) having an aesthetic sensibility. Ian Thompson in his book *'Ecology community and delight: sources of values in landscape architecture'*, alters the three primary sources of value in the landscape as *'ecology, community and delight'*. (Turner, *'Garden Visit.com'*, www.)

1.2.8 The Vitruvian categories of value are applicable to the suitability of plants for use in the Negev. In terms of ecology it is suggested that native plant species add ecological value, whereas the introduction of foreign species diminishes value. In Part 2 of the publication *'Ecology, Community and Delight'*, Thompson, (2000, pages 91 and 93), uses the word *'community'* to cover *'the social mission of landscape architecture'*. Tom Turner, (*'Garden Visit.com'*, www.), notes that community in Thompson's terms is a modern parallel to the Vitruvian quality of 'commodity', i.e. having function.

1.2.9 It is evident that planting needs to be functional in desert areas by providing shade, windbreaks against desert dust, enhancement of wildlife etc. The third issue that is of 'delight', has always been and will continue to be an important component of landscape and garden design. However, it is suggested that in arid environments the concept of treating all landscapes as gardens is not sustainable and thus there needs to be a change in the standard landscape paradigm. It is thus suggested that a landscape paradigm, which does not treat all areas in the same way would benefit sustainable development in the Negev, other arid lands and potentially other more temperate areas around the world. (The existing and transformed landscape paradigms are discussed in Chapter 4).

Testing the Hypothesis

1.2.10 This statement is written as a positive assertion, so that it can be tested. The hypothesis will be tested by analysing the plants relative to context through the field study data and literature review and by analysing the:

- Native plant species growing in the Negev Desert; and comparing them to

- Exotic species that are currently used and/or are available for use in the Negev.

1.2.11 The testing highlights the differences between the native versus the exotic species with regard not only to positive and negative ecological and landscape effects but also on water use and maintenance, which have economic implications. [6] Financial benefits or disbenifits are an important consideration for all developments and a key driver in creating more sustainable development.

1.2.12 A specific comparison has been carried out especially with the native trees of the Negev and two commonly used foreign species to assess their potentials to produce shade and generally to improve microclimatic conditions and human comfort as well as for improved conditions for fauna and other flora. (Refer to Chapter 7.)

1.2.13 Before making comparative assessments, factors relating to plant growth and function were reviewed to obtain an understanding of the plants themselves; how, where and why they grow in various areas, their characteristics, as well as local people's understanding and attitudes to them. The research thus attempts to provide an appreciation of the existing paradigm of plant usage and proposes an alternative paradigm. An alternative paradigm may better suite planting in the hostile and sensitive desert conditions, where water is in short supply and ecological and landscape values need to be conserved.

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[6] The economic principle forms one of the key criteria for measuring business, organizational and societal success as expressed in the 'triple bottom line' (3BL). The principle of the 3BL centres on including ecological and societal values as well as economic values when measuring organizational or business success. (Wikipedia, *'Triple Bottom Line'*, www.)

Analysis of the Hypothesis – The Basics of the Research Question

1.2.14 For many people deserts seem devoid of life. This is not the case in all deserts and in particular the Negev where life is abundant, although it can remain unnoticed by the passer-by. The range of flora and fauna to be found in the Negev is in part due to the fact that although the Negev Desert is relatively small it is not a homogenous desert region. Due to a number of factors including its geological location, edaphic, topographical and climatic and microclimatic conditions it is largely heterogeneous and thus it hosts numerous native plant species. The flora of Israel comprises approximately 2400 species (Zohary, 1982, p.29) and approximately 1300 of these are found in the Negev Desert. [7] This abundance in plant life relates directly to the overlap of four different phytogeographical regions, which have their local geographic limits more or less in the Negev region. (Refer to Figure 19, Appendix A)

1.2.15 The native plants of all deserts, including the Negev have evolved survival strategies to survive the harsh climate. Thus most of them are xerophytic, i.e. they are able to survive dry conditions and many of them are halophytic as well, i.e. being able to tolerate various levels of salinity, which is often a predominant condition of desert soils. [8]

1.2.16 The people who live in the Negev generally have some knowledge of the native plants. The Israeli Bedouin who are traditionally nomadic, but now

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7 This may not be considered a great amount of plants when compared to the 250 000 vascular plants found world wide or the floral Kingdom of for instance the Cape Peninsula in South Africa where 2285 species are found. However, it may be surprising for many to note that the number is quite similar to the 1492 species of flowering plants, (angiosperms) found in Britain.

8 Saline soils are common in areas with low precipitation as accumulated salts cannot be washed away. (Swartzell, D., '*Desert Soils*', www.).

are largely settled in the northern Negev were largely dependent on the native plants for grazing, medicine, food and other ethno-botanical purposes. The Israelis, (namely Jewish settlers from the Diaspora), who commenced settling the Negev Desert in the early to mid 1940's have also distilled a large amount of knowledge of the native plants of the region. But on the whole this knowledge is academic in nature and apart from a few exceptions, the plants have not been identified in any systematic way for significant landscape or other purpose. [9]

1.3 The Importance of Arid Plants - The Relevance of the Research Topic

1.3.1 The importance of arid plants was noted in the recommendations of the Kew International Conference on Economic Plants for Arid Lands, which was held at the Royal Botanical Gardens, Kew during July 1985. (Wickens, 1985, page IX) The recommendations were as follows:

1. The value of arid lands plants should be identified and publicised.
2. Although local knowledge of plants is frequently profound it is often ignored. All such information should be gathered nationally and internationally where appropriate.

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[9] A few native plants have been identified within an overall study of potential arid plant species, most of them, which are foreign to the region by the Institutes for Applied Research, Ben Gurion University of the Negev in a publication titled '*Plants for Desert Landscaping*', by Yossi Ben Dov, Meir Forti and Dov Pasternak. Other references are made to some plants namely geophytes by Prof. Gutterman in an article entitled '*Geophytes of the Negev as a Genetic Source for Ornamental Garden Plants, Cut Flowers and Pot Plants*', and elsewhere such as in a '*Handbook of Wildflowers of Israel - Desert Flora*' by Shmida and Darom, where plants are noted as having herbal or insecticidal properties.

3. This information is part of the cultural heritage and is of direct value to arid land utilisation and management.

4. Many arid land problems could be solved by using arid land plants. (Wickens, 1985, page IX)

1.3.2 For this research project, the last recommendation, (as noted in item 4 above), is the most important because although it may be recognised that arid plants can solve some problems in landscape architectural terms, in the Negev the native plants are largely ignored for landscape or other environmental purposes. As described briefly above, as yet no significant or comprehensive study on the potential landscape use of these indigenous plants has been made and thus 'solving arid land problems' cannot yet be achieved. There is little doubt that the broad spectrum of problems envisaged by the conference, relate more to the provision or lack of food, shelter, and the continued desertification of our planet. However, the degradation of landscape character, landscape quality and ecological integrity are also serious issues. This is the case, especially when one considers the use of large quantities of water that can result with the dominant use of foreign species and common attitudes to landscape design where there is little understanding of an appropriate model or paradigm for planting in arid zones.

1.3.3 The other recommendations made by the conference are also important as they further strengthen the case for research on the research subject. In the first instance, it is acknowledged, as noted above, that local knowledge is indeed profound but in terms of the potential use of the plants this knowledge is largely ignored. The reasons for generally disregarding the potential use of the plants will be discussed later in Chapter 4. The conference states that this information should be gathered nationally and internationally where appropriate and that this information should be published. The information gathered as part of this research will be made available to the SEPASAL (Survey of Economic Plants for Arid and Semi-

Arid Lands) database, [10] and also to Ben Gurion University of the Negev as the most notable research organisation in the region. It is recognised that the research information 'is part of the cultural heritage' as it is an extension of existing research and helps to expand some insight into cultural associations of plants and the people living in the area. Furthermore the research is of 'direct value to arid land utilisation and management' of the region and in other arid region as it provides relevant information for the design and management of the landscape in the Negev and in other similar arid land areas. This takes the form of establishing an alternative landscape/planting paradigm and providing comprehensive data with regard to the plants assessed, their physical characteristics, growing conditions, and requirements and potential uses.

The Relevant Issues

1.3.4 It is taken as a fact that arid areas are arid because there is generally a lack of precipitation and available water. Water, according to the United Nations, '*is becoming the world's most pressing environmental and development issue*'. (Vidal, 2003, pages.16-19) The waste and misuse of water is thus an important factor in arid areas and it has been stated on numerous occasions that in the future, wars will be fought over water. [11] In Israel as in all

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[10] The database is run by the Economic Unit at the Royal Botanical Gardens, Kew. The information has been compiled according to Economic Botany Data Collection Standard. (Cook, F.E.M. (1995). '*Economic Botany Data Collection Standard*'. Prepared for the International Working Group on Taxonomic Databases for Plant Sciences (TDWG). Kew: Royal Botanic Gardens, Kew, 1995).

[11] For example Anwar Sadat stated in 1979 that 'the only matter that could take Egypt to war again is water' and in 1988 Boutros Boutros-Ghali stated that 'the next war in our region will be over the waters of the Nile, not politics'. This is similarly the case in Israel where there is a continuing historical conflict over the water of the Sea of Galilee, the

countries water is seen as a resource which is first of all to be utilised for the health and welfare of the population, then in commerce and industry and agriculture, and lastly for the watering the landscape and garden areas. When water restrictions are imposed in most countries, it is usually the restriction with regard to the watering of gardens, which is first applied. Hosepipe and sprinkler bans are common occurrences in South Africa, Australia and the U.S.A and also now in the U.K. [12] The presumption of this research is that the use of native plants will help to save water in the Negev.

1.3.5 Another important issue is the changes in landscape character and landscape quality of the Negev by the introduction of foreign plant species e.g. Eucalyptus species. Although they are drought tolerant, they do not 'fit' in the Negev Desert environment. Other plant species are seen to be similarly ill placed in the landscape, or where they have been located they have spread uncontrollably to impact not only on the landscape character and quality but on the local ecology as well. In this regard, Pairon et al, (UCL, *'Xenophyte population biology'*, www.), note that

> *'the spread of invasive species into native ecosystems and habitats is believed to be the second largest cause of current lost biodiversity worldwide, after habitat destruction.'*

1.3.6 These issues will be discussed in Chapter 4.

Jordan River and water extraction from the ground amongst Israel, Syria, Jordan and the Palestinians. (Gleick, *'Water Conflict Chronology'*, www.)

[12] An example of water restrictions in the U.K is the ban on hosepipe and sprinkler usage by Southern Water in North Sussex commencing the 10th of June 2005. The hosepipe ban was greatly extended into other areas in the U.K. including London during 2006.

1.4 The Objectives and Scope of the Research

1.4.1 The main research objective is to test the hypothesis, which states that the plants of the Negev are suitable for use in landscape and environmental projects. The validation of the hypothesis could have positive impacts for the Negev environments with a greater use of the native plants of the Negev with benefits in:

- water reduction;
- positive rather than negative impact on landscape character and landscape quality; and
- positive rather than negative effects on ecology.

1.4.2 It is suggested that a positive result may focus attention on the potential use of these plants and that further studies and indeed plant trials may be undertaken by the author or others to further identify the positive and/or negative attributes of the individual species or the use of plant species in communities. In some cases, plants will be specified for certain purposes, as their growth and growing requirements are well understood and they appear to offer an alternative to foreign species of similar habit.

1.4.3 In order to test the hypothesis, the research has aimed to evaluate as many native Negev plants as possible and then to ascertain the veracity or otherwise of whether these plants would be suitable for use in landscape projects. Over a nine-year period with almost yearly and sometimes twice yearly field survey visits to the Negev Desert, over one hundred and sixty native and naturalised species in the region have been researched. This appears to be a small amount relative to the 1300 species that may be found in the Negev. However, of these 1300 species, nearly 700 [over 50%] of them are annuals, which are not widely used in landscape projects, as they are largely short lived and require increased management. Furthermore, the species that have been assessed are the main species that have been available during the field trips. The other species that have not been assessed, are rare or very rare or have just not been evident on the ground. With regard to those species that have been found and that form the basis for assessment, additional reviews of these plants in the international and Israeli literature as well as a review of their potential efficacy relative to other exotic species, which are generally used instead of the native species, has been carried out.

1.4.4 The research also includes an assessment of the ability of native xerophytic trees of the Negev to improve microclimate through the creation of shade. This comparative assessment was carried out to illustrate the ability of the trees of the Negev to improve microclimate for the benefit of people and other fauna and flora and was published during 2003. (Kotzen, Journal of Arid Environments, 2003, pages 231-274)

1.4.5 It is apparent that much of the scientific knowledge about the desert and plant survival mechanisms has not infiltrated into the landscape architect's palette of technical and design techniques. Thus, as an offshoot of the research, the investigation identifies micro landscape conditions that appear to assist in plant survival in the Negev and that suggest some means towards promoting plant establishment in the Negev and other desert regions around the world.

1.4.6 Further benefits of the research is the recording of plant species in certain areas in the Negev and the pH and soil salinity, (in the form of electrical conductivity), conditions in which they were growing. This research may benefit other researchers in the fields of plants and their pH and salinity tolerances and others noting specific soil pH and salinity records of various areas on the ground. (Refer to Appendix C)

1.4.7 The research also advances the knowledge of individual species with regard to the colour of plant stems, leaves and flowers, which have been recorded using the Royal Horticultural Society's Colour Chart. [13] The recording of

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[13] The Royal Horticultural Society's chart, which has 808 colour swatches arranged according to hue, brightness and saturation is the standard reference for specifying flower colour. It was first published in 1966 and it has been used 'extensively by the RHS, growers and specialist organisation such as the International Union for the Protection

this information has not, according to the literature been carried out on these plants, nor systematically on any other desert plants prior to this research.

1.5 Thesis Organisation

1.5.1 The thesis is arranged into two main parts. Part A includes the main body of the text in chapters and the bibliography, and the subsidiary part, Part B, which includes the Appendices, which are placed on a CD Rom located at the back of the document.

1.5.2 **Part A** includes nine chapters as follows: Chapter 1, *Introduction*, defines the hypothesis, background and framework for the thesis, and Chapter 2, the *'Research Methodology'* where the research approach is explained.

1.5.3 Chapters 3 to 5 comprise the main parts of the literature review. In the literature review, the core, as well as the background issues based in the literature that are relevant to the main analytical body of the research which follows in Chapters 6 and 7 are discussed. Chapter 3 *'The Negev: Physical and Human Geography – A Literature Review'* mainly discusses the physical aspects of the Negev Desert that are relevant to the research. Chapter 4, *'Landscape Paradigms for the Negev – A Literature Review'*, investigates planting in the Negev through a literature review of current strategies in the Negev and elsewhere as well as aesthetics and provides the case and defines a new landscape paradigm for planting in the Negev and other desert landscapes. Chapter 5, *'Plants and Planting in the Negev: Defining Plant Use and Aesthetic Criteria – A Literature Review'*, discusses the data collection criteria, a breakdown of potential uses of desert plants and the criteria for determining suitability for use. Chapter 6, *'Plant Use Suitability, Analysis and Comparison of Matched Pairs'* provides the main focus of the research, where plant use suitability is determined and comparisons are made with an exotic species according to core issues. Chapter 7, *'An Investigation of Shade Under Six Different Tree Species of the Negev Desert Towards*

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of New Varieties of Plants (UPOV) to identify and describe plant colour precisely.' (RHS leaflet accompanying RHS Colour Chart) *their Potential Use for Enhancing Micro-climatic Conditions in Landscape Architectural Development'* investigates the specific issues of trees and microclimate in the Negev and how effective the native trees are in creating useful shade. The penultimate chapter, Chapter 8, *'Micro-landscape Strategies for Plant Survival and Establishment in the Negev'*, looks specifically at micro-landscape conditions and where changes could be made that would enhance plant survival. Finally Chapter 9, *'Conclusions, Summary of Contributions and Future Research'*, discusses the conclusions, contributions and recommendations for further reserearch followed by a glossary and then the bibliography, which divides the key publications and other data in three parts, namely books, articles and web based data and information.

1.5.4 **Part B** comprises the Appendices A through to J. The appendices include relevant figures, diagrams, photographs, as well as text relating to plant descriptions, the bulk of the analysis and much of the matched pair sequences. This information is significant to the main body of the research but it has been located in the appendices to facilitate the better flow of the main text. The appendices have been copied onto CD Rom to save paper as part of the world –wide sustainability drive. Without the photographs of native and exotic species in Appendices H and I, the appendices run close to 900 pages.) Photographs are also better observed on a computer screen as they can be viewed larger and at a higher resolution.

1.5.5 The organisation of the dissertation is summarised in Table 1.1 below.

Table 1. 1 Organisation of the Dissertation

PART	CHAPTER	TASKS
(A) Main Part - Defining hypothesis and framework for thesis, literature review of key research components, analysis of native plants and matching pair comparisons, conclusions,	1. Introduction	To present the hypothesis, definitions and scope of the study and why the research is important.
	2. Research Methodology	Explains the evolution and structure of the research

PART	CHAPTER	TASKS
recommendations and bibliography.		and the methodology.
	3. The Negev: Physical and Human Geography – A Literature Review	Background information about the Negev (history, geology, climate, social etc.) Information about the Negev plants, phytogeographical regions, survival strategies as well as exotic plants and their use.
	4. Landscape Paradigms for the Negev – A Literature Review	Reviews native plant use from Jens Jensen to the present and especially in desert areas around the world. Native plant use in the Negev is also discussed.
	5. Plants and Planting in the Negev: Defining Plant Use and Aesthetic Criteria – A Literature Review	Discusses plant categorisation by landscape architects and others and different needs in desert areas and the compilation of plant data forms.
	6. Plant Use Suitability, Analysis and Comparison of Matched Pairs	Analysis of plant use from field studies and the literature review and comparison of matched pairs of native versus exotic species.
	7. An Investigation of Shade Under Six Different Tree Species of the Negev Desert Towards their Potential Use for Enhancing Micro-climatic Conditions in Landscape Architectural Development'	Study of microclimate, (shade), comparing effects for native and exotic tree species.
	8. Micro-landscape Strategies	Empirical conditions noted

PART	CHAPTER	TASKS
	for Plant Survival and Establishment in the Negev	on field trips with implications for landscape design. Includes literature review of these aspects.
	9. Conclusions, Summary of Contributions and Future Research	The extent of proof of the hypothesis and recommendations for further research.
	Glossary	Glossary of specific unusual words used in the research.
	Bibliography	Key publications used for the literature review.
(B) Subsidiary Part – Appendices providing key data and background information. . (In order to limit paper use the appendices have been placed on a CD-Rom located at the back of the thesis.)	Appendix A - Figures	Illustrations – Photographs and diagrams referred to in all Chapters.
	Appendix B – Plant Survey Proformas	Proformas used to collect physical data and aesthetic data in the field and from the literature review.
	Appendix C – pH and Salinity Data Recorded as Part of the Field Surveys	Explanation on collecting methods and collation of Ph and salinity measurements for each species relative to soils and location.
	Appendix D - Full List of Native Plants Assessed by the Author and their Plant Numbers and Photographic Reference Numbers as Referenced in the Text	List of Negev plants assessed with their plant numbers given by the author.
	Appendix E - Detailed Information on Physiognomic Categories, Floristic Subdivisions and Plant	Information on Negev plants and breakdown of areas that is too detailed to include in the main document.

PART	CHAPTER	TASKS
	Associations	
	Appendix F – Data and Analysis of the Native Plant Species F1 – Introduction and Annuals F2 – Climbers and Trailing Plants F3 – Geophytes F4 – Grasses F5 – Parasites F6 – Perennials F7 – Dwarf Shrubs F8 – Shrubs F9 - Succulents F10 – Trees F11 – Naturalised and Adventive Species and Foreign Escapees	Plant descriptions, analysis of potential uses and aesthetics in text and tables.
	Appendix G – Continuation of the Analysis of Native Species from Chapter 6 G1 - Annuals G2 –Geophytes G3 – Perennials G4 – Dwarf Shrubs G5 – Shrubs	Analysis of further species continued from Chapter 6.
	Appendix H – Native Plant Photographs	Photographic record of native plants taken in the field catalogued according to life form in appendices H1

PART	CHAPTER	TASKS
		to H11.
	Appendix I – Exotic Matching Pairs Photographs	Photographs of the exotic species used as a match for the native species.
	Appendix J – Chapter 7 Figures and Tables	Photographs and diagrams that form an integral part of Chapter 7.

2. CHAPTER 2 RESEARCH METHODOLOGY

2.1 Introduction

2.1.1 Following chapter one, which outlines the major issues and structure of the thesis the second chapter focuses on the research methods used to test the hypothesis including the literature review, field studies and the analysis of data.

2.2 Background to the Research

2.2.1 The research project began with the realisation that the author's knowledge of the plants of the Negev was rudimentary. This was rectified by the collection of plant data through the following methods:

1. Field research of the native plants at in-situ locations across the Negev;
2. A literature review of the native plants in Israeli, (Hebrew) and other international, (English) texts; and
3. Discussions with local people and academics who were working with desert plants.

2.3 Collection of Plant Data

Field Studies

2.3.1 With the above three methods of data collection in mind, the investigation of the native plants of the Negev commenced in the mid 1990's with the field data collection and literature review in the summer of 1997. The field data collection continued during various seasons of the year over a 9-year period. Annual and sometimes bi-annual field trips to the Negev were undertaken. The duration of the field trips was ten days to two weeks [14]. The phasing of the field trips at different times of the year related to a number of factors. In the first instance certain plants including most of the annuals and many of the geophytes and perennials are only evident towards the end of winter and in the spring when rain has fallen. Secondly, the field trips were spread over

[14] The final field trip was undertaken at the end of March 2007.

a period of time in order to record the changing seasonal and thus physical and visual characteristics of the individual plant species. These changes in physical and visual character are apparent in some of the perennials and most of the shrub and tree species. Furthermore it was important to analyse the plant species when they were in flower, and when they were fruiting as well as when they were dormant. It should be noted that that due to the unreliable nature of rainfall and vagaries in temperature, the sighting of plant species is also unreliable and thus additional field visits had to be made at similar times of the year for a number of years in order to expand the species sightings and thus the database.

2.3.2 Multiple field trips were thus carried out over several years during springtime, during the summer and in the autumn. The spring field trips coincided with the growth and flowering of most of the plants after the winter and spring rains. Summer field trips allowed for the observation and recording of the species during the hot, dry season and allowed for the investigation of those plants, which flower throughout the year. Late summer field trips allowed for similar observations but were also designed specifically to investigate the shade characteristics of the indigenous tree species when most of the native trees have minimal leaf cover after the long, hot, dry summer. Late summer and autumn field trips also allowed for the analysis of those plants, e.g. *Sternbergia clusiana, Urginea maritima* and *Pancratium sickenbergeri*, known as hysteranthous plants, which flower and then come into leaf prior to the winter rains. Investigations were not made during the winter as the plants could be best observed in the spring when most of them reach maturity or flowering. Field trips were also taken to assess the exotic species currently used in the Negev, but these surveys were generally undertaken later on as the research matured, and the hypothesis and the methodological strategy evolved under supervision to include the comparison of native and exotic species.

2.3.3 Two proformas devised by the author for the data collection. (Refer to Chapter 5 for more detail on the methods of recording plant information). The first pro forma allows the physical details of the plants, location, growing conditions etc. to be noted. The use of this proforma developed over the years. The plant species were also photographed at the time of the data collection. (Refer to Appendix B, pages 1 and 2 for details of the proforma).

2.3.4 The second pro-forma allowed for the in–situ scoring of the aesthetic character of the plant according to a point system. (Refer to Appendix B, page 3 for details of the proforma).

2.3.5 Additional field investigations centred on the trees of the Negev. Although the shade effects of the indigenous trees can be seen as well as felt, it was necessary to ascertain scientifically, the quality and quantitative values of the microclimatic modifications that the trees were making. Otherwise, the assessment of whether these trees would be appropriate for providing shade would not be able to be proven. Thus, this investigation considers 6 native trees of the Negev with regard to their ability to alter microclimate and to provide useful shade in for the region. This study includes a control group of two commonly used exotic species. [15] [16] (Refer to Chapter 7 and Appendix J)

Literature Review of Negev Plants

2.3.6 The field data was supplemented with information from the available literature on the plants, which forms part of the literature review. The review extracts information from 3 main Hebrew language publications, namely:

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[15] This work was published in 2003 in the Journal of Arid Environments. Kotzen, Benz, 'An investigation of shade under six different tree species of the Negev Desert towards their potential use for enhancing micro-climatic conditions in landscape architectural development', Journal of Arid Environments 55 (2003), pages 231-274

[16] The provision of shade is particularly important in desert areas where shade can help control the energy budgets of people as well as wildlife.

- Feinbrun-Dothan Naomi and Danin Avinoam, 1998, '*Analytical Flora of Eretz-Israel*', 2nd Edition, CANA Publishing House Ltd., Jerusalem.
- Shmida A. and Darom D., 1986, '*Handbook of Wildflowers of Israel - Desert Flora*', Keter Publishing House Ltd., Jerusalem.
- Shmida A. and Darom D, 1994 '*Handbook of Wildflowers of Israel - Mediterranean Flora*', Keter Publishing House Ltd., Jerusalem. [17]

2.3.7 The literature review of the plants, however, also includes international publications in English. Both Hebrew and English texts have been accessed through the British Library, the University of Greenwich Library and the author's own text collection as well as through the internet. The texts are noted in the bibliography at the end of the thesis.

Discussions with Local Academics and Local People

2.3.8 At the outset of the research, contact was made with Ben Gurion University of the Negev and Professor Gutterman, Head of the Department of Ecophysiology at the Jacob Blaustein Institute for Desert Research at 'Sde Boqer' agreed to an 'informal' supervisory role. The author was introduced to Prof. Gutterman by Yankele Yogev[18], an eminent dryland farmer on 'Kibbutz Revivim'. Periodic meetings were held with Prof. Gutterman at times of the field visits and contact was maintained via e-mail. Other Israeli academics and local people, (many of them who have considerable knowledge of desert plants) were consulted. These include:

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[17] The author's proficiency in Hebrew has improved as a result of this research. It should be noted that the translations of Hebrew texts have been done as accurately as possible and with the substantial assistance of the New Bantam-Megiddo Hebrew and English dictionary as well as with the short botanically focused dictionary provided within the Feinbrun-Dothan and Danin's 'The Analytical Flora of Israel.' (1998, pages 22 – 47)

[18] Yankele Yogev sadly passed away during 2006.

- Prof Dov Pasternak, Head of the Institute of Agriculture and Applied Biology, Ben Gurion University; [19]
- Yossi Ben Dov, Institute of Agriculture and Applied Biology;
- Pedro Berliner, Wyler Department of Dryland Agriculture, Jacob Blaustein Institute for Desert Research; and
- Ran Pauker, Garden and Landscape Consultant, 'Kibbutz Nir Oz'. [20]
- Yael Samuelson, Teacher, 'Kibbutz Revivim' [21].

2.4 Evolution of the Methodology and the Research Questions

2.4.1 Once the research gathered pace and numerous plant species had been recorded in the field, it became apparent that due to their physical and aesthetic characteristics a number of the native desert plants were probably unlikely to be suitable for general 'garden' usage. [22] This insight led to the realisation that it would be impossible, and unwarranted, to enforce a plant use paradigm requiring that all gardens in the region should be dry-type desert gardens using only xerophytic species. (This was an initial idea behind the research). It was thus found to be necessary to investigate existing landscape paradigms that suggested how the landscape in the region is generally perceived and then formulate a new type of model, which would be more suitable for the Negev and for other desert regions. This led to a review of the literature on landscape models and the formulation of a new

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[19] Numerous meetings were held over the period of the research and correspondence continued throughout the research period.

[20] Meetings were held with each person on a single occasion only.

[21] Numerous consultations were held with regard to plant identity with Yael Samuelson.

[22] This view is based mainly on the physical and thus visual characteristics of the plants where they may have appeared poor in form, straggly, dry-looking etc.

alternative paradigm. The most useful source was found to be John Dixon Hunt's '*Greater Perfections, The Practice of Garden Theory*'. (Hunt, 2000)

2.4.2 At the same time it became increasingly important to appreciate why the local population, led by landscape architects and plants-men did not value local plants as for use in their landscape designs, (apart from within nature). This question has led to an investigation of aesthetics and plant usage and potential reasons for and why the plants may not be used. This discussion has been strengthened by a literature review on the subject areas. (Refer mainly to Chapter 4)

2.4.3 Most significant in the evolution of the methodology was the introduction of a systematic comparison of matched pairs, which is discussed in section 2.7 below.

2.5 Literature Review

2.5.1 The review of the literature on the native plants of the Negev led to an investigation of the research that has been carried out with regard to native plants and their potential use. The review thus also covers how the use of native and particularly desert plants has progressed in the Negev, in other parts of the Middle East, as well as in other areas such as the USA, South Africa and Australia.

2.5.2 The literature review includes an investigation of the Negev, (climate, geomorphology, history, social etc.) as well as the survival strategies of desert plants and particularly plants of the Negev. This information is considered significant as it provides a contextual background to the plants, which is important when it comes to identifying those plants, which may be suitable for various purposes and locations in the Negev.

2.5.3 The areas covered in the literature review centre on a number of key topics which include:

- Deserts around the world;
- The Negev Desert: Its history, geology, climate, social aspects etc.;

- Negev plant species and territories;
- Landscape architecture in arid environments;
- Plant survival in arid environments;
- Issues of water in the Negev and elsewhere in the world;
- Native plant use in the Negev and elsewhere;
- Landscape planting in general;
- Ecology and the introduction of foreign plant species;
- Plant classification and plant use classification systems;

2.6 Analysis

2.6.1 The recording and cataloguing of the plant species of the Negev in the field, and expanding that data with information from the literature review, forms the first stage in the research. The next stage was to analyse this information with regard to potential plant use. Individual plant species were analysed with reference to their physical and visual characteristics and attributes in order to ascertain their potential suitability for use in landscape and environmental projects in the Negev. (This information is mainly located within Chapter 6, Appendix F and Appendix G.) The scope of potential suitability was extended to include the purpose of use, such as a hedge or a groundcover, as infill, shelterbelt or for shade. This approach has led to the investigation of the current plant species that are used for the equivalent purposes. These plants, which are invariably foreign, are then compared in groups of matched pairs to the native species in order to test the hypothesis.

2.7 Testing the Hypothesis

2.7.1 In an ideal situation, i.e. with the appropriate funding, land and time, the research could have followed a controlled experiment method where native plants could have been grown alongside the exotic (control) species and then tested against one another in terms of habit, water use etc. This type of method was not feasible and is not often feasible because not only does it require substantial funding and other resources such as the supply of land, water and manpower but also many years to undertake. However, where the ideal situation to carry out such controlled experiments is not feasible, a 'natural experiment' or a 'quasi experiment' provides an appropriate alternative. In the case of this research, the quasi experiment relies on the collection of appropriate data, the analysis of the data, and the matching of native and exotic species pairs in a relevant systematic way, to confirm/deny the hypothesis. [23] Although the quasi experimental method may not have the certainty of proof compared to a controlled experiment it fulfils the criteria of a scientific study[24] in that:

- It has purpose, and that it is necessary for someone to do this work in order to promote sustainable development in the region;
- The approach is methodical;
- It is rigorous; and finally
- It is as objective as possible.

2.7.2 The approach is scientific in the design of the parameters, which determine whether native plants could be effectively used in the Negev. It is rigorous in all its aspects in determining the characteristics of both the native and comparison group of plants and analysis of matched pairs, and it is objective in that other researchers/scientists could use the designed parameters and arrive at the same/similar results.

2.7.3 The seven main steps of this and most research are as follows: 1)

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[23] Information on controlled and natural experiments/quasi experiments from Wikipedia. (http://en.wikipedia.org/wiki/Experiment)

[24] Ross Koning states that there is '*no one scientific method*'. (E-mail correspondence between Ross Koning and the author on 4 July 2005. Dr Ross Koning, Department of Biology, Eastern Connecticut University, Willimantic, CT 06226 - Email: rkoning@snet.net).

Observation, 2) Question, 3) Hypothesis, 4) Parameters [25], 5) Comparison, [26] 6) Analysis and 7) Decision. [27] An explanation of this process in terms of the research is as follows:

2.7.4 The observation of a phenomenon has occurred. The author observed that many of the native plants of the Negev growing outside the developed areas appeared to be aesthetically pleasing and robust, but these weren't used in the past, nor in the present in the external areas of development projects. Rather, foreign exotic species had been introduced.

2.7.5 This led to the positing of a key question. This question can be phrased as such: *'Do the native plants of the Negev have sufficient merit for use in landscape and environmental works in the Negev?'* Another key question which suggested itself, is: *"Why don't the Israelis currently living in the Negev use the native plants or perceive the potential for their use?"*.

2.7.6 The next part of the scientific method is the formulation of a hypothesis as an 'educated guess' in answer to the 1st question posed above. The answer to the question or hypothesis is that indeed *'the indigenous xerophytic and*

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[25] When it is possible to undertake physical experiments, this stage is usually called the prediction phase. The prediction is a formal way of putting a hypothesis to the test by applying variables. There are two types of variable. The dependent variable and the independent variable. The dependent variable represents an obvious and definable way in which the hypothesis can be proved true. The independent variable represents ways in which the hypothesis may be proved false.

[26] When it is possible to undertake physical experiments, this stage is usually called the experimental phase and were it possible, field trials could have been undertaken to compare the native and exotic plant species. (Field trials would have taken many years to complete and large sums of money to be invested.)

[27] Extracted from website on the Scientific Method published by Ross Koning at http://plantphys.info/Plants_Human/scimeth.html

halophytic plants of the Negev are suitable for use in landscape design in the Negev Desert in Israel'.

2.7.7 In order to test the hypothesis a set of parameters against which to compare species was chosen. The physical and aesthetic characteristics and water demands of the native Negev species were first noted and then systematically compared as 'matched pairs' to similar exotic species especially in terms of potential use (native species) and actual use (exotic species) and also relative to a new landscape paradigm that has been posited. (Refer to Chapter 4) As the provision and alteration of microclimate by trees is largely a separate issue compared to the smaller plants, a comparison was also carried out of the native trees of the Negev relative to exotic trees planted in the Negev in order to ascertain whether the native trees can provide similar or possibly better shade characteristics. (Refer to Chapter 7)

2.7.8 In the comparison stage, native plant species and foreign, exotic plant species are compared according to a set of key parameters/issues that are considered significant. In many instances research experiments can be repeated and the analysis reviews the results of the iterations and in many cases the results are statistically tested. However, in the case of this research, the analysis is completed only once, as the experiment is not physical and statistical investigations would be unhelpful.

2.7.9 The decision is then made whether to 'reject the hypothesis' or that the 'hypothesis cannot be rejected'. According to Ross Koning [28] a hypothesis cannot be proved, as proof exists only when the chance for error is zero. In the case of this research the aim is thus to illustrate in the first instance, that the hypothesis cannot be rejected. However, it is suggested that in light of the evidence, a more positive statement may be made and that the

[28] Ibid.

hypothesis, although not entirely verified, can be substantiated [29]. However, actual scientific, physical proof will only ensue when the individual plant species have been subjected to appropriate plant trials or when they have been used for various purposes over a period of time.

2.7.10 A conclusion is arrived at in Chapter 4, with regard to the 2nd key question posited in paragraph 2.7.5 as to why the plants are not currently perceived as having potential for use by local Israelis. This discussion is linked to historical precedents for native plant use and current trends around the world.

2.8 Summary and Conclusions

2.8.1 This research centres on the verification or truth and/or falsity of the hypothesis that the plants of the Negev Desert are suitable for landscape use in the Negev. *'Truth'* defined by the FreeDictionary, (FreeDictionary www.) *'is a comprehensive term that in all of its nuances implies accuracy and honesty'*. Wiktionary, (Wiktionary, *'truth'*, www.) states that truth *'is the standard upon which an argument gains strength.'* [30]

2.8.2 The definitions of truth have been chosen as they provide the framework for this research. In order for the research to 'hold water' it needs to be as *'accurate'* as possible and be *'honest'*. It is within this framework or process that the argument has been placed so that it can gain or for that matter lose strength.

2.8.3 Verifying or disproving the hypothesis has relied on a number of sequential as well as interconnected iterative processes.

2.8.4 Firstly, the collection of data on the native plants of the Negev in the field and from the literature is a core feature of the process and forms the central

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[29] The term here is used in the sense of establishing *'the existence of truth or a particular fact through the use of competent evidence'*. (Thomson Gale Legal Encyclopaedia, Answers.com website).

[30] Arguments abound of what constitutes truth.

part of this research. However, the investigations generated a number of interesting key questions, which relate to:

- Why the Negev plants were not used;
- Available studies on plant choice in the Negev;
- The historical and current use of native plants elsewhere in the world;
- The problems associated with the introduction of exotic species;
- The Negev Desert as physical and human context; and
- Existing and alternative landscape planting paradigms and the role of the landscape architect in plant choice

2.8.5 These issues are discussed as part of the literature review, which forms the framework for determining the hypothesis.

2.8.6 The testing of the hypothesis is based on a methodology, which reveals the truth as to whether the plants of the Negev have potential for use. Although superior verification would have been possible through the use of field trials, this was not practical due to the financial and time constraints. The use of analysis of the physical and aesthetic characteristics relative to soils, pH, salinity etc. combined with the natural experimental/quasi experimental method, which analyses each native species and then compares them to similar exotic species according to a set of relevant criteria offers the next best solution for testing the hypothesis.

2.8.7 In short, the sequence and methodological approach was as follows:

- The author discovered that there were a large number of attractive xerophytic and halophytic native Negev plants;
- The author realised that very few of these plants were used;
- The author gathered information about the available Negev plants through field research and the literature review;
- A quasi-experimental method was used to test the hypothesis that the Negev plants have the potential for use. This method relies on the

collection and analysis of appropriate data, and the matching of native and exotic species pairs and comparing their suitability, functionally and aesthetically. Although controlled field experiments would have advantages in testing the potential suitability of each plant for use, this would take too much time. Time is however, not on the researcher's side as development pressures are increasing and landscape and ecological changes are escalating and thus the quasi-experimental method was adopted.

2.8.8 The research and adapted methodologies are linked to the specific physical and historical environment of Negev Desert. This specific context is discussed in the following chapter, Chapter 3.

3. CHAPTER 3 THE NEGEV: PHYSICAL AND HUMAN GEOGRAPHY – A LITERATURE REVIEW

3.1 The Negev – Introduction

3.1.1 Note that all Figures are located in Appendix A unless otherwise indicated.

3.1.2 Whereas Chapter 2 focused on the various research methodologies used in the research, this chapter investigates the key factors determining plant growth in the Negev Desert with particular reference to physical and human geography. [31] The phytogeographic context is described in the latter half of the chapter.

3.1.3 All plants growing in natural or semi-natural environments are dependent on contextual conditions for successful growth. The survival of different plant species in various areas of the Negev is considered context-related, relative to climate and microclimatic conditions, geology, landform and soils, as well to the settlement by people and their interaction with the land. This chapter thus outlines the main factors that influence plant growth in the Negev Desert.

General

3.1.4 The Negev Desert in southern Israel, (Figures 1 and 1a), is remarkable because although it is small, it is heterogeneous in its variety of landscape character types and biotic (living organisms), and abiotic (lifeless), forms. These include geological and edaphic conditions. Despite its limited size the Negev is the largest area of land in Israel. It is important ecologically and in

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[31] Physical geography generally includes: landform, rocks, soils, fauna and flora, hydrology and climate. Human geography generally includes: Populations, settlement, economic activities, transportation, social and political systems and urban and agricultural systems. (Physical geography.net, Chapter 1)

terms of its visual and landscape character [32], landscape quality/value [33] and as a development and military resource for the State. It is also an important tourist resource for Israelis and foreign tourists alike and particularly for the people living in the Negev. The size of the Negev is important as this heterogeneity and activities occur in a relatively small area of 13 000 square kilometres [34] compared to the other regional large scale deserts such as the Sahara at 9.1 million square kilometres, the largest in the world, and the Arabian Desert at 2.6 million square kilometres. (Moor, 1991, page 1).

3.1.5 For David Ben Gurion, the first Prime Minister of Israel, the Negev was a place of great opportunity and since his premiership in 1948, settlement and tourist developments have continued at an ever-increasing rate. For example, until recently, private development in rural areas did not occur. Now, private development has been encouraged in the northern Negev and

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[32] Landscape character refers to the different character zones, which may be identified within any given area taking account of local topography, built form, settlement patterns, land use, local materials, hydrology, vegetation and habitat, and other landscape and cultural/historical features.

[33] Landscape quality/value refers to character areas with regard to their, condition, and aesthetic appeal and attaching a value to these areas, e.g. high, moderate and low. It also takes into account an evaluation of the likely value or importance to the community and the authorities.

[34] This area constitutes 58% of the landmass of Israel, with only 8% of the country's population living there. The Negev region has the lowest population density in the country: 38.1 persons per square kilometre, versus a high density of 639 people per square kilometre in the rest of the country. By the year 2040, it is estimated that there will be 20 million people living within Israel's regional area, of which 12 million will be Israelis. (Ben Gurion University of the Negev, *'The Five Point Plan'*, www.)

Negev Highlands. These rural development types include small and large private vineyards, tourist caravanserai, ostrich farms etc. The impacts and potential impacts on the land are ever increasing. This increase in development is in line with a number of the principles outlined in the 34th Zionist Congress, (June 17-20, 2002), held in Jerusalem, which states that there needs to be

> *'encouragement and stimuli for the absorption of new settlers in the Negev and Arava'*, and to *'keep land reserves and open territories, to create green lungs, as a land reserve for coming generations, and as a contribution to the quality of life and environment of the citizens of Israel'*. (WZO, Hagshama, *'34th Zionist Congress Resolutions'*, www.)

3.1.6 Population growth in the Negev has indeed *'increased by 47%'* between 1991 and 2001, *'whilst Israel's population has grown by 40%'*. (BGU, www, pages 1 and 4) [35]

3.1.7 Growth in the region is seen as necessary, because the centre of the country is highly populated, (639 people per square kilometre [36]), and more developable land is required. The growth is spurred on by incentives for people to move to the Negev by lower house prices and a sense of being further away from the ever-present Israeli/Palestinian conflict which appears less dominant in the larger and less populated south of the country. However, the expansion of towns and cities, infrastructure and amenity facilities has created and will continue to have significant effects on the ecology and landscape of the region unless methods are found to create more sustainable development in the region

[35] New immigrants make up 25% of the population of the Negev's towns. In the rest of Israel, the figure is 12.5%. (Ben Gurion University of the Negev, 'The Five Point Plan', www.)

[36] As a comparison this is similar to the population density of Milton Keynes at 658 person per km2 – 1998 data. (Demographia www.)

Location

3.1.8 The Negev Desert is part of the great Saharo - Arabian Desert belt which extends from the Sahara and the Atlantic sea-board on the west side of Africa, over the Arabian Desert to the Desert of Sind in India to the east. Although there is no single accepted definition of the Negev, it is generally recognised to extend from a line running parallel to the 200mm isohyet in the north, to Eilat 250km to the south. [37] (Figures 1, 1a and 2) To the east the area is bounded by the 'Arava' (ערבה), and Jordan. The Arava is the Hebrew name given to that part of the Great Rift Valley, which extends from Eilat in the south to the Dead Sea to the north. [38] To the south and west the area is bounded by the Sinai Desert in Egypt. (Figures 1 and 1a) In the past the Negev and Sinai deserts were considered one unit and the Bedouin nomads did not distinguish between the two. In 1906 the British and

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[37] Parts of the northern Negev may not be considered desert but rather as being 'arid'. The FAO note the hierarchy of dry regions as follows: Desert: less than 100mm rainfall, Arid: 100 – 400 mm and Semi-Arid: 400 – 600 mm. (FAO, 'Table 1 – Major Climatic Zones' www.)

[38] The Great Rift Valley actually extends from Zambia in Africa through to Anatolia in Turkey. There are two parts to the Great Rift Valley, the eastern part as discussed above and a western part. In eastern Africa the valley divides into two, the Eastern Rift and the Western Rift. The Western Rift, also called the Albertine Rift, is edged by some of the highest mountains in Africa, including the Virunga Mountains, Mitumba Mountains, and Ruwenzori Range, and contains the Rift Valley lakes, which include some of the deepest lakes in the world (up to 1,470 meters deep at Lake Tanganyika). Lake Victoria, the second largest freshwater lake in the world, is considered part of the Rift Valley system although it actually lies between the two branches. (http://www.nationmaster.com/encyclopedia/Great-Rift-Valley) The Dead Sea is 396m deep at its deepest.

Turkish governments demarcated the border of the Negev with the Sinai and in 1922 the British government established Transjordan, east of the Jordan River, which determined the Negev's eastern border. The Israel/Jordan border runs approximately down the centre of the Great Rift Valley from the Gulf of Eilat/Gulf of Aqaba [39] with the city of Eilat to the west and Aqaba to the east, to the Dead Sea. Thus today, the boundaries of the Negev are largely political demarcations although geographical, historical and environmental issues are partly determining factors.

3.1.9 Prior to the foundation of the State of Israel in 1948, the region was inhabited mainly by Bedouin. A few Jewish settlements were set up in the 1940's as experimental stations to protect strategic interests in the area and further afield to the north, and to show how it was possible to live in the harsh environment. Prior to the foundation of Israel, the United Nations sent delegations to inspect these settlements. As these were found to be successful and the land was settled, the Negev was included in the boundaries of the State of Israel.

3.2 The Negev – Physical Geographical Context

Climate

3.2.1 The Negev comprises hot and dry desert and semi-arid desert areas [40] with hot summers and cool winters. Rainfall, when it occurs, falls within the winter months mainly between November and February. Rainfall and

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[39] Israel terms this stretch of coast the Gulf of Eilat, whilst Jordan calls it the Gulf of Aqaba. Eilat is mentioned in the bible in Deuteronomy 2:8 as Elath. *'We turned from the Arava Road, which come up from Elath...'* ('Holy Bible New International Version', page 183.) The name of Aqaba was given to the port city in the 14th century when it was ruled by the Mamluk sultan based in Egypt. Previously it was know as Ayla.

[40] There are four main types of desert: Hot and dry, Semiarid, Coastal and Cold. (UCMP, www.)

temperature are influenced by height above sea level and distance from the Mediterranean Sea. Annual rainfall decreases from north to south, from approximately 200mm north of Beer Sheva to 0 – 25 mm at Eilat. In the north, rainfall drops dramatically over short distances. (Figure 2) Rainfall however is unpredictable and is one of the major factors of this arid zone as with most arid zones. The quantity of rainfall an area receives, does not fully correlate with the amount of water available for plants. This is because on the one hand water does not necessarily reach or remain in the root zone and on the other hand topographical features, soils and geology types may enhance run off and thus increase the availability of water for plants. (Refer to Figure 6 and Chapter 4 paragraph 4.6.9).

3.2.2 Winters can be harsh in the central highland area. At 800 - 1000+ metres above sea level, snow may occur. In lower areas, winter temperatures are milder and Eilat is warm enough to be a warm northern hemisphere winter tourist destination. The average daily minimum temperature is $<6^0$C in the central highlands to $10+^0$C at Eilat. (Stern, 1986, page 62) The average summer temperatures in August range from $<32^0$C to $36+^0$C. (Stern, 1986, page 60) The average annual temperature ranges from $<17^0$C to $23+^0$C at Eilat. (Stern, 1986, page 60) Precipitation in the summer is usually nil, although fauna and flora take advantage of nightly dews, which occur due to the drop in temperature. In the central highlands dew occurs on approximately 200 nights of the year. (Danin, 1983, page 12)

3.2.3 Variations in microclimate in the different phytogeographic zones of the Negev are influenced by variations in slope and exposure to the sun. South facing slopes are exposed to more direct solar radiation and are thus relatively warmer. It is accepted that dark magmatic, metamorphic and chert rocks absorb more solar radiation and thus have an effect on microclimate. (Danin, 1983, page 13) It is also noticeable that in some localised areas of dark coloured rock, vegetation is absent whilst in adjacent similar areas with lighter rocks vegetation is more abundant (Figure 3) These are important factors relating to the successful establishment of native plant material which will be discussed in the section on micro-landscape strategies in Chapter 8.

Background to the Geology of the Negev

3.2.4 Although today Israel is the connecting link between Asia and Africa this was not always so, and during a long geological period it was part of the north eastern Afro Arabian continent, i.e. part of Gondwanaland, and was *'widely disjointed from Asia'*, (Zohary, 1982, Introduction), which itself formed part of Laurasia. (Figure 4) Thus the flora of Israel reflects the geographical and historical elements of both Gondwana [41] and Laurasia. [42] A further great geological event was the creation of the Jordan - Dead Sea depression that forms part of the Great Rift Valley, which extends from Zambia in Africa to South Anatolia in Turkey. Its formation started in the Paleozoic era and was completed in the Pleistocene. (Zohary, 1982, Introduction) The Paleozoic Era commenced approximately 570 million years ago and ended 240 million years ago. It includes six periods. These periods are, from oldest to youngest: Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Permian. Land plants developed from the green algae during the Silurian Period, and they became abundant during the

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[41] Palaeos: The Trace of Life on Earth website, (Palaeos, www.), notes that 'the continents of Australia, India, South America, Africa, and Antarctica, existed together as a separate landmass as long as 650 million years ago. And as these continents only began to break up some 130 million years ago, this great super continent had a life of around 520 million years; making it perhaps the most important geological structure of the last billion years'.

[42] The UCMP Glossary: Paleogeography website, ('Laurasia', www.), notes that Laurasia was 'a super continent that existed from the Jurassic to Early Tertiary after splitting from Pangea; composed of Laurentia, Baltica, Avalonia, (modern North America, Scandinavia, Greenland, Western and Central Europe); eventually fragmented into Eurasia and North America in the Tertiary with the opening of the North Atlantic Ocean'.

Devonian Period. The Pleistocene Epoch is believed to have begun about 2 million years ago and ended about 11,500 years ago. This is the geologic period before the present period. (World Book CD Rom, 1998)

Geographic Regions: The Edaphic Environment- Rock and Soils

3.2.5 The Negev Desert is not a homogenous desert region. It consists of many varying desert types. The area ranges in elevation from sea level at the Mediterranean and Eilat, to over 1000 metres in the Central Negev Highlands near the town of 'Mizpe Ramon' to minus 400 metres below sea level at the Dead Sea. This is the lowest place on earth.

Negev Desert Regions

3.2.6 Broadly speaking the world contains 3 types of hot deserts. These are usually known by their Arabic names. Sand deserts are called *erg*. Areas of bare rock are often called *hammada* or *hamada* and broad plains, which are covered by loose gravel, rocks or pebbles are termed *reg*. (Philips, 2000, page 7) (Figure 3)

3.2.7 The Negev contains these 3 broad types but can also be divided into the following areas, which relate also to their location and topography as discussed below:

<u>Desert Mountains</u>

3.2.8 These areas include the Eilat Mountains and southern and eastern slopes of the Negev Mountains and lowest part of the Judean Desert. (Figure 5) The slopes are usually bare of soil cover and are made up of coarse eroded material and desert alluvium. These areas are sparsely inhabited, have poor grazing and the potential land-use is restricted. However due to the high visual and physical quality of the mountains, cliffs and dry riverbeds the areas can be good for desert tourism. (Joel in Golany, 1979, page 216) Hammada which is the desert substrate made up of coarse, boulder-like stones, which are formed in-situ, is found on mountain tops, on flat hills and their slopes. (Zohary, 1982, page 21)

Large Desert Valleys

3.2.9 These areas include the Arava and Dead Sea regions where material has been deposited in the valleys from the surrounding mountains. The land is covered mostly with stony, gravely, coarse alluvium. Shallow groundwaters have become salinised, (known in Hebrew as 'sabkhas'), with finer sandy, silty, soils. In many gravelly soils there is gypsum and boron, which are not good for plant growth. (Zohary, 1982, page 21)

Reg Plains

3.2.10 These are mainly flat stony areas although there are some hills and escarpments. (See the description of Reg under Soils in paragraphs 3.2.17 to 3.2.20 below). (Figure 3) This desert pavement has little groundwater although the Bedouin grow wheat in it. (Zohary, 1982, page 21)

Sandy Desert

3.2.11 The sands extend from 'El Arish' in Egypt to 10km south of Beer Sheva to the Mediterranean Coast. It is wetter nearer to the coast. These areas support dates and other crops. (Refer to Figures 32 and 53)

Central Negev Highlands

3.2.12 The Central Negev Highlands are located between the sand dunes and the eastern part of the loess plains of the northern Negev. The terrain is hilly to mountainous. Hard limestone covers most ridges. Chalk and flint can be found on ridge escarpments whilst the valleys are made up of gravels, sand and loess. These areas flood more frequently allowing more vegetation to establish. Grazing is poor with the Bedouin growing winter grains in some depressions. (Zohary, 1982, page 21)

Negev Desert Soils

3.2.13 Soils provide a foothold for plants where water and nutrients may be absorbed as well as permanency, which allows the plant to be pollinated. In the wild, native plants are often associated with a particular soil or a range of soils and soil conditions and thus in order to understand which plants may have the potential for use, these contextual conditions should be considered.

3.2.14 There are several types of desert soils that can be recognised 'according to their water absorbing capacity and salt regimes'. (Danin, 1983, page 13) (Figure 6) Soil is defined here as the upper part of the earth's crust subject to penetration by plant roots and therefore includes rocky areas, which may act as reservoirs of water and minerals used by plants. The following description of the soils of the Negev is generally based on that described in Danin's 1983 publication '*Desert Vegetation of Israel and Sinai*'.

<u>Sands</u>

3.2.15 Sand areas comprising sand dunes are mainly found in the north western Negev in 'Cholot Haluza' (the Haluza Sands). (Figures 6 and 32. See also Appendix H3, photograph G63, Appendix H6, photograph P100 and Appendix H12, photograph AD9)

3.2.16 Sand is classified on the Wentworth Scale of having particle sizes between 0.0625-62 microns (Strahler, 1975, page 371), or 0.05-2.00mm. (Voelcker 1989) The rough texture of sand allows easy penetration of water but much of this water becomes unavailable to desert plants because of percolation beyond the root zone. Less infiltration occurs where there is more silt and clay as occurs *'at the edge of the sands in the Negev foothills'*. (Danin, 1983, page 13) Silt and clays at the surface increase run-off so that precipitation may be lost to the plants. Sandy soils can restrict the ability of trees to grow. For example in the Arava, *Acacia raddiana* [43]is restricted to those sandy soils, which also contain the finer silts and clays and thus those, which have a higher water holding capacity. (Danin, 1983, page 13) This is an important micro-landscape feature, which informs planting strategies for proposed schemes and which will be discussed in Chapter 8.

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[43] Refer to Appendix D for a list of all the plant species, which are catalogued alphabetically according to life-form.

Loess and *Regs*

3.2.17 Large areas of the Negev have been subjected to the deposit of windblown silt and clay with some sand.[44] This occurs mainly in the plateaux and valleys of the northern Negev. Loess has a high water holding capacity, which is due to its fine grain. (Figure 6) Water, which penetrates the surface of loess soils, is stored near the surface. The rains do not usually bring the capillary water to below 20cm and thus *'much of this water is lost through evaporation'*. (Danin, 1983, page 15) This is similarly an important lesson for landscape planting and the manipulation of micro-landscape conditions as discussed in Chapter 8. Furthermore, loessal soils accumulate salts, which concentrate over time through evaporation. The salts originate from the small quantities, which are in the rain. (Danin, 1983, page 15)

3.2.18 Loess is a particularly good growing medium as is evidenced by the variety of crops and exotic plants that are grown on kibbutzim with loessal soils.[45] It is the area where most development has occurred in the Negev and expansion in these areas is likely. (Figure 38)

3.2.19 Wind is also responsible for the formation of desert pavement called *reg*. These *reg* areas are characterised by large gravely plains and hills, which are strewn with small rocks. (Figure 3) They are caused by the process of

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[44] The clay and sand particles are noted as being blown in from the Sahara Desert. This has been studied by Frumkin and Stein. The transfer of dust occurs mostly in the spring where 'low-pressure systems may produce a dust storm belt approximately 1000 km wide and 1500-5000 m high, arriving from the Sahara Desert'. (Frumkin A. and Stein M., article, pages 453 and 460.)

[45] On 'Kibbutz Revivim', which has loessal soils, produce included: alfalfa, apricots, avocado pears, green beans, corn, dates, lilies, olives, peaches, pears, peppers, potatoes and tomatoes.

deflation where loose particles lying on the ground may be lifted into the air or rolled along the ground. (Strahler, 1975, page 567) The act of deflation occurs when the ground surface is thoroughly dried out and is littered with particles derived from rock weathering or previously deposited material. Reg and course desert alluvial soils are found in pockets throughout the Negev, but mainly in large areas in the southern Negev and Arava.

3.2.20 As a result of the high rate of run-off and evaporation only about 30 to 50% of rainfall is available to plants. (Danin, 1983, page 15) (Figure 6)

3.2.21 The author has noted that many *reg* areas, which are covered with dark coloured rocks are devoid of plants. It is the author's assertion that this has partially to do with the effect that the darker colour rocks absorb more solar radiation, whereas lighter surfaces reflect it. [46] (Figure 3) Danin (1983, page 13) similarly notes that dark magmatic, metamorphic and chert rocks absorb more solar radiation and thus have an effect on microclimate. (Refer back to paragraph 3.2.3). The soil temperature at the surface is thus much hotter where the top surface is darker. This effect of surfaces and materials reflecting solar radiation is termed albedo. Brown and Gillespie (1995, page 90), note that the albedo of white paint is up to 90% whilst that of tarmac is around 5%. This means that where the desert surface is darker, more radiation is absorbed and concomitantly less is reflected. The surface temperature is thus hotter and plants may find this increased heat unsuitable.

Chalk, Marl and Clay

3.2.22 These soils are made from underlying sedimentary rocks creating a loess type fine-grained surface, which accumulates after weathering. A biological crust often forms on these soils and results in high run-off rates and the soils accumulate salts in the same way as the loessal soils mentioned above. These

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[46] This assertion is based on observation and logic, which tie in the observations of Danin (1983, page 13), and the nature of albedo. The phenomenon has not been explored as part of this research, although it would be an interesting topic to follow.

soils only support a sparse vegetation. (Danin, 1983, page 13) Field studies by the author have, however, indicated species such as the shrub *Zygophyllum dumosum* growing directly in bare chalk. (Figure 40)

3.2.23 Water for plant uptake is estimated at 20 to 50% of available rainfall. (Danin, 1983, page 16)

Hard Bedded Limestone, Dolomite, Fissured Granite and Metamorphic Rocks

3.2.24 These areas are formed from *'weathered outcrops of fissured hard rock'*. (Danin, 1983, page 15) Water penetrates freely to a considerable depth. Most rainfall passes into the fissures and into the soft layers between the strata.

3.2.25 60-90% of rainfall is available to plants in these soils. (Danin, 1983, page 15) (Figure 6)

Cliffs and Smooth-Faced Outcrops

3.2.26 These areas comprise large outcrops of smooth faced dolomite, limestone, granite and sandstone deposits. Runoff is considerable as these rocks absorb less than 2% of their weight in water and they lack small depressions that might collect water. (Figure 6) However there are plants that grow directly out of fissures in the rock such as *Chiliadenus iphionoides* formerly *Varthemia iphionoides*. (Refer to Photographs DS161 and DS162, Appendix H7) With enough rainfall and once the fissures and cracks in the rocks are saturated, run-off is to the base of these outcrops and to pockets of loess which can support Mediterranean species such as *Narcissus tazetta* and *Sternbergia clusiana*. (Refer to Photographs G67 and G69, Appendix H3)

Saline Soils

3.2.27 Salt marshes occur mainly in the Arava and Dead Sea areas. Many desert soils are saline. These salts have been deposited through rainfall and *'accumulate in fine-grained soils to the depth of the mean water penetration. Thus soils that develop on loess, chalk, marl and clay are high in salt'.* (Danin, 1983, page 16)

3.2.28 Local agricultural irrigation often over-waters the soil thereby leaching the salts below the root level of the crops. [47]

3.2.29 The above geomorphologic or physiographic features which include mountains, plains, undulating areas, large valleys, young rift valleys and sand dunes, generate different landscapes and soil formations. [48] This affects vegetation patterns, which can vary in different physiographic units in the same climatic zone. This is an important feature for the landscape architect to note because it points to the fact that microclimatic, micro-landscape and soil conditions greatly affect species mix and plant survival. These conditions were well understood and managed by the Nabateans who lived and successfully farmed in the desert. (Refer to paragraph 3.3.2 below).

Soils, Landscape Types and Plants

3.2.30 The reasons why one species of plant grows in a particular area and not in another are extremely complex. Although plant adaptation mechanisms increase survival, (e.g. having waxy or hairy leaves which reduce water loss or temperature increases), it is certain that plant survival relates also directly to the available water that the plants require, climatic and microclimatic conditions as well as the edaphic conditions. Some plants can and do grow within a wide range of conditions, including soil conditions, but many prefer a specific environment and prosper only when these are suitable. Thus for example it is possible to find Mediterranean species such as *Narcissus*

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[47] The author has been involved in this practice in the Negev in the growing of crops and flowers (Bulb production for export), where with drip irrigation the salts were leached below the root zone.

[48] Geomorphic, or physiographic, regions are broad-scale subdivisions based on terrain texture, rock type, and geologic structure and history.

tazetta and *Sternbergia clusiana* (Refer to Photographs G67 and G69, Appendix H3), growing in small isolated populations far away from the main populations which are located to the north of the country. These so-called relict groups from the Mediterranean phytogeographic region that have remained from when the region was wetter have survived in small pockets. [49] They have thus survived where the soil and microclimatic conditions have continued to be suitable for growth.

3.2.31 In order to ascertain the nature of the soil, within which plants were growing in the Negev, the field research undertook to record the soil type, i.e. the pH and salinity levels, (in the form of conductivity levels), at the location where each plant was assessed. Although this method did not allow for an investigation of the range of pH and salinity levels tolerated by each plant species it at least provides an indication of the soil conditions in which the plants can grow and has provided an indication of some pH and salinity levels across the Negev. (Refer to Appendix C) Most of the soils tested in the Negev were found to be alkaline to strongly alkaline, that is between pH7.1 to pH8.0 and above. The salinity tests show that most of the plants assessed were growing in soils with a conductivity of between 101 - 600 μS/cm, (micro Siemens per centimetre), which is considered to be a low to medium salinity hazard. (Willens in Cochrane and Brown, 1978, page 51) Some species however were found in very saline soils with conductivity measurements ranging above 2250 μS/cm and even above 20 000μS/cm. Measurements above 2250μS/cm indicate a very high salinity hazard for plants. (Willens in Cochrane and Brown, 1978, page 51) Indeed, one species, namely *Arthrocnemum machrostachyum* was found growing directly in the waters of the Dead Sea, with a published conductivity

[49] The Free Dictionary, 'relict', www.), notes that in ecology, the term relict is used to refer to 'an organism or species of an earlier time surviving in an environment that has undergone considerable change'.

measurement of approximately 110 000µS/cm. [50] (The methods of conductivity testing are described in Appendix C).

3.3 The Negev – Human Geographical Context

Settlement, Vegetation and Plants

<u>Historical Perspective</u>

3.3.1 There is evidence that hunter-gatherers lived in the Negev from the Lower Paleolithic period [51], at least 300 000 years ago up until the Neolithic period about 8000 years BC. (Danin, 1983, page 16) (Figure 7) The Paleolithic communities lived mainly in the highlands whilst the Neolithic inhabitants lived mainly in the valleys and plains. (Danin, 1983, page 16) It is surmised that these peoples had a negligible effect on the vegetation of the region. From the Epipaleolithic to the Neolithic periods (15th to 4th Millennia BC) agriculture was developed in the Middle East. (Figure 9) During the Chalcolithic period (4000 to 3100 BC) archaeological sites in the semi-desert regions north of Beer Sheva show an organised and established agriculture. (Danin, 1983, page 17) Little impact was likely to have occurred on the trees of the area as people lived in caves, although further to the south, at Timna, approximately 20 kilometres north of Eilat, local trees would have been used to fire copper smelting operations. (Figures 1 and 1a)

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[50] The author's equipment would only measure up to 19,990µS/cm. Information on Dead Sea conductivity from http://www.qld.waterwatch.org.au/saltwatch/pdf/resource_book%20_a.pdf.

[51] The Lower Paleolithic spans a period 'from around 2.5 million years ago until ago when the first craft and use of stone tools by hominids appears in the archaeological record, until around 120,000 years ago when important evolutionary and technological changes ushered in the Middle Paleolithic'. (Wikipedia, 'Lower Paleolithic', www.)

3.3.2 In the Early Bronze period (3100 to 2200 BC), houses were built of stone and wood, and evidence of hundreds of nomadic settlements from 2200 to 1950 BC indicates that the nomads would have *'exerted considerable pressure on the vegetation through grazing and the cutting of woody vegetation for fuel'*. (Danin, 1983, page 17) After 1950 BC there is no evidence of substantial development for the following nine centuries. Revitalisation of settlement and the establishment of cities and farms occurred again from the Iron Age, 1200 BC to the end of the Byzantine period, 640 AD. Nabatean [52] settlers, (Figures 8, 9, 10 and 52), cultivated the valleys of the Central Negev Highlands by using techniques of water harvesting. This is particularly well evidenced at Avdat in the Negev Highlands where winter precipitation was collected and diverted from the hills to the valleys. (Figures 10 and 52) The sophisticated techniques of water harvesting meant that permanent settlements were established. Some of these techniques of collecting run-off and increasing run-off are important for this research as they point to methods of increasing plants survival in development projects. (Refer to Chapter 8.) Figure 10 shows the system of collecting rocks into piles so that runoff would be enhanced towards the lower lying areas. [53] Run off is significantly increased because surface rocks

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[52] Aptly, the verb *navat* (נבט) means sprout in Hebrew although Prof. Avraham Negev states that the verb *nabata* and the name deriving from it, mean "a man who digs for water". (Negev, www). *'They first entered the area of Israel in the 4th century BC, but they were already mentioned in an Assyrian list of enemies that dates from 647 BC'. 'In 63 BCE the Nabatean country was conquered by the Romans, but their king Aretas III (40 BCE - 9 CE) swore allegiance to the Emperor, and he was able to keep his lands. ... However, in 106 CE Rome annexed the Nabatean kingdom'.* (Schaalje, www.)

[53] Piles of stones were found on some slopes in the Negev Highlands. When asked what they were, the local Bedouin said that they were

and stones impede water flows and enhance immediate percolation. The area was also grazed by the Bedouin flocks.

Recent History

3.3.3 Following the Arab conquest in 640 AD there was a steep decline in population and in agriculture. For more than 12 centuries until about 1900 AD the Negev was dominated by nomadic Bedouin pastoralists, whose goats *'were extremely destructive to the natural vegetation'* (Danin, 1983, page 17) From 1900 the Ottoman rulers encouraged permanent agriculture amongst the Bedouin of the northern Negev. Similarly the Israeli government has tried to settle the Bedouin in the northern Negev and this has resulted in the establishment of permanent towns around the regional capital Beer Sheva. Following Independence in 1948 until the 1960's, settlement was concentrated in the north-western Negev with the establishment of rural 'kibbutzim' and 'moshavim' [54], as well as a number of small development towns. (Stern, 1986, page 9) Since then, many areas were protected from over-grazing and efforts have been made against soil erosion and the

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ancient and were used to collect dew for the growing of grapevines. It is now understood that this is not the case. Stones on the surface restrict water flow and improve percolation. Thus the stones were removed by Nabatean farmers in order to allow the better flow of water to the growing areas in the lower lying areas. The stones were located in piles as this was the most effective way of creating as much surface as possible to increase water runoff.

[54] A kibbutz is a collective farm, which has agricultural beginnings but now also accommodates factories and high-tech industries. It is owned by its members and members benefit according to their needs. A moshav is a collective where members have private ownership of their properties but share equipment and facilities. Kibbutzim (plural of kibbutz) and moshavim (plural of moshav) were developed in order to settle, control and protect the land often in outlying and border areas.)

preservation of valuable natural areas. However, the great increase in population and urban communities and the extension of kibbutzim and moshavim in the Negev have resulted in substantial changes to natural ecosystems. (Danin, 1983, page 17) (Figures 11, 35 and 38) Development in the Negev has also included numerous permanent, semi permanent and temporary military camps and ranges. Danin (1983, page 17) notes that these areas and especially the movement of tanks have had an impact on the vegetation of the Negev. (Danin, 1983, page 17)

3.3.4 Other types of development include large and small nature conservation zones and national parks have been set up throughout the Negev where conservation is controlled by national and local government organisations. (Figure 12) Although protection is a key factor in their management, these areas are affected by numerous tourists who visit the areas because of the outstanding natural and historical features. Apart from visits to nodal historical sites, tourist activities include hiking, jeep and camel tours, all of which follow marked and unmarked trails.

3.3.5 Ecosystems have been and are affected by erosion caused by traffic as well as the introduction of foreign species, sometimes deliberately introduced or distributed by wind, water, animals and people from areas further afield.

3.3.6 The long term effects of grazing by Bedouin flocks over the millennia on the vegetation of the Negev is largely unknown due to the lack of documentation. However, short-term observations indicate that grazing *'leads to the diminution in size of edible plants and temporary changes in their relative abundance but not to the total extermination of species'*. [55](Danin, 1983, page 17) Grazing also has the effect of allowing some species that are unpalatable to flocks to dominate plant communities. This is

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[55] Refer to Figure 1a. The photograph from the International Space Station shows a distinct line between the Negev and Sinai. The visible line is determined by the control/lack of control of grazing on either side of the border between the Negev/Sinai.

especially apparent with Mediterranean plant, *Asphodelus aestevus.* (Photographs G48 and G49, Appendix H3) Where it is found in abundance it is often a sign of overgrazing. (Shmida and Darom, 1986, page 42) The Bedouin mainly practice dry farming on loessal soils where shallow ploughing only disturbs the surface crust. The roughness of the soil reduces water run-off and therefore the phyto-mass is larger than areas that are unploughed. (Danin, 1983, page 18) However, Bedouin ploughing methods today are similar to those used by the kibbutzim and moshavim. But as yet they do not tend to use modern piped irrigation techniques except in isolated cases. Kibbutz and moshav fields are also treated with fertilisers, and herbicides. The weed species that occur in the Bedouin fields and those of the kibbutz and moshav fields tend to be different (Danin, 1983, page 18), but points to the impact settlement can have on the local habitat and ecology.

3.3.7 Human activity in the Negev has created new habitats, such as along roadsides where the natural vegetation is destroyed and those that thrive *'enjoy the absence of competition for water and nutrients'*. (Danin, 1983, page 18) In road building for example leached upper soils may be replaced with saline lower soils where native saline tolerant species such as *Salsola inermis*, (photograph A25, Appendix H1) and other *Salsola* and *Atriplex* species thrive. (Danin, 1983, page 18) (Appendix H7, photograph DS143 and Appendix H11, photograph FO388) These areas sometimes also provide the optimum conditions for invasive alien species from other countries. These include xenophytes (alien species) such as *Kochia indica* from India via Australia and *Nicotiana glauca* from South America, (photographs FO390 and FO391, Appendix H11), and the salt bush species, *Atriplex halocarpa,* (Figure 26) and *Atriplex semibaccata,* (photographs FO388 and FO389, Appendix H11), also from Australia. (Shmida and Darom, 1986, page 320) (Feinbrun-Dothan, 1998, pages 162-3)

3.3.8 With modern day settlement, the Negev has seen the introduction of numerous foreign plant species. Many of these are the same as those introduced to Israel as a whole. Contemporary landscape and garden planting in the Negev generally tends to follow trends of landscape planting elsewhere in the developed world. Thus planting strategies centre on a hierarchy of plants of mainly non-native species of trees, shrubs, groundcovers, climbers, hedges, flowering annuals and perennials, grasses and turf grass that are used for various functional and aesthetic purposes. (See Figures 11, 13, 14, 15, 17, 34 and 35) These provide shade, define space, provide colour or greenery, prevent erosion etc. Many of these plants are relatively drought tolerant. Some are very drought tolerant. (Figure 30) However it is quite possible to find a plant such as *Bougainvillea sp.* (originally from South America), (Figure 13), or *Leucophyllum sp.* (originally from Texas) (Figure 34), being used in urban environments as well as in a semi-natural environments for example at a car park at a rural historical site. (Refer to Figures 8, 29 and 34,) Although in rural locations there has been a recent attempt to use drought tolerant species that appear to better fit into the local rural surroundings and that appear to be native. This can be seen particularly with the use of *Prosopis* tree species originating in the Americas, (Figure 16), and the grass *Pennisetum setaceum (asperifolium)* originating in the southern Mediterranean and South Africa. (Figure 17) The issues relating to the current and potential effects of plant introduction is a key driver of this research and will be discussed in Chapter 4.

3.4 The Negev - Phytogeography

Introduction

3.4.1 Plant species that are noted in this Chapter have been located and assessed during field studies and are included in the assessment of potential use in Chapters 6 and 7 and Appendices D and G.

3.4.2 This chapter investigates the various ways plants of the Negev are classified according to a variety of systems, and also how they may inform the landscape architect/plantsman [56]. Different floristic life forms are then

[56] The term plantsman is used here as someone who is knowledgeable about plants as a garden professional, amateur or nurseryman.

examined to ascertain whether methodologies used by landscape architects can be improved upon in reference to arid climates.

3.4.3 The chapter notes the most relevant features of the work done by the authorities in the field such as Danin, Stern, Zohary and others. Understanding of these classifications and related areas is a key factor in the research. It pinpoints, according to broad sets of criteria, which plants are growing where and why they grow in these locations. For example, their relationships to certain soil types and/or amounts of precipitation.

3.4.4 Some of this information is very detailed and leads to a greater understanding of which plants could be used in certain areas, particularly in relation to preferred soil types, climatic preferences and minimum water requirements for survival. (Where this information is considered too detailed for the main body of the dissertation, it has been placed in Appendix E).

Negev plant studies and classification

3.4.5 The plants of the Negev have been studied for many years and plant studies are attributed to extend as far back as Aristotle in the 4th century BCE. Floristic exploration in Israel has been carried out since the 16th century as noted by Zohary (1982, page 23). Zohary writes that early studies include the following publications:

- Rauwolf, (1583), findings published in '*Flora Orientalis*' (1755) by Gronovius [57];
- Strand, (1756), '*Flora Palaestina*'. (Strand was a disciple of Linnaeus) [58];
- Hasselquist (1749-52) who travelled in the area and wrote in '*Iter*

[57] Leonhard Rauwolf born Augsburg, June 21, 1535, died September 15, 1596. (Some sources state that he was born in 1540).

[58] Carl Linnaeus, 1707 – 1778 writing under the Latin name Carolus Linnaeus, laid the foundations for the modern system of taxonomy.

Palaestinum' (1757). (Hasselquist was a student of Linnaeus);

- Forsskal, (1875), '*Flora Aegyptica-Arabica*'. (Forsskal was a student of Linnaeus) [59];
- Boissier E., (1867-1888), '*Flora Orientalis*', published in 5 volumes; and
- Posts, (1896), 'Flora of Syria, Palestine and Sinai'.

3.4.6 Zohary (1996, page v), notes that botanical investigations by scholars resident in Israel began with A. Aaronsohn whose *'collections were revised and published'* by H.R. Oppenheimer in 1931 and H.R. Oppenheimer and M. Evenari in 1941. J.E. Dinsmore who was a resident in Jerusalem and an American by birth published in 1912 and in the early 1930's, whilst A. Eig and E. Faktorovsky *'began their floristic studies'* in the early twenties. (Zohary 1996, page v) Most of the later studies have emerged in the last quarter of the 20th century by eminent Israeli scholars, including Michael Evenari, Avinoam Danin, Naomi Feibrun and Daniel Zohary. These later studies offer a framework of knowledge where the landscape architect, such as the author, can locate information, which relates not only to the taxonomy of the plants but also information that relates to their individual characteristics and community associations, growing conditions and origins. This information provides a valuable resource for the research, without which it could not possibly be carried out.

3.4.7 The United States Geological Survey, quoting Kent and Coker (1992) notes the objectives of vegetation classification, is to *'group together a set of observational units on the basis of their common attributes'*. (USGS - NPS Vegetation Mapping Program, Section 3.1, www.) The USGS notes furthermore, that the classification should be a set of groups where

> *'typically, units within a group share more attributes with one another than with units in other groups. For vegetation classification, the unit of*

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[59] Pehr Forsskål, was better known by the Latinised form of his name as Petrus Forsskål, 1732-63)

observation is typically the "stand," defined as a relatively homogeneous area with respect to species composition, structure, and function'. (USGS - NPS Vegetation Mapping Program, Section 3.1, www.)

3.4.8 The USGS, furthermore states that it is important that the process requires clear objectives. If for example the objective is to create an independent vegetation classification system then

> *'attribute data on species, cover, vegetation age and structure, leaf characteristics, bark characters, dispersal mechanisms and life history traits should be collected and organized'.* (USGS - NPS Vegetation Mapping Program, Section 3.1, www.)

3.4.9 This is seen to be different to the classification of ecosystems, where

> *' data on the key environmental features such as soils, hydrology, landform, etc., need to be collected'.* (USGS - NPS Vegetation Mapping Program, Section 3.1, www.) Thus,

> *'the biological and environmental information to be collected, organized, and described must be carefully chosen to meet the objectives of the classification'.* (USGS - NPS Vegetation Mapping Program, Section 3.1, www.)

3.4.10 In the Negev the author has noted that a number of vegetation classification systems have been developed. The USGS, notes that

> *'three have gained widespread acceptance: physiognomic classifications, floristic classifications, and site or ecosystem classifications. The intent of all three is to provide a systematic ordering of vegetation or ecosystem pattern and to relate these patterns to ecological processes'.* (USGS - NPS Vegetation Mapping Program, Section 3.1, www.)

3.4.11 The physiognomic systems and the floristic systems, which will be described below have indeed been used in the Negev, but the author has not yet come across an ecosystems classification of the Negev whose purpose is not to note the existing vegetation characteristics but to *'reflect the potential of a particular site to support various types of vegetation'*. (USGS - NPS Vegetation Mapping Program, Section 3.2.21, www.) [60]

3.4.12 This kind of assessment also considers climate, soils and existing vegetation. It is particularly useful when considering for example forestry planting when such vegetation does not, or no longer exists. A system, which focuses on the potential natural vegetation of the Negev that may become established under certain conditions would have been very useful to the research as it would have provided a means for testing the probability of plant suitability in terms of physical conditions in various regions of the Negev.

3.4.13 As noted above, the classification of plants in the Negev has been approached in a number of different ways, according to the various objectives of the various authors / researchers. These approaches are described below. However, the study would be incomplete without commencing with the broadest scale classification of the world into global biomes.

Global Biomes and the Negev

3.4.14 The layer of life found on earth is called the biosphere. The biosphere is divided into a number of aquatic or terrestrial global biomes, where areas are inhabited by a broadly similar flora and fauna. [61] (Figure 18) This division is somewhere between 9 and 15 biomes depending on the source. A division of the earth into fourteen biomes includes the following:

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[60] The most renowned example is that of Kuchler, who in 1964 and in 1985 mapped the potential natural vegetation, but this is limited to in its focus to only mature climax types.

[61] Biomes are also introduced at smaller scales e.g. for countries where the breakdown of individual areas is much finer. For example in South Africa where 7 distinct biomes have been identified. (http://www.ngo.grida.no/soesa/nsoer/general/about.htm)

- Polar ice;
- Arctic tundra;
- Taiga or boreal forest;
- Mountain zone;
- Temperate deciduous forest;
- Temperate evergreen forest;
- Warm moist evergreen forest;
- Tropical monsoon forest;
- Tropical evergreen forest;
- Chaparral (incorporates Mediterranean areas);
- Temperate grassland;
- Savanna;
- Semi desert; and
- Desert

3.4.15 The majority of the Negev falls within the desert biome and although this broad type of classification provides a starting point for identifying the origin of Negev Desert plant species, it is considered too general to be really useful in understanding plant characteristics, growing conditions and their needs.

Negev - Vegetation / Geographical Classification Systems

3.4.16 A number of hierarchies, which relate to the plants and their relationship to regions, climate, geology and geomorphology have been established for the Negev on its own or the Negev and immediately adjacent areas. These hierarchies are based on different levels of detail of information. The hierarchies, which have been extracted from a number of sources including Feinbrun-Dothan and Danin, (1998), Zohary (1982) and Stern, (1986), may be tabled as follows:

- Phytogeographical Territories: This system utilises 4 overlapping broad-scale territories. The hierarchy is used by Danin, Feinbrun-Dothan and Danin, Stern and Zohary and most other authors writing about plants in the region [62] (Figure 19);
- Physiognomic Vegetation Units: This includes 7 units described by Stern, (Stern, 1986, page 80 and xvi), which generally relates in particular to the *'vegetal appearance (i.e. physiognomy)'* of the area. (Figure 20) Plant species relate directly to edaphic and climatic factors;
- Floristic Subdivisons: Danin, (Danin, *'Flora and Vegetation of Israel and adjacent areas'*, www.) divides Israel as a whole into 19 sub divisions and the Negev is divided into 11 subdivisions. These subdivisions relate to amount of rainfall, soil types and temperature;
- Plant Associations: These are groups of plants, which can be identified with definitive species composition, whose species are repeated qualitatively and quantitatively. (Danin, 1983, page 36) These associations can then be identified specifically in geomorphological districts. Danin, (1983), identifies 10 districts, (Figure 21), and Zohary, (1982), identifies 14 areas in the Negev.
- Geomorphological – Ecological Subdivisions of Vegetation: This hierarchy divides the Negev into 29 units differentiated by Stern, (Stern, 1986, pages 78 to 79), relating mainly to edaphic conditions. (Figure 22)

3.4.17 The above methods of identifying plants relative to their regions and growing conditions thus varies from the broader scale to more refined scales, i.e. from 4 units as far as phytogeographic regions are concerned to 29 units

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[62] The most comprehensive breakdown of the world into phytogeographic territories has been undertaken by the botanist Ronald Good in *'The Geography of Flowering Plants'* (1947), and then by Armen Takhtajan in *'Floristic Regions of the World'*, (1986). Takhtajan, identifies thirty-five floristic regions, each of which is subdivided into 152 floristic provinces.

as far as the geomorphological – ecological units as characterised by Stern. (Stern, 1986, pages 78 to 79) Most of these hierarchical breakdowns are useful, but the amount of detail required about the background of plants that may potentially be used for landscape and/or environmental purposes is also relative to the sensitivity of the area within which the planting is likely to be located as well as the function of the planting. The usefulness of the hierarchies is discussed below.

Phytogeographic Territories

3.4.18 The eminent authors on plants in the region all note that the region may be divided into four phytogeographic territories. (Evenari et al, 1982, Feinbrun-Dothan and Danin, 1998, and Zohary, 1973, 1982.) (Figure 19)

3.4.19 Danin (1983, page 35) states that within Israel these regions coincide with isohyets and with isotherms. [63] The four phytogeographic territories, which are also called phytochoria, or chorotypes, (Danin, 1983, page 35), that intersect the 13 000 square kilometres of the Negev are:

1. Mediterranean: As the name suggests this region is linked to the Mediterranean Sea and the region covers most of central, western and northern parts of Israel. The region also extends southwards into the north eastern Negev. Danin, (1983, page 35), states that in the Negev this area is defined by the 300 mm isohyet. The 300 mm isohyet is located more or less on a west - east line that almost demarcates the northern boundary of the Negev.
2. Irano - Turanian: The Irano - Turanian region extends northwards and eastwards across Turkey, Afghanistan and central Asia to Tibet. The western most part of this region culminates in a regional strip linked to the higher topography and the eastern part of Israel extending into

[63] An isohyet is a line joining places of equal precipitation on a map. An isotherm is a line of equal or constant temperature on a graph, plot or map.

the Negev Highlands. Danin, (1983, page 35), states that the Irano – Turanian region lies between the 300 mm and 80 mm isohyets.

3. Saharo - Arabian: This covers an extensive area including the Sahara Desert extending to the east across Sinai and most of the southern Negev and eastwards across the Arabian peninsula to the western edge of Iran. Danin, (1983, page 35), states that the Saharo-Arabian region dominates in areas receiving less than 80 mm of rainfall.

4. Sudanian: The Sudanian region extends up from Africa, on the eastern edge of the Sinai Peninsula and into Israel towards the southern Negev at the Gulf of Eilat / Gulf of Aqaba. Danin, (1983, page 35), states that the *'boundaries of the entire area coincide with the isotherm of 23°C'.*

3.4.20 Figure 19 extracted from Feinbrun-Dothan and Danin, (Feinbrun-Dothan, 1998, page 10), indicates the approximate extent of the four phytogeographic territories in the Negev and the breakdown of species belonging to each area. It must be noted that these areas overlap and plants from one territory may be found growing in the same area with plants from another territory.

3.4.21 Approximately 900 plant species are found in the Negev out of approximately 2400, which are found in Israel as a whole. (Zohary, 1982, page 29) Of these species many are associated with one or more phytogeographic region. Most of these species are annuals. A study of the breakdown of species calculated from Feinbrun-Dothan and Danin's 'Analytical Flora of Eretz-Israel' with regard to phytogeographic territory and plant origination undertaken by the author as part of this research shows the following territorial/species breakdown in the Negev:

Table 3. 1 Phytogeographic Territories and Number of Species Found in the Negev

Phytogeographic Territory	Number of Species found in the Negev out of a total of approx. 900 species
Mediterranean	310
Irano - Turanean	176
Saharo - Arabian	242
Sudanian	71
Mediterranean / Irano - Turanian	243
Mediterranean / Saharo - Arabian	24
Irano-Turanian / Saharo - Arabian	59
Saharo-Arabian / Sudanian	39
Mediterranean / Irano-Turanean / Saharo - Arabian	24
Irano-Turanian / Saharo - Arabian / Sudanian	5
Tropical and Subtropical including African	55
North and/or South American	20
Australian	4
Most Regions	8
South Asian	1
Central African	1

Cells coloured in grey note numbers of non-native species and their origin.

3.4.22 The above table illustrates that the majority of plants are Mediterranean, Irano - Turanian or Saharo - Arabian. The table also shows that many of these plants are found in more than one region. Danin, (1983, page 35), notes that *'such a chorotype is called bi - regional or pluri - regional'*. The most number of species are from the Mediterranean territory, but it must be noted that the Mediterranean species are generally restricted to the northern Negev closer to the Mediterranean itself and cannot be found in the hotter, more arid regions further to the south and east.

3.4.23 Table 3. 1 above illustrates that there are approximately 84 species (cells coloured grey), which do not belong to any of the 4 major regional phytogeographic territories. (The reason why this figure is approximate is because some of the species may be found in more than one region). However, all of these are foreign or alien species that have been introduced willingly, (for example *Eucalyptus* [64] species) or inadvertently such as *Nicotiana glauca*, over the years. (Refer to Figures 24, 26, 32, 36 and photograph FO391, Appendix H11) This means that almost 10% of the species found in what may be called natural areas in the Negev, are foreign to the region. This is extremely significant in terms of the potential effects these plants can have on the environment, although it appears less significant compared to what has occurred elsewhere in the world. (The effects of the introduction of foreign plants around the world are discussed below in Chapter 4).

3.4.24 The understanding of which plants belong to which phytogeographic territories is considered by the author to be important to landscape architects working in the region, as the categorisation indicates to some extent the likely plant associations, and climatological conditions within which the

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[64] Note: All species that have been assessed in the field are highlighted with a dotted underline.

plants grow, and thus their potential requirements for survival and thus conditions for potential use. As mentioned above, Danin, (1983, page 35), points out that the boundaries of the Mediterranean, Irano - Turanian and Saharo – Arabian territories coincides with the amount of rainfall received, and the boundaries of the Sudanian region coincides with the average daily temperature of 23°C. Thus, for example, Mediterranean species do not naturally grow beyond areas of the northern Negev, which generally receive less than 300mm of rainfall [65]. (Refer to Figure 2.)

3.4.25 Thus the definition of the territories and the breakdown of species within each is considered here as a useful start for the landscape architect working in the region as it broadly sets limits for the use of plant species based on water and temperature requirements.

Stern's Physiognomic Categories

3.4.26 The Negev can be divided into seven physiognomic [66] categories as illustrated in Figure 20 and as described by Stern, (Stern, 1986, page 80 and xvi). The amount of information relating plant species to these broad regions is rather limited but it does provide the researcher and the landscape architect with some clues, which also relate to annual precipitation and water availability as well as the edaphic conditions relating to rocks and water run-off. The breakdown of these areas are as follows with the descriptions in Appendix E.

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[65] There are exceptions to this, where relict species grow in pockets where additional water can collect, e.g. where there is run off of precipitation into soil pockets. This additional water replicates the amount of water received in core areas. This occurs with *Sternbergia clusiana* and *Narcissus tazetta* in the foothills around the town of Yerucham where rainfall is approximately 100 – 120 mm per annum. This is less than half the amount found at the border of the Mediterranean region.

[66] Appearance of the vegetation.

1. Savanoid;
2. Halophytic trees and shrubs;
3. Cultivated zone;
4. Steppe with semishrubs;
5. Steppe with trees;
6. Semisteppe batha [67]; and
7. Contracted vegetation [68].

3.4.27 Danin's floristic subdivisions (Danin, (1), www.), are similar to the physiognomic territories described above. However, Danin describes 11 subdivisions found in the Negev out of 19, which are located across Israel.

Floristic Subdivisions

3.4.28 Danin's 11 floristic subdivisions found in the Negev, (Danin, (1), www.), include important information for the research with regard to dominant plant species and communities and the climatic and soil conditions in which they grow. This detail is especially important for the research as it identifies the tolerance of species in terms of water supply and temperature and their growing conditions in terms of types of soil that they tolerate and/or prefer. Plant specific data and soils information is excluded here and included in Appendix F where it can be more readily extracted and utilised in reference to species characteristics, plant choice and the potential for better plant establishment through the improvement of micro landscape conditions. Danin's 11 floristic areas include:

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[67] Batha is an Israeli term for the Mediterranean habitat usually called garigue. Garigue is *'open rocky ground dominated by dwarf shrubs generally less than 50 cm high'*. (Burnie, 1995, page 22).

[68] Contracted vegetation refers to vegetation that is restricted to wadis (dry river courses). The term derives from Monod in 1931, who referred to this semi shrub vegetation. (Danin, (1), www).

1. Semisteppe batha;
2. Steppe vegetation;
3. Shrub steppe with trees of *Pistacia atlantica*;
4. Desert vegetation;
5. Sand vegetation;
6. Oases with Sudanian trees;
7. Desert savannoid vegetation;
8. *Haloxylon persicum* on sands;
9. Swamps and reed thickets;
10. Wet Salinas; and
11. Synanthropic [69] vegetation:

3.4.29 The research that the author has carried out partially centres on the problems associated with some of these synanthropic plants, which have been deliberately or inadvertently introduced into the landscape by people. The plants have then started to colonise greater areas of land with detrimental and/or potential detrimental effects on ecological conditions and landscape character and landscape quality.

3.4.30 Danin's 11 floristic divisions are extremely useful. This work breaks down the Negev into well-defined and recognisable areas as well as providing information on the main species and their relationship to the local conditions; soils, temperature, topography and water regimes. This work provides a strong foundation for the understanding of these areas and plant growth and helps with the categorisation and indexing of the plants relative to their needs and growing conditions.

[69] Ecologically associated with humans

Plant Associations

3.4.31 Danin, (1983, pages 36 to 54 and page 63) divides the Negev into ten 'geomorphological districts' where he notes the dominant plant associations. Within each district he observes the main plants, whose names are used as the name of the association, which relates to the dominant ecological community, with its dominant species. Danin furthermore relates these associations to the edaphic substrate and the precipitation this receives. This information is highly useful to the research, as it provides data on plant species as well as general growth requirements with respect to soil type and water demand. The hierarchical breakdown of these districts and their plants associations and edaphic conditions is outlined below. The explanation of these areas and associations is located in Appendix E. (Refer to Figure 21, which is derived from Danin, 1983, pages 36 to 54 and page 63. The numbers below correlate to the numbers on the figure except for number 10 which corresponds to number 15 on the figure.)

1. Judean Desert;
2. Dead Sea Valley;
3. Northern Negev Highlands;
4. Central Negev Highlands;
5. Negev Lowlands;
6. The Coastal Plain of the Negev;
7. Arava Valley;
8. The Mediterranean Sands and Salt Marshes;
9. Gravely Plains of Central Sinai and Southern Negev; and the
10. Coastal Plain and Foothills of the Gulf of Eilat. (The area is noted as number 15 on the Figure.)

Geomorphological - Ecological Subdivisions of Vegetation

3.4.32 Stern et al, (1986, pages 78 and 79), have divided up the Negev according to

29 geomorphological – ecological subdivisions as the ecology of a location is directly linked to geomorphological conditions, i.e. to the structure and make up of the earth's crust. Naming these 29 areas they have also noted the most prevalent plant species, which make up the floristic part of the ecology of each area and the prevalent edaphic conditions. This breakdown is illustrated in Figure 22. (Stern et al, 1986, page78) This information is included in Appendix E.

3.4.33 The plant species mentioned by Stern et al, (1986 pages 78-79), which have been identified in the field by the author and which will be analysed in terms of their characteristics and potential use are as follows:

Trees

3.4.34 *Acacia gerrardii, A. raddiana, A. tortilis, Moringa peregrina, Pistacia atlantica, Phoenix dactylifera, Populus euphratica Salvadora persica, Tamarix nilotica, Ziziphus spina-christi.*

Shrubs

3.4.35 *Anvillea, garcinii, Asteriscus graveolens Anabasis articulata, Anabasis setifera, Artemisia monosperma, Artemisia sieberi, Arthrocnemum macrostachyum, Atriplex halimus, Calotropis procera, Calligonum comosum, Cleome droserifolia, Convolvulus lanatus, Fagonia mollis, Gymnocarpos decander, Halogeton alopecuroides, Haloxylon persicum, Hammada scoparia,, Helianthemum kahiricum, Helianthemum vesicarium, Lycium shawii, Nitraria retusa, Noaea mucronata, Ochradenus baccatus, Pituranthos tortuosus Prosopis farcta, Pulicaria crispa, Reaumuria hirtella, Retama raetem, Salsola tetrandra, Salsola tetandra Salvia lanigera, Sarcopoterium spinosum, S. fruticosa, Suaeda monoica, Thymelaea hirsuta, Zilla spinosa, Zygophyllum dumosum.*

Perennials

3.4.36 *Alhagi graecorum, Ballota undulata Echinops polyceras, Erodium crassifolium, Fagonia mollis, Peganum harmala, Urginea maritime, Zygophyllum album.*

Annuals

3.4.37 *Mesembryanthemum nodiflorum, Salsola inermis.*

Geophytes

3.4.38 *Narcissus tazetta, Sternbergia clusiana, Tulipa systola.*

Climbers

3.4.39 *Ephedra foeminea*

3.5 Plants of the Negev – Floristic Life Forms

3.5.1 Plants in arid climates have to endure difficult growing conditions. They include heat, lack of available moisture, desiccating winds and poor soil conditions with salts and other phytotoxic chemicals. When specifying plants for landscape and environmental purposes, landscape architects mostly use a common horticultural hierarchical system to define plant character, but with xerophytic and halophytic plants, which grow in arid climates some adjustment is useful and indeed required.

3.5.2 In horticultural terms, plants are classified by a range of criteria. Thus plants are classified according to their size and woodiness, e.g. trees and shrubs, to their growth habits, e.g. climbers and ground covers, to their life-span, e.g. annuals, perennials and biennials and according to vegetative reproduction e.g. bulbs. However, there are a number of different ways of classifying floristic life forms, which may be useful in understanding plants and plant use in arid climates.

3.5.3 The first and most important of these classification methods, which is not usually used by landscape architects is Raunkiaer's classification method, which is based on the *'assumption that species morphology is closely related to climatic controls'*. (Kent, 1992, page 29) The system works on distinguishing the height of the perennating [70] buds of each species above the

[70] Perennating buds are the renewal buds where growth commences in the next season.

ground. (Figure 23)

3.5.4 Küchler's method, uses two broad categories that of woody and herbaceous plants. (Kent, 1992, page 32) Other systems of classifying vegetation and habitat include Fosberg's structural system, (Kent, 1992, page 35) and the habitat description approach of Elton and Miller. (Kent, 1992, page 35)

3.5.5 Raunkiaer's classification method is perhaps the most pertinent for assessing the plants of the Negev as the method indicates part of the survival strategy of the plant within the dry, hot environment. As noted above, the method uses the location of the perennating or renewal buds, as well *'on which plant parts are shed during the season unfavourable for growth'*. (Danin, 1983, page 24) (Refer to figure 23) The method also introduces a group of plants called chamaephytes where the perennating buds are close to, but above the ground. Israeli literature refers to these plants as "*benei siach*" (שיח בני). This can be translated as semishrub (Danin, 1983, page 25) or dwarf shrub and is in contrast to the larger phanerophytes, which constitute the larger shrubs and trees. There is, however, some difference between how the terms are used by Raunkiaer and by the literature in Israel. For Raunkiaer, a phanerophyte is above 2 metres and a chamaephyte below 2 metres, whereas in Israel it is interpreted as a dwarf shrub, which would be in actual fact much smaller than 2 metres in height. A translation of a dwarf or semishrub as classified by Feinbrun-Dothan and Danin is as follows:

> *'They are low perennials 20 - 50 cm in height, part of which is woody and where the upper parts of the branches or parts of the plant dry out and die from year to year'*. (Feinbrun-Dothan and Danin, 1998, page 24)

3.5.6 Danin explains in his publication on the *'Desert Vegetation of Israel and Sinai'*, that the upper branches become dry after seed dispersal and thus the dwarf size of the shrub is retained. (Danin, 1983, page 5) Thus these shrubs never grow into large shrubs. The most notable point about Chamaephytes, however, is the fact that their low stature has to do with their survival strategy. They remain dwarf sized and are classified by Kent and Coker, (Kent, 1992, page 40) as follows:

- Suffruticose chamaephytes - upper limbs die and only lower parts of plants remain in unfavourable periods.
- Passive chamaephytes - shoots weaken and drop off on onset of adverse conditions.
- Active chamaephytes - shoots are only produced along the ground.
- Cushion chamaephytes - a modification of the passive types where shoots are massed close together and the close packing of shoots creates a cushion.

3.5.7 The other life forms within Raunkiaer's system, (refer to Figure 23), are therophytes, geophytes, hemicrophytes and phanerophytes and are described as follows:

- Therophytes – Danin, (1983, page 24), describes these as annuals, which have their *'renewal bud in their seed'*. He notes that *'during the dry season all other parts of the plant are dead'*.
- Geophytes – These have their perennating buds under the soil and are protected by dry leaves and *'sustained by food reserves in a storage organ'*. (Danin, 1983, page 24) During the dry season, the parts above ground dry out and are shed. (Danin, 1983, page 24)
- Hemicryptophytes - These are perennial plants, where the renewal bud is located *'at the soil surface at the top of a storage root or system of thick roots'*. (Danin, 1983, page 24) The dry leaves desiccate during the summer and protect the bud. (Danin, 1983, page 24)
- Phanerophytes – These include the larger shrubs and trees where the renewal buds are located some way above the ground. Danin, (1983, page 25), notes unlike the chamaephytes, that shed branches, phanerophytes do not shed their branches. Leaves are replaced seasonally and any branch loss, *'depends on the water regime'*.

3.5.8 The description of life forms of plants in the Negev used in this research is based on that used by most landscape architects in the U.K. and which is also used in the literature on the plants of the Negev and Israel. In the definitive publication of plants of the region by Feinbrun-Dothan and Danin, titled '*Analytical Flora of Eretz - Israel*' (1998), the plant species are classified according to their growth and seasonal characteristics as well as their life form. The system broadly uses Raunkiaer's method and thus describes the species as being either

- Annuals;
- Biennials;
- Perennials;
- Semishrubs / Dwarf shrubs
- Shrubs; and
- Trees.

3.5.9 This is similarly the case for the publications by Shmida and Darom, namely the '*Handbook of Wildflowers of Israel – Desert Flora*', and '*Handbook of Wildflowers of Israel - Mediterranean Flora*'. However here the classification indicates whether the plant species is a geophyte, (from Raunkiaer's system where the renewal bud is below ground) or a climber / creeper or perhaps even a parasite. The classification system is as follows:

- Annuals;
- Perennials;
- Perennials (with large leaf rosettes);
- Geophytes;
- Semishrubs / dwarfshrubs;
- Shrubs;
- Trees;
- Climbers;
- Grasses; and
- Parasites

3.5.10 This system comes closest to that mostly used by landscape architects when identifying and using plant species, except for the distinction made above to plants that have large leaf rosettes and semishrubs. In the United Kingdom, for example, plants for landscape use are usually classified as:

- Annuals;
- Biennials;
- Bulbs and Corms;
- Grasses
- Herbaceous Perennials;
- Shrubs; and
- Trees.

3.5.11 Distinctions are made as to whether perennials are hardy, half-hardy or tender and plants are often grouped together under the categories of groundcover and climbers. The category of semishrubs does not exist, although it is quite likely that some shrubs do lose their limbs and remain smaller due to harsh winter conditions.

3.5.12 A study of the breakdown of species types with regard to life form undertaken as part of the research is shown in Table 3.2 below.

Table 3. 2 Numbers of Different Types of Plants and Percentage of Total Negev Species

Life Form	Number	% of Total of 1282 Negev Species
Trees	19	1.4%
Shrubs	58	4.5%
Semi-shrubs	136	10.6%
Perennials (including	374	29.3%

Life Form	Number	% of Total of 1282 Negev Species
geophytes, grasses and reeds)		
Annuals (including grasses and reeds)	695	54.2%

3.5.13 It must be noted that in some cases life-form depends on the availability of water and micro-climate and thus for example some species may be considered to be shrubs in one area but may develop into trees in more favourable conditions. Similarly some annuals may develop into perennials or biennials or even into semishrubs and vice-versa in differing conditions. Furthermore, it must be noted that the perennials here include the geophytes and the perennials and annuals include numerous grass and reed species.

3.5.14 The above noted primacy of annuals at 695 species and 54.2% in the region does not provide the landscape architect with a wide palette of plant choice for normal use in landscape schemes as the annuals are usually only evident during and immediately after the rains. However, the hypothesis that the native plants of the Negev are suitable for potential use relies on the availability of a range of native plant types. A suitable palette of plants for landscape/environmental and horticultural purposes in the region thus needs to be available. This will be assessed in Chapter 6.

3.6 Summary and Conclusions

3.6.1 The Negev Desert is an ancient and important region. It is important historically and it is of strategic significance to the development of Israel, for its growing population, defence forces and for local, national and international tourism. Its heterogeneity is a key and positive feature, which provides large variations in biotic and abiotic features.

3.6.2 As a hot dry and semi-arid desert region water is a key determining factor for living organisms including people. Rainfall is scarce and diminishes southwards and eastwards, but this is not the only factor that determines plant growth. The heterogeneity of the soils also has a great effect on plant locations where water may become available, be concentrated or lost to the root zone through run-off and/or percolation. Most of the soils are highly alkaline and many plants are saline tolerant, with some being extremely tolerant.

3.6.3 Man has been present in the Negev for thousands of years and well before the Common Era there is evidence that people had a destructive effect on the natural vegetation. These negative effects have continued into the 20th and 21st century with the grazing of flocks and the introduction of foreign exotic species, some of which have become dominant and others, which have the potential to oust the native species. The main effects of introducing foreign species such as *Eucalyptus sp.*, *Nicotiana glauca* and *Acacia longifolia* are current and potential changes to local ecology, landscape character and landscape quality.

3.6.4 These foreign species are located in various homogeneous areas that are defined by a number of prominent Israeli scientists according to a range of different determining factors. These hierarchies are important in understanding the relationships of plants to territories, edaphic and landscape conditions and help to understand and appreciate the native plants relative to the growing environment, which include geogmorphological, ecological and physiognomic conditions, soils, water regimes and climate. Of most use for the author is the breakdown of the Negev into 4 main phytogeographical regions, which include the Mediterranean, Irano - Turanian, Saharo - Arabian and Sudanian regions. It is also important to realise that many of the plants species overlap territories and that they form plant associations. Danin's, (1983, pages 36 to 54 and page 630), breakdown of the Negev into 10 geomorphological districts where the dominant plant associations are described relative to soils, edaphic conditions and water regimes is particularly useful. An understanding of the physical context in which the native Negev plants are found provides relavant information as to the potential likely growing conditions required for the native species that are considered suitable for use.

3.6.5 The types of plants that are found in the Negev and their life-forms are a key consideration of defining plants for use. In the United Kingdom, landscape architects use a traditional hierarchy based on size, morphology and life-form. In desert areas, Raunkiaer's life-form classification system, which relates directly to the location of the perennating bud and the survival strategy of the plant within the dry, hot environment where some life-forms shed parts to survive is particularly important. Semi shrubs / dwarf shrubs belong to one of these groups and they form a significant part of the floral Negev environment. This life-form is not generally recognised or used in more temperate climates. The understanding of the strategies used by plants to survive drought thus helps to inform the framework for plant use in the Negev. Annuals for example, evade the drought season by setting seed before the drought commences and the seed only sprouts once the drought has ended. Raunkiaer's life-form classification system is thus important for the landscape architect to define suitable use in desert areas.

3.6.6 The issue of plant suitability and choice is not, however, straightforward in arid climates including the Negev and the issues relating to how plants are used within the Negev, within the existing landscape paradigm and within an alternative landscape paradigm is discussed below in the next chapter, Chapter 4.

4. CHAPTER 4 LANDSCAPE PARADIGMS FOR THE NEGEV – A LITERATURE REVIEW

4.1 Introduction

4.1.1 Following on from Chapter 3, which forms part of the literature review, and which focuses on the physical and human geography of the Negev as well as on life-form characterisation systems, this chapter concentrates on current plant use and research in the Negev and an analysis of why native plants are not generally used. This is followed by a review of the historical and contemporary use of native plants with particular reference to Jens Jensen, the American landscape architect who initiated the use of native planting and to Roberto Burle Marx who use native plants in numerous remarkable projects in Brazil. The effects of using foreign, alien species and particularly the issue of water and the issues of ecology, landscape character, landscape quality and quality of life are investigated.

4.1.2 The concept of using native plants to benefit biodiversity, ecology and wildlife is quite common. In the U.K., the use of native plants and especially native tree planting, is often encouraged by the local planning authorities even in more urban settings. [71] The idea of using native plants has evolved and become even more robust and rigorous, where not only is there the requirement to use native plants but these plants also need to be sourced from plant material and seed sources located as close by as possible to the proposed planting area. This rigorous procedure thus ensures that the genetic makeup of the introduced plants remains as close as possible to the original species in the locality. The term 'local provenance' is used when

[71] The author has experience on numerous projects where the local council, e.g. Maidstone in Kent have insisted that native trees are used unless proved that this would be unfavourable.

describing plant stock or seeds from the locality. [72] In this regard, The Natural History Museum states that

> *'when gardening for the benefit of wildlife, it is important to use seeds and plants of known British (and preferably local) provenance (the term British native-origin is used to denote stock that has been produced from material originally collected from British populations). Using such material helps prevent the loss of distinct local varieties by pollution of the local gene-pool'.* ('Natural History Museum' www.)

4.1.3 The use of plants of local provenance is thus seen to be important in the U.K. and the principles of maintaining the local gene pool and retaining genetic distinctiveness should be pertinent to other areas as well, including the Negev Desert. Indeed it is considered that in an area such as the Negev, with its heterogeneous character and where plant populations are subsequently scattered and diffuse, that local genetic distinctiveness probably abounds. This should be recognised where there is the potential for reintroducing native plants or where they may be introduced close to existing native populations.

4.2 Planting in the Negev Desert

Introduction

4.2.1 Over the last fifteen years some valuable research has been undertaken with regard to the suitability of plants for use in the Negev. Most of this work, which focuses on the issue of water and the need to use plants that have minimal water demands, has been carried out by the Institute of Applied Research, Ben Gurion University of the Negev. It includes three important studies, which have investigated various plants from around the world for landscape purposes as follows:

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[72] The use of native stock from the locality is advocated by many wildlife and landscape organisations including the 'Natural History Museum' and 'Floralocale' (www. sites)

- Ben Dov Y., Forti M. and Pasternak, D. 1993, *'Plants for Desert Landscaping'*, Institute for Applied Research, Ben Gurion University;

- Ben Dov Y., Forti M., Pauker R. and Pasternak, D. 1997, *'List of Recommended Plant Species From Four Locations in the Negev Desert'*, Institute for Applied Research, Ben Gurion University.

- Ran Pauker, 1996, *'Water Wise Gardening - List of Recommended Plants & Water Wise Landscaping'*, Ben Gurion University of the Negev Institute of Applied Research and Kibbutz Nir Oz.

4.2.2 A fourth study looks at fodder production with saline water. It is an important document as it lists plants that are suitable for landscape purposes using seawater as a water source:

- Pasternak D., (Compiler), 1990, *'Fodder Production with Saline Water'*, The Institutes for Applied Research, Ben Gurion University of the Negev.

4.2.3 The article and database by Pauker, (1996), discusses plants which have been assessed for 'water-wise' gardening. However, despite the effort that has gone into this research there was no comprehensive investigation of native species. It is surprising that local professionals in the field have ignored their own floral heritage and have investigated foreign species instead. Furthermore, the research indicates that little or no account has been taken of the potential ecological and landscape consequences of such planting. Plants are deemed suitable for use as long as they establish and thrive. (In this respect, the author has witnessed at first hand the introduction by The Institute for Applied Research, of *Pennisetum* grass species, probably *P. setaceum* from Africa and its spread by the wind from the trial grounds into neighbouring fields north of Beer Sheva.)

4.2.4 Most importantly, the research by Ben Dov, Pasternak and Pauker, also ignores the fact that not all landscapes for plant use are gardens. In many respects the studies mentioned above echoes research that has been going on since the boom development periods in the 1970's and 1980's in the Middle East and is still being carried out today. Whereas, the main thrust of the research by the author is to 'discover' plants that are drought tolerant and/or saline tolerant and that are suitable for use for a variety of landscape and environmental purposes.

4.2.5 Apart from Adams and Willens, (1978), many examples of the past and present research and publications, such as Clouston 1977, Miller 1978, Van Ollenbach 1978, Duffield and Jones 1981, Krieg, 1999 and Jones and Sacamano 2000 largely ignore the potentials of native species as well as disregarding the issues of the potential effects the use of foreign species may have on the local landscape ecology, landscape character and landscape quality. The documents furthermore generally do not differentiate between native plant species and non-native species and plant use strategies rely principally on plant growth / use characteristics, (tree, shrub, groundcover, climber etc.) and little else. Furthermore, the advocated plant use does not generally relate to any defined landscape character planting zones. Additionally an effective strategy or paradigm for plant use in various and different landscapes in arid regions has not generally been considered.

Considerations of Three Negev Planting Texts

4.2.6 The authors of *'Plants for Desert Landscaping'*, Ben Dov, Forti and Pasternak, (1993) note that their research

> *'presents the accumulated knowledge of more than 50 man-years dedicated to the search for, and identification, domestication and development of plant material that can play a role in desert gardening and landscaping'.* [73]

4.2.7 The summary of the research is written with pride and indeed the researchers have created a remarkable document and database of information in its objectives to find suitable plants which would help to *'improve quality of*

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[73] The 1993 publication, which is in Hebrew, was kindly given to the author by Yossi Ben Dov and Dov Pasternak with an English translation of introductory text to the schedule of plant species. The translated text does not have page numbers.

life' through the creation of *'attractive gardens and landscapes'* in desert environments. (Ben Dov et al, 1993). The authors of the publication state that their motivation was to find suitable plant material from around the world that *'could wisely be incorporated into desert landscaping'* and that they hope that the material in the book *'will help ... gardeners, landscape architects, planners and others ... in creating beauty spots in the desert* and *'to do so in a most satisfying and thoughtful way'*. (Ben Dov et al, 1993). This research is valuable for the trials that were carried out with the plants and the establishment of a garden on the hostile terrain of the Dead Sea Works at 'Sedom'. Furthermore the research notes the origin of the species, potential uses, and additional amounts of water required above 200mm that would be required as well as a range of saline tolerances that can be accepted by the different species.

4.2.8 Although the research is remarkable, Ben Dov et al's attitude towards finding generic solutions for desert environments appears ill-judged in the context of sustainable development in desert environments. A core principle of sustainable development is the consideration of contextual criteria and the use and development of locally based solutions. The introduction of foreign species 'flies in the face' of this precept, not least because the identity of each location is ignored but also because the introduction of foreign plant species changes the landscape and ecological character and quality of an area and thus the area is not sustained. In the second instance, the heart felt idea of *'creating beauty spots in the desert'* is based on the same misplaced idea that the desert needs to be greened for it to have value. (Refer to paragraphs 4.2.16 and 4.2.17 below.) The greening the desert and *'making the desert bloom'* is also a prime goal of the JNF, (Jewish Nation Fund).

4.2.9 The overall number of species and sub species that are considered within the publication is 395. This includes 37 *Eucalyptus* and 25 *Melaleuca* species from Australia. However only approximately 50 of the species considered are native to the Negev. The identification of so many foreign species as opposed to native species raises some questions. In the first instance, why were so few native species considered suitable for inclusion in the publication?

4.2.10 It is possible that the answer to the initial question lies with the fact that a professional landscape architect was not part of the research team. Although the scientific excellence of the team is acknowledged it is doubtful that the team had the knowledge and experience that a landscape architect would have brought to the research. It is suggested that the scientific aspects of the research have been well considered, for example with regard to water demands and soil salinity but that the landscape potentials of plants have not been adequately considered. Furthermore, it appears that the plant material was chosen relative to a preconceived idea of suitability relative to the functions and aesthetics of planting in a 'garden' rather than in the landscape, which, like the Negev, is heterogeneous.

4.2.11 The scientists' perception of a garden is likely not to take much account of ecological and habitat considerations and the establishment of plant communities [74]. Additionally it is apparent that the suitability criteria for choosing the plants relates to the ideal of the garden as being uniformally 'green' and as a 'beauty spot'. It is thus suggested that the team was suited to undertake the scientific aspects of the research but they were not totally qualified and open to take a holistic view of the landscape, as a professional landscape architect might have done. Furthermore, the researchers have not considered what the potential effects of the introduction of foreign species may have on the ecology and landscape character of the Negev and where foreign plants may be suitable and where they may not.

4.2.12 The objectives in the selection of plant species by Ben Dov, Forti, Pauker and Pasternak in *'List of Recommended Plant Species From Four Locations in the Negev Desert'*, is for *'afforestation and landscaping in arid*

[74] The reference to scientists here does not mean ecologists or botanists an drefers to the scientists undertaking the research under discussion.

conditions'. (Ben Dov et al, 1997, page 1) The 16 page publication [75] notes that trials were held in 4 locations in the northern Negev at kibbutz 'Nir Oz' located east of Beer Sheva towards the Gaza strip, 'Sede Teiman' and 'Omer', located immediately north east and northwest of Beer Sheva and at kibbutz 'Sapir' located in the Great Rift Valley, the 'Arava'. Nir Oz receives approximately 250 mm of rainfall being closest to the Mediterranean coast whilst the two sites near Beer Sheva receive approximately 180 – 200 mm of rainfall per annum. The plants in these locations were not given any additional irrigation. Precipitation at Sapir is approximately 25 mm per annum and irrigation water was supplied which contained *'up to 2000 ppm salts'*. (Ben Dov et al, 1997, page 1) The field tests carried out by the researchers were carried out over a 10 year period and the species lists include trees, tall shrubs, shrubs and prostrate plants for *'afforestation, ground cover, landscaping etc.'* taking into account *'phenology,* [76] *sensitivity to environmental factors etc.'* (Ben Dov et al, 1997, page 1)

4.2.13 This research published in the *'List of Recommended Plant Species From Four Locations in the Negev Desert'*, ties into the aforementioned research undertaken by the same authors in the publication *'Plants for Desert Landscaping'* discussed above in paragraphs 4.2.6 to 4.2.11. The research notes the recommended species from the three sites in individual sections and details the origin of the plants. At the 'Omer' plot, 48 species are recommended. Most of these are Australian species. It is not apparent if any native species were included in the trials but no native species were

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[75] This booklet in English was kindly given to the author by Yossi Ben Dov and Dov Pasternak.

[76] 'Phenology is the study of the timing of recurring biological phases, the causes of their timing with regard to biotic and abiotic forces, and the interrelation among phases of the same or different species'. (European Phenology Network www.)

recommended. 89 species are recommended at the 'Sede-Teiman' plot. Only 8 of these are native to the Negev. At the 'Nir Oz' plot 48 species are recommended. 5 of these are native to the Negev. At 'Sapir', in the Arava, 56 species are recommended. Four of these are native to the Negev.

4.2.14 Although the native versus foreign mix of species actually trialled is not evident in the publication it is clear that the recommended plants are mostly alien to the Negev. This suggests, as argued above that the authors have not taken into consideration the potential effects these plants may have on the intrinsic landscape settings as well as ecological and biodiversity characteristics of the Negev. Native plants, on the whole appear to have been excluded and/or discarded. This is probably because the aesthetic sensibilities of the researchers, as noted above in paragraph 4.2.10 are for an idealised verdant landscape. The possible reasons for this type of aesthetic sensibility is noted in section 4.3 below. Furthermore as suggested above in the context of the previous publication, the research would have benefited from the inclusion of a professional landscape architect, although Ran Pauker is a noted gardener on Kibbutz 'Nir Oz'.

4.2.15 The third publication written by Ran Pauker and entitled *'Water Wise Gardening – Drought Resistant Plant Introduction and Acclimatisation - List of Recommended Plants'*, consists of a 6 page list of plants that have been assessed over a ten year period [77]. The plants are noted as either *'A – thrives under restrictions specified in "Remarks" column* or *'B – less successful but worth trying'*. (Pauker, 1996, page 1.) The schedules also note where additional irrigation above the approximately 240 mm of precipitation was given.

4.2.16 The Pauker study notes 160 species. Of these, only two tree species are native, namely *Pistacia atlantica* and *Tamarix aphylla*. It appears evident that in the study carried out by Pauker, the emphasis has been on the

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[77] A copy of the 6 page publication was kindly given to the author by Ran Pauker.

introduction of foreign species. Once again, the criticism of the study is that the native plants have been largely and intentionally ignored and the potential impacts of introducing foreign species, has similarly been disregarded. Although it is acknowledged that Pauker is an accomplished gardener and experienced researcher, the fundamental weakness of the study relates to the fact that not every landscape project needs to be treated as a garden. The apparent criteria for selecting plants, which are suitable or not for use, for Pauker and the other authors discussed above appears too limited and narrow. This is because their idea of the landscape is an ideal one, *'creating beauty spots in the desert.'* (Ben Dov et al, 1993). Their vision is for a changed Negev, one that is green and verdant and this can be achieved by introducing foreign species that can accept the local conditions. In general, this vision of the Negev appears mistaken as the Negev's landscapes are unique and should not be turned into something else, and in the worst-case scenario, little versions of arid Australia. The photograph in Figure 24 illustrates the point where, the most dominant feature is the stand of *Eucalyptus* trees that has been planted deliberately. Figure 26 shows *Atriplex halocarpa*, formerly named *A. spongiosa* that was brought to Israel as a fodder plant and that has escaped.

4.2.17 The authors of the above texts have not given due consideration in principle to the importance of locality, of 'genius loci' or spirit of the place and that the Negev Desert like many other deserts have intrinsic landscape and ecological values that are sensitive to development. The studies that they have undertaken centre on the suitability of the plants to survive and grow and to their credit to reduce the demands for water. However, local plant species have largely been ignored as part of these studies and the possible reasons for this are discussed below in Section 4.3.

4.3 Why Native Plants Are Not Used in the Negev

4.3.1 It is unusual to see native Negev plants being used for any purpose in the Negev except on the odd occasion where small tree plantations have been created by the Jewish National Fund, (JNF), using local *Acacia raddiana* species. (Figure 25). And yet many of the native plants are seen to be visually attractive by local people, when they are viewed in their local habitat. [78] The fact that these plants are seen to be attractive or aesthetically pleasing to the eye is not at all strange, because the forms, shapes, colours, textures and smells of the plants sometimes are very similar to many of the species used in western gardens today. Thus for example, we find tulips and anemones, iris and other flowering bulbs, shrubs, annuals, perennials and trees growing in the wild that are not generally dissimilar to the species found in many gardens around the world.

4.3.2 The landscape planner Tom Turner suggests that the principles relating to the use of native plants is no different in deserts as it is in more temperate climates .[79] Most people, he says, are reluctant to have wildflowers in their gardens as they are too vigorous and not exotic looking and because they appear to look better in nature. [80] However, apart from the many hybridised varieties that are available today, all plants are native to some location or other around the globe and vigorous and healthy growth; apart from rampant growth, must surely be a positive trait for a plant.

4.3.3 The clue to the use of plants may, however, be as Turner suggests, that the local everyday species may not be exotic enough for the creators of gardens. [81] The term exotic derives from the Greek exōtikos meaning foreign or from outside. It is perhaps this foreignness, which is divorced from localised

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[78] This fact has been borne out by many discussions with local people with the author on the native flora during field trips, (called a טיול 'Tiul' in Hebrew), to view the local flora and landscape.

[79] Private discussion with Tom Turner and written about by Benz Kotzen on the Landscape Architecture Electronic Forum <LARCH-KISTSERV.SYR.EDU>, 3/12/1998.

[80] Conversation with Tom Turner at the University of Greenwich, April 2001.

[81] Ibid.

nature and which is seen by people to make gardens alluring and inviting. What becomes certain then is that in principle, the garden is a cultural phenomenon and is opposite to nature.

4.3.4 J. Douglas Porteous, (1996, page 81), sees rather that the landscape garden is *'nature transformed into an idealised conception of the landscape form'*.[82] Garden making and planting is thus a cultural transformation and not just a physical manifestation. It is an intellectual exercise.

4.3.5 The renowned anthropologist Claude Lévi-Strauss (1973, page 174), states in his book *'Totemism'* that the *'advent of culture coincides with the birth of the intellect'*. Cultural activities including garden making are thus intellectual activities as well, in the sense that they are planned and developed in the mind before they are created on the ground.

4.3.6 Although, this means that garden making can be seen as a cultural manifestation of nature transformed into an ideal, people generally do not create their gardens in the character of the local surrounding natural habitat. The question should then be asked, why is this the case? Furthermore, it begs the question to be asked to why they would not take attractive and useful native plants and place them into their gardens. This problem appears similar to the problem and dialectic on art, artefact and aesthetic value. [83]

4.3.7 Regarding art, Vasquez (1973, page 78), states that Palaeolithic man used art as a means of objectifying nature and it was through this objectification and subsequent humanisation that man found a means to relate to the *'alien and terrible power'* of nature *'which he could not integrate'*. He, (Vasquez, 1973, page 79), further argues that natural phenomena become aesthetic only when they acquire a social and human significance. Aesthetic value can thus

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[82] J. Douglas Porteous is a Professor in the Geography faculty, University of Victoria, Victoria, Canada.

[83] The author first came across this line of enquiry whilst researching a Masters degree in Fine Art.

be viewed not as a property or quality inherent to natural objects, *'but rather something they acquire in human society by virtue of the social existence of man as a creative being'*. (Vasquez, 1973, page 92)

4.3.8 Many ancient and modern philosophers writing on aesthetics agree that the appropriate composition of the object(s) is the key consideration when it comes to beauty. Plato (427 - 347 BC) makes a distinction between objects of sense perception, i.e. those objects we see, and the ideal form, but he also sees that beauty has order, symmetry and proportion. (Thompson, 1999, page 14) Thompson (1999, page 14) notes that Aristotle (384 - 322 BC), Plato's pupil states in his *'Metaphysics'* that the chief forms of beauty are order, symmetry and definiteness. The Neoplatonist, Plotinus (AD 204 / 5 - 270), argued that unity *'is the essential characteristic of beauty'*, and that an object should have unity, regularity, simplicity, proportion, balance, measure and definiteness. (Thompson, page 15) Marcilio Ficino (1433 - 99), the Italian Neo-Platonist philosopher, sees beauty in harmony and appropriate arrangement, and that proportion and adornment are important characteristics of harmony. (Thompson, pages 15 - 16) The ideal of beauty created through proportion is important during the Italian Renaissance and Leon Batista Alberti (1404 - 72) and Andrea Palladio (1508 - 80) formulated ratios that would produce visual harmony. In the Baroque period, however, exaggeration and theatricality was heralded as being aesthetic virtues and today we may still admire showy baroque plants and flowers. Similar to the previous philosophers, William Hogarth (1697 - 1764) suggests that *'all questions of visual beauty are questions about lines'* because all shapes and solids can be reduced to them. (Thompson, pages 18 - 19) The beauty of a line is related to its fitness, variety, uniformity, simplicity, intricacy and quantity (size). (Thompson, page 20) The 20th Century American philosopher George Santayana (1863 - 1952) suggests that we are able to appreciate the formal qualities of objects through their unity, balance, proportion, and harmony. (Thompson, pages 20 - 21)

4.3.9 The above discussion on the philosophy of aesthetics and beauty illustrates that we usually find objects including plants or flowers aesthetically pleasing when they have harmony, proportion, simplicity and perhaps theatricality or other noteworthy qualities as mentioned above. Yet the discourse does not begin to explain why some of the local plants of the Negev are not seen to have the appropriate aesthetic characteristics, despite having some of the above qualities, and then why they are not taken out of nature and used in the garden or in the general landscape.

4.3.10 Plato states in the 'Republic' that the

> *'virtue and beauty and rightness of every manufactured article, living creature, and action is assessed only in relation to the purpose for which it was made or naturally produced'.* (Osborne, 1970, page 34)

4.3.11 It is exactly this point that perhaps holds the key. It is because the plants of the Negev have not yet been seen to have a purpose beyond the natural and therefore they have yet to become objectified and 'acquired', (as suggested by Vasquez, 1973, page 92) by the local people. (Refer back to paragraph 4.3.7, above.) Nor have they acquired a social, cultural or any other human significance within the local society and therefore they are not considered worthy of use. In contrast, by extracting plants from the wild from places such as China, Australia, and South Africa, numerous plant hunters have elevated those collected native plants seen to have specific aesthetic and other merits, beyond the natural to the cultural and perhaps towards their intended purpose as Plato suggests. In the west, exotic foreign plants are readily accepted or acquired, because they have been collected, and have been through a physical trans-location process and a process of culturalisation, which has not happened to the local Negev plants. The local plants of the Negev have not yet been given a purpose other than a natural purpose. The local plants have thus neither been translocated in theory, nor in practice. In contrast to the exotic plant species which have been introduced, the local plants remain part of the *'alien and terrible power'*, which Vasquez, (1973, page 78), says Palaeolithic man *'could not integrate'*.

4.3.12 For local people living in the Negev, the Negev Desert is thus perhaps still an alien and terrible environment, which remains hostile and difficult to integrate into normal life. The plants remain part of this antipathetic world beyond the realm of the civilised, cultural oasis in which local people try to cocoon themselves. [84] It is thus possible that by analysing, discussing and advocating the potential of these plants for use in this research that the process of the culturalisation and acquisition of these plants will commence. In theory they will be elevated beyond the natural into the cultural realm. The virtue, beauty and rightness of these plants will then come to the fore as garden plants, or indeed as plants that may be used for other purposes.

4.4 Planting in the Negev

4.4.1 As mentioned above, plants in a natural setting and in planted situations as a cultural phenomenon add value to our existence. This is particularly acute in arid environments where plants feature in living contrast to the often barren appearance of the landscape. In his *'Planting Design Handbook'*, referred to above, Nick Robinson (1992, page 8), suggests that there are three major purposes of planting design, which are: functional, ecological and aesthetic. It is fair to say that these three categories actually cover all the apparent characteristics of all plants themselves whether placed in nature by nature

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[84] It is interesting to note that western settlers have tended to create enclosed settlements, mainly for security reasons. These enclosures are in contrast to some of the traditional Bedouin tribesmen who appear to interact much more closely to the desert environment. The mindset of the two groups also appears totally opposite. By grazing their flocks and using materials from the desert the Bedouin appear to have a natural symbiosis with the desert. In contrast the western settler tries to conquer the desert through technology, such as through the use of air conditioning. (It should be noted that contemporary Bedouin houses sometimes also incorporate all the 'mod cons', including washing machines and air conditioning units). The western settler has also tried to change the character of the desert through the introduction of foreign plants.

itself, or planted in nature or in man made areas by man.

4.4.2 In the past, in the Negev, it is quite reasonable to surmise that the first arrangements and use of plants were functional adaptations and expressions derived from agriculture as they were elsewhere in the world. This would tie in for example with the earliest Persian gardens, which were adapted from agricultural landscapes with irrigation canals, and regularly spaced fruit trees. (Robinson 1992, page 3) These gardens would also have been walled off or demarcated similar to agricultural fields in order to protect the garden from grazing animals and trespassing people. However, the functional aesthetic would further have had some ecological significance and no doubt led to a concept of beauty or visual aesthetic, which we find pleasing even today.

4.4.3 But in the Negev, this agricultural aesthetic or link to the distant past appears to be largely lost. Thus, for example there is little evidence of Nabatean forms of agriculture, for example, using run-off water systems that create a contemporary aesthetic of plant usage. [85] There have, however, been experimental investigations since the 1940's in the use of these run-off systems for agriculture and for the planting of tree groups in 'microcatchments' and *'negarim'* (נגרים) (See Figure 27). Microcatchments are areas that have been enclosed which trap run-off water when it rains and negarim are contour ridge microcatchments. (Barrow 1999, pages 58 - 60)

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[85] The Nabateans were an 'ancient' Arabic people who settled and traded in the area and elsewhere. The most famous settlement is at Petra, just east of the Negev and the Arava valley. The most famous settlements in the Negev are at Avdat, Mamshit, Haluza, and Shivta. (Refer to Chapter 3). The first mention of the Nabateans is in 312 BCE but it is conjectured that they inhabited the area from around the 6th century BCE until 106 CE when the Romans under Trajan took control after the death of the Nabatean King Rabbel III. (The Hashemite Kingdom of Jordan, Nabatean www site and NET, Nabatean www site).

4.4.4 Prior to the resettlement of the Negev commencing in the 1940's by Jewish pioneers, the Negev was populated by Bedouin nomads who relied on grazing their flocks and not on fixed agricultural infrastructure. The use of the plants, except by the Bedouin for grazing, and other ethno-botanical uses such as medicine, wood, rope, etc had not emerged. The steep decline in population and agriculture, following the Arab conquest in 640 AD for more than 12 centuries until around AD 1900 meant that the Negev was dominated by the nomadic Bedouin pastoralists. And although from AD 1900 the Ottoman rulers encouraged permanent agriculture among the Bedouin of the northern Negev, the harsh climate and lack of water meant that there has not been a settled agricultural tradition, which could have created an aesthetic of agricultural and native plant use.

4.4.5 The Jewish populations on kibbutzim and moshavim in the region have mostly settled from the Diaspora from the cities and towns of the 'west' where there has been neither traditional use nor the creation of an aesthetic of desert plants. Rather, the aesthetic has been for temperate and tropical climate plants whose verdant growth habits counteract the hot, dry, ochre desert environment.

4.4.6 Whereas most planting in the Negev in the past used tropical plant species there have been successful attempts to create landscapes using xerophytic plants from around the world. A particularly successful example of this is located at the burial site for David Ben Gurion and his wife on the edge of Wadi Zin, adjacent to the University of Ben Gurion Campus at Sde Boqer. (Figure 28)

4.4.7 In the United States the emphasis on the use of plants in dry areas has not been on native plants but rather on xeriscaping. The *'Xeriscape* TM' [86] concept was developed by the Denver Water Authority to *'identify and describe a water-efficient landscape concept to replace traditional water-*

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[86] Xeriscape™ is a registered trademark of Denver Water, the City of Denver's Water Department. (http://en.wikipedia.org/wiki/Xeriscape)

wasting landscape practices'. (Jones and Sacamano, 2000, page xvii)

4.4.8 The concept of xeriscape has filtered out from the U.S.A. where it has developed into a 'nationally recognised concept', in other countries including Australia and Mexico. (Jones and Sacamano, 2000, page xviii) In Israel, xeriscaping has been attempted, in principal, and in practice and in research by Prof. Gutterman, where cactus and succulents and other desert plants are grown for use. [87] (Figures 29 and 30) Ran Pauker, (refer to paragraph 4.2.1 above), uses the term 'Water Wise' gardening where plants have been selected and the landscape treated to reduce water demand.

4.4.9 Thus in some areas there appears to be some recognition of the aesthetic qualities of non-native drought tolerant species and the other water-saving principles of xeriscape which include:

1. Water-conserving design,
2. Restricted use of lawn grass,
3. Use of drought-tolerant or water efficient plants,
4. Water harvesting techniques,
5. Appropriate irrigation methods,
6. Use of mulches and
7. Proper maintenance techniques (Jones and Sacamano, 2000, pages xviii-xx)

4.4.10 But there is no recognition within the xeriscape concept of the benefits in the use of local native plants. This is evidenced in the web sites published by Denver Water, (Denver Water, www.) and the Colorado WaterWise Council,

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[87] Prof Gutterman is Head of the Ecophysiology and Plant Introduction Unit of the Jacob Blaustein Institute for Desert Research, Ben Gurion University of the Negev, Sde Boqer Campus. He has set up a research nursery, which grows plants from desert areas from around the world, and he supplies plants to the local councils.

(Colorado WaterWise Council www.) Although this is the case in the Negev, there may be other areas where local xerophytic plant use is encouraged.

4.4.11 It must also be noted that the principles of xeriscaping are meant to be applied to domestic and other larger garden types. However, as will be suggested below, not all landscapes should be treated as gardens. It does not appear to be acceptable to try to improve sustainability by reducing water use and then being less sustainable by ignoring local ecological and landscape character conditions.

4.4.12 Thus it is considered that although the principles of xeriscaping will help to reduce water usage, it will not help top maintain ecological integrity, landscape character and landscape quality. It appears then that the first principle of xeriscaping should be that due recognition should be given to the fact that all landscapes need not be treated as gardens. It follows that planting should respect local conditions and native flora and fauna in an attempt to maintain landscape character and ecological biodiversity where possible. The effects of using native plants compared to the use of foreign plants are discussed below in Section 4.6.

4.5 Early and Contemporary History of Native Plant Use

Introduction and Early Examples of Native Plant Use and Exotic Plant Introduction

4.5.1 All plants used in agriculture or in gardens have their origins in nature. The initial culturalisation of the landscape first saw the extraction of plants from their natural locations in the landscape into more controlled conditions for harvest and into gardens for food as well as other symbolic, medicinal, aesthetic and additional functional considerations such as the provision of shade. The culturalisation of plants, i.e. the extraction, and transference of wild food and other plants and seeds is considered to herald *'the beginning of civilization, for civilization began when man found that he could make sure of a plentiful supply of food by planting seeds'*. (Wright, 1934, page 8) From here, plant husbandry and seed manipulation continued through hybridisation as well as via the importation of exotic species, as trading and indeed wars amongst nations and the transference of spoils increased and spread.

4.5.2 The first traces of agriculture and thus the use of native plants, planted more or less in-situ, occurred about 12, 000 years ago, whilst before this humans subsisted as hunter gatherers. (Lewin, 2005, page 247) [88] Although man first planted for food, he must have been conscious of the scent and colours of some of the flowers, fruit and leaves. Man was at some unrecorded stage, *'moved with an impulse to use them in some* (other) *way'*. (King, 1979, page 15)

4.5.3 Religion and mythology were an integral part of early civilizations and it is most likely that the practice of cultivating plants, which would have been native plants, for their ornamental, scented and symbolic qualities *'arose from their use in religious practices'*. (King, 1979, page 15). There is evidence of various early civilizations' interest in plants and flowers including China, (2000 BCE), and the Sumerian civilization at Ur, (4th millennium BCE). (King, 1979, Page 16)

4.5.4 On the other hand, apart from an interest in local native species, there is also written evidence of the move towards introducing exotic species. The conquesting King Sargon of the state of Akkad [89], to the north of Sumer *'brought back foreign trees, vines, figs and roses to grow in his own land'*.

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[88] Lewin, in his publication *'Human Evolution'*, notes that agricultural innovation commenced at various centres as follows: The Fertile Crescent of the Tigris and Euphrates (10, 000 years BP [Before Present], with wheat, barley, lentils, peas, Meso America (9,000 years BP), in southern Mexico with maize, squashcotton, beans, gourds and in China (7, 000 years BP), with rice, millet, soya beans, yam, taro and peas. (Lewin, 2005, page 247).

[89] Sargon of Akkad reigned from 2334 to 2279 BCE creating an empire that united Mesopotamia. (Hyperhistory, *'Sargon of Akkad'*, www.)

(King, 1979, page 16). Around 1100 BCE, Tiglath-Pileser, King of the Assyrians left records stating

> *'cedars and box and allakanu wood have I carried off from the countries I have conquered, trees that none of my forefathers have possessed, these trees have I taken and planted them in mine own country...'* (King, 1979, page 17)

4.5.5 Native plants were also used in ancient Egypt, where every temple had its sacred grove and trees were used to shade the houses of the nobility. One of the '*short biographies of the Old Kingdom high officials (c.2350-2150 BC)*', notes

> *'I came from my town; I returned to my estate; I built a house and set up doorways; I dug a pool and planted trees'*. (John Baines and Helen Whitehouse in Taylor, 2006, page 144)

4.5.6 Planting, was, however, formal and geometric, as it was located within a system of protective walls and irrigation channels and *the natural landscape was not imitated...'*. (John Baines and Helen Whitehouse in Taylor, 2006, Page 144). Native plants included water plants as well, combining *'the lotus in the pool and papyrus on the pool edge'*. (John Baines and Helen Whitehouse in Taylor, 2006, page 144)

4.5.7 From the New Kingdom, (c.1500-1250 BCE) there are paintings of estate gardens, the earliest of which, (c.1480 BCE), includes a list of trees among them, sycamores, doum palms (*Hyphaene thebaica*), moringa trees, willows and tamarisks as well as other fruiting species. [90] (John Baines and Helen

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[90] Apart from planting for fruit, non-fruiting trees must have been planted for shade, aesthetic and potentially symbolic reasons. The sycamor tree is *Ficus sycamorus,* which is native to the banks of the Nile and was brought to the Negev in ancient times. *Hyphaene thebaica*, the doum palm is also native and one such group is located in the southern Negev (Arava), as well. *Moringa peregrina,* (also native to the Negev), which has tamarisk like leaves as well as the willows and tamarisk

Whitehouse in Taylor, 2006, page 145)

4.5.8 Patrick Taylor, (Taylor, 2006, Page 29), notes that until now, there has been no archaeological or Babylonian textual support for the Hanging Gardens of Babylon, but it is considered that the gardens were located at Nineveh and built by the Assyrian king Sennacherib, (704-681 BCE).[91] Trees, which most likely included native species, were located on the various levels of the garden which, *'was laid out and constructed to imitate a naturally hilly landscape with trees and running water'*. (Patrick Taylor in Taylor, 2006, page 29)

4.5.9 The planting of native species is also evident in the bible, where for example, Susannah's *'adventures took place in Babylon during the exile in which oaks and mastic trees (Pistacia lenticus) grew around a pool.'*[92] (King, 1979, page 25)

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species do not produce fruit and thus must have been planted for other purposes.

[91] Taylor notes that Nineveh and Babylon were confused by biblical, classical as well as later writers. (Taylor, 2006, page 29).

[92] In Daniel, Chapter 13, Sussanah is falsely accused of sleeping with a young man after refusing to be blackmailed by two elders. Daniel intercedes and *'after separating the two men, they are questioned about details of what they saw, but disagree about the tree under which Susanna supposedly met her lover. In the Greek text, the names of the trees cited by the elders form puns with the sentence given by Daniel. The first says they were under a mastic (υπο σχινον, hupo schinon), and Daniel says that an angel stands ready to cut (σχισει, schisei) him in two. The second says they were under an evergreen oak tree (υπο πρινον, hupo prinon), and Daniel says that an angel stands ready to saw (πρισαι, prisai) him in two. The great difference in size between a mastic and an oak makes the elders' lie plain to all the observers. The false accusers are put to death, and virtue triumphs'*. (Wikipedia, *'Susanna'*, www.)

4.5.10 Further to the west, the Cretan civilization, whose *'art reached standards of taste and excellence fully the equal of that of Egypt'*, was lost about 1450 BCE. (King, 1979, page 27) Painted examples of native flowers and trees are evident on vases, other vessels and the decoration of palace rooms, depicted in *'a most pleasing way'*. (King, 1979, Page 27) King, (Page 28), however, notes that although fruiting trees were used in ancient Greek gardens that native flowers were not. The reason for this is because *'Greece was, and still is, a natural-flower garden'* with natural areas abounding in carpets of flowers. (King, 1979, page 27) For the ancient Greeks *'to have moved plants nearer to their houses solely because they were beautiful would have been a senseless act in their eyes because the plants there already were just as beautiful'*. (King, 1979, page 28)

4.5.11 During the Peloponnesian wars between Athens and Sparta, the countryside became deserted as rural populations moved to towns. Town life flourished and the places where athletes and philosophers congregated *'began to* (be) *planted with trees and* (began) *to assume a park like aspect'*. (King, 1979, Page 28) Flowers are noted and for example, *'Herodotus speaks of a many-petalled sweetly scented rose that grew in Macedonia, and Demosthenes mentions rose-gardens'*. [93] (King, 1979, page 30)

4.5.12 Later on in ancient Greece, King notes that Greek Hellenistic gardens became more extravagant and *'these luxurious Hellenistic styles became Roman styles'* and the *'Hellenistic gardens ... became the gardens of the Roma villa'*. (King, 1979, page 30) Town and rural estate gardens included many native trees and shrubs, including plane trees, box, oleander and fruiting species. Sacred (temple), and sepulchral (funerary) gardens included native trees and shrubs as is evidenced by the rows of holes cut into the rock

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[93] Herodotus Halicarnassus was a Greek historian from Ionia who lived in the 5th century BC.. (Wikipedia, *'Herodotus'*, www.) Demosthenes (384–322 BCE), was a prominent Greek statesman and orator of ancient Athens. (Wikipedia, *'Demosthenes'*, www.)

for planting at the temple at Gabii in Italy. (Maureen Carroll in Taylor, 2006, Page 412). Maurrreen Carroll, (Taylor, 2006, page 412), notes that in the middle of the 1st century BCE, Roman aristocrats established parks and gardens using native as well as exotic trees and garden species which were brought back by the Roman generals from their campaigns. Practices for growing and increasing introduced species using clay pots was very successful and it is very similar to horticultural practice today. Pliny the Elder, [94] notes that a cherry tree native to the Black Sea had got as far as Britain 120 years after it was first introduced into Italy in the 1st century BCE. (Maurreen Carroll in Turner, 2006, page 412)

4.5.13 Patrick Taylor, (Taylor, 2006, page 305), notes that gardens and plant use between the end of the Roman Empire and around 1500, i.e. in the Middle Ages are generally poorly documented. (Patrick Taylor in Taylor, 2006, Page 305) However, many illustrations *'show something that remains for many people the chief delight of gardens - a love of plants and cultivating them.* (Patrick Taylor in Taylor, 2006, page 305) Various illuminated illustrations show arbours, topiary, raised beds and climbing roses in generally enclosed gardens. Many gardens grew herbs for culinary and medicinal purposes as well as vegetables and fruit. However, the planting of local native species is uncertain and the *'interest in flowers seems, however, to have remained limited until quite late'*. (King, 1979, page 78) A comprehensive list of 97 species is listed in John Gardiner's 14th century English language book *'The Feate of Gardening'*. (King, 1979, Page 78) Plants include numerous native English species including cowslips, and foxgloves but also non-native species including lavender (from western Europe), and hollyhock (probably of Asian origin). (King, 1979, page 78)

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[94] *'Gaius or Caius Plinius Secundus, (AD 23 – August 24, AD 79), better known as Pliny the Elder, was an ancient author, naturalist or natural philosopher and naval and military commander of some importance who wrote Naturalis Historia'*. (Wikipedia, 'Pliny the Elder', www.)

4.5.14 Patrick Taylor, (Taylor, 2006, page 305), states that the finest gardens made in the medieval period are undoubtedly the 10th to 14th century Islamic gardens made in Andalusia, southern Spain.

4.5.15 As early as the 10th century plants from the Iranian uplands and other eastern areas were carried to the eastern Mediterranean and from there through North Africa to Spain. (Penelope Hobhouse in Taylor, 2006, page 237) Islamic gardens in Spain included exotic as well as native species. Penelope Hobhouse, (Taylor, 2006, page 239) explains that

> *'with plane trees, cypresses, fruit trees and flowers, often with symbolic meanings, the original Persian or Iranian garden with individual and topographical interpretations, has remained the basic model for Islamic gardens in Iran, North Africa, Spain, Central asia and India.*

4.5.16 With regards to exotic plant introductions, Turner, (Gardenvisit.com, *'Islamic Gardens in Spain'*, www.) describes one example of exotic plant introduction, where the founder of the Omiad Dynasty in Spain, Abd-ur-Rahman I tried to *'ornament his new residence at Cordoba as far as possible in the Eastern fashion'*. In one location *'he attempted to build on the model of a similar one at Damascus* ... (and) *he endeavoured to perfect the likeness to home surroundings by growing Syrian plants in his garden, in particular the well-beloved palm-tree ...'*.

4.5.17 The history of plant use, whether exotic or native in the Negev desert during various historical periods is well described by Danin, in the 1983 publication *'Desert Vegetation of Israel and Sinai'*, which has been summarised in Section 3.3, 'The Negev – Human Geographical Context' of this thesis. The main periods of activity and thus planting occurred when the Negev was occupied by the Nabateans. (Refer to paragraph 3.3.2) Native plant use is uncertain but the inhabitants of the Nabatean towns, such as Avdat, which were scattered across the Negev and the near east were expert in growing crops with collected water run-off. Danin (1983, page 17) states that there was a decline in population and agriculture in the Negev after the Arab conquest in 640 AD and that the Negev was dominated by Bedouin pastoralists until 1900 whence the Ottoman rulers encouraged permanent agriculture amongst the bedouin of the Northern Negev [95]. Local plant use by the Bedouin then, is likely to be similar to what has occurred in recent history where plants were and are extracted from the wild and used for various medicinal and other ethnobotanical purposes. Although it is more than likely that domesticated fruit trees, such as the date palm (*{Phoenix dactylifera)* and grape vines (*Vitis vinifera)* were planted it is unlikely that native plants would have been cultivated as they grew in the immediate vicinity and were immediately accessible.

Later Examples of Native Plant Use

4.5.18 The contemporary landscape architect and academic Nick Robinson notes that the application of ecological principles in ornamental planting *'was first advocated by William Robinson (1870) in a style which he called wild*

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[95] The remarkable 14th century Arab traveller / explorer Ibn Battutah passed through the northern part of the Negev, (then part of Syria), on his way from 'Ghazzah' (Gaza) to the town of al 'Khalil' (Hebron). Ibn Battutah was an ethnographer, biographer, anecdotal historian, gastronome and occasional botanist. However, no reference is made to native plants on this part of his journey. Tim Mackintosh-Smith, author of the English language publication *'The Travels of Ibn Battutah – Abridged, introduced and annotated by Tim Mackintosh-Smith'* notes in e-mail correspondence with the author of this thesis, that in *'IB's Negev section ... unfortunately he says nothing about that part of his journey - he just says "I travelled from Gaza to the town of al-Khalil". In general he does have quite a bit to say about plants, but more so the further he travels into exotic parts'*. 'Sources: [1] e-mail correspondence with Tim Mackintosh Smith, (15/01/2008); [2] Abridged and annotated version by Mackintosh-Smith, 2002, of Ibn Battuta's journeys dictated 7 years after his return to a scholar named Ibn Juzay; [3] Medieval Sourcebook: Ibn Battuta: Travels in Asia and Africa 1325-1354, www.)

gardening'.[96] (Robinson, 1992, page 251) Robin Lane Fox writes in his introduction to the republished *'The Wild Garden'* by William Robinson, (1st published in 1870), that *'to Robinson, the taste of gardeners in the mid 1860's was abominable'*. (Fox in Robinson, W., 1979, reprint of 1894 edition, page xiii). Robinson railed against the fanciful style of the grand Victorian gardens and their new rich patrons, as he became a *'militant protagonist of naturalistic planting and opponent of floral bedding'*. (Turner, 1986, Page 168) Turner, in his caption to the illustration of naturalistic planting at Gravetye Manor, (1986, page 177), notes that in *'The Wild Garden'*, Robinson's theory on wild planting, *'was an unwitting return to* (Uvedale) *Price's principles of planting Design'*..[97] However, Robinson was, not necessarily advocating the use of native plants, but rather an emulation of how plants grow and thus their aesthetic appearance as found in certain areas of nature. Thus, for example, in *'The Wild Garden'*, in a section headed *'Early Flowering Bulbs in Meadow Grass'*, he notes his planting of thousands of blue Apennine anemones, and that these were placed in *'light broken groups and masses'*. (Robinson, 1979, reprint of 1894 edition, pages 16 and 17) The Apennine anemone, *Anemone*

[96] 'William Robinson was born in Ireland in 1838 and studied horticulture at the National Botanic Gardens at Glasnevin near Dublin. He went on to become a most influential and respected gardener and horticultural writer. He was a formidable character, hot tempered and outspoken but also energetic and diligent with a classic Victorian zeal for reform. In 1861, he moved to London and spent some time working in Regent's Park'. (Topp, Great British Gardens www.)

[97] Sir Uvedale Price (1747-1829), author of the '*Essay on the Picturesque, As Compared With The Sublime and The Beautiful*' (1794), argued against the sweeping away of natural features as practiced by Capability Brown, in preference for a *'less formal and asymmetrical interpretation of nature'*. (Wikipedia, '*Uvedale Price*', www.)

appennina, originates in southern Europe, and is not native, in the United Kingdom [98]. Robinson's ideas for naturalistic planting using a mix of exotic hardy species is evidenced in the third last and penultimate chapters of the *'The Wild Garden'*. Here he describes exotic hardy flowering plants and then he provides lists of exotics, which are suitable, for example for *'hedgebanks and like places'* or that have *'fine foliage or graceful habit suitable for naturalisation'*. (Robinson, 1979, reprint of 1894 edition, page 199) [99] Robinson, however, decries the non-use of native British species in the final chapter of *'The Wild Garden'*, when he states that *'the passion for the exotic is so universal that our own finest plants are never planted…'*. (Robinson, 1979, reprint of 1894 edition, page 211) He writes,

> *'we search the world over for flowering shrubs – not one of which is prettier than the Water Elder (Viburnum Opulus), common in Sussex woods, and often seen near the water-side in Surrey.* (Robinson, 1979, reprint of 1894 edition, pages 211 and 212)

4.5.19 Robinson intimates that exotic species are seen to be more worthy than Britain's native species and he notes that few people *'have any idea of the great number of flowers that are wild in our own country, and worth a home*

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[98] The 'Global Compendium of Weeds', (GCW), notes some sources where the species is considered naturalised. (Global Compendium of Weeds, *'Anenome appennina'*, www.) The GCW notes that naturalisation means the species has self-sustaining and spreading populations with no human assistance but not necessarily impacting on the environment. A species capacity to naturalise in foreign environments, however is a good indicator of weed potential. (Randall, www.)

[99] In his further publication *'The English Flower Garden and Home Grounds'*, William Robinson provides an even more extensive, all in one, alphabetised list of suitable exotic and native British flowering plants. (Robinson 1921, thirteenth edition. First edition in 1883).

in gardens - at least in those of a picturesque nature'. (Robinson, 1979, reprint of 1894 edition page 212) Robinson describes a number of 'beautiful' native British species, both small and large, from anemones to willow trees, but the numbers of plants mentioned are rather few compared to the many hardy exotic species he suggested for use in the two previous chapters. He does, however, note that the chapter was but a rapid glance of British wildflowers and trees and that much more space would be required to *'do justice to the many delightful aspects of vegetation that they give rise to.* (Robinson, 1979, reprint of 1894 edition 1894, page 212) Whilst advocating the use of exotic species, albeit in naturalistic ways, William Robinson should still be considered a key figure in the history of using local native plant species.

Four Early to Mid 20th Century Exponents of Native Plant Use

4.5.20 Four of the most prominent early to mid twentieth century advocates for native plant use include Jacobus P Thijsse in the Netherlands, Willy Lange in Germany, Jens Jensen in the USA, and Roberto Burle Marx in Brazil.

Jacobus Thijsse

4.5.21 Jacobus Thijsse, (1865-1945), was a teacher, naturalist and considered the father of the ecological movement in the Netherlands. He was concerned about the *'despoliation of the countryside and loss of nature'*. (Jan Woudstra in Taylor, 2006, page 468) He conceived of the idea of constructive gardens where native plants were used to educate ordinary people and schoolchildren. In this regard, Woudstra, (in Taylor, 2006, page 468), observes that the garden at Thijsse's Hof, constructed during 1925 *'aimed to contain all the plants growing in sand dunes in the region'* and this *'established the potential for native plants in gardens'*. In the Netherlands, this idea of the 'Heempark' (Homepark) was implemented in the 'Thijsse Park' in Amstelveen. Woudtsra, (in Wolschke-Bulmahn, 1997, page 185), comments that *'he influenced landscape architects to think differently about planting and about the function of Parks...* (and) ... *the use of native plants is now regarded as normal rather than exceptional'*.

Willy Lange

4.5.22 Willy Lange, (1864-1941) [100], in the early apsrt of the 20th century presented the then modern concept of natural garden design *'and claimed to apply the most recent scientific findings of ecology and plant sociology'*. (Gröning and Wolschke-Bulmahn, www, page 22) Lange's 'biological approach' was considered modern *'in the sense that is applied science to design'*. (Gröning and Wolschke-Bulmahn, www, page 22) However from a social standpoint it *'promoted dubious ideas about the assumed relationship between the German people and nature'* (Gröning and Wolschke-Bulmahn, www, pages 22 and 23) and hostility towards foreigners and foreign plants. [101]

Jens Jensen

4.5.23 The contemporary use of native plants in landscape design commenced in the U.S.A. in the first half of the 20th Century [102]. Robert E Grese, (1992, pages 55-56), in his publication on Jens Jensen (1860 - 1951), the famous

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[100] Willy Lange was a German garden designer who started his carreer in 1903 as a teacher and head of department for plant production at the Royal Corticultural College at Berlin-Dahlem. (Gert Gröning in Taylor, 2006, page 274.)

[101] Lange became part of the National Socialist movement and he *'felt rewarded'* as the *'racist and nationalist ideas for garden design* (which he) *had already developed became mainstream'*. [101] (Gert Gröning in Taylor, 2006, page 274.) On his 75th birthday, in 1939, Adolf Hitler conferred on him the Adolf Hitler Medal.. (Gert Gröning in Taylor, 2006, page 274.)

[102] An earlier use of native plants is attributed to Carl Linnaeus, (1707 – 1788). The University of California Berkley, Museum of Palaeontology web pages notes that he tried to find native Swedish plants to grow but these were to replace foreign imports of mostly tropical produce in order to boost the economy. (University of California Berkley www site).

American landscape architect points out that an essay by Stanley White in Victor Shelfors's *'Naturalists Guide to the Americas'* (1926) advocated the saving of natural plants and natural areas as models for design. Some other books advocating the use of native plants in design included *'Taming the Wild Thins'*, by Herbert Durand, and *'American Plants for American Gardens'*, by plant ecologist Edith Roberts and landscape architect Elsa Rehmann. (Grese, 1992, pages 55-56) Durand stated *'the trees and shrubs used in landscape pictures mostly be restricted to those that grow naturally in the vicinity'*. He asserted that this was essential to the creation of *'harmony with the surrounding scenery'*. (Grese, 1992, pages 55-56) Grese, (1992, pages 55-56), further points out that Roberts and Rehmann advanced the idea of using plant ecology as a basis for landscape design and that they noted that in plant ecology, *'observations are made as to what plants grow together and how they compose the groups known as associations'*. They suggested that these observations should inform the landscape architect and gardener in designing the landscape. (Refer to Figures 55 and 56 where photographs of a wadi in the northern Negev illustrate the variety of plant species growing together and a high visual quality.) In selecting plants, attention should

> *'be focused upon those that really belong to the particular scene and compositions made of them may be true reproductions or sympathetic interpretations of the landscape'*. (Grese, 1992, page 56)

4.5.24 Jens Jensen advocated the use of native plant communities, but Grese (1992, page 194), points out that in his early designs he tended to choose native plants because of their individual beauty, much as he might have used exotics in the same design in a horticultural style. However, Grese (1992, page 194), notes that later on Jensen demonstrated a clearer understanding of plants and soils and sought a community approach, emphasising the combined aesthetic of the plant community. His work at Columbus Park shows that Jensen arranged plants as they would be found in nature, although Grese (1992, Page 195), points out that he (Jens Jensen), did not fully understand the altered conditions in urbanised areas with degraded soils, altered hydrology and diminished native seed-sources.

Roberto Burle Marx

4.5.25 Ironically, the Brazilian Roberto Burle Marx [103] only became interested in the native plants of Brazil, on visits to the Berlin-Dahlem Botanical Garden between 1928 and 1930 [104]. (Eliovson, page 22) His interest in native plants continued on his return to Brazil and he became a leader of the conservation movement whose aim was to halt deforestation and to preserve the local flora. (Eliovson, page 22) Through his close liaison with Henrique Lahmeyer, a botanist, he learned about native plant associations and *'so developed the understanding of how to plant them in gardens'*. (Eliovson, pages 22 and 23).

4.5.26 Sima Eliovson, a South African, who is an expert on gardening in South Africa with native plants and who has written two of the first books on using native South African species in South African gardens, (Refer to paragraph 4.5.32 below), notes in her book on *'The Gardens of Roberto Burle Marx'*, that Burle Marx is *'guided by nature in his planting'*, emulating what he had seen in nature and from his *'intimate vision of wild nature'*. (Eliovson, pages 48 and 49) Like Jens Jensen, he realises the importance of plant associations and he *'arranges plants in ecological groups'*, (Eliovson, page 52), thereby promoting conservation and biodiversity but also

> *'he demonstrated how to create low maintenance landscapes by choosing plants that thrive in the climate in which they are planted'*. (Eliovson, page 52)

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[103] Roberto Burle Marx (August 4, 1909, São Paulo - June 4, 1994, Rio de Janeiro) was a Brazilian landscape designer , painter, ecologist and naturalist.

[104] Burle Marx was taken to Germany by his father when he was 18 to consult an opthalmologist due to his eye problems. He stayed for 2 years studying painting and music. (Eliovson, page 22).

4.5.27 Burle Marx is rightly recognized to be one of the world's most unique and influential garden designers and place makers, using natural as well as geometrical forms. He saw the use of geometrical forms as part and parcel of landscape design, where the landscape is no longer natural. In a similar way native plants are extracted from their natural settings and used by Burle Marx. He called this act of transformation from the natural realm to a cultural realm a "transposal". (Eliovson, page 45) However, Burle Marx did not rely only on the use of native plants, but he chose and grew plants because of their *'beauty of form and foliage'*. (Eliovson, page 55) Most plants he collected and used are Brazilian but many also came from other parts of South and Central America as well as from further afield such as Madagascar. (Eliovson, page 55)

Native Plant Use Around the World

4.5.28 The trend in landscape design in arid areas is currently towards xeriscaping, i.e. using drought tolerant species and other landscape methods, e.g. mulching to reduce water demand and not necessarily towards the use of native plants. However, the plethora of web sites that are available which aim to increase the use of native plants around the world is considerable. For example, each state of the United States of America has its own Native Plant Society. The aims of these societies is mainly similar and in New Mexico, an arid region of the USA, the aims are to encourage

> *'the use of suitable native plants in landscaping as a water conservation measure, for the improvement of wildlife habitat and because native plants are integral to the environment of the Southwest'*. (Native Plant Society of New Mexico, www.)

4.5.29 In New Zealand, for example, Leonard Cockayne [105] a botanist and plant

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[105] Leonard Cokayne (1855-1934) was born in Derbyshire with an interest in ecology. He moved to New Zealand in 1903 and wrote the *'The Vegetation of New Zealand'*, Part XIV of Engler and Drude's *'Die Vegetation der Erde'*, which was published in Leipzig in 1921.

geologist championed the use of native plants in gardens and in 1924 wrote a popular guide to growing them, but native plants were not used extensively in gardens until the 1980's. [106] Growing native plants in New Zealand was popularised by Muriel Fisher, and Laurie Metcalf through their respective publications, which helped break down the widespread perception that they were drab and difficult to grow.[107]

4.5.30 The Society for Growing Australian Plants was founded in 1954 by Mr. A. J. Swaby of Melbourne. According to the societies web pages,

> *'Mr. Swaby had a deep conviction that Australian plants deserve a prominent place in Australian horticulture, and these excellent articles attracted a great deal of interest from persons scattered across Australia'.* (The Society for Growing Australian Plants, www.)

4.5.31 The Alice Springs Town Council promotes the use of native plants above the use of foreign species. The database of plants species does not include any non - Australian plants *'even though some of these can be grown in Alice conditions'*. The purpose of this database is to

> *'encourage wider use of local native species, to create gardens better suited to local conditions and ones that fit better with our bushland setting'.* (Alice Springs, www.)

4.5.32 In 1924, Dorothea Fairbridge, published the book *'Gardens of South Africa – With some Chapters on Practical Gardening under South African Conditions and some Notes on the Cultivation of South African Wild Flowers'*. This was

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(Encyclopedia of New Zealand 1966, *'Cockayne, Dr. Leonard, C.M.G., F.R.S.,'* www.)

[106] Te Ara, The Encyclopedia of New Zealand, *'Horticultural Use of Native Plants'*, www.

[107] Fisher, M. E. and Ford, M. L., 1970, *'Gardening with New Zealand Plants, Shrubs and Trees'*, Bateman publishers, and Metcalf, L. 1993, *'The Cultivation of New Zealand Plants'*, Godwit Press.

followed in 1951, in South Africa, when Sima Eliovson published a book advocating the use of native South African plants in South African gardens titled '*South African Wild Flowers for the Garden*', (Gunn, page 149), and with E. Eliovson she authored also in 1951 '*Flowering Shrubs and Trees For South African Gardens*'. However, most gardening and landscape projects in South Africa continued to use exotic species. Only in the 1990's did the use of native plants become more prevalent. This is especially evident in the use of native trees and shrubs in larger schemes as well as in private gardens. [108]. One of the objectives of the South African National Biodiversity Institute, (SANBI), as set out in the mandate within the Environmental Management: Biodiversity Act, 2004, is the promotion of South Africa's biodiversity and taxonomy. As part of this remit, the institute has established 'PlantZAfrica.com' which has web pages on 'Gardening with South African Plants'. (PlantZAfrica.com, www.)

4.5.33 Although native plant use is improving in areas around the world and it may be current common practice to use plant communities and native plant mixes in ecological projects in the U.K. this practice is generally not carried out in Israel or in the Negev, or in many other desert areas around the world. In desert areas including the Negev, the objectives lean towards xeriscaping and water wise gardening.

4.5.34 The KKL - JNF, (Keren Kayemeth LeIsrael - Jewish National Fund), [109] is

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[108] The current increase in the use of native species has been spurred on by the publication of a number of books on the subject. These include: Van Jaarsveld E., 2000, '*Water-wise gardening with indigenous plants*', Tafelberg and Joffe, P., 2001. '*Creative Gardening with Indigenous Plants*', Briza Publications, Pretoria.

[109] The JNF was started in 1901. It was recently recognized as a Non-Governmental Organization (NGO) by the United Nations, but it is responsible for many aspects of development in Israel, including building water reservoirs, building roads, and planting trees.

largely responsible for planting in non-private areas of the Negev. Although one of its afforstation objectives is to follow an *'ecological approach that will be implemented consistent with the natural ecosystem, and not counter to it'*, (KKL-JNF, *'KKL-JNF Afforestation Objectives'*, www.), this is not evident in the Negev. The non-use of native species is apparent in their nursery stock, located at their large nursery at 'Gilat', where the hundreds of species comprise nearly all foreign plants. On inspection of their nursery in June 2004, by the author, there was no evidence of native species being grown. (Refer to Appendix A, Figure 37). This fact is also substantiated by their website, where the Director of the Southern region notes on a tour for foreign visitors that *'we experiment with plants from all over the world and I'm sure we have some trees or shrubs that originated in your home countries'*. (KKL-JNF, *'Desertification – Participants Tour Northern Negev'*, www.)

4.5.35 The effects of planting foreign species are largely not considered in the Negev. These effects will be discussed immediately below

4.6 The Effects of Using foreign, Alien Species

The Use of Foreign Plants and the Issue of Water

4.6.1 Nabhan and Felger in their chapter *'Wild Desert Relatives of Crops; Their Direct Uses as Food'* (Wickens 1985, page 19), suggest that it is ironic that

> *'much of the modern agricultural developments in arid zones depend on temperate or tropical crop species that are not well adapted to high heat, low soil moisture and low humidity'.*

4.6.2 These plants require large amounts of irrigation water as well as micro-environmental modifications to be economically productive. Furthermore, these strategies *'are costly, both economically and energetically'*. (Wickens 1985, page 19) Although Nabhan and Felger were writing almost twenty years ago the situation has not changed considerably since that time.

4.6.3 On the 28th of February 2006, 'The Independent' newspaper's front page led with the following headline *'World's most precious commodity is getting* *even scarcer'* [110], and with the sub headlines *'Water Wars: Climate change may spark conflict'*, and *'Armed forces are put on standby to tackle threat of wars over water'*. [111] Water is undoubtedly an issue in the Middle East and 'water stress' elsewhere around the world is creating tensions, which may lead to war. [112] Quoting Tony Juniper, the executive director of Friends of the Earth, the authors state that the most acute problems are in the Middle East and North Africa. [113]

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[110] Written by Michael McCarthy, www.independent.co.uk/environment/article348195.ece

[111] Written by Ben Russel and Nigel Morris www.independent.co.uk/environment/article348195.ece

[112] Ben Russel and Nigel Morris note that water was a contributing factor for the 1967 Arab-Israeli war and that this situation is still critical.

[113] Israel's water shortage has been described as reaching extreme proportions. In their web site, (Jewish National Fund, www.), they state this state has been exacerbated by drought as well as over-consumption. Whereas currently the water resources yield 449 billion gallons per annum the 'population growth and a general increase in the standard of living have boosted annual consumption to 580 billion gallons.' This is a deficit of 131 billion gallons and thus Israel is over-consuming by 25%. Whereas in the past, 72% of the water was used by agriculture, this has dropped to 60%, but this has 'put many farmers out of business.' (Jewish National Fund, www.) It is noted that any further drop in quotas would create 'the inability to sustain communities in the Negev, Arava and Galilee...'. In order to help this lack of water Israel is to import 13.2 billion gallons of water per annum from Turkey but at a cost of 'approximately three times what it would cost for the same amount of recycled water and about twice that of desalinated water'. (Jewish National Fund, web site).

4.6.4 Water is the controlling factor, which determines the physical character of the world's landscapes (including the Negev), as well as the socio-economic and political status quo. Agriculture is an important land use especially in the northern Negev and parts of the Arava where crops include flower bulb production, beans, potatoes, tomatoes, peppers, maize etc. Farming in the Negev is carried out as well organised and economically viable operations and thus varieties and farming procedures including drip irrigation methods have been devised to increase yields, reduce costs, (including water costs), and to increase profitability. However, Russell and Morris, (Independent.co.uk.www.), note the high water requirements for the production of agricultural crops as well as meat. The water requirements to produce one kilogram of a potatoes, maize and wheat is as follows:

- Potatoes = 1,000 litres;
- Maize = 1,400 litres; and
- Wheat = 1,450 litres. [114]

4.6.5 These figures are staggering and indeed even more water is required for other crops, and because water demand and thus use in arid areas is significantly increased due to higher evapotranspiration [115] rates brought about by increased temperatures, low humidity, increase wind speeds and

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A 'new Ashkelon seawater reverse osmosis (SWRO) plant - the largest desalination plant of its kind in the world - commenced initial production in August 2005 ... it will ultimately provide an annual 100 million m^3 of water, roughly 5% to 6% of Israel's total water needs or around 15% of the country's domestic consumer demand'. (water-technology.net www.)

[114] Russel and Morris note the water requirements for the production of 1kg of chicken and beef as well. These are 4,600 litres for 1kg of chicken and 42,500 litres for 1kg of beef.

[115] Evapotranspiration is the sum of the evaporation from the soil surface and the transpiration by the plants

solar radiation. The FAO, the Food and Agricultural Organization of the United Nations notes the water requirements for certain key crops in millimetres. A short list [116] of these crops and their water needs is noted below. The higher values shown in the second column are more likely in arid areas and thus in the Negev as well.

Table 4. 1 FAO List of crops and water requirements and sensitivity to drought

Crop	Crop water need (mm/total in growing period)
Alfalfa	800-1600
Barley/Oats/Wheat	450-650
Beans	300-500
Citrus	900-1200
Cotton	700-1300
Maize	500-800
Melon	400-600
Onion	350-550
Pepper	600-900
Potato	500-700
Soybean	450-750
Tomato	400-800

4.6.6 Although, most of the crops produced as noted above have high water

[116] The list relates to the crops that the author knows have been grown in the Negev.

dependency, there also has been some experimentation with xerophytic crops such as with the Jojoba, (*Simondsia chinensis*), the oil of which is used in the cosmetic industry and it is used as an ornamental landscape plant and varieties of prickly pear (*Opuntia ficus-indica*), some of which are spineless, which are used for juice and table fruit.

4.6.7 This trend in the growing of water demanding crops is similarly found in the use of landscape plants, which are used in private and public gardens or within the landscape as a whole. Most landscape planting in the Negev is based on the use of temperate or tropical species. Although most of these species are heat tolerant and they can tolerate low humidity, they generally do not tolerate low soil moisture regimes. (See Chapter 3).

Table 4. 2 Garden Planting Water Demands

Plant Type	Approximate amounts in litres per day per plant
Trees	63 - 100
Palm trees	120
Shrubs and groundcovers	10 per m^2
Grass/turf areas	10 per m^2
Refer to paragraphs 4.6.11 to 4.6.14 for more detail	

4.6.8 In the Negev, there has also been some investigation, as noted above, notably by Ben Dov, Forti and Pasternak in *'Plants for Desert Landscaping'*, (Ben Dov Y., Forti M. and Pasternak, D. 1993) and by Pauker in *'Water Wise Gardening'* of non-native xerophytic plants for garden and other landscape purposes. These studies include a range of plant types including cacti [117] and aloe species as well as other drought tolerant species from Australia, South Africa and the Americas. However, whereas there has been

[117] Cacti are only native to the Americas.

the shift in landscape tastes, as in the Southwest U.S.A. where more and more people have been led to *'appreciate the arresting beauty and unique character of arid-land plants'*, (Jones and Sacamano, 2000, page xvii), this has not yet occurred in the Negev. On the whole, gardeners, plantsmen and nurseries mainly rely on sub tropical or temperate and Mediterranean stalwarts that can cope with the heat but may still be reliant on copious amounts of water. (Figures 11, 13, 14, 15, 16, 17, 29, 34, 35, 37 and 38)

4.6.9 Even in the northern to central Negev, where rainfall is greater than in the rest of the Negev at approximately 100mm per annum there is still a huge water deficit. This water deficit is extreme at Eilat where annual precipitation is approximately 30mm. [118] (In some years there may be no precipitation at all at Eilat, and this can indeed continue for a number of years in a row.) As precipitation decreases from north to south, evaporation concomitantly increases from north to south. Average annual evaporation is 2200mm at Beer Sheva in the northern Negev to over 3200mm at Eilat in the southern Negev. (Stern, Gradus, et al, 1986, page 66) Thus, evaporation is approximately 11 times greater than precipitation at Beer Sheva and more than 100 times greater at Eilat. In other words, this means that at Beer Sheva there is a shortfall in precipitation of approximately 2000mm and at Eilat more than 3000mm per annum.

Native Plants, Precipitation, Costs of Water and Water in the Root Zone

4.6.10 The physical conditions of the Negev are well known. Soil, types, wind patterns and precipitation have been and are continuously measured at different locations. The spread of each plant species is well known and it is thus it appears relatively easy to determine the amount of precipitation that each plant species requires. However, this is not the case and a simplistic

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[118] Annual precipitation decreases from about 200mm at Beer Sheva to 30mm at Eilat. (Stern, Gradus, Meir, Krakover and Tsoar, 1986, page xii.)

relationship of between plant species and isohyets tells but one part of the story. Thus for example it has been noted in before in Chapter 3 with some expansion in Chapter 8 that soils and topography and microclimate play a large part in plant survival and as to how much water is available to be used by the plant. It must be noted that the only precipitation that is useful for a plant is that water that is available in the root zone, which is described in agricultural terms as *'effective rainfall'*. [119] Effective rainfall is thus the rainfall that accumulates and is available in the root zone and it does not include water that sits on the surface and is dissipated by evaporation. Nor does it include runoff water or for that matter water that percolates below the root system beyond the reach of the roots. Thus *'effective rainfall'* in other words, *'is the total rainfall, minus runoff, minus evaporation and minus deep percolation'*. (Brouwer and Heibloem, www, Section 4.2) (See Figure 31)

4.6.11 This lack of water over most of the Negev Desert and the need to get water into the root zone for plants to survive, means that any vegetation that is not growing naturally will thus need irrigation of some kind. In reference to the information required for crops noted above the author has obtained figures for the growing of trees in the northern Negev. For example, a medium sized fruit tree planted at Kibbutz Revivim, requires 23 000 litres, i.e. 23 cubic metres per annum to be productive.[120] [121] This equates to approximately 63 litres of water per tree per day. On Kibbutz Revivim, so

[119] The term effective rainfall defines 'this fraction of the total amount of rainwater useful for meeting the water need of the crops'. (Brouwer and Heibloem, www, Section 4.2)

[120] Information provided by Mike Samuelson, Dry Land Farmer, Kibbutz Revivim, 2000. Kibbutz Revivim is located 35km south of Beer Sheva.

[121] 23 cubic metres equates to a pool of water almost 4 metres long by 3 metres wide and 2 metres deep.

called drought tolerant species such as *Albizia lebbeck* [122] require approximately 120 litres per week and other species will require even more.

4.6.12 From the author's experience in the Middle East (Qatar, Kuwait, Bahrain and Saudi Arabia), general calculations for irrigation presume that a normal large tree needs 70-100 litres per day (25-36 cubic metres per annum). A palm tree, (*Phoenix dactylifera*), may indeed require as much as 120 litres per day (44 cubic metres per annum). $1m^2$ of shrubs or grass requires 10 litres per day (3.6 cubic metres or 3600 litres per annum). Alan Willens suggests that a tree would require 45 litres per day, shrubs 9 litres per day, succulents 4.5 litres per day and grass areas 27 litres per square metre per day. (Adams and Adams, article, 1976, page 128)

4.6.13 As noted above, the amount of water required by plants depends on the amount of water uptake by the plant and evapotranspiration, as well as the physical local conditions. In some cases and during the winter months however, water needs would be less because of the winter rains. However, the Negev is a desert like many other deserts, not only because of low rainfall but because the rainfall is unpredictable as well, and thus in fact in very dry years more water may indeed be required than noted above. The amount of water used in domestic gardens in the Negev has not been is not available but in arid-land communities in the U.S.A., studies have indicated that single-family residences use up to 50% of their water outdoors. (Jones and Sacamano, 2000, page xvii) [123]

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[122] Albizzia lebbek of the Fabaceae family is a tree often suggested for planting in the Middle East and in other arid areas. The tree is considered invasive in many countries and areas, (e.g. in Floriada in the USA) and a 'high risk' specimen in the Pacific, according to the 'Pacific Island Ecosystems at Risk (PIER)'. (Refer to www.hear.org/Pier/wra/pacific/albizia_lebbeck_htmlwra.htm)

[123] In the U.K., 'Southern Water' notes that garden water accounts for 6% of use, but on hot days this can rise to 70%. (Southern Water www

4.6.14 In 2003, Kibbutz Revivim in the Negev, with a permanent population of 800 people, (including children), used 2,886,155 (two million, eight hundred and eighty six thousand and one hundred and fifty five) cubic metres of water. [124] This would equate to a reservoir approximately 536 metres long by 536 metres wide and 10 metres deep. This was not all 'sweet' potable water as some of it is brackish from underground sources as well as reclaimed wastewater, which can be used in agriculture and other areas. (In some cases sweet water is also mixed with brackish water to lower the salinity levels so that it may be used on certain crops or in the gardens). The total sweet water component was 894,822 cubic metres. Of this water 173,535 cubic metres was used in the domestic and industrial sectors, which includes the gardens. [125] Sweet water use per capita in these sectors can thus be calculated as follows: 173,535 cubic metres, which is divided by 800 persons and divided by 365 days per annum. This is 595 litres per day. It should be noted that this figure is not the total sum as this is for sweet water only. The total water use (sweet water, brackish water and reclaimed waste water) for domestic use, industry and gardens is 10 cubic metres per capita per day on Kibbutz Revivim [126]. This is 10,000 litres per day. This is a considerable amount of water.

4.6.15 The above figures are cited in order to demonstrate the vast amounts of water that are used in populated areas in the Negev.

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site). These figures are similar to those produced by the Environment agency in the U.K. (Environment Agency www site).

[124] This information and the following information on water use on Kibbutz Revivim is from Mike Samuelson, Dry Land Farmer, Kibbutz Revivim, in a letter to the author received 25 March 2006).

[125] The kibbutz does have separate water use figures for industry/households and gardens.

[126] Information obtained from Mike Samuelson, Drylands Farmer, Kibbutz Revivim, 2006

4.6.16 The problem of water usage in the Negev is exacerbated by the fact that people living in the Negev do not pay the full cost for their water. In 2001, one cubic meter for domestic use cost U.S$ 0.40 and for agriculture U.S.$ 0.16 whereas in the centre of the country the price is U.S.$ 1.20.[127] [128] Water for landscape irrigation on a large institution such as a kibbutz, is charged at the agricultural rate. Freshwater for agriculture is U.S.$0.16 for the first 50% of quota, U.S.$0.19 for the next 30% and U.S.$0.26 for the next 20% although at present only 70% of the quota is allowed by law.

4.6.17 Thus the cost of domestic water in the Negev is subsidised at 1/3rd of the cost of water for the centre of the country and agricultural water and some landscape water is charged significantly lower at approximately 1/8th of the cost. [129130]

4.6.18 As demonstrated above, the use of water in Israel and in the Negev is a serious issue. Israel, Palestine and Jordan do not have enough water, which has and may lead to war and the costs of importing water is prohibitive. If the authorities are making cuts in the amounts of water for agriculture as noted above, which has socio-economic effects there is no doubt that the use

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[127] Information obtained from Mike Samuelson, Drylands Farmer, Kibbutz Revivim, 2001

[128] Contemporary prices for domestic water have doubled and are U.S.$0.80 (exclusive of delivery and maintenance charges. Reclaimed water is U.S.$0.13,6 or U.S.$0.18,3 for reclaimed sewage water for agricultural purposes depending on quality. (Source from M. Samuelson, Kibbutz Revivim, e-mail dated 08/04/06).

[129] Water is subsidised for various reasons. One reason is to entice settlement and development in the region.

[130] The world's largest desalination plant located north east of the Negev along the Mediterranean coast at Ashkelon commenced operations in August 2005. The cost of water from this plant is U.S.$0.527 / m^3. (Water Technology.net www site)

of water for landscape purposes is a low priority. Where water is in short supply, it needs to be used wisely and efficiently and even where this is done in the landscape, domestic, industrial and agricultural use will always have precedence.

4.6.19 The need to cut down on water demand in the landscape is thus a key issue in the decision about the use of native plants, that demand less water or no additional water supplies and the creation of a more appropriate landscape planting paradigm which does not treat each and every landscape as a green, lush garden.

4.6.20 The growing of crops that have high water demands perhaps may be justified socio-economically and politically, but the use of high water demanding foreign plant species for landscape purposes is less easily defended. However, the issue of foreign plant introduction, however, does not stop with the issue of water but also because foreign plant introductions can also have dramatic effects on the local ecology as well as the intrinsic landscape character and landscape quality [131] in areas where they are planted, including the Negev Desert.

4.7 The Use of Foreign Plants and the Issues of Ecology, Landscape Character, Landscape Quality and Quality of Life

4.7.1 The negative effects of introduced foreign plants on the environment are

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[131] Landscape Character refers to the different character zones, which may be identified within any given area taking account of local topography, built form, settlement patterns, land use, local materials, hydrology, vegetation and habitat, and other landscape and cultural/historical features.

Landscape Quality / Value refers to an evaluation of different character areas with regard to their character, condition, and aesthetic appeal and attaching a value to these areas. It also takes into account an evaluation of the likely value or importance to the community.

generally well known in the landscape architectural and ecological professions. In the United Kingdom, Giant Hogweed, (*Heracleum mantegazzianum*) [132], and Japanese Knotweed, (*Fallopia japonica*) [133], to name just two species introduced by the Victorians and (*Rhododendron ponticum*) introduced as far back as the Roman occupation of Britain have become a great nuisance [134]. They have had a negative effect on the ecology of certain areas principally by constricting and dominating local flora. The effect on ecology can also result in negative effects on landscape character and landscape quality of an area as well, by dramatically altering the physical and thus the concomitant visual and aesthetic characteristics that create sense of place in the landscape. Thus, a reduction in floristic diversity may have an effect on visual character as well as on other related aspects that go to make up a person's experience of landscape including, smell and texture.

4.7.2 There are many other faunal and floral examples worldwide where introduced species have created economic difficulties and problems as the removal of unwanted species can have enormous financial costs. In South Africa, for example, the cost of removing introduced foreign species is greater than the land value on more than half the farms. (Botha, 2001, Veld & Flora article, page 59) In the United Kingdom it would cost £1.5 billion to control Japanese Knotweed, *Fallopia japonica*. (Shaw, 2003, 'The

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[132] The problems associated with Giant Hogweed may be referenced at Netregs, the UK government website , (Netregs, *'Giant Hogweed'*, www.)

[133] The problems associated with Japanese Knotweed are well known. Further information is available on Netregs, the UK government website, (Netregs, *'Japanese Knotweed'*, www.)

[134] Refer to 'Rhododendron ponticum - A killer of the Countryside', (Offwell Woodland & Wildlife Trust www.) for more information on R. ponticum.

Garden' article, page 465.)

4.7.3 Alien plants are also a major problem in the Negev Desert where species have been introduced and are still being introduced. There has for instance been the introduction of *Eucalyptus* species, particularly in the northern loessal areas of the Negev. These trees are usually planted in a grouped grid, which is surrounded on 3 sides by earth mounds. (Figure 24) Winter rainfall directed to these trees from higher ground provides enough water for the trees to survive until the next rains. Although these trees provide shade for Bedouin, the army and picnickers they nevertheless can create ecological problems. Apart from providing shade and other microclimatic changes, which may promote some under-story grasses to survive, these trees are not part of the existing ecosystem and thus are detrimental to maintaining the local ecological balance of an area.

4.7.4 In contrast to these large leafed species, generally, trees in desert areas are small and broad in shape and have small leaves, which restricts transpiration. The *Eucalyptus* species are generally much taller than the native tree species and. (Refer to Figure 24) The leaf and overall dimensions of the trees is too large to appear natural in the Negev Desert landscape.

4.7.5 The *Eucalyptus* trees described above, were planted as part of the well-intentioned Jewish National Fund's objective to *'make the desert bloom.'* (Stern, Gradus, Meir, Krakover. and Tsoar, 1986, page XI) A further ecological problem relates to the self-propagation of these and other species. Self-seeded *Eucalyptus* species have been seen many kilometres away from a parent source within a natural desert environment. (Figure 32) In contrast, plantings of native *Acacia raddiana* and *Tamarix aphylla* appear much more natural in the landscape, as they are smaller and their leaves are smaller. (Figure 25) However, the planting of *Tamarix* creates other problems. (Refer to Appendix H10, Photographs T373-T378) Leaf litter of the highly saline leaves, increases soil salinity below the tree, in which very little else will grow thereby creating minimal competition for the tree.

4.7.6 Many other Australian species have been found to thrive in the Negev

Desert. Of particular note is *Acacia longifolia*, also known as *A. salicina*, which is a medium sized densely crowned tree with long leaves as the species name suggests; (longifolia – long leafed, saligna – like a willow). The tree is extremely hardy in the harsh conditions but again the leaf shape is atypical of plants of the Negev and it is disturbing that specimens have been found many miles from any planted source. (Refer to Appendix H11, Photographs FO392 and FO 393) It is especially disconcerting to find these escaped specimens within nature reserves within natural wadis amongst the native flora. (Figure 36) Other Australian escapees include a number of *Atriplex* (saltbush) species, such as *Atriplex semi-baccata,* and *Atriplex hallocarpa* formerly named *A. spongiosa,* which can be found growing along the road verges and other areas of the central highlands and northern Negev. (Refer to Figure 26 and Appendix H11, Photographs FO388 – FO389) (Refer also to Chapter 6)

4.7.7 In terms of altering landscape character, the species *Nicotiana glauca* [135] (Refer to Appendix H11, Photographs FO/S390, FO/S391) is perhaps the most visible manifestation of this problem in the Negev, as its year-by-year spread and increase along roadsides and wadis has been noted by the author. This South American shrub or small tree is so virulent in some wadis and roadsides of the northern Negev that it appears that it would be difficult to eradicate it.

4.7.8 Introduced species of grasses are of particular concern and there is evidence of the spread of introduced grass species from research fields used by the Institute of Applied Research at Ben Gurion University, north of Beer Sheva.

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[135] The plant is considered invasive by many countries and organisations including the United States Department of Agriculture, Natural Resources Conservation Service. (Refer to http://plants.usda.gov/java/profile?symbol=NIGL)

[136]

4.7.9 The problems that can occur with planting exotic species is demonstrated in the Judean Desert [137]. Introduced species of the tree *Ficus benjamina* at 'Kibbutz Ein Gedi' in the Judean desert causes great concern for the nature authorities. The fruit of the tree is eaten by birds and the seeds are deposited and grow in the protected local nature reserves [138].

4.7.10 A statement made in an Environmental Impact Appraisal of the 'Ramat Hovav' chemical complex approximately 15 kilometres south of Beer Sheva in the northern Negev, illustrates how in the past no consideration was made regarding planting and its effects on landscape, and on ecological and sustainability issues. The statement declares that *'grass and trees will be planted to significantly increase the vegetation in the area'.* [139] This statement is problematic as no concern at all was registered for the local landscape and ecological conditions, or for that matter, the issue of sustainability. The planting of grass, (turf), is neither functional, nor ecologically sound. The planting also requires substantial amounts of water to maintain it. The planting of trees, other than native species has a similarly negative effect, particularly on the ecological character of the area, which is characterised by rolling sands and loessal scrub.

4.7.11 With regards to biodiversity it is generally agreed that the retention and

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[136] The author has noted the spread of grasses on and beyond trial grounds north of Beer Sheva. Trials of various plant species were being carried out by the Institute of Applied Research.

[137] The Judean Desert is located in the hills too the north eats of the Negev, to the west of the Dead Sea.

[138] Information from Mani Gal, Botanical Gardens, Kibbutz Ein Gedi, 30 April 2007.

[139] Brachya V. and Marinov U., Chapter 3, *'Policies for Planning Environmental Quality in Arid Zones'*, Golany 1979, page 79.

appropriate enhancement of native flora is an important part of maintaining biodiversity. The introduction of foreign plant species does exactly the opposite. The international partnership, the Global Invasive Species Programme, (GISP), [140] notes that *'the spread of invasive alien species is now recognized as one of the greatest threats to the ecological and economic well being of the planet'*. (Burring and Van der Walt, article, page 18) They also note that the *'vehicle responsible for the introduction of the majority of these...whether intentionally or by accident, is humankind'*. (Burring and Van der Walt, article, page 20)

4.7.12 Lisa Lofland Gould [141] notes that core problem with plant introduction centres on

> *'concern for global biodiversity', where there is that 'wonderfully complex mix of bacteria, fungi, plants, animals ... all the organisms that create the living component of ecosystems and keep life on the planet functioning.' (Gould, www.)*

4.7.13 Gould notes that in temperate zones there are at least 12 species of organism that rely on each plant species and in the tropics this ratio increases to approximately 30 to 1. (Gould, www.) The importance of this is not only do foreign invasive species out-compete the native species, thereby displacing native plants but also a *'whole community of organisms'* is affected.

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[140] 'The Global Invasive Species Programme (GISP) was founded in 1997 as a small, mainly voluntary partnership programme, by three international organizations: IUCN - The World Conservation Union, CAB International, and the Scientific Committee on Problems of the Environment (SCOPE). Since then, it has built upon a productive and highly technically skilled base to become the pre-eminent global partnership on invasive species'. (GISP www.).

[141] Lisa Lofland Gould, is a Senior Scientist with the Rhode Island Natural History Survey. Co-author Coastal Plants from Cape Cod to Cape Canaveral and Vascular Flora of Rhode Island.

Whereas native flora and fauna have evolved together over millennia, non-native species *'fragment those relationships.'* (Gould, www.) Gould also notes that in the USA, 42% of the plants and animals on the US Endangered & Threatened species list are at risk *'primarily because of non-native invasive species'*. (Gould, www.)

4.7.14 David Pimentel of Cornell University, notes that in the USA, 50, 000 alien plants and animals cost the USA more than $125 billion a year, *'by sparking fires, blocking waterways and destroying crops'*. [142] Gould states that the cost is $20 billion. The economic losses affects

> *'food crops, golf courses, the growing of turf and ornamentals, industrial sites, forestry, aquatic sites, recreational areas, real estate values, and municipal water supplies'*. (Gould, www.)

4.7.15 In Australia, *Emex australis*, which is commonly called "doublegee" originates from South Africa. *'It was intentionally imported into Western Australia (WA) in 1830 as a vegetable (Cape spinach)'*. (CSIRO Entomology www.) It has now spread throughout Australia's southern-temperate regions.

> *'It is an annual weed that competes with crops and pastures and is estimated to cost $40 million a year in crop losses/production costs in WA alone'*. (CSIRO Entomology www.)

4.7.16 The World Wildlife Fund, (WWF, Australia Briefing Note, www, page 2), notes that

> *'escaped invasive garden plants make up two-thirds of the foreign plants now establishing in Australia as weeds'* and that *'weeds are one of the*

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[142] Juliet Eilperin quoting David Pimentel of Cornell University in Washington Post article of 25 July 2005 on world wide web. This figure is assumed to be incorrect and perhaps is meant to relate the worldwide economic effects, which Gould says is $138 billion or it, should read $25 billion, which is similar to Goulds's figure of $20 billion.

major threats to Australia's environment and wildlife, and cost agriculture $4 billion per year.'

4.7.17 The estimated economic impact on the world as a whole is $228 billion to $1.4 trillion per year, (Margolis, Newsweek, page 39), and Gould states that *'these figures do not include damage to native species and ecosystems'*. This is because *'we are so ignorant that we cannot begin to put a monetary value on them'*. (Gould, www.)

4.7.18 In the Negev, the environmental cost as well as the economic costs of invasive foreign species remains largely unknown, but the author has seen at first hand the invasion of numerous exotic species within the agricultural fields in the northern Negev. These species, which include *Amaranthus, Kochia, Solanum* and *Datura* species to name but a few are removed with herbicides as well as by hand weeding. But they still return year by year. In the Negev, as elsewhere the use of herbicides may be seen as the most cost effective way of annually removing weed cover, but the environmental effects are not considered positive. In the Negev the cost of hand weeding can only be accomplished with the importation of cheap foreign labour from China and Thailand. [143] The social impact of migrant labour in the Negev is unknown but the employment of poorly paid and generally poorly housed migrant labour, who live on the fringes of the society does not appear favourable to the author.

4.7.19 The above section has noted some of the disbenefits of utilising foreign plant species. However, it is also important to note that the converse is true, in that there are obvious ecological benefits in utilising native species in appropriate locations. The literature review as well as field studies by the author have noted species that are being exploited by other plant, animal and insect species for shelter or food. In one example, in an article Wilby and

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[143] Israelis would not undertake this kind of work and Palestinians, who once undertook this work are no longer allowed to do so under the present tense circumstances.

Shachak, (OIKOS, 2004, page 210), note that the small dwarf shrub *Noaea mucronata* act as a nurse species for annuals. (See photographs DS217 and DS218, Appendix H7) They furthermore note that there is

> *'considerable evidence'* that *'suggests that such nurse plants moderate the local environment allowing higher rates of productivity, survival and establishment of under-storey plants'* and that *'nurse plants may affect the stability of populations by buffering climatic extremes'*. (Wilby and Shachak, OIKOS, 2004, page 210)

4.7.20 The article, which centres on harvester ants emphasises the dependence of the ant species on the seeds produced by the various plant species. It is this complex relationship of plant associations and individual plant species with other species, which forms a cornerstone of this research. Whereas native species have the ability to provide shelter and sustenance for other species the introduction of foreign species can create large-scale ecological problems.

4.8 Understanding the Need for Planting in the Negev

4.8.1 Walton in his book 'The Arid Zones' states that the *'application of science and technology'* through the use of solar energy, desalination of the ground, new architecture etc. is only one part of the successful occupation of hot dry environments. (Walton, 1969, page 160) He states that, to these advances in knowledge and technology must be added

> *'the creation of the right attitude towards life in the hot dry lands through education, social reform and sound political organisation'*. (Walton, 1969, page 160)

4.8.2 Only then he says will the economic prosperity and occupancy of the hot dry lands of the world be ensured.

4.8.3 The current occupation of the Negev Desert has been partially successful and this is probably due to some of the criteria advocated by Walton above. However, it is suggested here by the author of this dissertation, that long-term sustainable settlement in the Negev requires more than sound socio-political attitudes. It is suggested that long-term prosperity also requires regional government as well as individuals to understand the issues of sustainability with regard to desert living and to respect the ecological characteristics of their desert environment. This respect and sensitive approach needs to encompass the 'genius loci' of the Negev, expressed as landscape character, landscape quality and habitat. In order not to destroy the uniqueness of each individual desert locality, the right kind of environments need to be planned, created and where necessary protected.

4.8.4 In order for larger groups of people to live permanently in the Negev or most other hot desert environments the first issue is the creation of appropriate and comfortable homes set within appropriate and comfortable urban and / or other types of settlement environments. The term comfort is important as people will not live permanently without comfort as can be seen by the manipulation of microclimate by people living in deserts with the creation of shade, shelter, air conditioning etc. Within the home, this management of microclimate is relatively simple as microclimate can readily be moderated for example through good arid climate design, insulation and as a last resort by air conditioning. [144] Inside the home and within private space, the individual can create any comfortable environment to suit their own taste. Behind closed doors, plants, pictures, furniture, aquaria, birds in cages, for example can all create comfort and 'a kind of paradise' for the family. Externally in the domestic environment people also try and create their own types of paradise or havens, in the creation of their own private or communal gardens. The type of gardens people create very often relates to their cultural upbringing and their education about gardens. In most cases the idea of a garden paradise manifests itself in its most simple terms as combining areas of green manicured turf, with areas of flowering shrubs and areas of annual and perennial flowers. Furthermore, it is apparent that the character of the garden must be lush and verdant at all times. This image is,

[144] In most cases, air conditioning is used as the initial and sometimes only response.

however, in stark contrast to the desert, which lies immediately beyond the limits of the city, town, kibbutz or moshav settlement.

4.8.5 The ideal, as noted above in paragraph 4.2.8, of greening the desert and *'making the desert bloom'* as suggested by the JNF, (Jewish Nation Fund), appears to be appropriate in order to satisfy the needs of Israel in terms of providing appropriate places for people to live and in terms of agriculture. (Stern et al, 1986, page XI) But the statement appears to presume that the desert is somehow not a valuable asset in its own right, and that it requires greening and blooming in order for it to be of value. (Discussions and correspondence with Israelis, by the author furthermore also indicates that many people want the desert to be 'greened'.) With regard to the concept for a Negev Desert Botanical Garden, [145] a correspondent states that it is his *'wish is to voluntarily contribute time and effort of friends and neighbours to get the Negev looking greener every time we visit it'.* [146] Although professional landscape architects recognise that degraded areas may need remedial works, we also know that the desert landscapes and ecosystems are valuable as intrinsic natural resources in themselves, as well as being an important asset for tourism. Thus, the statement and ideas advocated by the JNF and others needs to be tempered by the knowledge that the 'greening' and 'blooming' can only be sanctioned in appropriate areas and should not provide a comprehensive strategy that can negatively affect the intrinsic natural character and qualities of the heterogeneous regions.

4.8.6 There is no doubt, however, that if we use the terms 'greening' and 'blooming' in the broadest sense, i.e. the use of plants then the appropriate use of plants in the desert is positive. The use of plants, however must be

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[145] This is a concept that has been put forward by Benz Kotzen, the author of the dissertation. (Refer to website http://www.benzkotz.dircon.co.uk/web.html)

[146] Private e-mail correspondence between the author and Mr Michael Gordon who lives in the north of Israel.

gauged and balanced against the maintenance, retention and enhancement of degraded and devalued habitats. Through this approach, the desert may be seen to bloom and the quality of life for the population in the Negev will be enhanced.

4.8.7 The concept of retaining and improving quality of life is manifested in the assessment approach called 'Quality of Life Capital', (QoL), advocated in the United Kingdom by the Countryside Agency [147], who are the government's statutory authority with regard to planning and management of the countryside in England and Wales. The main idea of QoL assessment

> *'is that the environment, the economy and society provide a range of benefits for human life, and that it is these benefits or services which we need to protect and / or enhance'.* (Countryside Agency, (b) www.)

4.8.8 An example is given using a *'small mixed woodland on the edge of town'.* (Countryside Agency, (b) www.) The document states that it is not the size of the woodland that matters but it is the

> *'capacity of the wood to provide tranquil recreation, habitat for rare species, stabilise the soil, retain water, mop up carbon dioxide and local air pollution – and perhaps also support a livelihood in charcoal burning or coppice timber products'.* (Countryside Agency, (b) www.)

4.8.9 As suggested by the QoL assessment philosophy, it is important that the environmental character and qualities of the land, and its potentials, needs to be addressed as the character and quality of the land and how it is used can have a marked impact on the quality of life for people.

4.8.10 The criteria for attributing importance to the features or situations, which concern various disciplines varies. With regards to environmental conditions the following criteria are seen to be important:

- *'Environmental distinctiveness;*

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[147] The Countryside Agency became part of 'Natural England' in October 2006.

- *Quality;*
- *Rarity;*
- *Representativeness;*
- *Setting/context;*
- *Historical continuity;*
- *Recorded history;*
- *Accessibility; and*
- *Popularity'.* (Countryside Agency, (b) www.)

4.8.11 With regard to the Negev Desert, all the above criteria are relevant to the protection, creation and enhancement of the local environment and are also relevant to the use of native plants versus the use of foreign species. Whereas in most instances it can be argued that native plants would help to retain and enhance most of the criteria noted above, the introduction of foreign plants may have the opposite effect especially when they are used indiscriminately. The Global Invasive Species Programme (GISP), notes that the negative impacts *are a major concern, seriously affecting biodiversity, water resources, land use',* and even *'human health'.* (Burring and Van der Walt, article, page 19) The use of alien species thus can have a negative impact on quality of life by affecting human health as well as by diminishing environmental distinctiveness and the rarity value of a place. The indiscriminate use of foreign species can also affect the value of an area in terms of changing its setting and context and by obscuring historical continuity.

4.8.12 Thus, we note that the use of planting and good planting design in all areas including all arid areas can help make the best use of the environment and improve quality of life for people.

4.8.13 Nick Robinson, (1992, page 3), states in *'The Planting Design Handbook',* that good planting is *'an essential element in the creation and management of a landscape'* and it can *'help to restore the balance between people and nature by recognising and maintaining valuable plant communities'.*

4.8.14 Apart from the overall environmental benefits, it should also be remembered that planting offers *'enjoyment of aesthetic delights of both cultivated and wild plants'*. Robinson, (1992, page 3) eloquently notes that

> *'the sight, scent and sensation of flowers, foliage and fruits, even the sound of wind and rain in the branches of trees, shrubs and other plants all can add immeasurably to the quality of people's daily lives'.*

4.8.15 The author agrees whole-heartedly with Robinson with regard to the aesthetic benefits of plants, but in sensitive areas the introduction of foreign species, albeit aesthetically pleasing may introduce negative effects. The Australian *Acacia longifolia* found in an isolated natural wadi is not a joy to behold. It may have pretty flowers and be verdant but it changes the character and the quality of the immediate area to an extent that it in the author's opinion it should be removed. Similarly the verdancy and pretty flowers of *Nicotiana glauca* is not to be admired as its spreads across the desert landscape. The Negev Desert like any other desert has its own unique ecosystems, which create unique areas of landscape character and as stated previously, these areas in the Negev should not be turned into smaller desert versions of the Australian or South American deserts.

4.8.16 Plants can thus be seen as an integral part of quality of life and lead to an enjoyment of the environment. However, in order to further promote this particular part of the quality of life equation, an understanding is required of the kinds of environments where plants are found and used. Plant use needs to be analysed / assessed and structured according to some type of philosophy that retains the ecological and landscape integrity of a place and maintains and improves quality of life. It is thus suggested that the existing landscape model needs to be addressed and if possible, a new and more effective and less damaging landscape paradigm, for plant use should be developed.

4.8.17 The discussion on the existing and proposed landscape paradigms will follow below in section 4.9, 'A Landscape Paradigm for Desert Areas'.

4.9 A Landscape Paradigm for Desert Areas

Introduction

4.9.1 It is assumed from the author's own experience and practice that most landscape architects in the United Kingdom do not generally ascribe their planting strategies to any particular landscape model or paradigm. Up until recently (i.e. during the late 1990's and the 21st century), planting strategies would not necessarily look towards sustainability as a major issue, although the survival of the plants would be high on the agenda, and minimising maintenance would be an economic concern for clients and thus the landscape architect. Planting strategies now and in the past have done, and do of course take account of soil conditions, the hydrological character of the soil, microclimatic conditions as well as the functional and aesthetic demands of the particular project. Planting in desert areas generally follows a similar strategy but the emphasis appears to be in 'greening' the desert and creating garden type landscapes.

Landscape Character Zones with Regard to Plants and Planting

4.9.2 It is quite common for American books and other international publications on landscape architecture, plants and gardening to relate plants to hardiness zones thereby ensuring plant well-being at least as climate is concerned. [148]

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[148] For example Duffield and Jones, 1981, *'Plants for Dry Climates,'* Jones and Sacamano, 2000, *'Landscape Plants for Dry Regions'*, Clark David, (Ed.), 1979, *'Sunset New Western Garden Book'*, and Krieg, 1999, *'Desert Landscape Architecture'*. Lord Tony, Chief Consultant, *'Flora – The Gardener's Bible'*, Cassell, London 2003.

[149] These zones usually relate to the minimum average temperatures experienced geographically across the globe and thus the hardiness of the species to withstand various degrees of cold. These broad scale regions are illustrated on maps. (Figure 33) With regard to desert areas in the USA these publications usually subdivide the desert areas into a 'low zone', an 'intermediate zone' and a 'high zone'. [150]

4.9.3 The books on the plants of the Negev Desert, in principle, undertake a similar task as they locate in zones where the native and naturalised plants grow. Thus for example, Feinbrun-Dothan and Danin (1998, page 7), have divided the Negev into 5 zones. (Figure 1) This zonal classification system is extremely useful as it allows for the partial understanding about the conditions within which the plant grows. However, none of the American publications, or those published in Israel, nor the recent research noted in Section 4.2 above, notes the different types of landscape planting character zones that may be found and the links that this may have to landscape design and plant use. It must be stated, however, that in his book *'Vegetation of Israel and Adjacent Areas'*, Michael Zohary (1982), has indeed written a definitive discourse on the physical characteristics of the Negev Desert, the phytogeographical territories, the various zonal and azonal vegetation formations and the numerous vegetation classes, associations and their respective plant species constituents. The characteristics of the landscape relative to plant associations is also the topic of Danin's publication *'Desert*

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[149] The system and mapping was developed in the 1960's by the United States Department of Agriculture (USDA). (Lord, 2003, Page 20). The system divides the USA and subsequently the world into 12 zones. The Negev falls within Zone 10 where plants generally need to be able to withstand minimum temperatures of –1°C to 4°C.

[150] The Sunset *'Western Garden Book'* and American publication assesses all the zones on the western seaboard of the United States and has a greater subdivision of zones.

Vegetation of Israel and Sinai.' (Danin, 1983).

4.9.4 The identification of different types of landscape use and character zones is also an important asset in understanding plant distribution and plant use. The analysis of different landscape planting use and character zones is helpful because it allows for a clearer understanding of how the plants grow and how they may be used in a region. This type of zonal characterisation appears to the author to be important in allowing the designer to categorise plants for different zones and for different functions. Due to the size of the desert areas in the U.S.A. it is probably impossible to undertake such an exercise. But in the Negev this may be attempted, as the Negev is relatively small.

4.9.5 In respect of this research, landscape character planting zones are identified on a macro scale as noted below as urban, agricultural, natural areas etc in paragraphs 4.9.6 to 4.9.26 below. Additional micro landscape character planting zones are identified within the natural habitat category. The inclusion of these zones within the baseline information of the native plants helps to inform the potential use of these plants.

4.9.6 The Negev may be seen to have seven broad scale or macro landscape character planting zones relating to settlement patterns as well as use. These are:

1. Urban and suburban areas and rural settlement areas;
2. Rural nature reserves and historical tourist sites;
3. Jewish National Fund plantations and other plantations;
4. Agricultural fields;
5. Agricultural field boundaries;
6. Natural habitat; and
7. Disturbed habitats.

1. Urban and Suburban Areas and Rural Settlements

4.9.7 These are characterised by major urban towns, ('Dimona', 'Yerucham' and 'Mizpe Ramon') and cities, ('Beer Sheva' and 'Eilat') and numerous rural kibbutzim and moshavim. The vegetative character of these areas is dominated by foreign and introduced species, which are used in private and public gardens, parks and other private and semi private zones, and alongside roads. The character of the private gardens is based mainly on western domestic garden traditions where properties are bounded by hedges and where tree, shrub and flower planting are arranged within borders and defined planting areas. (Figures 11 and 34) Turf areas are also an important part of most planting schemes. (Figures 11 and 35) Plant material varies considerably but most species originate from the standard stock of plants generally grown in temperate and Mediterranean climate gardens in Europe and the USA. These also include drought tolerant plants that originate in other arid, Mediterranean climate zone and arid and semi-arid areas of Australia, South Africa, USA and South America.

4.9.8 The urban character predisposes the use of a variety of plants from various sources and it is unlikely that escapees from the urban environment where water is used liberally will colonise natural habitat areas, cause ecological damage and diminish landscape character and quality. However where developed areas are located immediately adjacent to natural areas there is some possibility for escapees. This is evidenced by the location of *Acacia longifolia* found deep within the wadi of the nature reserve at 'Nahal Zin', which lies below 'Kibbutz Sde Boqer', and the Ben Gurion University campus at 'Sde Boqer' and where *Acacia longifolia* has been planted. (Figure 36, Appendix A, Photographs FO392 and FO393 Appendix H11 and Figure 3 in Appendix J)

2. Rural Nature Reserves and Historical Tourist Sites

4.9.9 These locations are characterised by fairly remote areas or points of natural or historical interest. Most of these areas may be accessed by the main metalled road infrastructure whilst some are accessed via minor dirt roads.

These areas are usually located within areas of natural habitat but man has had impact through the creation of roads, paths and trails, way marking, car parks and toilet facilities etc. Other than the native plants species, planting has been placed to provide shade and to fulfil other design criteria ranging from boundary hedging, architectural and visual focal points and as general green aesthetic elements. (Figure17)

4.9.10 Non-native species planted in these areas do create a considerable risk of altering the adjacent natural habitat areas with the potential of causing ecological and landscape changes.

3. Jewish National Fund Plantations and other Plantations

4.9.11 The Jewish National Fund (JNF) has been responsible for the planting of small plantations of trees within the Negev as part of their task of 'reclaiming the land'. '[151] [152]

4.9.12 Large areas of forest have been planted mainly in the centre and north of Israel, whereas in the Negev activities have centred on small plantations and wadi reclamation where wadi beds are contained and trees planted within the wadi sands and silts. Tree plantations mainly comprise *Eucalyptus* species, (Figure 24) and *Tamarix aphylla.* (Appendix H10, Photographs T375 – T376) There are however some small plantations with *Acacia raddiana* species, (Figure 25), as well as some with *Pistacia lenticus* and *Pistacia palaestina* species, which are native to the centre and north of Israel. These plantations of around 10 to 30 trees provide shade for Bedouin, travellers, picnickers and the army.

4.9.13 Prior to the founding of the State of Israel in 1948 the British and before them the Turks of the Ottoman Empire created *Tamarix aphylla* and *Eucalyptus* plantations of many hundreds of trees mainly to halt the drifting

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[151] Jewish National Fund Web site, http://www.jnf.org

[152] The author visited their nursery in the northern Negev and conducted a survey of the species that they were growing. (Figure 37)

sands of the northern Negev. (Appendix H10, Photographs T373 – T377)

4.9.14 As previously stated *Eucalyptus* escapees have been noted many kilometres away from their original plantations. (Figure 32)

4. Agricultural Fields

4.9.15 The visual character of agricultural fields largely depends on the crop, the location and the boundary conditions. Apart from orchards, which have some longevity, crops are generally rotated and thus the visual character of the fields tends to alter according to the crop and the seasons. The planting of crops is likely to have some effects on local natural habitats and wildlife due to the potential leaching and drift of fertilisers, pesticides and herbicides. Some crops may in fact benefit some wildlife by providing food for animals such as deer and porcupines. (Crops such as gladioli bulbs have to be protected from being grazed by deer by electric cattle fencing. [153]) (Figure 38) Crops usually do not self-seed or manage to move far away from their immediate planted fields, as without continuous irrigation the plants cannot survive. (However, the long-term effects of, for example, planting and processing gladioli bulbs may be uncertain. The author has seen at first hand where specially hybridised drought tolerant gladioli bulbs are processed. Here, as part of the cleaning process of the bulbs and after extraction from the ground, some were inadvertently washed down from a washing plant into the local desert environment. [154] These bulbs have remained and may shoot and multiply year after year.)

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[153] The author was involved in the planting, growing, protection and harvesting of these and other bulb species.

[154] The production of bulbs is as follows: 1. Bulbs are planted and irrigated until after flowering. Bulbs are lifted by machine and transported to a washing plant adjacent to the growing fields to clean them prior to drying, size sorting, packing and delivery/export to cut flower growers.

4.9.16 During the crop-growing season and after harvest the fields are subject to numerous weed infestations with species, which include *Amaranthus, Solanum, Kochia (Maireana), Datura* and other ruderal type species but these generally do not spread beyond the disturbed ground of the field and where water is available. Some of these synanthropic [155] weed species are indeed foreign imports, e.g. *Datura innoxia* and *Datura stramonium* from tropical South America and Africa/Asia/America respectively. (Feinbrun-Dothan and Danin, 1998, pages 592-3) *Kochia indica (Maireana brevifolia)* for example was brought to Israel during the 1960's as a garden plant. (Feinbrun-Dothan and Danin, 1998, page 168)

5. Agricultural Field Boundaries

4.9.17 Vegetative field boundaries are usually planted with a few select species, which act mainly as windbreaks, and against sandstorms. The species most commonly used are *Eucalyptus* species, *Tamarix aphylla* and *Casuarina equisetifolia* the horsetail tree and *Calocedrus decurrens*, the incense cedar. In most cases these trees are irrigated. However mature specimens of *Tamarix aphylla*, which is the only above native tree mentioned above, can continue providing a good screen without irrigation. *Casuarina equisetifolia* was introduced from Australia whilst *Calocedrus decurrens* is a native of the Californian mountain transition zone. (Jones and Sacamano, 2000, page 83)

4.9.18 Although self seeded *Eucalyptus* specimens have been identified, the other species do not tend to spread beyond their planted lines although mature specimens of *Tamarix* can spread significantly within range of the original plant through the rooting of branching which when old sag and touch the ground. These branches re-root forming secondary trunks. [156]

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[155] Ecologically associated with humans.

[156] This ability to root easily is used in propagation of the species where branches planted 1 - 2 cm in the ground will root. (Jones and Sacamano, 2000, page 317).

6. Natural Habitats

4.9.19 Numerous and varied areas of natural habitat and plant communities (micro landscape zones) exist across the Negev. The types of plants include trees, shrubs, dwarf-shrubs, climbers and creepers, grasses, parasites, geophytes, annuals and perennials. The plants are well adapted to their geographical regions and physical conditions, climate and microclimate and the availability of water. (See section on Phytogeographic Regions in Chapter 3.) The character of the habitat depends on many physical factors with regard to soils, geomorphology, altitude, aspect, and distance from the Mediterranean etc. The quality of the habitat depends on many other factors including the extent of man's interventions such as grazing as well as military and tourist activities.

4.9.20 Plants have adapted to survive in these regions through various physiological means and plant reproduction and distribution is part of the ongoing ecological and natural cycle. Man can obviously have an effect on these actions by overgrazing, by collecting wood for fuel, by causing erosion, by creating artificial barriers and by the introduction of foreign species, which alter the habitat and growing conditions as well as creating competition for the native species.

7. Disturbed Habitats

4.9.21 These areas are best described as areas that are left over after interventions by human activities mainly through construction. These areas include road verges, roadside ditches, embankments and gullies, dam creation etc.

4.9.22 Road verges, roadside ditches and gullies can be subjected to significant amounts of additional runoff water and it is not unusual to see natural vegetation being concentrated alongside the roads passing through the Negev. In fact about one fifth of the total species in Israel occurs along waysides. (Zohary, (b), 1982, page 53) Yaacov Orev states that in the 1950's and 60's road building increased vegetation, which accumulated linearly along the roads, which is credited to increased run-off. Borrow pits also collected rain and *Tamarix* established itself from windblown seeds. (Orev, 1979, in Golany, pages 279 - 281) [157] The species of plants that may be found in these disturbed areas are those that are also generally found within the greater area, but may only occur where this additional water accumulates.

4.9.23 Rainfall that falls on the tar macadam roads runs off the impervious surface onto the verges and into the drainage ditches. An average 7 metre wide road, with a 1.5 metre hard edge on either side, which is cambered in one direction, would thus provide 10.0 square metres of hard surface for run off per metre run. Thus in an area that may receive 100mm of rainfall per annum, run off from the road will increase the surface water available at the outer verge edge from 100mm to 1100mm with the additional 1000mm of runoff. (Figure 39) This equates to 1 cubic metre (1000 litres) of additional water per metre run. This is considerable as it means that plants may receive 10 times the amount of water they would normally receive. If the camber is in both directions, then the additional run-off will be approximately half under the same conditions. This means that plants, which would not normally grow in the immediate surrounding landscape, can thrive alongside roads.

4.9.24 Road embankments and cuttings are also often colonised by local native plant species. Long term examples of this can be seen in the northern Negev on the railway embankments of the disused Turkish railway, which ran southwards from Beer Sheva towards the Red Sea. Here the man made embankments of loessal material collected from the surrounding areas have been colonised mainly by the dwarf shrub *Hammada scoparia* that grows close by. (Appendix H12, Photograph AD10)

4.9.25 Later examples of infrastructure works show the colonisation of roadside embankments and cuttings also of *Hammada scoparia* and by other species

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[157] Orev Yaacov, 1979, 'Revegetation of the Arid Range', Golany Gideon, Editor, 'Arid Zone Settlement Planning, The Israeli Experience', Pergamon Press, Oxford,.pages 279-281.

such as the shrub *Zygophyllum dumosum.* (Figure 40)

4.9.26 Recently disturbed habitats usually show a large increase of ruderal species including *Rumex cyprius, Salsola inermis* and others. (Appendix H1, Photographs A24 and A25 and Appendix A, Figure 41)

4.10 Defining a Suitable Landscape Planting Paradigm for the Negev and other Desert Areas

4.10.1 It has been asserted above that the introduction of and the current use of foreign species, is and may be extremely damaging to the environment. But the question that then arises is whether this is true in all cases, and if so does this mean that all planting in the region should be based on native planting?

4.10.2 A further related question then needs to be asked as to whether a landscape architect or plantsman or indeed for that matter the local authority, have the right to dictate, for example, what a person may or may not plant within his or her own private garden? This is particularly relevant in the desert as the garden may be seen as a kind of paradise in contrast to the surrounding hostile external environment.

4.10.3 The word paradise was first used in Persia to describe the hunting parks of Persian Kings and later, Greek translators of the Bible used the word to refer to the Garden of Eden.[158] Today the Greek word *paradeisos* means park. (Funk, 1956, page 951)· This idea of the garden, being a place of perfection, rest, peace, just rewards, safety, coolness, verdancy and beauty is similar to how we are likely to see a garden today. In the past as well as now, it is in distinct contrast to the hard, dusty, parched, dangerous, dry, hot and harsh character of the surrounding desert lands.

4.10.4 It is suggested by the author that it would be unwise to destroy the idea of the garden as a kind of paradise and to dictate that all gardens should be of the same type and that in desert landscapes all the plants should be xerophytic and of native origin and that large, lush, verdant species should

[158] Hallman Joseph M., 'Paradise', World Book Encyclopaedia,

be discarded. However, there are good reasons to advocate the use of drought tolerant species as water demands and maintenance can well be reduced. As noted above in paragraph 4.6.5 to 4.6.6 people living in the Negev do not pay the full cost for their water and water used in the landscape is charged at approximately 1/8th of the cost of water used in the centre of Israel and the cost of water across the whole of Israel is itself subsidised by the State.[159] However, even if the subsidy on water in the Negev were to be halted this argument in itself is not likely to be enough to dictate the use of native xerophytic plants for all garden use.

4.10.5 In order to find ways to reduce impacts and water demands, it is thus important to try and ascertain how plants are used in the Negev and then to build a model, which would support planting which does not have the potential to create environmental damage. The discussion towards this model is set out below.

4.11 An Existing Landscape Paradigm and an Alternative Landscape Paradigm

4.11.1 In his book *'Greater Perfections, The Practice of Garden Theory'*, John Dixon Hunt draws attention to a tripartite paradigm for the garden or *'any piece of landscape architecture'*. (Hunt, 2000, page 51) Hunt divides the world into three natures which is based on the ideas of the 16th century Italian humanist Jacopo Bonfadio who *'reads the landscape, with its gardens'* as a *'trio of natures'*. (Hunt, 2000, page 34) For Hunt, the 'First Nature' is nature as in wilderness. (Hunt, 2000, pages 58 - 62) The 'Second Nature' for Hunt is agriculture / urban development. It consists of what he calls the *'middle landscape'* and includes the places and spaces where people live, i.e.

[159] Water is subsidised for various reasons. One reason is to encourage settlement and development in the region.

'places where humans have made over the environment for the purposes of survival and habitation, where labour and productivity dominate, and where traces of that work are everywhere visible'. (Hunt, 2000, page 59)

4.11.2 It must be stated that the term 'middle landscape' can be confusing as it is used by a number of theorists to mean many different things. For J. Douglas Porteous it equates to the pastoral and bucolic ideal. (Porteous, 1996, page 78) In history there is a great appeal for this pastoral idyll, even in the Old Testament, such as in the book of Ruth and to the opposite where *'there are many negative references to wilderness'*. (Porteous, 1996, page 79)

4.11.3 For Hunt, 'Third Nature' is the garden. (Hunt, 2000, pages 62 - 75) Porteous sees the garden as *'nature transformed into an idealised conception of landscape form'*. (Porteous, 1996, page 81) Hunt, (2000, page 63) uses the phrase *'third nature'*, which is taken from Bonfadio and Taegio where initially the phrase referred to villa gardens. Hunt says that the term can be

'extended to describe, as was implicit in Bonfadio's letter anyway, those human interventions that go beyond what is required by the necessities or practice of agriculture or urban settlement'. (Hunt, 2000, pages 62)

4.11.4 Hunt's broad tripartite landscape paradigm, as represented in Figure 42, is a useful theoretical starting point, which helps towards an understanding of our environment in the past as well as today. But it appears that it does not cover the full range of existing landscape types that may be found around the world and in the Negev as well. In order to be useful in understanding and determining landscape strategies as far as planting is concerned and to better illustrate the broad landscape zones apparent in our present world it is possible to expand on and re-arrange the paradigm. (Figure 43)

4.11.5 It can be argued that rather than Hunt's 3 Natures, we may observe 4 Natures as main categories with 2 sub categories as follows:

1. <u>Main Category - First Nature</u>

4.11.6 The First Nature is Wilderness with a capital W. The term is used in a qualitative and descriptive sense, but is much more rigorous than that described by Porteous. For Porteous, Wilderness *'involves wild, uncultivated, unspoiled land inhabited by wild creatures and where humans are only visitors'*. (Porteous, 1996, page 76) However, for this paradigm, Wilderness describes landscape character zones that are untamed, unmanaged and totally or almost totally unadulterated by man. These areas are usually extremely remote. The landscape character of these natural habitats is determined by the climatic, geological and the geomorphological character of the area. They usually include areas where climate is extreme and include large parts of the hot and cold deserts, polar regions, some mountain regions and some tropical rainforest areas. They would include areas where man never or very seldom treads. In Israel and the Negev there would be very few areas such as this, although small pockets of largely untouched areas are likely to found, for example, in the higher reaches and precipices of the Eilat Mountains. However, in the Negev, even apparently remote and untouched areas are likely to be traversed either by Bedouin and their flocks, the military, or hikers and other tourists.

2. Main Category - Second Nature

4.11.7 Second Nature is wilderness with a small w. Hunt points out how areas of Wilderness or as he calls it First Nature can be altered. He uses the example of the climbing of Mt. Everest where with its *'abandoned oxygen canisters and dead bodies'*, First Nature can be *'colonised physically as well as metaphysically'*. (Hunt, 2000, page 51) Thus, these areas appear to be untouched by man but in many cases they have indeed been altered and colonised by man. Many of them are natural habitat areas some of which are managed as wildlife/nature reserves. They may also include military ranges and be areas of open pasture and rangeland that are utilised for grazing by local peoples. They are generally areas that are less remote than Wilderness with a capital W and may in fact abut settlement areas and agricultural areas. Some of these are open to various intensities of tourist / management activity. The underlying landscape character is determined by the climatic, geological and geomorphological character of the area as well, but man has had some influence in determining the character of the landscape through management regimes, grazing practices, roads, paths, picnic sites, fencing and through other controls. In the Negev there are many such areas, which form part of protected national parks and nature reserves as well as other areas, which as a result of their difficult topography are largely left untouched apart from the grazing of Bedouin flocks.

3. <u>Main Category - Third Nature</u>

4.11.8 Third Nature is agriculture as part of this alternative paradigm. Whereas Hunt groups agriculture and human settlement together and calls this the *'middle landscape'*, in this part of the paradigm, agriculture is considered a landscape zone in its own right. This is because agricultural landscapes, like inhabited areas usually have a recognisable underlying structure. These structures are generally apparent in the creation of fields and paddocks, field boundaries of walls, hedgerows, markers and drainage ditches as well as drainage and irrigation structures, etc. The practice of growing crops and keeping animals thus creates a very different landscape character and form and is thus very distinct from inhabited areas. This type of landscape also varies in landscape character depending on the region and its climatic, geological and geomorphological character and by the agricultural methods used over time. In the Negev the present agricultural landscapes range from large open fields, irrigated croplands, fruit orchards, glasshouses, dairy paddocks, and chicken sheds within kibbutzim and moshavim to small valley and lower hillside wheat and barley fields planted by Bedouin. The grazing of Bedouin flocks occurs mainly on wilderness with a small w.

4. <u>Main Category - Fourth Nature</u>

4.11.9 Human settlement is the Fourth Nature in this revised paradigm suggested by the author and the landscape character of these developments not only depends greatly on the climatic, geological and geomorphological character of the area but also on cultural factors. Settlement in the Negev takes the form of kibbutzim and moshavim as well as small towns and larger cities. These are characterised by an organised infrastructure of roads and civic, public, commercial and domestic buildings as well as open space areas including public parks. Those Bedouin who have not yet been integrated into towns have created temporary settlements with an organic pattern of temporary tents and corrugated steel sheet houses and dirt access tracks.

a. Sub Category - Garden

4.11.10 This sub landscape character area corresponds to Hunt's Third Nature. It is the Garden.

4.11.11 There are many definitions of what constitutes a garden. As with art it would futile and unwise to try and limit its scope and intent. [160] But for the purpose of this research the garden, is seen to constitute areas, which generally have ornamental horticultural elements [161] and are purposefully designed, created and maintained by individuals or groups as aesthetically pleasing spaces. (These areas include tracts of land that are designed for aesthetic delight as well as physical use.) They generally require high input, are high cost and require high maintenance. They generally are <u>use</u> areas; places and spaces that are meant to be well visited and / or well looked at and are designed and maintained to benefit the viewer and user. (There is little point in having a garden if it is not used or looked at.) In most cases these areas are closely associated with and are located close to buildings. (In the public sphere however, gardens may not be associated with buildings.) These include gardens such as botanical gardens, zoological gardens and arboreta. Parks in many respects can also act like gardens.

4.11.12 Within the context of this thesis it is proposed that the form and content of gardens should not be restricted. This is especially the case of private gardens, which may be based on the classical European conception of the garden as *'an extension of the house into a natural environment'*. (Jellicoe,

[160] There are many definitions of art and it appears pointless to the author to try to limit its scope.

[161] Some gardens may indeed not have plants, e.g. an electronic garden where light and electronic images may be used.

1966, page 89) People's gardens may provide a kind of paradise or at least outdoor rooms formed in many styles and characters. In desert areas, some of these may indeed utilise a natural style based on xerophytic plant material, but others may still want to create a tropical jungle effect. Garden as illustrated in the alternative paradigm diagram, (Figure 43), shows that it can be located within settlements, within agricultural areas as well as within wilderness with a small w. Gardens within settlement areas include many types of private and public gardens. Some gardens may be found in agricultural areas and some agricultural areas may in themselves be seen as gardens where people may find delight in say for example a date palm plantation, where they may sit and picnic. (Figure 44) Gardens may be found in wilderness areas where areas around historic sites, car parks and other tourist facilities are interlinked with areas planted as gardens. However, these areas should not really be considered to be gardens but as a new type of 'middle landscape' as explained below.

b. Sub Category - Middle Landscape

4.11.13 This sub landscape character zone relates to those external places within agricultural, settlement and wilderness (small w) areas, which are treated as gardens, but which if treated differently would be of benefit to the environment and some principles of sustainable development (lower cost, using local materials, ecologically sound, wildlife friendly etc.) They would also be more sustainable in terms of reduced water demands and inputs. In many cases they are secondary-use areas, (but not exclusively so), and their uses can be seen to be secondary as opposed to primary. They are thus areas that usually support other spaces with primary functions and include areas of transition, passage and border / margin / boundary zones as well. They include, for example, tracts alongside roads and within the grounds of institutions; hospitals, universities, research establishments, industrial zones, business parks, military bases and recreation areas. They are often secondary pieces of land that lie between the primary functional pieces of land such as buildings, roads, pathways, gardens, sports fields etc. Within this alternative landscape paradigm, this is the **'middle landscape'**.

4.11.14 In most cases at present, these middle landscape areas are treated as Garden and where they are treated as Garden, they are unnecessarily high cost and high maintenance. In cases where they are transition zones and they provide the ecotone [162] between areas influenced by man and wilderness, treating them as Garden can have a detrimental effect on the ecological character and quality as well as the landscape character and quality of the landscape.

4.11.15 The argument in the case of this research is that these areas in the **middle landscape** should not be treated as Garden but as something else. As shown in the 'Alternative Landscape Paradigm' diagram the **middle landscape** can fall within the zones 2, 3 and 4 of wilderness, agriculture and settlement and it can overlap with Garden. If these areas should not be treated as Garden, they also cannot be seen to be Wilderness (with a capital W) as they are designed and created by man. However, they could be recreated either as zones of agriculture or as wilderness (with a small w), i.e. as natural habitat. In many cases treating these areas as agriculture would be unfeasible due to the lie, shape or scale of the land. Road verges, cuttings and embankments for example may have difficult and dangerous access, be steep and divided into many parts and may be subject to pollutants from vehicles. Furthermore agriculture can in itself be high cost and high maintenance. It is thus much more feasible to treat the middle landscape as wilderness (with a small "w") i.e. as natural habitat where topography and the scale of the land are not so important and where cost and maintenance demands are likely to be low. Treating these areas as habitat also has advantages in creating ecological and landscape character benefits and as ecological buffer areas to other wilderness areas.

4.11.16 Thus, the realisation and understanding of the **middle landscape** is a key issue in providing a background and theoretical methodology for planting in

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[162] The term ecotone has been borrowed by the author from the discipline of ecology where the ecotone is the area where two different habitats intersect.

the Negev and indeed for other arid areas around the world, and for general landscape architecture and landscape planting. The argument is as follows:

1. Wilderness areas with a capital "W" as 1st Nature should be maintained and retained as primeval or original Wilderness [163]. There are too few areas of pristine habitat that are untouched by man and these areas of natural habitat should be protected and allowed to remain pure and untainted for the benefit of nature and ultimately man.

2. Man has many wilderness areas with a small "w" (2nd Nature) that he can observe and "play" in. These habitat areas should be managed and controlled to conserve and / or improve them for the benefit of wildlife, nature and man himself.

3. Agricultural areas as the 3rd Nature should be designed so that the impacts on Wilderness ("W") never occur and that impact on wilderness ("w") is controlled. This control can take many forms and may be extremely difficult to accomplish. In simple terms it may include the restriction of herbicides, insecticides and fertilisers and the control of crops where the seeds may be distributed unwittingly through the actions of water wind and wildlife.

4. The 4th Nature of the built environment should similarly, like agriculture, never impact on Wilderness ("W") and have controlled and limited impact on wilderness ("w").

5. The identity and idea of the Garden should remain as open as possible. Garden planning and design should allow for and mirror the fashions

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[163] It is the opinion of the author that the concept of wilderness for most people is changing. This is probably mostly due to the broadcasting of nature and travel programmes on television. It appears that no longer are untamed areas seen to be barren, or forsaken and as being barren and forsaken.

and tastes of the people who use them and create them. They should be the jewels of delight and invention of individuals and groups and be used for numerous purposes. However, the argument for using xerophytic and drought tolerant species cannot easily be questioned in areas where there is a shortage of water and where water is best used for the health and wealth of the people. Thus, it must be stated that individuals and groups should be persuaded, if at all possible, to use water wisely and to use drought tolerant plants where possible. But restrictions on types and plants used should be limited and should only relate to those species, which are a nuisance and are likely to become weeds. Furthermore, it must be stated categorically that irrigation water for gardens should not be subsidised as it is at present. Garden owners and managers should have to pay the full amount for their water that they use. In this way, people will realise the value of their water and are likely then to start to consider the character of their gardens relative to the hot, dry desert conditions that they live in.

6. Finally, the middle landscape should be treated as habitat. Thus, areas that would be high cost and high maintenance when treated as Garden would be less costly and require less maintenance. Landscape areas treated as habitat will likely improve wildlife conditions and create a much better interface with wilderness (small "w").

4.11.17 The kind of hierarchical landscape paradigm advocated above is similar to one of the methods used in xeriscaping, (water efficient landscape design), termed 'hydrozoning irrigation'. (Jones and Sacamano, 2000, page xx) (Figure 45) This hierarchical approach to irrigation divides the landscape into zones from the wettest to the driest. The wettest areas should be the smallest areas and these 'mini-oases' can include areas of lawn and other high water use treatments. (Jones and Sacamano, 2000, page xx) These areas are high use or are located close to high activity areas, but they should not be larger than necessary to satisfy user needs. Beyond these high-water areas there is a zone where plants will use substantially less water. This can be a transitional zone between the small lush area of high water-use and an even lower water zone near the perimeter. One of the goals for this low-water zone is that little or no water may be required after establishment. (Jones and Sacamano, 2000, page xx) This penultimate zone leads on to a final zone, which is populated by the most drought tolerant plants where only infrequent water is envisaged. (Jones and Sacamano, 2000, page xx) This area is likely to be the largest in size.

4.11.18 The relationship between the alternative paradigm and the hydrological zoning method is clear as wettest and most intensively used zones equate to the Garden. Whereas the two drier zones, i.e. the dry transitional zone and the driest perimeter zone equate to the 'middle landscape'. (Figures 44 and 45)

4.11.19 Now that an appropriate landscape paradigm has been set, which suggests, whether plants would be better suited to garden type situations or in the middle landscape or in some cases, in both, it is appropriate to discuss, further ways of collecting, cataloguing and analysing the plants themselves. This follows below in Chapter 5.

4.12 Summary and Conclusions

4.12.1 In the Negev, despite research into plant use by many notable researchers, and the admirable ecological objectives of the JNF (Jewish National Fund) who are responsible for general planting in the Negev, the native Negev plants have not been systematically assessed for use. This contrasts to some other areas across the world especially in the USA, Australia and South Africa where there are increasing trends towards native plant use in gardens and elsewhere in the environment. In the U.K. where ecological values are increasingly seen to be important, only plants that have a local provenance and can maintain the local gene pool are currently perceived worthy of use.

4.12.2 The focus of plant introductions into the Negev has been on foreign exotic species and the omission of the native species leads to a conclusion that the assessors have not adequately considered the detrimental effects exotic plant introductions can have on landscape character and on ecological values. The omission of considering native plants suggests that the Israeli researcher have an idealistic vision for the Negev and that all landscapes should be treated as if they were gardens and that they should be ubiquitously green. This outlook is flawed because the Negev in its heterogeneity is unique and the floristic and landscape 'genius loci' have not been considered.

4.12.3 The reasons for not using the native Negev species in the Negev are complex. One likely explanation is that the desert and its constituent parts including its flora are considered hostile. Garden making and landscape design are cultural activities and they thus stand in contrast to the harsh natural environment. Although many of the native species are considered to have aesthetic qualities and the characteristic forms of harmony, symmetry, regularity etc., required by philosophers writing on the subject of beauty and aesthetics, the native plants are only valued within their natural context. The process of taking the plants out from their natural context and culturalising them has yet to occur. It is only then that some of them may be regarded to have the aesthetic merit for use in garden and other situations. This research provides a crucial culturalising step towards the use of these native plants.

4.12.4 Water is a key issue in the Middle East. A recent trend in gardening in arid areas including Israel and the Negev is xeriscaping or 'water-wise' gardening. However, most planting in the Negev has followed a western aesthetic using similar plants to those used in temperate and tropical climates and although the conservation of water is important in xeriscaping, the technique in Israel and the rest of the world does not focus on the use of native plants. Using native can significantly reduce water demand. In the Negev, water is subsidised by the state and local consumers do not meet the actual cost of water. In the Negev, the first priorities for water are for the health and economy of communities and using water in garden type landscapes is not sustainable. Using native plants, will reduce water demand and thus will help to create more sustainable development in the Negev and elsewhere in the world.

4.12.5 The introduction of exotic plant species is problematic in the Negev and creates an enormous worldwide problem with extreme deleterious consequences on biodiversity and costs to the environment. The spread of alien species is considered a great threat to the ecological and economic wellbeing of our planet. Exotic species also affect and have the potential to affect the ecology and the intrinsic physical and visual character of local areas.

4.12.6 Exotic as well as native plants improve quality of life by their positive environmental effects and by giving delight, but how and where they are used needs to be considered. In the Negev there are 7 distinctive homogenous zones/habitats where plants are used or are located. Defining these areas is the first step in determining an alternative landscape paradigm, which offers a more sustainable planting model compared to the existing model, which is followed where most landscape areas are treated as a garden. Gardens have high capital as well as maintenance costs and water demands. The alternative paradigm provides a solution that is considerably more sustainable. The main concept behind this model is that garden areas are restricted to zones of high use intensity. Other areas, which are termed the 'middle landscape' should be treated as habitat using native plants.

4.12.7 The numerous issues discussed as part of the literature review in Chapter 4 lead to a discussion in Chapter 5 as to why landscape architects have the appropriate skills to determine plant suitability and use in the Negev and other desert areas. This leads to the creation of appropriate systems for determining plant use based on existing standards and hierarchies.

5. CHAPTER 5 PLANTS AND PLANTING IN THE NEGEV – DEFINING PLANT USE AND AESTHETIC CRITERIA – A LITERATURE REVIEW

5.1 Introduction

5.1.1 Chapcr 5, follows on from the literature review in Chapter 4, where a variety of issues regarding the effects of using / not using native plants are discussed and an alternative landscape paradigm is proposed. As part of the literature review, Chapter 5 investigates the role of the landscape architect in plant choice, illustrating the skills and benefits that landscape architects can bring with regards to assessing and understanding plant characteristics and defining uses. It also reviews existing existing botanical data collection standards and other plant use hierarchies and the plant data collection methodology and proformas used to collect and analyse the physical and aesthetic characteristics of the Negev plants and their growing conditions.

5.2 The Role of the Landscape Architect in Native Plant Choice

5.2.1 Nick Robinson, (1992, pages 23 and 24), poses the question what is distinctive about the landscape designer's skill. In attempting to assess the native plants of the Negev for potential use, the question similarly arises as to why a landscape architect should have the right or prerogative to impose on others, which plants may be suitable for use. In other words, what is distinctive about the landscape architect's training and experience which allows him or her to do this better than anyone else when many people have a professional or for that matter recreational interest in plants? [164] Robinson, (1992, page 13), suggests that in the professional field, there are *'many technical and scientific disciplines that endeavour to understand plants and*

[164] In this case a landscape architect is considered to be a qualified person who has trained at a university or similar institution. In the U.K. the Landscape Institute is the governing body. (Refer to Landscape Institute website).

to use them in profitable ways'. These include botanists, ecophysiologists, taxonomists, and ecologists to name a few.

5.2.2 In answer to these questions, in the first instance, Robinson (1992, page 13), suggests that the approach of the landscape architect is broader than most. As designers, landscape architects must understand something of botany, soils and be familiar with the basic principles of ecology and use some of the techniques of gardening and forestry. They must also have the painter and architect's eye for line, texture and colour and *'a flower arranger's ability to combine plants to create a mood appropriate for the occasion'*. (Robinson, 1992, page 13) Most importantly, Robinson suggests that there is one specialised understanding that no other discipline shares and *'which provides the essence of visual and spatial composition with planting'*. This is the understanding of plants as structural elements in the landscape. (Robinson, 1992, page 13) The use of the term structural elements implies architecture which itself can be considered to be *'any ordered arrangement of the parts of a system'*. (Funk, 1956, page 75) Thus, landscape architecture, in one sense can be defined as the ordered arrangement of parts of a system in the external environment. [165] The landscape architect who has the right training

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[165] There are many definitions of landscape architecture. The American Society of Landscape Architects (ASLA) states that 'landscape architects design the built environment of neighborhoods, towns and cities while also protecting and managing the natural environment, from its forests and fields to rivers and coasts'. (Tom Turner quoting from the ASLA website, LIH Landscape Hub www.) The UK Landscape Institute (LI) states that landscape architects are professionals, 'comprising designers, managers and scientists, concerned with enhancing and conserving the environment' in both rural and urban locations. (Tom Turner quoting from the LI website, LIH Landscape Hub www.). Tom Turner defines landscape architecture as 'the art of composing landform, water, vegetation, buildings and paving to make good outdoor space'. (Tom Turner, LIH Landscape Hub www.)

in aesthetics, spatial design and ordering of elements including planting, is thus in an appropriate position to assess the merits and potential use of plants. The landscape architect is also in a unique position as Robinson suggests as he has the ability to combine science with aesthetics.

5.2.3 The United Kingdom's governing body for landscape architects, the Landscape Institute states that landscape architects

> *'have responsibilities to the character and quality of the environment; they should seek to manage change in the landscape for the benefit of both this and future generations, and they should seek to enhance the diversity of the natural environment, to enrich the human environment and to improve them both in a sustainable manner'.* [166]

5.2.4 This statement taken from the first paragraph of the Landscape Institute's 'Code of Standards and Conduct for Landscape Architects' notes that the duty of landscape architects is not only to the scientific areas of the landscape such as *'diversity'* but also an *'enrichment of the human environment'*. This enrichment may be manifested in many physical ways but also perhaps in similar ways as art and artists do in making art enrich the environment for human beings.

5.2.5 Geoffrey Jellicoe [167] states that *'landscape design has proved itself to be one of the great arts'*. (Jellicoe, 1966, page 1) However, whereas Jellicoe sees landscape architecture as art, which even includes elements of the

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[166] Landscape Institute 'The Landscape Institute Code of Standards of Conduct and Practice for Landscape Architect' (Landscape Institute www.)

[167] Geoffrey Jellicoe was born in 1900 and died in 1996. 'Geoffrey Alan Jellicoe was an English architect, town planner, landscape architect and garden designer'. (Gardenvisit.com, 'Sir Geoffrey Jellicoe - biographical information', website).

subconscious, [168] a scientist is unlikely to show a professional interest in the aesthetic characteristics of plants such as the appearance of leaves and the smell of leaf litter, shade qualities and rustling sounds they create [169]. Nor is the scientist likely to be interested in the physical texture of bark or the silhouetting and shape of branches and canopies and the changes over the seasons and the attraction of wildlife. All these factors and many more are considered by the author, to be features of plants and planting which improve the quality of life for people. The scientist is not likely to view a plant in a poetic nor in an artistic way, nor as ornament where it *'contributes to the beauty or elegance of a thing'*. (Funk, 1956, page 929) [170]

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[168] Ian Thompson notes that for Jellicoe, the inclusion of the subconscious was an important part of art and also landscape architecture. Thompson quotes Jellicoe

as follows where he states that 'the effect upon human beings is the ultimate objective of all landscape design, whether rural or urban. To obtain this impact we have already established that it is necessary to have subconscious as well as conscious appeal'. (Thompson quoting Jellicoe - Thompson www). Thompson disagrees with Jellicoe and states that he is wrong 'in making' the subconscious 'the rigid foundation stone of a theory of art, which in turn has to support a theory of landscape design'. (Thompson www.)

[169] Leaf litter can be sightly or unsightly. It can create a pleasant sound when crunched underfoot and it can smell delightful, e.g the leaves of the *Katsura japonica* tree smells like ripe strawberries when they fall from the tree in the autumn.

[170] The idea that scientists do not have aesthetic sensibilities is obviously way off the mark as many of them must obviously do. This is evident for example in the way plants are arranged and displayed at the Royal Botanical Gardens at Kew. Darwin notes in Chapter 1 of *'The Voyage of the Beagle'* that on February the 20th 1832 that *'half-way up the*

5.2.6 In 1997 the distinguished ecophysiologist in the Negev region, Prof. Gutterman introduced a paper, entitled *'Geophytes of the Negev as a Genetic Source for Ornamental Garden Plants, Cut Flowers and Pot Plants'*, which discussed geophytes and their potential for ornamental use. (Gutterman, 1997, Acta Horticulturae) Gutterman identifies various geophytic plant species for ornamental uses including potential species for pot plants, ornamental garden plants and cut flowers. Although the author's own assessment of the plants discussed, is generally in accord with Prof. Gutterman's analysis, his assessment was not based on all the criteria that landscape architects would expect. For example, the process of selection does not include any discussion on why and how the species could be used and there is little information regarding aesthetics or form, colour, height, leaf texture, smell etc. There is furthermore no discussion as to whether these plants could be used singly or in groups or where they could be used, for example, in borders, in grass areas, in road-side locations, on embankments etc. In terms of landscape and horticultural use, the investigation does not fully succeed because the analysis is botanical rather than being landscape architectural. In other words, the study does not

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mountain, some great masses of the columnar rock, shaded by laurel-like trees, and ornamented by others covered with fine pink flowers but without a single leaf, gave a pleasing effect to the nearer parts of the scenery'. (Bartleby.com www.) This shows that Darwin was not immune to the obvious beauty of the scene created in part by the plants, but his objective like most other scientists involved with plants was not an analysis of the aesthetics but of the plants and themselves. Plant hunters, such as George Forrest who made seven collecting expeditions to Yunnan province in China in the early 20th century, collected and documented *'over 31,000 plant specimens, several hundred of which are still in cultivation today'* was obviously spurred on by the aesthetic qualities and not only the potential practicality of plants that he collected. (LetsGoGardening www) comprehensively analyse the multiple and varied functions that the geophytes could fulfil. [171]

5.2.7 Since the earliest of times plants have had multiple functions. A tree or a shrub can produce edible fruit as well as be used for wood and fencing, but it can also provide shade and formal structure. It can define space as well as having aesthetic characteristics such as introducing a play of light and/or colour. It can also have symbolic and religious meanings. *Acacia raddiana,* which grows in the Negev and in other desert areas in North Africa is a good example. It provides shade for people and wildlife, (refer to Chapter 6 and especially Chapter 7), it provides large amounts of leaves and pods for grazing animals and herds (Sanon et al. www.) and gum arabic, which is used in the food industry as a stabiliser. [172] It is also considered to be the tree from which the wood was taken to build the Israelites' ark of the covenant. [173] It is thus symbolic in its religious context for Jews, Muslims and Christians. And, for the Freemasons it represents the *'the immortality of the soul'*. (Freemasons, www.) The decision to use a certain type of plant is therefore not only tied into its practical function but also its aesthetic and sometimes symbolic function.

5.2.8 The potential use of plants is the central and driving theme in the field of economic botany. Plants have been used through the ages as food and

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[171] The critique of the research paper does not in any way diminish the significance of the study. The study is important for this research as it notes ten species, which have potential for garden plants and/or for pot plants. Of notable importance is the information given that certain plants will remain evergreen with some additional water.

[172] The gum is extracted during the dry season and is used for medicine manufacture, for confectioneries and the textile industry. (FAO Document Repository www.).

[173] *'And they shall make and ark of shittim wood...'* (Biblicalgardens.org www.)

medicine and for the creation of everyday products as well as in horticulture. The Royal Botanic Gardens, Kew published the *'Economic Botany Data Collection Standard'* by Francis E. M. Cook in 1995 in order to

> *'provide a system whereby uses of plants (in their cultural context) can be described, using standardised descriptors and terms, and attached to taxonomic data sets'*. (Cook, 1995, page 1)

5.2.9 This publication is extremely pertinent to the author's research as one of its main functions is its *'Use/value'*, where plant descriptions need to include *'what the plant* (is) *used for, or what negative values does it have (e.g. as a weed affecting food production, or as an accidental poison)?'* (Cook, 1995, page 1) Most importantly, the comprehensive and well established standard list of uses has provided the basis for the hierarchy of potential uses utilised in this research. A discussion of the operation of the standard is noted below and a number of potential improvements are noted.

5.2.10 The first level of the standard, according to which plants are described is the Level 1 state, which records the use(s) of the plant. Thirteen uses are noted including *'Environmental Uses'*.[174] (Cook, 1995, page 5) The Level 2 state allows for a more detailed breakdown of the use, and in the Level 3 state the breakdown is increased.

5.2.11 The Level 2 state, for *'Environmental Uses'* is *'based on the major kinds of environmental uses that have been identified'*. (Cook, 1995, page 71) There are four Level 3 descriptors: *'Specific Environmental Uses, Materials Used, Plant Parts Used and Environments Where Used'*. (Cook, 1995, page 71) These are illustrated in Table 5.1, Table 5.2 and Table 5.3 below which have been extracted from the publication.

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[174] The 13 use areas include: 'Food, Food Additives, Animal Food, Bee Plants, Invertebrate Food, Materials, Fuels, Social Uses, Vertebrate Poisons, Non-Vertebrate Poisons, Medicines, Environmental Uses (and) Gene Sources'. (Cook, 1995, Page 5)

Table 5. 1 Schematic Diagram Showing the Relationship Between the Three Levels of the Economic Botany Data Collection Standard – Environmental Uses (After Table 3, Cook, 1995, page 11)

LEVEL 1 states	Level 2 states	Level 3 states
ENVIRONMENTALUSES (As noted above there are 12 other uses) [175]	- Unspecified environmental - - Uses - Erosion Control - Shade/Shelter - Revegetators - Indicators - Soil Improvers - Ornamentals - Boundaries / Barriers /Supports - Agroforestry - Firebreaks - Pollution Control	- Specific Environmental Uses - Materials Used - Plant Parts Used - Environments Where Used

Table 5. 2 Matrix Showing Level 3 Descriptors (The shaded elements are redundant combinations) (After Table 36, Cook, 1995, page 71)

	Specific Environment al Uses	Materials Used	Plant Parts Used	Environments Where Used
Environmental Uses – Unspecified Environmental Uses				
Environmental Uses – Erosion Control				
Environmental Uses – Shade/Shelter				
Environmental Uses – Revegetators				
Environmental Uses – Indicators				
Environmental Uses – Soil Improvers				

[175] Ibid.

	Specific Environmental Uses	Materials Used	Plant Parts Used	Environments Where Used
Environmental Uses – Ornamentals				
Environmental Uses – Boundaries/Barriers/Supports				
Environmental Uses – Agroforestry				
Environmental Uses – Firebreaks				
Environmental Uses – Pollution Control				

5.2.12 The states for the Level 3 descriptors is included in a further table, Table 5.3, which is as follows:

Table 5. 3 States for the Level 3 descriptors for environmental uses
(After Table 36, Cook, 1995, page 71)

Specific Environmental Uses [1]	Materials Used	Plant Parts Used	Environments Where Used
(Agroforestry) intercrops/alleycrops nursery crops **(Boundary/Barriers/Supports)** boundary markers animal barriers plant/agricultural supports fence supports **(Soil Improvers)** fertility improvers nitrogen fixers soil moisture conservers soil structure improvers **(Pollution Controllers)** waste water purifiers	Hedges Live fences Live stakes Brushwood Contour strips / ridge / bund plants Ground covers Lawns Turfs Mulches Green manures Fertilisers Nodulated plants Potted plants Cut flowers Everlasting flowers Dispersed trees Shelterbelts	Live plants *in situ* Entire plant *ex situ* Unspecified aerial parts Leaves Seeds Seed cake Leaves Roots Fruits Inflorescences wood	Landscapes Towns Roads / streets / highways Parks Sports grounds - golf courses football pitches gardens homesteads greenbelts croplands / orchards rangelands forested lands industrial wastes / dumps mined land waterholes degraded land

Specific Environmental Uses [1]	Materials Used	Plant Parts Used	Environments Where Used
air purifiers/air pollution regulators sewage treatment	– Multi layer - Single layer		eroded land burnt land clays sands dunes rocky soils gravels acid soils alkaline soils brackish soils saline soils waterlogged soils mineral soils heavy metal soils copper-rich soils lead-rich soils tin-rich soils zinc-rich soils selenium-rich soils chromium-rich soils aluminium-rich soils magnesium-rich soils mercury-rich soils molybdenum-rich soils nickel-rich soils antimony-rich soils arsenic-rich soils coastlines coastland intertidal zones slopes gullies watercourses groundwater underground water

Specific Environmental Uses [1]	Materials Used	Plant Parts Used	Environments Where Used
			uplands wetlands sea lakes moors / heathland deserts
[1] The terms in brackets are Level 2 not Level 3 character states: They are included only to indicate the hierarchical relationships.			

5.2.13 It is considered that although the standard covers most aspects of plant use, especially in terms of environmental uses, it is not yet definitive with respect to landscape uses [176]. Furthermore it appears that the 4 categories used in the Level 3 descriptors are unpersuasive and confusing. This is evident in Table 5.2 itself, where almost half the cells (shown in grey) are noted as illustrating *'redundant combinations'*. (Cook, 1995, page 71) It is suggested that two of these categories, which are *'Materials Used'* and *'Plant Parts Used'* should be revised. Thus it is considered that the first state and the last state should be retained and the two other states should be changed to 'Function and 'Plant Parts which Define Use'. 'Function' will define the use much more clearly than the Stage 2 descriptors. In 'Plant Parts which Define Use', the identification of the part of the plant, which is the predominant factor in its use, also appears to offer valuable information. For example the shade producing ability of the *Acacia tortilis* species is largely due to its dense branching structure. [177] Thus the states for the level 3 descriptors would read as follows:

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[176] The author has corresponded with Ms Cook and she agrees in an e-mail of 20/04/2006 that when the document gets revised that a landscape architect should be involved.

[177] This Level 3 descriptor is used with most of the other Level 1 states.

Table 5. 4 Alternative States for the Level 3 Descriptors for Environmental Uses

Specific Environmental Uses	Function	Plant Parts which Define Use'	Environments Where Used

5.2.14 It is also suggested that the environmental use of *'revegetator'* should be altered to the more appropriate and contemporary term 'habitat creation'.

5.2.15 *'Gene Sources'*, is the last of the thirteen Level 1 use categories. (Cook, 1995, page 73) Its role is to determine *'beneficial genetic traits'*, such as *'disease resistance, pest resistance, drought resistance, high yields, cold tolerance, waterlogging tolerance'* and *'salt tolerance'*. (Cook, 1995, page 73) A final group of descriptors are termed *'Stand Alone Descriptors'* (Cook, 1995, page 73) and *'Weeds'* forms one of these stand alone descriptors. The role of this descriptor is to note whether the plant may be considered a *'weed of cultivated land'*, a *'weed of urban areas'*, a *'weed of rangeland or pasture'*, an *'aquatic weed'* or a *'weed of forested areas'*. (Cook, 1995, page 76)

5.2.16 It is considered that when it comes to landscape uses both these strands of information should form an integral part of the Level 3 descriptors. However it is also suggested that it would be preferable to broaden the parameters for weeds to include other potential environmental problems e.g. toxicity.

5.2.17 Thus for example if the plant that is being analysed is the shrub *Retama raetem* the data could be organised for a number of specific environmental uses as follows:

Table 5. 5 Alternative Matrix Using *Retama raetem* as an Example Species

Specific Environ-mental Uses	Function	Plant Parts which Define Use'	Environments Where Used	Beneficial Genetic Traits	Problems Weed / toxicity
Erosion	Wind erosion	Whole plant–	Mostly on	Drought	Considered

Specific Environ-mental Uses	Function	Plant Parts which Define Use'	Environments Where Used	Beneficial Genetic Traits	Problems Weed / toxicity
Control		Roots stabilise soils, Tall dense branching creates shelter	sands and loess	tolerant High salt tolerance	a weed in California, Australia Toxic to livestock
Shade / Shelter	Good for shelter belt - no canopy thus no vertical shade	Upright branching to 4 metres. Creates shade when altitude of sun is lower	Not used specifically for shade but good in agricultural areas and settlement edges	Drought tolerant High Salt tolerance	Considered a weed in California, Australia Toxic to livestock
Ornamental	Large plant therefore space required. Attractive all year round. White flowers with vanilla smell very attractive in Spring Good in groups or as specimen plants in larger areas or as informal hedge Possibly could be pruned to create smaller shrubs and dense landscape swathes	Whole Plant	Mostly on sands and loess	Drought tolerant High Salt tolerance	Considered a weed in California, Australia Toxic to livestock

5.2.18 The changes that have been suggested above with regard to the data collection standard are a response by the author as a landscape architect and it is considered that many other landscape architects would advocate similar changes.

5.2.19 It is therefore the contention of this research that the decision as to whether a plant may be suitable for landscape, environmental or horticultural purposes is appropriately left to a review by a landscape architect who can analyse plants and plant use suitability in a broad and holistic way [178]. The landscape architect can consider physical attributes as well as aesthetic and other characteristics (e.g. symbolic), and also take account of the required botanical and physiognomic [179] features and the appropriate planting conditions.

5.2.20 Mixing art or at least aesthetics with science is often an integral part of the landscape architect's job. This drawing together of different aspects of design towards an appropriate totality is mentioned in Chapter 1, with specific reference to Marcus Vitruvius Polio who defines the 3 main principles of architecture as *commodity, firmness and delight.* Chapter 1 also mentions the redefinition of these aspects by Ian Thompson in his publication *'Ecology community and delight: sources of values in landscape architecture'.* Whereas Thompson changes the two initial cornerstones of the Vitruvius' architectural theory from *'commodity'* and *'firmness'* into the landscape architectural cornerstones of *'ecology'* and *'community'* he leaves the third cornerstone, namely the issue of *'delight'* well alone. The principle of delight as a foundation for good design remains thus for both the 1st century BCE Roman and Thompson, the contemporary writer.

5.2.21 It is this issue of delight, which cannot generally be considered adequately by those that are not part of the design fields. Although scientists may have intuitive and even intellectual responses to plants it is part of the landscape architect's job to look at plants in a holistic way. The issue of delight and aesthetics is always part and parcel of how a landscape architect looks at the world and it is always a potent consideration in the understanding and use of plants. It is thus the landscape architect, who can best realise the full

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[178] This thesis is not meant to be rigid as other trained and skilled people, such as garden designers and other individuals may be as proficient or even more proficient than the average landscape architect.

[179] The word is used in the sense of outward appearance.

potential of the native plant species of the Negev and their suitability for a variety uses in the Negev.

5.2.22 The advancement of the landscape architect as the appropriate person to undertake broad scale as well as smaller scale planting in the landscape is also endorsed in Chapter 4.

5.3 Plants - Types of Use

5.3.1 Considering the 422 000 plant species found around the world [180], the numbers of plants which may be used for garden purposes is quite high. [181] An astonishing 73 000 are listed in the 'RHS Plantfinder' in the U.K. [182] However those species that may be suitable for general landscape amenity projects and those used by most people in the 'first world' number only about 8000. [183]

5.3.2 The plants that are suitable for amenity use generally have a number of key character traits. In order for them to be useful in the garden and in the

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[180] David Bramwell states that there are approximately 422 000 species of flowering plants worldwide. *'This is about 100,000 more than the previous highest estimate'*. (Plant Talk, www.).

[181] The Royal Horticultural Society *'Plant Finder 2005-2006'* notes 73 000 plant species available in the U.K. (http://www.rhs.org.uk/rhsplantfinder/plantfinder.asp)

[182] Landscape amenity planting refers to plants and planting areas as horticultural features and gardens using trees, shrubs other flowering specimens. Thus amenity planting *'is planting carried out for aesthetic and other non-forestry or conservation purposes'*. (Wildlife Trust ,www.).

[183] The Missouri Botanical Garden website states that 'Preliminary calculations reveal that there are about eight thousand species of ornamentals available in commercial trade catalogues today'. (Mobot.org, www.)

landscape they generally need fulfil a function and be:

1. Healthy and relatively disease free;
2. Strong, but not overly vigorous;
3. Visually pleasing and/or;
4. Visually striking and/or;
5. Appropriate in form and structure.

5.3.3 In general these plants need also to have one or more of the following features:

1. Good leaf cover;
2. Interesting and/or attractive flowers and or interesting and attractive seeds / pods, bark etc and have a
3. Good and not an offensive smell.

5.3.4 However, whether the plants are chosen for temperate climates or for arid regions, the greatest determinant for use, is use itself, i.e. the function that the plants(s) need to fulfil. Jones and Sacamano, in their publication *'Landscape Plants for Dry Regions'* (2000, pages xxxi-xxxiv), term these functions as *'design elements'*. The authors have created a design palette of 32 design elements for arid regions as noted alphabetically below: (Comments by the author of this thesis on the design elements and the characteristics are made in brackets.)

<u>Accent</u> - Bold forms to emphasise points, dramatise entrances and intersections.

<u>Background</u> - Non-attention seeking background shrubs used for screening and providing a foil for other plants in the foreground.

<u>Bank</u> - Used on slopes, similar to erosion control plants. They must root deeply and spread and endure more exposure and drying conditions. (Shallow but extensive rooting plants are also important as these bind the

soil surface and mitigate erosion. Deep rooting plants on their own would not be effective.)

Barrier/Hedge - Restrict passage of people and animals and define property. (In the U.K., hedge planting would also be used to provide physical and visual spatial definition, containment as well as decorative features in their own right, for example, box edges.)

Border - Narrow strips along paths and wider garden beds, often using perennials or flowers for special displays. (In the U.K. annual bedding plants would also form an important part of this group.)

Buffer Zone - Protect an area from undesirable climatic or site use conditions. These are often called shelterbelt areas.

Close Up Viewing - Planting specimens with interest, which are used in areas where close viewing will occur. (This should possibly not be included as a function on its own, but rather as a sub-function. Plants for close up viewing would be chosen because of visual interest but for many other reasons as well, including leaf and bark interest, absence of bad smells and horticultural problems etc.)

Colour - Planting used to display colour. (Colour may be seen as a sub-factor for use as colour as well as other criteria such as form, structure, leaf shape, contrast, smell etc. may determine use.)

Container Planting - For areas where plants cannot be placed in the ground or cold tender plants which may need to be relocated indoors or protected. (Containers may also be used for design effect.)

Contrast - Planting that combines and juxtaposes flowers/foliage/forms for dramatic effect and visual interest. (This category appears redundant as plants may harmonise or contrast or indeed clash with one another. Much depends on the mix of plants used.)

Desert Effects - Uses desert plants such as cacti, yuccas and desert trees. (This is a strange category especially for a publication on desert plants. However, cacti and succulents do provide a particular kind of visual character reminiscent of the American south west. It is always worth remembering that cacti are only native to the Americas.)

Erosion Control - Planting that counteracts runoff and drainage problems. (Erosion control should also include wind erosion, which is a major problem in many desert areas. This planting is also very similar in kind to the planting for banks noted above.)

Espalier - Plants that are trained against walls. (The text omits to instruct on the benefits of microclimatic control by planting against walls where the plants absorb and reflect heat which, would otherwise be absorbed by the walls.)

Foreground - Low planting placed in the front of larger plants. (This appears to be the same as groundcover planting.)

Foundation - Similar to foreground planting, foundation planting is placed at the base of structures. The planting relates the structure to the site. (In the U.K. the term foundation would refer more particularly to planting which acts as the backbone of a scheme.)

Groundcover - Low growing planting that carpets areas. (This could also be foundation planting, or foreground planting, erosion control etc.)

Medians or Parking Islands - must be tolerant of wind, heat, sun and pollution. In medians they are generally low growing. (Also other hostile environments including roadside embankments, areas against walls where heat accumulates etc.)

Minoasis - This is a term used in Xeriscape™ design and incorporates lush areas of planting and lawns adjacent to high use areas.

Parks/Plazas/Urban Areas - Planting appropriate to busy paved areas enduring reflected heat, pollution, and wind funnelled by urban structures.

Patio - Plants used in an outdoor living space. Patio trees are those that can be trained into an umbrella shape. (Patio plants could well include, container plants, accent plants, colour plants etc. The author has found that most native trees growing in the Negev are indeed broader in shape than taller. Refer to Chapter 7.)

Revegetation - These plants are used to restore cover on denuded land, e.g. agricultural land which is being retired because lack of water. (It is considered ill conceived to revegitate land using anything but the native flora when returning areas of land to natural local habitat. Thus any plant for revegetation should be, if possible, native to the local area. The term "habitat creation" appears to be more suitable than revegetation.)

Roadside - Plants that can endure narrow planting areas and endure wind, pollution and little care. (Roadside edges often favour plant survival in desert areas because of increased run-off from the road surface, which can provide up to 10 times the amount of precipitation as well as effective seed dispersal caused by increased run-off and wind movement created by vehicles. (See Figure 39)

Rock Garden - Plants that 'revel' in such situations. (The rock garden is seen as a character type of garden using natural rock and 'tastefully composed formations'. (Jones and Sacamano, 2000, page xxxiii). (It is assumed that the type of garden noted above is perceived to appear natural.)

Screen - Plants that provide privacy and are like background plants and provide wind and dust control. (These plants may be hedges and may be in the foreground and therefore the effect as described appears confusing.)

Shade - Trees to provide shade and dappled light, cooling effect and rustling of leaves. (Climbers on man made structures can also provide shade.)

Silhouette - Provide a dramatic see through pattern when viewed against a plain wall or against the sky.

Space Definer - Used to articulate divisions of use areas and spaces including hedges.

Specimen - Single plants used for dramatic or unusual form or colour, like a piece of sculpture.

Transition Zone - Plants that are used between concept zones such as between a lush zone and a dry zone. (Although plants may be used in transition areas, it is not feasible to consider a plant as a transition plant per se. This is because whereas in one scheme a plant may be used in a transition zone, in another scheme the same plant may be of use in a more primary zone.)

Tropical Effects - Lush and bold, leafy and evergreen often with colourful flowers. (This appears similar to the aforementioned 'Minioasis'.)

Understorey - Planting that thrives under trees and larger shrubs.

Woodsy Landscape - Using trees so that the canopies interlace and intermesh. (In the U.K we would refer this as upper storey woodland canopy.)

5.3.5 The above list of design uses appears over elaborate as some effects could rather be used to inform decisions with regard to the choice of plants within the main categories. For example, the colour of a plant may well be a criterion for the choice of an accent plant, or a groundcover, or a patio plant etc. Furthermore a transition zone plant may indeed be a plant which in one scheme may be transitional but in another main stream. Barriers/hedges and space definers could indeed be used within one effect and not two as described above.

5.3.6 Some vital effects or uses have furthermore, not been defined by Jones and Sacamano. Most importantly, environmental design uses have not been considered. These are as follows:

Climbers - These are important plants in any landscape whether climbing on walls, pergolas or through trees. They ameliorate microclimate, by providing shade and absorbing solar radiation and creating visual and aesthetic interest.

Rangelands - These areas require native plants, which are suitable for grazing whilst at the same time maintaining and protecting bio-diversity.

Reclamation of polluted and industrial sites - These plants can be used as they tolerate various kinds of pollution and pollution levels and may also ameliorate pollution. Some saline tolerant plants can absorb large quantities of salt from the soil

Habitat Creation and the Middle Landscape - Native plants used in association with one another can be used to create valuable habitat.

Wildlife - Plants can be used to attract, provide shelter and protect wildlife, including bees, insects, birds etc.

Shade - This is a primary design effect as some plants may be used for this primary purpose.

Water and water margins - Even in desert areas there are areas with water and there are plants that are associated with water.

Roof Gardens - This effect is likely to tie in with container plants, but may be considered as a section on its own.

5.3.7 Taking Jones's and Sacamano's elements and the additional elements described above it is possible to arrive at an overall palette of design elements. Thirty one use categories have been devised as noted immediately below. However, this range of uses is still perceived by the author to be too complex, but it does form the basis for the breakdown of potential uses as noted in Chapter 6 and as noted in Appendix F. The 31 revised elements in alphabetical order are as follows:

Accent - Bold forms to emphasise points, dramatise entrances, intersections and architectural features.

Architectural integration and interface - Noted as foundation planting by Jones and Sacamano, these plants can be used to help the interface between architecture and the external environment and to provide architectonic elements which relate to architectural elements.

Background - Non-attention seeking background shrubs used for screening and providing a foil for other plants in the foreground.

Bank - plants that can be used on slopes.

Barrier/Hedge/ Space Definer - Informal and formal hedges that may define and confine space, physical movement and views.

Border - Plants that can be used in planting beds.

Buffer and Shelterbelt Areas - Broad areas where plants used to ameliorate microclimate, particularly wind and to provide abroad buffer to negative external influences.

Climbers and Espalier - Plants used on walls, pergolas, and to climb through and on other plants.

Container Planting and Roof Gardens - Plants suitable for use in containers where, and on roof gardens.

Courtyard and Patio - Plants that are suitable in enclosed/semi enclosed intimate and well-used areas.

Desert Effects - Cacti and other plants that convey an image of the desert.

Erosion Control - Plants that can be used to stop water and wind erosion of soils.

Foreground - Low planting which is closest to the viewer.

Groundcover - Low planting which covers large areas of the ground.

Habitat Creation and the Middle Landscape - local native plants which are used to create or recreate local habitat types for the benefit of local ecology and particularly wildlife.

Oasis - Plants that are visually and physically associated with water and provide a lush oasis type image.

Parkland - Plants that can be used in areas of turf.

Plazas/Urban Areas - Plants that can be used in built up areas surrounded by paving and buildings and people movement.

Rangelands - Native plants which are suitable for grazing whilst at the same time maintaining and protecting bio-diversity.

Reclamation of polluted and industrial sites - Plants that can be used on sites with particular pollution problems and to remediate pollution.

Revegetation - These should be native plants, which are used to create habitat.

Roadsides and Medians - Plants that can survive along side roads and in medians.

Rock Garden - Plants that are appropriate to rock and gravel gardens.

Screen - Planting that provide a visual screen.

Shade - Plants, mainly trees and climbers that are used to provide shade.

Silhouette - Plants with particularly interesting branching and form, which are to be viewed against an architectural or floral foil or against the sky.

Specimen - Plants that have the visual character and stature to be used as single specimens.

Tropical Effects - Big leafed and lush plants in high-use areas.

Understorey - Plants that grow under trees and other plants.

Water and water margins - Plants that grow directly in water or on the water's edge.

Wildlife - Plants that attract and protect and enhance wildlife potential

Woodland Trees - Trees that can be used to create an upper storey canopy.

5.4 Negev Plants – Field Study Review and Analysis

5.4.1 One hundred and sixty three Negev plants were assessed during field surveys of the Negev during the late 1990's and the early years of the 21st century. Two proformas were used to collect this information. (Refer to Appendix B)

5.4.2 The first proforma is titled 'Landscape Plants of Desert Origin – Plant Survey Sheet'. [184] The function of this proforma was to allow the author to

[184] The title 'Plant Survey Sheet' would have sufficed.

record as much data in the field with regard to the physical character of each species visited as well as the immediate and local growing conditions and then to record additional information gathered that day or in the immediate following weeks from a literature review of the plant species.

5.4.3 The second proforma was titled 'Grading System for Assessing the Value of Xerophytic and Halophytic Plants for Amenity/Ornamental Purposes'. [185] This form centres on the grading of the plant species in the field with regard to aesthetic criteria. (Scans of the proformas are included in Appendix B)

5.4.4 The format of the data collection forms was black and white double sided A4 for the 'Landscape Plants of Desert Origin – Plant Survey Sheet' and single sided A4 for 'Grading System for Assessing the Value of Xerophytic and Halophytic Plants for Amenity/Ornamental Purposes' form for ease of printing and duplication and use with a clip-board. (See Appendix B). The breakdown of items that could be collected on the proformas was considered and expanded to be as broad as possible and to allow others, if necessary to locate, identify and compare the plants analysed. However, it became apparent, during its use that the forms were overcomplicated and that only certain information was relevant to the research.

Landscape Plants of Desert Origin – Plant Survey Sheet

5.4.5 This proforma, illustrated in Appendix B, is double sided with a checklist of 16 main categories and 152 items. The form also included a series of checklist boxes and pictograms, which could be checked/ticked. (As noted above many of these were not used on site as 1) they were meant to be filled in when information became available from the literature review, 2) the information related to later parts of the research, e.g. the kinds of suitable uses, or to research that would need to be carried out as additional studies.

5.4.6 The recorded data included is as follows:

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[185] A more apt title would have been 'Grading of Plants According to Aesthetic Criteria'.

1. Background Information:

- Headers at the top of the page: Location where plant found, the date of data collection, and sheet and photographic reference numbers. A grid location was also noted. The grid was 'read off' the 1:100 000 mapping published by the Israel Nature Conservation Authority (טבע שמורות), mainly off maps 4, 5 and 6 which cover the Negev. The function of this grid was to allow the author to note as far as possible the exact location of the plants found and analysed. [186] The land use was also noted;

2. Nomenclature and Associations;

- Family, Genus, Species/Variety/Cultivar – This identifies the plant;
- English/Common names and Local Names – This information is necessary as many people would only know the local or commonly used name. The source for this information is in the literature review of the plants;
- Country/Area of Origin and Biome Association – The country of origin is necessary as not all the plants found are native. The biome is too broad a category and was thus not used. The source for this information is in the literature review of the plants;
- Phytogeographic Territory Association and Other Associations - This information is sourced in the literature review mainly according to Feinbrun-Dothan and Danin, (1993); and
- Conservation Status. This information is important as it gives an indication of the rarity of the species and whether it was protected.

3. Habit:

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[186] At the start of this search and during most of the research 1:100 000 scale mapping was the most detailed mapping available. Recently more detailed mapping at 1:50 000 has been published.

- Categorisation according to: Tree, palm, shrub, sub shrub, geophyte, annual, perennial, grass, climber, succulent;
- Xerophyte and/or Halophyte: Noting whether the plant was drought and/or salt tolerant;
- Tree Height: Large (15m+), Medium (5-15m), Small (to 5m)
- Heights of species other than trees: Large (1.5m+), Medium (0.5-1.5m), Small (0-0.5m);
- Maximum height and maximum spread – This information is a composite of the data from specimens analysed in-situ and from the literature review;
- Maximum creeping and hanging for climbers and creepers – Similarly this information is a composite of the data from specimens analysed in-situ and from the literature review;
- Single or multi-stemmed;
- Evergreen / semi-evergreen / Deciduous – This was meant to include information on the periods where leaf loss was experienced.

4. <u>Character</u>

- Shape – This category was divided into broad, narrow, or weeping. This category could also have been confirmed by checking the pictograms on the right hand side of the proforma;
- Foliage Texture – Three types were noted; fine, medium, or coarse;
- Foliage Colour – The author realised at the outset that a description of plant colour would not be absolutely clear and people may have very different perceptions of what 'bluey green' may mean. In the initial field trip the author made water colour swatches of the colours, (Refer to Figure 46) but later on this was replaced by using

'RHS Colour Chart' colour swatches. [187] (Figure 47) The chart *'is the standard reference for specifying flower colour'*. (The Royal Horticultural Society, 1995, page 1)

- Autumn Colour / Colour Under stress – Plants may show differences in leaf colour in the autumn and when they may have drought stress;
- Significant Bark Feature – Noting bark and bark colour when this was a feature;
- Significant Fruit / Nuts / Seeds – This information would add to knowledge about the visual character of the plant and potential wildlife value as well;
- Significant Flowers and Colour – Information regarding flowers, size, season and colour. The colour analysis of flowers followed the same course as foliage. The bulk of plants were analysed using the RHS Colour Chart;
- Flowering Periods – The field notes observe whether the plant was in flower. Further information on flowering periods is mainly taken from Feinbrun-Dothan and Danin, (1993), and both of Shmida's publications, (1986 and 1994.)
- Spines / Thorns / Irritant – Many desert plants are spiny or thorny and cause irritation. These kinds of plants would be difficult to use in areas where children may play or where pedestrian traffic was high. This information is based on field analysis and in the literature review of the plants;

[187] As a trained artist, with two degrees in Fine Art, the author deemed himself proficient in replicating colour with watercolours. However, the analysis of the colours with the RHS swatches, is more robust, easier to convey and a more expedient method to use in the field. It is likely that, the author is the first person to have undertaken such a study using the RHS colour fans in the Negev.

- Poisonous to humans and/or animals – Some or all the parts of some plants are poisonous if digested. This information is based in the literature review of the plants;
- Wildlife Use – A check in the field and in the literature whether the plants are used by wildlife for shelter, nesting, shade, food etc;
- Percentage Density of the Species in the Area – This was used but it is in an inappropriate location and would have better been located at the top of the proforma. Broadly identifying the percentage of the species in the area gives an indication of the suitability of the geographical, climatic and other growing conditions of the particular species;

5. <u>Aspect</u>

- Altitude – This refers to the location of the plant above local sea level as shown on the maps;
- Aspect / Exposure – This refers to whether the plants were facing a particular direction with regard to the points on the compass. The information is noted here as well graphically at the top right hand side of the page within a typical north, south, east, west cross form;
- Shaded by Plants or Topography – Some plant only grow where they are shaded by other plants or topographical features;
- Exposure to Full Sun – This would mean that the plant is open to all directions and not shaded by other plants and / or topography;
- Exposure to Wind – This similarly means that the plant is exposed and not sheltered.

6. <u>Climate</u>

- Hardiness Zones – This information is established where it is available from the literature;
- Hardiness Minimum – Degrees of frost noted in degrees centigrade noted in the literature;

- Hardiness Max – Maximum heat tolerance in degrees centigrade noted in the literature.
- Saline Winds – This category was not used as it was not safe for the author to travel into Gaza;
- Inland Hot and Cold Inland Winds – This was not used as the information is not available;
- Rainfall – Noted as summer or winter rainfall in millimetres from the literature review. In the Negev, the rainfall is considered winter rainfall although rains may commence at the end of autumn and continue into spring.

7. pH

- This information is divided into a number of sub categories and has been analysed by the author using soil samples taken from the area immediately around the plant's roots. The methods for pH sampling are noted in Appendix C. The tolerances are noted as follows:– Wide pH tolerance 5-7.8, strongly acidic below 6.0, acid pH 6.0-6.9, neutral pH 7.0, alkaline pH 7.1-8.0, strongly alkaline above 8.0.

8. Salinity

- Soil salinity, which is known as EC is traditionally measured by electrical conductivity in (μS/cm) [188]. As with pH, this information is divided into a number of sub categories and has been analysed by the author using soil samples taken from the area immediately around the plant's roots. The methods for pH sampling are noted in Appendix C. The tolerances are noted as follows: EC below 100 μS/cm, 101–600 μS/cm, 601-1500 μS/cm, 1501-300 μS/cm, 3001-

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[188] microSiemens per centimetre.

4500 μS/cm, 4501-6000 μS/cm, 6001-9000 μS/cm, 9001-19990 μS/cm, above 1990 μS/cm.

9. Soils

- Landform of Immediate Area – This information relates to whether the area is a wadi or plain etc. It is also identified in a pictogram at the top right hand side of the sheet;
- Landform of the Surrounding Area – Notes the landform of the greater area;
- Soil name – Where possible this would be noted from the literature review;
- Soil Colour – Initially soil colour was noted with soil colour chart, similar to those used to identify flower and leaf colour. However after initial field surveys it was deemed by the author that this information was tangential to the research and not required;
- Texture – This information is redundant as it is better noted below according to soil types;
- Horizons and depths – This information was considered to detailed and not useful for the research;
- Dry Consistency and Plasticity – These categories were not used. This information was considered to detailed and not useful for the research;
- Permanently Wet – Some soils were found to be permanently wet especially near perennial streams and low lying sabkhas; [189].
- Heavy, Moist, Wet – This category was not used;

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[189] 'Sabkha is an Arabic name for a salt-flat that has come into general use in sedimentology.... They are flat and very saline areas of sand or silt lying just above the water-table'. (West, www).

- Dry Soils, Depth of Water Table - This category was not used as most soils were dry and the depth of the water table is not readily available in the literature;

- The following types of soils were noted: Solid Rock, Boulders/Rocks, Stony/Gravels, Sands, Dunes, Loams, Silty Loams, Sandy Clay Loams, Silty Clay Loams, Clays, Sandy Clays, Silty Clays, Silts, Clay, Sandy Clay, Silty Clay, Loess, Reg Desert Pavement and Hammada – The number of definitions was too great. Most soil types noted were sands, gravels, rock and boulders, dunes, silts and loess in various combinations.

10. <u>Geology/Parent Material</u>

- Type – This reference was not used as it was considered too detailed in that it was the surface soils that contributed to the plants geographic range and survival rather than the underlying material. The data would however be useful in determining plant root extent and related water availability to plants.

11. <u>Root System</u>

- This information is considered important as it forms a vital part of the survival strategy of each species. The information was gleaned, as far as possible from the literature.

- Various types of root systems and information could be noted as follows: Tap root (depth), very fine roots (less than 1mm diameter), fine roots (1-2mm diameter), medium course roots (92-5mm diameter), course roots (over 5mm diameter), palm like roots, root spread in metres and root depth in metres.

12. <u>Performance</u>

- This information relates to the speed of growth and longevity of the species, which would be obtained from the literature. The information is divided up as follows: fast growth rate, moderate growth rate, slow growth rate, and effective life in years. This information was not collected from the literature, but would be useful during any additional research stages.

13. Problems

- Subject to pests or diseases – This information was obtained where evident in the field and from the literature;
- Weed or nuisance – Information from the literature review;
- Creates leaf litter, drops gum, or resin, seeds, pods – Information from observation and from the literature about problems relating to 'detritus' created by the tree.

14. Environmental Uses – Level 2

- The 'level 2' heading relates to the Level 2 states as noted in the Economic Botany Data Collection Standard. This part of the form was meant to filled in on site and then reassessed with the literature review of the plant species. The categories adapted from the Economic Botany Data Collection Standard are as follows:
- Natural Use / Habitat Creation – Noting particular types of habitat or plant associations;
- Providing food and shelter for wildlife – Most notably shade and food for insects birds and lizards and some mammals as well as grazing animals;
- Providing food and shelter for people – Most notably shade. Some plants do have the capacity to provide food, e.g. oil from *Balanites aegyptiaca* and small fruits from *Ziziphus spina-christi.*
- Wind and/or water soil stabilisation – This is an important potential function of some desert plants;
- Sand dune stabilisation – This category was seen to be extremely important and therefore was highlighted in its own category;
- Pioneer/nurse planting – This information is taken from the literature, e.g. Evenari et al (1982, page 266) point out that the

ruderals such as *Salsola enermis* are important initiators of soil stability;

- Soil fertility improver, nitrogen and potassium – One of the Level 2 descriptors of the Economic Botany Data Standard as noted in Table 5.2 above. Some plants have the added advantage of fixing nutrients in the soil;

- Soil moisture conserver – One of the Level 2 descriptors of the Economic Botany Data Standard as noted in Table 5.2 above. Some plants use less water than others. This information is obtained mainly from the literature review;

- Soil texture/structure improver - One of the Level 2 descriptors of the Economic Botany Data Standard as noted in Table 5.2 above. Some plants provide litter and matter that can decay and help improve the soil around the plants. Where it is available, this information is obtained mainly from the literature review;

- Pollution Control – One of the Level 2 descriptors of the Economic Botany Data Standard as noted in Table 5.2 above. Some plants have the ability to help purify polluted air as well as purify wastewater. Where relevant, this information is obtained from the literature review;

- Agroforestry [190]: - One of the Level 2 descriptors of the Economic

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[190] 'Agroforestry is the growing of both trees and agricultural / horticultural crops on the same piece of land. They are designed to provide tree and other crop products and at the same time protect, conserve, diversify and sustain vital economic, environmental, human and natural resources. Agroforestry differs from traditional forestry and agriculture by its focus on the interactions among components rather than just on the individual components themselves'. (Agroforestry Research Trust, www)

Botany Data Standard as noted in Table 5.2. Using both trees and agricultural / horticultural crops together. Where relevant, this information is obtained from the literature review and noted as potential by the author;

- Food: Livestock / animal fodder – Many desert plants in the Negev are grazed by Bedouin flocks and have the ability to provide fodder. Where relevant, this information is obtained from the literature review;

- Revegetators – One of the Level 2 descriptors of the Economic Botany Data Standard as noted in Table 5.2 above;

- Grazing/Rangeland [191] - One of the Level 2 descriptors of the Economic Botany Data Standard as noted in Table 5. 2. Plants that are grazed by Bedouin flocks and that from part of areas that are called 'rangelands' in the USA. Where relevant, this information is obtained from the literature review;

- Fuel – Wood used by local people for fire or other purpose. Where relevant, this information is obtained from the literature review;

- Boundaries / barriers / supports - One of the Level 2 descriptors of the Economic Botany Data Standard as noted in Table 5.2 above. Plants used as fencing or other similar uses. Where relevant, this information is obtained from the literature review or the author's observations;

- Other Economic / Ethnobotanical Uses – This category probably should not be included under environmental uses. However, it was seen to be important to note from the literature, plants that have been used or could potentially be used by local people. For example,

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[191] 'Rangelands are natural ecosystems where the native vegetation consists of grass, grass like plants, forbs or shrubs'. (United States Geological Survey, www.)

Artemisia sieberi and *Artemisia monosperma*, (types of wormwood), are used by the Bedouin as a herbal tea and have the potential to be exploited commercially;

15. Landscape Use – Amenity / Horticulture / Ornamental /Agricultural

- Ornamental planting is noted as one of the Level 2 descriptors of the Economic Botany Data Standard as noted in Table 5. 1 Schematic Diagram Showing the Relationship Between the Three Levels of the Economic Botany Data Collection Standard – Environmental Uses (After Table 3, Cook, 1995, page 11) above.

- Hedging – Plants are identified, by the author, which have the potential to create a variety of different types of hedging; clipped or more natural;

- Group planting - Plants are identified, by the author, which have the potential to be used in groups as a mono-species or with other species;

- Public gardens – Plants considered by the author to be suitable for use in public gardens where they would appear *'attractive'* and would not be hazard to people and especially children;

- Woodland – Plants identified by the author that could be used for upper storey, middle storey or ground flora/lower storey woodland planting. Middle and lower storey plant would need to have the ability to survive under a tree canopy;

- Suitable in Plant Beds - Plants identified by the author that may be suitable for use usually en-masse in plant beds as annuals, perennials or shrubs;

- Suitable in Grass/Turf - Plants identified by the author that may be suitable for use in grass or turf areas as single specimens or in groups. These plants have to appear appropriate emerging directly out of turf;

- Suitable in Rockeries [192] - Plants identified by the author that may be suitable in rockeries as single specimens or in groups. In the Negev, plants suitable for a rockery would in general be smaller, compact and have interest most of the year round;
- Suitable in Courtyards – A variety of plant life-forms that could be placed in containers or directly in the ground that are suitable for constant close inspection and that provide shade, and/or interest;
- Suitable for Pergolas/Shade Structures: These are climbing plants that have the ability to climb or be adhered to structures to help create additional shade and visual delight;
- Not suitable for Children's areas: Spiky, spiny, thorny and poisonous plants are noted which are not suitable in children's areas, such as playgrounds, school yards etc.

16. <u>Propagation</u>

- This category was premature, as very little information is known about the propagation of species for horticultural purposes and this would need to be followed up after this research. It was intended that the method and ease of propagation would be identified, either by seed or cutting as being easy, moderately difficult or difficult.
- By Seed - Easy, moderate or difficult;
- By Cutting – Easy, moderate or difficult.

17. <u>Establishment</u>

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[192] A broad definition of a rockery is as follows: *'A mound formed of fragments of rock, earth, etc, and set with plants'*. (Biology-Online www). In most instances rockeries or rock gardens combine rocks with plants that are adapted to such terrain. In the U.K rockeries often include alpine plants, but may also include dry planting schemes of hardy Mediterranean species.

- The reason for including this item was to identify the difficulty or ease of establishing these plants, after propagation other than in their immediate core native environments as well as water and maintenance requirements. This category was largely premature, as very little information is known about the establishment of species and this would need to be followed up after this research.
- Establishment other than in native environment – Easy, moderate or difficult;
- Amount of additional water required – High, moderate, low. The amount of water required relates directly to identifying from field visits and the literature review relating plant locations to area, rainfall and topography/soils;
- Amount of other maintenance – This information would relate to how the plant may be used and observations in the field and information from the literature review relating to certain plant characteristics that may have maintenance implications. An example of this is the need to prune large *Tamarix aphylla* trees as they are week wooded or to collect the leaf litter of the tree as it salinates the soil, which in turn prohibits other plants from growing underneath the tree. The amount of maintenance is noted as high, moderate or low.

Grading System for Assessing the Value of Xerophytic and Halophytic Plants for Amenity/Ornamental Purposes – Plant Survey Sheet

5.4.7 This proforma, illustrated in Appendix B, is single sided with a checklist of 9 main categories and 29 items. The driver for this form is the initial assessment of the intrinsic characteristics of the plant. A set of desirable traits and characteristics has been established against which the plants are scored. However, it must be remembered that this is only the first stage of a process of defining plant suitability and the initial stage of the plant introduction process. This needs to be followed by trials and consultations with amongst others *'focus groups from the nursery industry, the gardening public, native plant enthusiasts*...and *horticultural groups*... ' (O'Brien, 1996, www.)

5.4.8 There are many examples of awarding scores to various types of plants which are entered in competitions e.g. with roses where the American Rose Society awards points to competition roses as follows:

Table 5. 6 Example of a points scoring system used by the 'American Rose Society [193]

Factor	Points
Form	25
Colour	20
Substance	15
Stem and Foliage	20
Balance and Proportion	10
Size	10

5.4.9 The scoring of competition roses against various criteria has been established according to criteria, which can be seen to mix objectivity and subjectivity. Thus for example most people would be able to identify the form of a rose stem as being straight or not, by looking down the rose stem, but when it comes to 'balance and proportion' the element of subjectivity and experience creeps in.

5.4.10 Thus it should be noted that the scoring of the aesthetic value of species is a subjective exercise, but the judgement of the aesthetic merit relies on the professional expertise of the author. This type of subjective evaluation is not

[193] The American Rose Society www.

uncommon in the horticultural industry in the United Kingdom as well. It is used by the Royal Horticultural Society (RHS) in determining the many trials of garden plants that are undertaken. This reliance on subjectivity has been acknowledged by the Head of Trials of the RHS, Linda Jones on the 5th of June 2006 in e-mail correspondence with the author. Ms Jones states that

> *'much of the assessment is subjective based on their collective knowledge of what makes a "good garden plant". The Floral Committee assess each trial on a fortnightly basis over 3 years - they mentally score each entry out of 20 using predetermined 5 criteria e.g. impact, vigour, floriferousness, uniformity...'*

5.4.11 Other criteria that are important for choosing the plants relate to the type of plant that is being considered; for example the characteristics that are considered important for *Begonia rex* includes *'habit, leaf shape, markings, health, tolerance of dryish conditions and atmosphere'*. (Royal Horticultural Society, 1, www.) For the trials of garden chrysanthemums the criteria includes *'vigour, habit, health, length of flowering period, colour/colour stability, quality of bloom and weather tolerance.'* (Royal Horticultural Society, 2, www.)

5.4.12 An example of the tables used by the author to assess aesthetic quality is illustrated immediately below, with explanatory notes following immediately after. It is considered by the author that although other numerical methods may have been utilised, the system used is comprehensive and robust and that it could well be used by other professional landscape architects to determine similar results.

5.4.13 Table 5. 7 Annuals - Example of Table to Score Aesthetic Criteria Used in the Field' illustrates the tables used by the author in the field. During the field analysis, it was realised that the table was overcomplicated for the field analysis and many of the categories were not required, being premature, as discussed below. The parts of the table highlighted in grey were then considered to be the core issues to be assessed. (Refer also to Table 5.8

below.) The remainder of the issues are still considered important, but secondary with regard to the suitability of the individual plant species for use in the Negev. These issues such as longevity and ease of propagation would be best tackled once the initial plant suitability sieving process has been undertaken, for example during plant field trials.

Table 5. 7 Annuals - Example of Table to Score Aesthetic Criteria Used in the Field (Refer also to Appendix B)

Name:	*Adonis dentata*	SUMMER	AUTUMN	WINTER	SPRING	SCORE TOTAL
	AESTHETIC CRITERIA					
1a	Form/Shape close up (0, + or - 1)		1			
1b	Form/Shape at a distance (0, + or - 1)		0			
2	Leaf Colour/Shape/Texture (0,+ or -0.25)		0.25			
3a	Flower Interest (0, + or - 0.25)		0.25			
3b	Flower Smell (0, + or - 0.25)					
4a	Fruit/Seed Interest (0, + or - 0.25)					
4b	Fruit Edibility Smell (0, + or - 0.25)					
4c	Fruit Smell (0, + or - 0.25)					
5	Trunk/Limb Interest (0, + or - 1)					
	DISEASE RESISTANCE					
6a	Disease Resistant (+1)					
6b	Semi Disease Resistant (-1 to -5)					
	MAINTENANCE REQUIREMENTS					
7a	Low Maintenance Requirement (+1)					
7b	Moderate Maintenance Requirement (0)					
7c	High Maintenance Requirement (-3)					
	EASE OF ESTABLISHMENT					
8a	Easy to Establish (+1)					
8b	Moderately Easy to Establish (0)					
8c	Difficult to Establish (-5)					
	EASE OF PROPAGATION					
9a	Easy to Propagate (+1)					
9b	Moderately Easy to Propagate (0)					
9c	Difficult to Propagate (-2)					

	WEED CHARACTER					
10	May Become/Cause Weed(s)(-1 to -5)					
	GROWTH CHARACTER					
11a	Fast growing (+1)					
11b	Moderately Fast Growing (+0.5)					
11c	Slow Growing (0)					
	LONGEVITY					
12a	Long Lived (+1)					
12b	Moderately Long Lived (+0.5)					
12c	Short Lived (0)					
	HEALTH RISK					
13	13. Poisonous if eaten (**)		**			
14	14. Spines (*)					
					TOTAL	1.5**

5.4.14 The aesthetic assessment uses a scoring system where positive factors are noted as + or – scores. Major factors are given a score of +1 or –1 or 0 for being neutral. [194] Factors that are considered not as crucial as the major factors are given a score of +0.25 to –0.25. These scores are then added together. It is considered that plants that have a score less than 1 are likely to be unsuitable for landscape purposes.

5.4.15 The recorded data included is as follows:

1. <u>Aesthetic Criteria</u>

   - Form/Shape Close up – A score of -1, 0 or +1 to be given to plants with regard to the quality of their shape and form when viewed close up;

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[194] The table illustrates some criteria that have a marking range from +5 to -5. These items were not used in the final analysis of the plants, as the assessment of these issues is considered premature for this stage of the process.

- Form/Shape Close up – A score of -1, 0 or +1 to be given to plants with regard to the quality of their shape and form when viewed at a distance;
- Leaf Interest: Colour/Shape/Texture – A score of 0 or + or – 0.25 given for plants that have leaf interest;
- Flower Interest: Colour/Shape/Texture – A score of 0 or + or – 0.25 given for plants that have flower interest;
- Flower Smell – A score of 0 or + or – 0.25 given to the smell of plants and mainly their flowers;
- Fruit/Seed Interest – A score of 0 or + or – 0.25 given to the species relative to their fruits and seeds;
- Fruit Edibility/Smell - A score of 0 or + or – 0.25 given to the species relative to the edibility of their fruits and seeds;
- Trunk Interest - A score of 0 or + or – 0.25 given to the species relative to their bark and trunks as features;

2. Disease Resistance

- This criterion was not used as the information is not available and would be better analysed after trials. However the criteria and scoring that would have been used are as follows:
- Disease Resistant – A score of +1 is given if the plant is resistant to diseases;
- Semi Disease Resistant – A score of –1 to –5 is given according to how prone the plant is to diseases. A plant susceptible to diseases would not be suitable for landscape purposes.

3. Maintenance Requirements

- This criterion was not used as the information is not available and would be better analysed after trials. However the criteria and scoring that would have been used are as follows:

- Low Maintenance Requirement – A score of +1 is given if the plant is requires low maintenance, say once a year or every other year;
- Moderate Maintenance Requirement - – A score of 0 is given if the requires a moderate amount of maintenance, say twice a year;
- High Maintenance Requirement – A score of –3 is given to plants that require continuous maintenance.

4. Ease of Establishment

- This criterion was not used as the information is not available and would be better analysed after trials. However the criteria and scoring that would have been used are as follows:
- Easy to Establish - A score of +1 is given if the plant is easy to establish;
- Moderately Easy to Establish - A score of 0 is given if the plant is easy to establish;
- Difficult to Establish - A score of -5 is given if the plant is hard to establish;

5. Ease of Propagation

- This criterion was not used as the information is not available and would be better analysed after trials. However the criteria and scoring that would have been used are as follows:
- Easy to Propagate - A score of +1 is given if the plant is easy to propagate;
- Moderately Easy to Propagate - A score of 0 is given if the plant is easy to propagate;
- Difficult to Propagate - A score of -2 is given if the plant is hard to establish;

6. Weed Character

- A number of plants are known to be invasive and could be considered weeds. In general, however, this information would best be gathered during field trials at a later stage. A literature review of each plant is however used to identify whether these plants are considered weeds in other countries. The criteria and points scoring is as follows:

- May become/cause Weeds – A score of –1 to –5 is given according to the severity of the potential for becoming a nuisance.

7. Growth Character

- It is considered that fast growing planting are generally better than slower growing plants. However, this may not always be the case. This category was not been used, as it is generally not available from the literature. The criteria and points scoring would have been as follows:
- Fast Growing - +1 given to fast growing plants;
- Moderately Fast Growing – 0 points given to moderately fast growing plants;
- Slow Growing – 1 for slow growing plants.

8. Longevity

- Longevity is an important consideration with regard to most life-forms except for annuals and biennials. This category was not used as it is generally not available in the literature review. The criteria and points scoring would have been as follows:
- Long Lived - +1 given for plants that are long-lived;
- Moderately Long Lived – 0 points given for plants that have a moderate lifespan;
- Short Lived – Plants that are short lived would have been given –1 points.

9. Health Risk

- This criterion was used especially in relationship to children and children's areas. No points are given but the risk is pointed out by an asterix as follows:

- Poisonous if Eaten - ** A double asterix is noted if any part of the plant is considered poisonous if digested;

- Spines/Thorns/Sap - * A single asterix is noted if any part of the plant could scratch or puncture the skin of create some kind of allergic reaction.

5.4.16 In essence, although the proforma illustrated above included 9 main categories, only the first one on aesthetics was used. This is because, as noted most of the discarded issues are deemed premature and would be best carried out during planting trials. The criteria that have been used to judge the aesthetic characteristics of each of the native plants are considered the prime criteria necessary to make an initial choice of which plants may be suitable for use. These are noted in the table below.

Table 5. 8 Annuals - Example of Final Table to Score Aesthetic Criteria

Name: *Adonis dentata* Plant No: 1

Life Form: Annual

	AESTHETIC CRITERIA	TIME OF YEAR	SCORE
1a	Form/Shape close up (0, + or - 1)	Spring	1
1b	Form/Shape at a distance (0, + or - 1)		0
2	Leaf Colour/Shape/Texture (0,+ or -0.25)		0.25
3a	Flower Interest (0, + or - 0.25)		0.25
3b	Flower Smell (0, + or - 0.25)		
4a	Fruit/Seed Interest (0, + or - 0.25)		
4b	Fruit Edibility Smell (0, + or - 0.25)		
4c	Fruit Smell (0, + or - 0.25)		
5	Trunk/Limb Interest (0, + or - 1)		
	WEED CHARACTER		
6	May Become/Cause Weed(s) (-1 TO -5)		
	HEALTH RISK		

7a	13. Poisonous if eaten (**)		**
7b	14. Spines (*)		
		TOTAL	1.5**

5.4.17 A number of issues have been and should be considered as part of this judgement process. These are as follows:

- Plants with a score of 1 or below 1 are likely not to have sufficient aesthetic merit to be used in higher quality garden locations;
- All other issues regarding soil conditions, altitude, water requirements, frost and other tolerances will dictate whether a plant is suitable for use in specific locations but these issues are not considered important with regard to the intrinsic characteristics of the plant and its aesthetics;
- Whether a plant attracts wildlife may be considered a benefit or a hindrance depending on its location and therefore the issue of wildlife benefits has not been included in the equation;
- The judgement of whether certain aspects of a plant's character is positive or negative is subjective. The grading has been undertaken by the author, but this can be justified on the basis that the author is a qualified and experienced landscape architect who has knowledge of aesthetics generally as well plants specifically;
- A plant may well be suitable in some locations and not others despite its aesthetic qualities.

5.5 Summary and Conclusions

5.5.1 There are many technical and scientific disciplines that study and use plants in 'profitable ways'. (Robinson, 1992, page 13) Landscape architects have a broader understanding of plants than most including the ecological, aesthetic, symbolic as well as the spatial opportunities that plants offer. The landscape architect has the ability to mix art and science. A further role of the landscape architect as defined by the Landscape Institute in the U.K. is to manage change in the landscape and in doing so enhance biodiversity and enrich the human environment in a sustainable manner. With planting, the landscape architect has the ability to provide sensory delight for people, which is unlikely to be a priority of others working with plants. This is evident in the shortcomings of studies that have been undertaken on the geophytes of the Negev.

5.5.2 The *'Economic Botany Collection Standard'* provides the accepted worldwide methodology for determining plant characteristics as well as plant use. (Cook, 1995) Although the standard adequately covers environmental uses there are parts that could be improved and it considered that the suggested improvements have arisen due to the scrutiny of the document by the author as a landscape practioner.

5.5.3 Plants are used to perform a function or a variety of functions. The contemporary publication by Jones and Sacamano, (2000) on desert plant use presents an over-elaborate palette of functions, however, some notable uses such as 'climbing plants' have been omitted. The Jones and Sacamano list has thus been adapted and added to. It has been combined with functions from the *Economic Botany Collection Standard* to inform the list of potential uses for each native species in the field assessed in the field using two proformas and as part of the literature review attributed to the native plants of the Negev combined in Chapter 6.

5.5.4 The proformas that were used were vital for data collection and assessing the aesthetic qualities and functions and are considered successful. However, a number of characteristics that were thought to be relevant to the data collection and analysis were discarded once the process gathered pace. These items were omitted when it became clear that they were not necessary for the aesthetic or potential use assessment at this stage.

5.5.5 The function of this chapter has thus been to identify and support the role of the landscape architect in plant choice for use, the way plant use may be defined and to reveal appropriate ways to list and categorise the plants that the research has identified in the field and that are reviewed as part of the literature review.

5.5.6 The data and analysis for each species follows in Chapter 6 and in Appendices F, G and H. Chapter 6 tests the hypothesis for each individual native species, whether it may be suitable for use in the Negev.

6. CHAPTER 6 PLANT USE SUITABILITY, ANALYSIS AND COMPARISON OF MATCHED PAIRS

6.1 Section 1: Introduction

6.1.1 Whereas Chapter 5 as part of the literature review, considers and determines the landscape architect as having the appropriate skills for plant choice and and ways to list and categorise the plants of the Negev, Chapter 6 focuses on the 163 native Negev plant species located by the author in the Negev and on testing the hypothesis with regard to potential use. The chapter is divided into 13 sections as follows:

- Section 1: Introduction;
- Section 2: Materials and Methods;
- Section 3: Annuals - Analysis of the Individual Plant Species and Comparison of Matched Pairs;
- Section 4: Climbers - Analysis of the Individual Plant Species and Comparison of Matched Pairs;
- Section 5: Geophytes - Analysis of the Individual Plant Species and Comparison of Matched Pairs;
- Section 6: Grasses - Analysis of the Individual Plant Species and Comparison of Matched Pairs;
- Section 7: Parasites - Analysis of the Individual Plant Species and Comparison of Matched Pairs;
- Section 8: Perennials - Analysis of the Individual Plant Species and Comparison of Matched Pairs;
- Section 9: Dwarf Shrubs - Analysis of the Individual Plant Species and Comparison of Matched Pairs;
- Section 10: Shrubs - Analysis of the Individual Plant Species and Comparison of Matched Pairs;

- Section 11: Succulents - Analysis of the Individual Plant Species and Comparison of Matched Pairs;

- Section 12: Trees - Analysis of the Individual Plant Species and Comparison of Matched Pairs;

- Section 13: Naturalised and Adventive Species and Foreign Escapees - Analysis of the Individual Plant Species and Comparison of Matched Pairs; and

- Section 14: Conclusions of the Suitability Analysis and Matching of Native Negev Species Versus Exotic Species.

6.1.2 Each individual plant species is considered important and is thus tested whether it has potential use in the Negev or not. Defining the main characteristics and uses for each species and then comparing them against a suitable exotic species to compare positive and negative values is a lengthy process and thus much of the background data has been transferred to Appendix F. Furthermore, a maximum of 10 species per life-form has been included per life-form section in order to condense the main body of this dissertation. The remaining species are located in Appendix G.

6.1.3 A summary of the evaluation for each life-form, which includes the analysis from within Chapter 6 and from Appendix G, is located towards the end of each life-form section with an overall evaluation at the end of the chapter.

6.1.4 The field surveys of the 163 plant species and the field assessment process were informed by a literature review of the plant species investigated in the field. The literature review was used to gather information about their growing conditions and locations and to inform the assessment of these plants for potential use. Three main Hebrew publications have been used [195]. These are:

[195] (The Hebrew language texts have been translated by the author of this thesis to the best his ability as no English language translations are known to exist.)

1. Feinbrun-Dothan Naomi and Danin Avinoam, 1998, Analytical Flora of Eretz-Israel, 2nd Edition, CANA Publishing House Ltd., Jerusalem.
2. Shmida A. and Darom D., 1986, *'Handbook of Wildflowers of Israel - Desert Flora'*, Keter Publishing House Ltd.
3. Shmida A. and Darom D., 1994, *'Handbook of Wildflowers of Israel - Mediterranean Flora'*, Keter Publishing House Ltd.

6.1.5 *'Flora Palaestina'*, in English, Parts 1 and 2 by Michael Zohary and Parts 3 and 4 by Naomi Feinbrun-Dothan (1966) have also be used. A further useful publication which was employed specifically to obtain more information about the families and uses of the species is Hutchinson J., 1973, *'The Families of Flowering Plants'*, Oxford University Press.

6.1.6 The arrangement of this review of the 163 species follows the system used by most landscape architects in the United Kingdom where plant use is linked to physical attributes rather than just plant life-form, which would be used by botanists. Thus for example, climbers and geophytes and grasses are separated out from their main life-form type of being annuals or perennials. The system also introduces a group of plants, which are noted in all three publications and translated from Hebrew as sub shrubs, semi-shrubs or dwarf shrubs. This group of woody shrubs as explained in the chapter of *'Plants of the Negev, Floristic Life Forms'* in Chapter 3, section 3.2 remain small because they lose their outermost branches during drought conditions. (Evenari et al 1982, page 251) Dwarf desert shrubs have a slow growth rate even in good years and remain small even after 200 - 300 years. But experiments show that with additional water, growth can be greater.

6.1.7 The cataloguing of species is as follows: Annuals, Climbers, Geophytes (mainly bulbs), Grasses, Parasites, Perennials, Dwarf Shrubs, Shrubs and Trees. A final category *'Naturalised and Adventive Species and Foreign Escapees'*, is used to describe and analyse various life-form species that the author located in the desert but that are native to the Negev. These have been separated out from the main categories as it is considered that they should be dealt with as a separate group.

6.1.8 This following catalogue located below and in Appendix F and Appendix G includes a literature based description, of the plants and their growing conditions and locations. It also includes relevant comments by the author with regard to field observations. It should be noted that the authors do not always agree on the life-form of the plant. In some cases one author may consider the plant to be a perennial, whereas in other texts the species is considered to be a dwarf shrub. The author of this research has noted where other life forms have been suggested in the tables in the 'Comments and Flowering Period' column.

6.1.9 The flowering period is noted because in many cases this is an important period for the plant, in terms of aesthetic qualities and thus its potential use and also in its attraction for wildlife in terms of providing pollen and nectar.

6.1.10 The function of this chapter is thus to identify the suitability of each individual species and then compare these as matched pairs against foreign species that are used at present. Due to the magnitude of this information much of it is located in Appendix F and in Appendix G.

6.2 Materials and Methods

6.2.1 The question of whether the native plants of the Negev are potentially suitable for planting use is considered in this chapter and Chapter 7. It is here that the hypothesis is tested.

6.2.2 Testing of the hypothesis is dealt with in two ways.

Analysis of the Field Data and Data from the Literature Review

6.2.3 The first way that the hypothesis is tested, relates the field research to the literature review. Field data was analysed with regard to the physical characteristics of each individual species and its aesthetic characteristics. Each native plant species was evaluated and an 'aesthetic criteria' rating is applied. This data was then evaluated by the author with regard to potential suitability for use. Due to the magnitude of the task and amount of data collected in the field and from the literature, the majority of this data and analysis is included in Appendix F. The appendix provides a composite of the field data and literature review data as text and in a series of 3 tables and the necessary information regarding aesthetic value was utilised below as part of the comparison of matched pairs.

Comparison of Matched Pairs

6.2.4 The second method of testing the hypothesis, located in this chapter, involves a comparison of matched pairs. The matching method comprises a native plant and an exotic plant, which has been used for similar purposes in the Negev or it is grown and / or it is obtainable in plant nurseries in Israel and thus it is available for the same use. The sequence of the process was that first the native species were located f in the field. Secondly the species were researched as part of a literature review and and finally a suitable exotic species was chosen as a match A table for each matched pair utilises a numerical valuation system in order to quantify the advantages and disadvantages of potentially using the native species relative to an exotic species, which is used as a control. Brief comments on the matching of the species and the benefits or otherwise of using the native species follows. Finally, after the analysis of the 163 species the results of the findings is discussed.

6.2.5 The numerical valuation system was devised to illustrate the potential use of the individual plants for various purposes. This method quantifies the use value relative to the three main landscape types within each may be used. These are for 'Environmental Use', i.e. for use in semi-natural and natural landscapes, 'Middle Landscape Use' and 'Garden Use'. (Refer to the discussion on garden, middle landscape and natural environments in Chapter 4.)

6.2.6 The 163 plant species assessed were initially evaluated using a star rating system, which was later discarded for a numerical system.

Table 6.0 A Discarded Rating of Potential and Suitability of Use Table Using the Star System

Numerical Rating	Environmental Use and / or Landscape Use
***	Very Good potential of suitability for use
**	Moderate - Good potential of suitability for use
*	Low - limited potential of suitability for use and / or use in very specialised locations
<*	Less than a star - Poor potential of suitability for use.

6.2.7 The numerical system was considered superior as it allowed the ratings to be used as part of a total numerical evaluation method and also because it allowed for better statistical analysis. The numerical method notes the potential of each native plant species for use in a hierarchy from 3 down to -1 as illustrated in the following table.

Table 6.0 B Adopted Rating of Potential and Suitability of Use Table Using the Numerical System

Numerical Rating	Environmental Use and / or Landscape Use
3	Very Good potential of suitability for use
2	Moderate - Good potential of suitability for use
1	Low - limited potential of suitability for use and / or use in very specialised locations
-1	Poor potential of suitability for use.

6.2.8 The assessment of each plant species for potential use commences with a description of each plant according to its life form and or growth characteristics, commencing with annuals. In the first instance the information notes the plant reference number commencing from the number 1 as follows:

1. ***Adonis dentata*** (toothed [196]) - Family: Ranunculaceae [197]

(דמומית משוננת- Demumit meshunenet - Toothed Demumit), Photo A1. [198]

6.2.9 The genera, species, the meaning of the Latin species name [199], the family group, Hebrew name and the phonetic translation of the Hebrew name follows. Where possible an explanation of the Hebrew name has been added

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[196] The author advocates that the understanding of the Latin name helps in the identification of the species even if this is to a small extent. It has not always been possible to locate the meaning of the Latin name. The most useful publications for identifying the meaning of Latin plant names include Stearn's *'Botanical Latin'*, 1998 and the websites: www.calflora.net/botanicalnames/index.html, compiled by Michael Charters and Karen Fletcher's *'Glossary of Roots of Botanical Names'* - http://www.biologie.uni-hamburg.de/b-online/library/glossary/botrts.htm.

[197] Order of Ranunculaceae: Perennial and annual herbs with radical and alternate leaves, or shrubs or climbers. Useful products: many beautiful garden plants.

[198] Photographs are referenced to each plant according to number and a prefix relating to the life form of the plants and thus A1 refers to the first annual. The numbering is sequential throughout the thesis but the prefix allows the reader to know immediately whether the plant is an (A)nnual, or a (T)ree or for example a (Su)cculent.

[199] This was included as in many cases it helps with plant identification as the Latin name describes some aspect of the species.

[200]. The plant species description using field data as well as information from the literature would have been located here but the amount of information prohibits its insertion within the Chapter. This information is located in Appendix F. A brief discussion of the potential uses is discussed as this leads on to the matched pairs assessment.

6.2.10 The comparison in the form of matching the native species with a foreign species already in use in the Negev or which would be used if it were available, is performed in the form of a table for each matched pair as illustrated in Table 6.0 C below.

6.2.11 The matching of species uses in the first instance exotic species, which the author has noted growing in the Negev, in the second instance exotic species growing in Israel or available in Israeli nurseries and finally, in some instances, where matching the native species with an introduced foreign species has not been possible, the species has been matched with those commonly available in the developed world. In these cases, the author has consulted a number of publications and websites including 'Landscape Plants for Dry Regions' by Jones and Sacamano, (2000), and RHS 'Plant Selector' database. (RHS, 'Plant Selector', www.) It is considered that this final category of selection is suitable as is evidenced by the fact that a large variety of plants have been introduced into Israel and the Negev from external sources and it is likely that most species available in nurseries around the world are or would become available in Israel.

6.2.12 The matching of the exotic and native species was based on the potential type of use in the landscape with regard to the native species and the actual use of the matching exotic species. The matching was thus as far as possible based on the same life forms, for example, a perennial native species with a perennial exotic species and similarities in physical and thus visual characteristics of size, form and shape, colour and where possible flower type and colour. Marked differences were noted.

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[200] This was included, where possible, as the name also sometimes refers to a specific characteristic of the species.

Table 6.0 C Example of Ratings for Use and Comparison of Matched Pairs using the Annual *Adonis Dentata*

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
1	N	*Adonis dentata*	G, ML, E	2.5	2	3	3	3	3	3	**19.5**
1	E	*Eschscholzia californica 'alba'*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = actual or potential exotic introduced species noted being used. * = Landscape character effects outside of the Garden. ** = For Negev species evaluation refer to Appendix X. ◊ = predominant use. Middle Landscape Use also implies environmental use. The numerical evaluation uses a hierarchical system which equates numbers as follows: 2.5 - 3 = High Value / Effect, 2 = Moderate Value / Effect, 1 = Low Value / Effect, 0 = Neutral Value / Effect, -1 = Poor Value / Effect, -2 = Very Poor Value / Effect, -3 = Extremely Poor Value / Effect. † = spiny. †† = poisonous if eaten. With respect to Water Demand the higher values equate to lower water demand and the lower values to higher water demand.

6.2.13 The matched pair comparison identified the potential uses of the native and the matching exotic species and then evaluates the native plant relative to the chosen exotic species with regard to crucial issues that determine its value in the landscape. These evaluations issues included:

- An aesthetic rating with a maximum of 3 points, (extracted from the 'Aesthetic Criteria' analysis located in tables for each species in Appendix F;
- A rating for each broad type of use; garden, middle landscape and for environmental use in natural areas out of a maximum 3 points;
- A rating for the landscape character and ecological benefits / disbenefits that may result as well as a rating with regard to water demand/use.

6.2.14 For each plant species, a score was given in reference to the water demand above or below 200mm. A score of 3 means that the plant does not require additional water above 200mm. A score of 2 means that the plant is likely to require irrigation above 200mm. A score of 1 or less means that the plant will require greater amounts of irrigation above 200mm. The 200mm water demand benchmark relates to the demand for water used in the study carried out by Ben Dov et al, (1993), entitled *'Plants for Desert Landscaping.'*

6.2.15 The 'landscape character benefit' rating relates to areas beyond the garden. It was considered that this rating should be 0 (zero) for all the exotic species. This is because although the exotic species may appear visually pleasing in the landscape the effects on character needs to take account of numerous factors which include its essential intrinsic and appropriate character, which is most likely to be altered by the sudden introduction of exotic species.

6.2.16 An overall cumulative evaluation is carried out in order to illustrate the differences in quality relative to all the criteria examined. The maximum score that can be achieved is 21. It is considered that any native species with a cumulative score of eighteen (18 - 19) has good overall potential for use in the Negev. An overall cumulative score (value) of nineteen (19) or above is considered to be a high score, which denotes the high quality and overall potential use of each individual native species with regard to the criteria of evaluation. A score of 19 or above indicates that the species may be suitable for garden use. However, a score of less than 19 does not however, preclude potential use of some species in specific locations and for specific purposes.

6.2.17 The table is divided into grey and white rows so that the reader may readily distinguish the different valuations for the native species (grey row) and the exotic species (white row).

6.2.18 A number of the native species investigated by the author are known to be poisonous or are thorny and their use may need to be restricted. Attention is drawn to these plant characteristics by the use of symbols, † = spiny. †† = poisonous if eaten, as identified in the notes below the tables as well as in the text. An issue of using poisonous plants arises, but this is not restricted to the use of desert plants. Indeed many plants commonly used in landscapes and gardens in the UK and other countries have various degrees of toxicity. The Royal Horticultural society, (RHS), states that it *'recommends restricting access to the potentially most harmful plants by care in choice of plants and planting positions in gardens'*. (Royal

Horticultural society, 'Potentially harmful garden plants', www.) The RHS also notes that cases of serious poisoning by plants in the U.K are rare and deaths are very infrequent. (Royal Horticultural society, *'Potentially harmful garden plants'*, www.) It is suggested by the author that great care should be taken with regard to the location of poisonous and spiny plants and the first steps towards avoiding harm to humans and animals is to acknowledge the potential problems there are with some of these plants.

6.2.19 Finally a cumulative assessment is carried out for each-life form in the section 'Results of the Matching of the Native Versus the Exotic Species' towards the end of the chapter.

Development of Methods, Alternatives and Limitations

6.2.20 One hundred and sicty three native and naturalised/adventive species were found growing in the Negev. The field surveys to locate and investigate the native plants of the Negev were carried out extensively across the Negev. The surveys firstly concentrated on areas where access was readily available, such as along roads and tracks and within readily accessible nature reserves. Surveys were then undertaken in more remote areas, which required leaving a car at a convenient parking spot and then hiking into more remote desert areas.

6.2.21 It should be noted that the amount of species located by the author has partially been determined by the accessibility of areas, where movement within the landscape is relatively free and inaccessibility of some areas. Inaccessibility was largely due to two factors. In the first instance, large areas of the Negev are controlled by the Israeli military. (Refer to Figure 1b.) Some of these areas contain permanent military bases and accessibility is completely denied and thus the author could not undertake surveys in these areas. Other areas, which are used occasionally for military manouvres are open to the public on weekends and holidays and some of these were accessed to locate native plant species. Secondly many areas of the Negev are protected nature reserves, which are controlled mainly by the Israel Nature and National Parks Authority. Some of these areas overlap with the military areas and thus accessibility is restricted. (Refer to Figure 1b.) The nature reserves fall into two main types. This includes those that are well known and that are readily accessible and controlled with an entry fee and those, which are less well known, with no permanent daily presence of the parks authority and where access is largely uncontrolled. Both these types of protected nature reserve areas and some military areas were accessed by the author on numerous occasions.

6.2.22 The methods for evaluating each individual native species investigated in this research for potential use in the Negev grew as the research progressed. In the initial phases of the research, the plants themselves were the main focus. This was similarly the case with the research, which centred on the trees of the Negev and their ability to provide shade, which the author carried out and which has been located in Chapter 7. It became apparent through the writing of an article based on the research, published in the Journal of Arid Environments, (Kotzen, 2003), that it was essential that the shade characteristics of the native trees should be assessed relative to a group of exotic species, (the control species) in order to appropriately evaluate the effects of the native species. Thus it became clear through the review of this article and through supervision that it was necessary to consider the characteristics of the native plants and various benefits / disbenefits relative to a chosen exotic species.

6.2.23 It is clear that the best way to evaluate the efficacy of the native plants for use in a garden or middle landscape location would be to grow the plants on site and record their effectiveness with regard to purpose over a period of time. This scenario was however, not possible due mainly to cost, finding suitable land, the time that would be required to undertake such trials and because the author is based in the U.K. and not in the Negev Desert. The assessment of the plants according to a set of qualitative criteria and then evaluating them against the same set of criteria for the exotic (control) species appeared to be an effective method to follow.

6.2.24 The author however, realises that the findings of the matched pair comparisons are not absolute and that the methodology is not totally objective as it is imperfect. The deficiencies in the methodology are as follows:

- The aesthetic evaluation of each plant species is based on the author's professional and experiential judgement. Others may have different assessments;

- The author has attempted, as far as possible to view the native plants at different times of the year to assess their changing characteristics. However, the differences noted may relate only to a particular group of plants located by the author, whereas other specimens not seen by the author may have had different characteristics brought about by differences in soils, microclimate and available water. Thus the characteristics note by the author are not absolute;

- The evaluation for potential use is also based on the experience of the author as a professional landscape architect. Others may have different evaluations;

- The choice of a matching pair is not clear-cut. The author has attempted to use species from the same life-form with similar growth and aesthetic characteristics that may be found being used in the Negev. (In order to facilitate this, the author visited both municipal and private nurseries in the Negev and listed a variety of plants that were being grown and/or being sold[201]. (See Figures 13, 14, 15 and 37) The author also listed species that he noticed growing within the public and private realm areas of the local towns, institutions and kibbutzim. However, in some cases it has not been possible to find a match for a native species as no appropriate equivalent plant has been located in situ. In these cases plants that are available in Israeli nurseries, and noted in catalogues, (such as in the Meltser Nursery Plant Catalogue, משתלות מלצר קטלוג צמחים [202]), as well as

[201] Namely the JNF (Jewish National Fund) nursery near Ofakim in the northern Negev and 'Druyan Nursery' משתלות דרויאן.Beer Sheva

[202] 284 page nursery catalogue published in Hebrew in 2007 by the Meltser Nursery.

located on the World Wide Web, (such as Yagur Nursery, משתלות יגור[203]), have been chosen to match the native species. It is thus quite possible that other plants could readily be chosen, by others as the matching plant; and

- The scoring of the aesthetic quality for each native and exotic matched pair is not equal. Each exotic species is given the highest score of 3 marks. This implies that the species is worthy of the highest points at all times. This is not the case as most species do not appear at their best at all times of the year. Very few native species were given the highest 3 points. This difference, however, should not significantly affect the overall results comparison of the matched pairs;

- All the exotic species score from (0) zero down minus three (-3) for the issue on ecological benefits and disbenefits. The degree of negativity in the score is relative to the potential adverse effects the exotic species may have on the ecology as considered by the author. Although others may have a different evaluation for each species, and for some the scoring may appear to be weighted in favour of the native species, the author considers that he has extensively illustrated in Chapter 4 that importing exotic species can have serious unforeseen ecological and landscape impacts. The logic of this assessment is carried forward in the scoring of the naturalised, adventive and foreign escapees. (Refer to section 6.13) These species that were deliberately or inadvertently introduced into the Negev achieve low scores despite their aesthetic merits as they may have negative effects on landscape as well as ecological values and thus their use should be limited;

- The exotic species were all given a score of (0) zero in regard to their use in the middle landscape and natural/environmental areas and in terms of their effects on landscape character. The consequence of these low scores is that the overall cumulative scores for the matching exotic species is considerably lower than for the native species. The rationale behind the low scores is the author's consideration that using foreign species alters

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[203] http://www.yagurgan.co.il/HTMLs/home.aspx

landscape character divorcing it from its intrinsic nature and thus reducing landscape quality/value. Furthermore the author considers that landscape character is partly determined by ecological character and quality and thus landscape quality is diminished when ecological quality is reduced. The issue of altering landscape character and thus diminishing landscape quality in natural areas is perhaps much more clear-cut compared to the middle landscape. However, it is a significant outcome of this research, (as argued in Chapter 4), that states that the middle should planted with appropriate native species in the creation of ecologically worthwhile habitat which will then help to create areas of appropriate landscape character and thus a higher landscape quality.

6.2.25 It is considered that the findings on the native species cannot be absolute. Absolute certainty of use will only be achieved, when the plants are grown and tested in the field. However, despite the known flaws in the methodology, it is considered that these deficiencies do not invalidate the findings. In the first instance the findings are based on an objective assessment of the native plants through the field and literature research and secondly the matching of pairs and consideration of issues is logical, methodical and based on the scientific method.

6.2.26 The analysis for the potential use for each plant noted below is based on the on the collected, collated and analysed data located in Appendix F. Due to the considerable quantity of this work it has been unfeasible to include it within the chapter.

6.2.27 Refer to Appendix H for photographs of the native illustrations and to Appendix I for photographs of the exotic matched species. Note that each pair has the same number in order to help identify the matched pair.

6.3 Annuals - Analysis of the Individual Plant Species and Comparison of Matched Pairs

6.3.1 The annual plants of the Negev Desert have a very short life span and most of them have set seed and died by the coming of summer in May. During the summer months desiccated vestiges of the plants may be apparent on the ground but in the winter months and in springtime the plants can make the desert appear green and flowering can turn the desert into a brightly coloured landscape. (Figures 48, 55 and 56) The use of annuals for ornamental purposes is limited but in natural areas and the middle landscape there are opportunities. They are also especially important for their abilities to hold soils in place, thus inhibiting erosion from both wind and water. They are also significant for grazing.

6.3.2 The information gathered for annuals is not as detailed as that for the other life forms because, in general, annuals are not commonly used by landscape architects in schemes as they require significant maintenance and in desert areas only grow and flower in the short winter/spring. However, they have been included as they may well be utilised in projects that require habitat creation and in the middle landscape, where according to this thesis habitat creation is its main function.

6.3.3 In this section all the annuals are categorised as xerophytes. This is because all annuals may be considered 'drought evaders' as they set seed and overcome the dry conditions and only generally sprout when enough water becomes available. Seeds may lie dormant for many years if conditions are not favourable. According to Raunkiaer's classification of plant life-forms, which utilises the location of renewal buds to determine the life-form, they are termed *'Helophytes'*. Danin, (1983, page 24) after Raunkiaer notes that *Therophytes* are annual plants and that *'they have the renewal bud in their seed'*. He notes, (1983, page 24), that during the dry season, all other parts of the plant are dead. Detailed data for each species is located in Appendix F1. The list of annuals and descriptions are as follows:

Table 6.0 D List of Annuals

NO. [204]	ANNUALS	FLOWERING PERIOD & COMMENTS [205]
1	*Adonis dentata*	February to April
2	*Anthemis melampodina*	March to April
3	*Anthemis pseodocotula*	March to May
4	*Arnebia decumbens*	January to April
5	*Centaurea pallescens*	March to May
6	*Chaetosciadum trichospermum*	March to April
7	*Chrysanthemum coronarium*	March to May
8	*Cichorium pumilum*	Annual or biennial – April to June
9	*Crepis sancta*	February to April
10	*Erodium lacianatum*	February to May
11	*Erucaria rostrata*	January to May
12	*Hyoscamus desertorum*	Annual or biennial – March to May & sparsely until August
13	*Matthiola livida*	February to May & sparsely until August

[204] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

[205] Information re flowering is mainly from Feinbrun-Dothan and Danin, 1998. Note the flowering times are for the whole of Israel and not only the Negev. Should other references note earlier or extended flowering times these are included. Comments where applicable are included.

NO.[204]	ANNUALS	FLOWERING PERIOD & COMMENTS[205]
14	*Papaver polytrichum*	March to May
15	*Pulicaria incisa/desertorum*	April to June
16	*Rumex cyprius*	January to May
17	*Salsola inermis*	Mid April to September (summer annual = unusual)
18	*Silene colorata*	February to April
*	*Verbesina encelioides*	Summer (summer annual = unusual)[foreign]
19	*Zygophyllum simplex*	December to May & some to October

* This species is located in the section on 'Naturalised and Adventive Species and Foreign Escapees'. Note: Analysis of plant species in grey is located in Appendix G1.

6.3.4 The following section notes the potential use for each native annual and the comparative evaluation of the native species matched to an exotic species. Note the section below includes the first 10 annuals, (alphabetically ordered), whilst the remainder are included in Appendix G1. (Refer also to Appendix F1 for additional data and analysis.)

6.3.5 An overall evaluation of the annuals follows after the individual assessment of each annual species below and in Appendix G1 commencing from paragraph 6.3.48.

1. *Adonis dentata* (toothed) - Family: Ranunculaceae[206] (דמומית משוננת - Demumit meshunenet - Toothed Demumit), Photo A1.

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[206] Order of Ranunculaceae: Perennial and annual herbs with radical and alternate leaves, or shrubs or climbers. Useful products: many beautiful garden plants.

Brief Description

6.3.6 *Adonis dentata* is an upright annual plant growing 13-20cm tall with deeply cut bright green leaves and yellow-orange flowers. (Shmida, 1986, page 102)

Potential Suitable Uses

6.3.7 Lord, (2003, Volume 1, page 101), states that the Adonis genus plants *'are for the rock garden or front of border...'*. *Adonis amurensis*, *A. vernalis* and *A. volgensis* are used as border perennials in the U.K. (Wright, 1984, page 328) Although attractive, *Adonis dentata* is small and although it could possibly be used as an annual in borders, its most appropriate location would be in the middle landscape. It could be used for habitat creation and along roadsides.

Comparison of Matched Pair

6.3.8 The exotic plant chosen as a match for the native *Adonis Dentata* is *Eschscholzia californica 'alba'*, the California poppy, originally from the California, but now hybridised.)

Table 6. 1 *Adonis dentata* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
1	N	*Adonis dentata*	G, ML, E	2.5	2	3	3	3	3	3	**19.5**
1	E	*Eschscholzia californica 'alba'*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.3.9 *Adonis dentata* has similar high aesthetic qualities to the matched foreign species, *Eschscholzia californica 'alba'*. It can be used in gardens, the middle landscape and natural situations with minimal maintenance, no additional water above 200mm, with positive ecological and landscape effects as opposed to the foreign species, which could only be used in gardens, with potential negative ecological effects if used outside the garden and the need for additional water.

2. *Anthemis melampodina* - Family: Compositae [207] (קחון הנגב- Kachvan hanegev - Negev Anthemis), Photos A2 and A3.

Brief Description

6.3.10 An upright annual that grows to 15-25cm tall with yellow and white flowers. (Shmida, 1986, page 80)

Potential Suitable Uses:

6.3.11 Anthemis species such as *A. cupiana, A nobilis, A sancti-johannis* and *A. tintoria* are grown as border perennials and as edging in the U.K. (Wright, 1984, page 270)

6.3.12 *Anthemis melampodina* is a very attractive low tightly mounded annual, which has the potential to be used in the middle landscape, along roadsides and as a spring flowering annual in borders as well as in gravel areas. Indeed it appears that it can be used in many different locations as it grows on a variety of soils and perhaps it can even be used in tubs and baskets. Used en-masse it could create a carpet of blooms.

Comparison of Matched Pair

6.3.13 The exotic plant chosen as a match for the native *Anthemis melampodina* is *Argyranthemum frutescens*, the Marguerite daisy, originally from the Canary Islands, but now hybridised.

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[207] Order of Compositae: Herbs, shrubs, flowers crowded into heads or single flowers male or male and female, outer ones often ligulate (rayed), the inner tubular, or all ligulate: bellis, aster, dahlia...

Table 6. 2 ***Anthemis melampodina*** **- Ratings for Use and Comparison of Matched Pair**

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
2	N	*Anthemis Melampodina*	G, ML, E	2.5	2	3	3	3	3	3	**19.5**
2	E	*Argyranthemum frutescens*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.3.14 *Anthemis melampodina* has similar high aesthetic qualities to the matched exotic species *Argyranthemum frutescens*. It appears suitable for use in gardens, the middle landscape and natural situations with minimal maintenance, and no additional water above 200mm, with positive ecological and landscape effects as opposed to the foreign species which could only be used in gardens, with potential negative ecological effects if used outside of the gardens and the need for additional water.

3. *Anthemis pseudocotula* - Family: Compositae (קחון מצוי- "Kachvan Matsui" - Common Anthemis), Photo A4.

Brief Description

6.3.15 Mediterranean annual 20-40cm tall, (Shmida A., 1994, page 84), with yellow and white flowers.

Potential Suitable Uses

6.3.16 As mentioned above, *Anthemis* species such as *A. cupiana, A nobilis, A sancti-johannis* and *A. tintoria* are grown as border perennials and as edging. (Wright, 1984, page 270) *Anthemis pseudocotula* is an open ground species and it is best suited to natural areas, but also could be used to bind soils mainly on flat areas. It is best suited in the middle landscape and in the creation of habitat and wildflower areas.

Comparison of Matched Pair

6.3.17 The exotic plant chosen as a match for the native *Anthemis pseudocotula* is *Dimorphotheca sinuata*, the African daisy, from the Cape region of South Africa – available in nurseries in Israel.

Table 6. 3 *Anthemis pseudocotula* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
3	N	*Anthemis pseudocotula*	G, ML, E	3	1	3	3	3	3	3	**19.0**
3	E	*Dimorphotheca sinuata.*	G	3	3	0	0	-3	0	3	**6**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.3.18 *Anthemis pseudocotula* has similar high aesthetic qualities to the matched exotic species *Dimorphotheca sinuata.* It appears suitable for use in gardens, the middle landscape and natural situations with minimal maintenance, and no additional water above 200mm, with positive ecological and landscape effects as opposed to the foreign species which could only be used in gardens, with potential negative ecological effects if used outside of the gardens and the need for additional water.

4. ***Arnebia decumbens*** (lying flat or prostrate but with a tip growing upwards) - Family: Boraginaceae [208] "Arnavit Sherua" ארנבית שרוע (- Outstretched/extended Arnavit), Photo A5.

Brief Description

6.3.19 *Arnebia decumbans* grows 7 - 15cm tall with small yellow flowers. (Shmida, 1986, page 102)

Potential Suitable Uses

6.3.20 The species *Arnebia echioides,* the 'prophet flower', is grown as a border perennial in the U.K. (Wright, 1984, 256) However, *Arnebia decumbens* does not have the potential to be a good border plant but would be useful for revegetating areas or creating habitat on loessal and sandy soils. It would also be useful in the middle landscape as part of a plant mix. The root can be used to make a reddish/purple dye and thus has some potential for craft/commercial use. This is confirmed in the SEPASAL database. (RBGK www) It is definitely not suitable in areas where children would play as it is bristly and uncomfortable to the touch.

Comparison of Matched Pair

6.3.21 No matched pair is suggested, as *Arnebia decumbens* is suited mainly for habitat creation and in the middle landscape.

[208] Order of Boraginaceae: Herbs, numerous in the Mediterranean. Some beautiful garden plants.

Table 6. 4 *Arnebia decumbens* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Natural Use Rating Environmental /	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
4	N	*Arnebia decumbens*	ML, E	1	0	1	1	2	1	3	9

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.3.22 *Arnebia decumbens* is considered unsuitable for garden use and thus the species has not been matched with a foreign species. However, middle landscape and environmental use is considered reasonably positive.

5. *Centaurea pallescens* - Family: Compositae (המדבר דרדר - "Dardar Hamidbar"- Desert Thistle), Photographs A6 and A7.

<u>Brief Description</u>

6.3.23 *Centaurea pallescens* is a spiny thistle like plant with pale yellow flowers.

<u>Potential Suitable Uses</u>

6.3.24 In the U.K this includes a group of border perennials known generally as knapweeds and are used mainly on alkaline soils in the sun. (Wright, 1984, page 278) *Centaurea pallescens* is a dense compact spiny species. As an annual it is best suited to natural areas and perhaps the middle landscape where physical contact is unlikely to be made. It could be used en-masse in the middle areas of planting and also to deter pedestrian movement. It is useful as it grows on many kinds of soils, and also could be used to bind soils on flat areas. It is a very high saline tolerance as it has been noted by the author as growing in soils of 15920 μS/cm.

Comparison of Matched Pair

6.3.25 The exotic plant chosen as a match for the native *Centaurea pallescens* is *Centaurea cineraria.* The Dusty Miller, which is originally from the Isle of Capri in Italy is commonly grown in Israel as an annual or perennial garden plant. It is similar in size and with small yellow/white flowers. Although without spines, is considered a reasonable match.

Table 6. 5 *Centaurea pallescens* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
5	N	*Centaurea pallescens*	ML, E, G	1†	0	1	1	2	1	3	**9**
5	E	*Centaurea cineraria*	G	2	2	0	0	-3	0	1	**2**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.3.26 *Centaurea pallescens* appears best used in the middle landscape and natural situations and perhaps in some garden situations, with minimal maintenance, and no additional water above 200mm, with positive ecological and landscape effects as opposed to the exotic species, *Centaurea cineraria,* which could only be used in gardens, with potential negative ecological effects if used outside of the gardens and the need for additional water.

6. *Chaetosciadium trichospermum* - Family: Umbelliferae [209] שערור שעיר (- "Sa-arur Sair" - Hairy Sa-arur), Photograph A8.

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[209] Order of Umbelliferae: Herbaceous, very rarely woody, with furrowed and wide soft pith. Useful products: Celery - *Apium graveolens*, carrots, coriander.

Brief Description

6.3.27 An annual growing to 30cm high with delicate bright green carrot like leaves and light pink to purple feathery flower umbels.

Potential Suitable Uses

6.3.28 This is a delightful delicate small, delicate plant with bright green cut leaves and delicate puffy lilac umbels. It would be best used in natural landscapes, but may also be used en masse in rockeries and for springtime flowering on roadside embankments with rocks and perhaps in planting beds.

Comparison of Matched Pair

6.3.29 The exotic plant chosen as a match for the native *Chaetosciadum trichospermum* is *Anethum graveolens*. The annual herb dill with its feathery characteristics provides an appropriate match. It is grown in Israel.

Table 6. 6 *Chaetosciadium trichospermum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
6	N	*Chaetosciadum trichopsermum*	ML, E	1.5	2	2	2	2	2	3	**14.5**
6	E	*Anethum graveolens*	G	3	3	0	0	0	0	1	7

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.3.30 *Chaetosciadum trichospermum* appears best used in the middle landscape and natural situations and perhaps in the rockery garden. The plant would require minimal maintenance, no additional water above 200mm, with positive ecological and landscape effects as opposed to the exotic species *Anethum graveolens* (dill), which could only be used in gardens, with potential negative ecological effects if used outside of the gardens and the need for additional water.

7. ***Chrysanthemum coronarium*** (Crown daisy) -Family: Compositae

חרצית עטורה (- "Chartsit aturah" - Crown daisy), Photographs A9 and 10.

Description

6.3.31 The crown daisy is a characteristic Mediterranean plant 20 - 55mm tall with bright yellow flowers.

Potential Suitable Uses

6.3.32 This is a very attractive wayside plant that also does well on embankments providing soil stability and strong colour in the springtime. It is good for natural areas where grazing may be a problem, (as the plants are disliked by grazers) and on roadsides. It could be a good plant for some middle landscape areas. The SEPASAL database notes the plant is used in situ for ornamental use and 'everlasting flowers' and the leaves are eaten as a green vegetable. (RBGK, SEPASAL, *'Chrysanthemum coronarium'*, www.)

Comparison of Matched Pair

6.3.33 The exotic plant chosen as a match for the native *Chrysanthemum coronarium* is *Chrysanthemum leucanthemum,* the ox eye daisy. The species is available in Israel and used as an annual / perennial. Other *Chrysanthemum* species are also available as are other daisy type annuals.

Table 6. 7 *Chrysanthemum coronarium* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
7	N	*Chrysanthemum coronarium*	G, ML, E	2.25	1	3	3	3	3	3	**18.25**
7	E	*Chrysanthemum leucanthemum*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.3.34 *Chrysanthemum coronarium* appears best used in the middle landscape and natural situations and perhaps in expansive garden situations. The plant would require minimal maintenance, no additional water above 200mm, with positive ecological and landscape effects as opposed to the exotic species *Chrysanthemum leucanthemum*, the ox eye daisy, which could only be used in gardens, with potential negative ecological effects if used outside of the gardens and the need for additional water.

8. *Cichorium pumilum* (low/dwarf) - Family: Compositae (עולש מצוי - "Olesh matsui" - Common Chicory), Photograph A11.

Brief Description

6.3.35 An annual or biennial herb, which hugs the ground with lilac daisy like flowers.

Potential Suitable Uses

6.3.36 In Europe, *Cichorium intybus*, which is much taller, is used as a vegetable but also sometimes as a decorative border plant. (Wright, 1984, page 280) Visually, the flowers are very similar. As a single specimen the plant is inconspicuous except when viewed from close up. The flowers are very attractive. This plant has the potential for use mostly in natural areas, waysides and the middle landscape. In the middle landscape, planted en-masse flowering would present a magnificent sight.

Comparison of Matched Pair

6.3.37 The exotic plant chosen as a match for the native *Cichorium pumilum* is *Nolana paradoxa* 'Blue Bird', the Chilean bell-flower, originally from Chile is available in Israeli nurseries. It has blue flowers and it is similar in scale and form to *Cichorium pumilum.*

Table 6. 8 *Cichorium pumilum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
8	N	*Cichorium pumilum*	G, ML, E	1.25	1	3	3	3	3	3	**17.25**
8	E	*Nolana paradoxa* 'Blue Bird'	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.3.38 *Cichorium pumilum* appears best used in the middle landscape and natural situations and perhaps in expansive garden situations. The plant would require minimal maintenance, no additional water above 200mm, with positive ecological and landscape effects as opposed to the exotic species *Nolana paradoxa* 'Blue Bird', which could only be used in gardens, with potential negative ecological effects if used outside of the gardens and the need for additional water.

9. *Crepis sancta* (of sacred places) - Family: Compositae (נסנית דו קרנית - "Nisanit Do-Karnit"), Photograph A12.

Brief Description

6.3.39 An erect annual/biennial 12- 35cm high with long flower stalks with small bright yellow flowers.

Potential Suitable Uses

6.3.40 In the U.K., *Crepis*, or hawkweed, is considered to be a plant to be used amongst rocks for poor soils. (Wright, 1984, page 436) *Crepis sancta* grows in masses in open areas and is good for open wildflower areas and could be well utilised in the middle landscape on flat as well as rolling ground. It would also be good to stabilise soils as seeds are deposited at the mother plant but also seeds may be distributed elsewhere and thus it could spread. However in the Negev it is rather short lived from February to April.

Comparison of Matched Pair

6.3.41 The exotic plant chosen as a match for the native *Crepis sancta* is *Tagetes tenuifolia*. The French marigold is commonly used in gardens in the Negev.

Table 6. 9 *Crepis sancta* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
9	N	*Crepis sancta*	G, ML, E	1.25	1	3	3	3	3	3	**17.25**
9	E	*Tagetes tenuifolia*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.3.42 *Crepis sancta* appears best used in the middle landscape and natural situations and perhaps in expansive garden situations. The plant would require minimal maintenance, no additional water above 200mm, with positive ecological and landscape effects as opposed to the exotic species *Tagetes tenuifolia*, the French marigold, which could only be used in gardens, with potential negative ecological effects if used outside of the gardens and the need for additional water.

10. ***Erodium lacianatum*** [slashed into narrow parts with taper-pointed incisions] (Stearn,1998, page 438) - Family: Geraniaceae [210]

מקור חסידה מפוצל (- Makor-Chasida Mefustal- Divided/split up Storks Bill), Photograph A13.

Brief Description

6.3.43 A small ground hugging variable cranesbill 4-10 cm tall with a spread of 16-30cm with small pink flowers.

Potential Suitable Uses

6.3.44 Although the plant is small it could be used en-masse for ornamental purposes. It is likely to be particularly suitable on sands and partially stabilised sands to increase sand stabilisation in the middle landscape. Erodium species, i.e. storksbills or cranesbills in the U.K are used as rock plants, as groundcovers and on walls.

Comparison of Matched Pair

6.3.45 The exotic plant chosen as a match for the native *Erodium lacianatum* is *Erodium reichardii*. This species of stork's bill is available in nurseries in Israel.

[210] Order of Geraniaceae: Annual herbs or shrubs, rarely arborescent; leaves alternate or opposite, mostly lobate. Useful products: Chiefly cultivated for their handsome flowers and scented leaves; geranium, pelargonium etc.

Table 6. 10 *Erodium lacianatum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
10	N	*Erodium lacianatum*	G, ML, E	1.25	2	3	3	3	3	3	**18.25**
10	E	*Erodium reichardii*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.3.46 *Erodium lacianatum* appears best used in the middle landscape and natural situations especially on sands. En-masse it could also be used in gardens on sand. The plant would require minimal maintenance, no additional water above 200mm, with positive ecological and landscape effects as opposed to the exotic species *Erdodium reichardii*, storksbill, which could only be used in gardens, with potential negative ecological effects if used outside of the gardens and the need for additional water.

6.3.47 Note that the analysis of the individual annual species continues in Appendix G1 and that the plant and table numbering continues numerically in the appendix as follows:

Table 6. 11 *Erucaria rostrata* - Ratings for Use and Comparison of Matched Pair

Table 6. 12 *Hyoscamus desertorum* - Ratings for Use and Comparison of Matched Pair

Table 6. 13 *Matthiola livida* - Ratings for Use and Comparison of Matched Pair

Results and Discussion of the Values Assessed for Each Native Annual Species Compared to the Exotic matched Pairs

6.3.48 The following discussion is reliant on the detail information located in Appendix F1 and Appendix G1. The evaluation process is described in paragraphs 6.2.3 to 6.2.19.

6.3.49 Table 6.0 E illustrates the evaluations of all the native species against the exotic matched pair species.

Table 6.0 E Comparison of Values for the Native Versus the Exotic Species - Annuals

Plant No.	Plant Species Name	Native Species Cumulative Value	Exotic Species Cumulative Value
1	*Adonis dentata*	19.5	5
2	*Anthemis melampodina*	19.5	4
3	*Anthemis pseudocotula*	19.0	6
4	*Arnebia decumbens*	9	No match

Plant No.	Plant Species Name	Native Species Cumulative Value	Exotic Species Cumulative Value
5	*Centaurea pallescens*	9	2
6	*Chaetosciadum trichopsermum*	14.5	7
7	*Chrysanthemum coronarium*	18.25	4
8	*Cichorium pumilum*	17.25	4
9	*Crepis sancta*	17.25	4
10	*Erodium lacianatum*	18.25	4
11	*Erucaria rostrata*	16.25	No match
12	*Hyoscyamus desertorum*	20.75	4
13	*Matthiola livida*	17.25	5
14	*Papaver polytrichum*	19.25	5
15	*Pulicaria incisa*	20.25	4
16	*Rumex cyprius*	17.25	4
17	*Salsola inermis*	17	No match
18	*Silene colorata*	19.25	5
19	*Zygophyllum simplex*	20.25	5

Note those native species that have not been matched are not considered to have value for garden use.

6.3.50 19 annuals were located in the Negev. As noted in the table, two of these, *Arnebia decumbens* and *Centaurea pallescens* have very low evaluations of 9 out of a total of 21, (9.5%), and are thus most likely only suitable for use in natural areas and for specific environmental purposes. 7 others, (33%), have low evaluations, between 14.75 and 18.25 and thus have the potential for use in middle landscape [211] areas as well. Those native species that do not achieve a score above 19 [212] do so because their aesthetic qualities are not high and thus their garden use potentials are not clear-cut. Eight out of the nineteen annuals assessed, (42%) have a high score of 19 points or above as illustrated in the table below. Three of these score above 20. This is 15% of the total 19 annuals assessed. (The exotic species have extremely poor evaluations as it is considered that their use is largely confined to garden areas, they have greater demands for water and have the potential to diminish ecological and landscape character/quality values.)

6.3.51 The annuals with the highest scores of 19 or above include:

Highest Scores Table 1 - Annuals

Plant No.	Plant Species Name	Cumulative Value
1	*Adonis dentata*	19.5
2	*Anthemis melampodina*	19.5
3	*Anthemis pseudocotula*	19.0
12	*Hyoscyamus desertorum*	20.75
14	*Papaver polytrichum*	19.25
15	*Pulicaria incisa*	20.25
18	*Silene colorata*	19.25
19	*Zygophyllum simplex*	20.25

[211] The middle landscape is discussed in Chapter 4.

[212] An overall cumulative score (value) of nineteen (19) or above is considered to be a good score, which denotes the high quality and overall potential use of each individual native species with regard to the criteria of evaluation. A score of less than 19 does not however, preclude potential use of some species in specific locations and for specific purposes.

6.3.52 All the above annuals shown in the above table are considered to show potential for use in garden situations as well as in the middle landscape as well as in,suitable natural locations. A more in depth analysis is included towards the end of the chapter. A more in depth analysis is included towards the end of the chapter.

6.3.53 The assessment of climbing species follows. Note that the plant and table numbers follow on from the numbering of the further annual species located in Appendix G1.

6.4 Climbers and Trailing Plants - Analysis of the Individual Plant Species and Comparison of Matched Pairs

6.4.1 The category of climber or trailing plant does not denote life-form as do most of the other categories used to classify plants. The term climber, rather relates to the physical characteristic of the plant to attach itself or be fixed to an external object be it floral such as a tree, or man made, such as a wall or fence or pergola or to trail on the ground or over other objects.

6.4.2 Not many climbing or trailing plants are found in Israel and the Palestinian territories. An investigation of the publications by Shmida (1986 and 1994) on *'Desert Flora'* and *'Mediterranean Flora'* by the author shows that there are 9 plant species that have climbing characteristics. Only 3 of these species may be located in the Negev and one of these, namely *'Prasium majus'* is located in a remote area alongside the Egyptian border and remains unseen by the author. The other species are also relatively rare and are noted to by the author in a very few locations. A further species *Convolvulus althaeoides* is not addressed by Shmida but is included by the author and the *Cocculus* and *Convolvulus* species are considered by Feinbrun Dothan and Danin, (1998, pages 202 and 518) to be elongated woody perennials. The climbers assessed are noted in the table and individually below.

6.4.3 An overall evaluation of the climbers follows after the individual assessment of each species.

Table 6.0 F List of Climbers

NO.[213]	CLIMBERS / TRAILING PLANTS	COMMENTS & FLOWERING PERIOD [214]
20	*Cocculus pendulus*	Woody – December to March and some to July
21	*Convolvulus althaeoides*	Herbaceous perennial – March to June
22	*Ephedra foemina*	Shrub forms also exist – March to October (unusual summer flowering)

6.4.4 The following section notes the potential use for each native climber and the comparative evaluation of the native species matched to an exotic species. (Refer to Appendix F2 for additional data.)

20. *Cocculus pendulus* (hanging down) - Family: Menispermaceae [215]

(סהרון משולשל-Saharon meshulshal - purgative saharon {sahar means moon}), Photographs C30, C31 and C32 - PROTECTED!

Brief Description

6.4.5 *Cocculus pendulus* grows on rocks and in fissures in very dry and hot areas receiving less than 100mm of rain as well as in wetter areas climbing up trees to 10m tall.

6.4.6 Flowers: December to March with some to July. March-July (Zohary, 1966,

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[213] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

[214] Information re flowering mainly from Feinbrun-Dothan and Danin, 1998. Note the flowering times are for the whole of Israel and not only the Negev. Should other references note earlier or extended flowering times these are included.

[215] Order of Menispermaceae: Twining or rarely erect shrubs or small trees.

page 216) (Feinbrun-Dothan and Danin, 1998, page 202)

Potential Suitable Uses

6.4.7 The plant appears to be a very robust, saline tolerant and drought tolerant climber on rocks and up trees. Its form is made up of hanging strings or nets of stems. It may be useful trained on walls and on fences and pergolas as an amenity climber.

Comparison of Matched Pair

6.4.8 The exotic plant chosen as a match for the native is the hybridised *Wisteria sinensis*, which is available in nurseries in Israel. *Wisteria sinensis* is not a perfect match as it has large flower panicles, whereas *Cocculus pendulus* does not, but that they do have similar woody stems and dense foliage.

Table 6. 20 *Cocculus pendulus* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
20	N	*Cocculus pendulus*	G, ML, E	2.25	3	3	3	3	3	3	**20.25**
20	E	*Wisteria sinensis*	G	3	3	0	0	-1	0	-1	4

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.4.9 *Cocculus pendulus* is very drought tolerant requiring less than 100 mm of water per annum to survive. With water it remains green. The species would require minimal maintenance, no additional water with positive ecological and landscape effects as opposed to the hybridised exotic species *Wisteria sinensis* which is an outstanding garden climber but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

21. ***Convolvulus althaeoides*** - Family: Convolvulaceae [216] חבלבל כנפי (- Chavlebal kapani- palm Chavlebal), Photograph C33.

Brief Description

6.4.10 A herbaceous perennial creeping along the ground, 0.5 - 3 meters diameter. (Shmida, 1986, page 238) and even up to 5 metres. The leaves are silvery, the flowers pink (60mm) across. (Burnie, 1995, page 179)

6.4.11 Flowers: March-June (Feinbrun-Dothan and Danin, 1998, page 518)

Potential Suitable Uses:

6.4.12 Wright, (1984, page 352) describes the species as being moderately to very hardy, which may grow 1ft x3ft as a ground cover plant. The plant grows on rocks and on other soils and thus could be used as an attractive perennial ground cover. In the Mediterranean region the plant also grows up supports up to 1 metre tall, (Burnie, 1995, page 179) and thus the plant could also be used as a low growing climber on supports or on trees or other shrubs.

Comparison of Matched Pair

6.4.13 The exotic plant chosen as a match for the native *Convolvulus althaeoides* is *Ipomoea x imperialis* 'Cameo Elegance', one of the smaller morning glories, which are available in Israeli nurseries and originate in tropical South America. *Ipomoea x imperialis* 'Cameo Elegance' and *Convolvulus althaeoides* grows to 1 metre, although *I.* '.Cameo Elegance' is also known to grow taller.

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[216] Order of Convolvulaceae: Herbaceous or woody, often climbing, juice usually milky . Useful Products: Sweet potato -*Ipomoea batata*, flowering plants – *Ipomoea* and *Convolvulus*.

Table 6. 21 ***Convolvulus althaeoides*** **- Ratings for Use and Comparison of Matched Pair**

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
21	N	*Convolvulus althaeoides*	G, ML, E	1.5	3	3	3	3	3	3	**19.5**
21	E	*Ipomoea x imperialis* 'Cameo Elegance'	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.4.14 *Convolvulus althaeoides* would be best used as a ground cover plant The species would require minimal maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species *Ipomoea x imperialis* 'Cameo Elegance' which is commonly found climbing and rambling in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

22. *Ephedra foemina* (female) - Family: Ephedraceae [217] (שרביטן מצוי- Sharvitan Matsui - Common Sharvitan -Shirbeit means aimless doodling), Photographs C34, C35 and C36.

Brief Description

6.4.15 An attractive dense climber up to 8 metres or more with red berries and very high tolerance to saline soils. (Ben Dov et al, 1993, page 78)

6.4.16 Flowers: April-October (Feinbrun-Dothan and Danin, 1998, page 92)

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[217] Order of Ephedraceae: Upright shrubs, climbing or hanging from cliffs.

Potential Suitable Uses

6.4.17 This would make a very good evergreen climber on fences, walls, pergolas, within trees to contribute to shade and to attract wildlife, particularly birds and it has a very high saline tolerance. For more formal situations it would need training and pruning.

Comparison of Matched Pair

6.4.18 The exotic plant chosen as a match for the native *Ephedra foemina* is *Solanum seaforthianum*, the Potato Vine, native to Brazil and common in Israel.

Table 6. 22 *Ephedra foemina* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
22	N	*Ephedra foemina*	G, ML, E	2.25	3	3	3	3	3	3	**20.25**
22	E	*Solanum seaforthianum*	G	3	3	0	0	-2	0	0	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.4.19 *Ephedra foemina* would provide a good climber requiring minimal maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species *Solanum seaforthianum,* which is commonly used in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

Additional Climber Species

6.4.20 The species *Loranthus acaciae* may also be considered a climber as it clambers through trees, although it does not have roots in the earth, as it is a parasite of certain trees. However, the species does have the potential to be used as a climber if it is planted in association with a host species. Please refer to plant number 0 in the section below on Parasites.

Results and Discussion of the Values Assessed for Each Native Climbing Species Compared to the Exotic matched Pairs

6.4.21 The following discussion is reliant on the detail information located in Appendix F. The evaluation process is described in paragraphs 6.2.3 to 6.2.19.

6.4.22 Table 6.0 G illustrates the evaluations of all the native species against the exotic matched pair species.

Table 6.0 G Comparison of Values for the Native Versus the Exotic Species – Climbers

Plant No.	Plant Species Name	Native Species Cumulative Value	Exotic Species Cumulative Value
20	*Cocculus pendulus*	20.25	4
21	*Convolvulus althaeoides*	19.5	3
22	*Ephedra foemina*	20.25	4

(Note there is no Highest Scores Table 2 for Climbers as there are only 3 species.)

6.4.23 3 climbing species were located in the Negev. All 3 species achieve scores of 19 and above, which means that they have significant potentential for use within gardens, middle landscape and for environmental purposes in natural areas. (The exotic species have extremely poor evaluations as it is considered that their use is largely confined to garden areas, they have greater demands for water and have the potential to diminish ecological and landscape character/quality values.)

6.5 Geophytes - Analysis of the Individual Plant Species and Comparison of Matched Pairs

Introduction

6.5.1 The geophytes are some of the most spectacular plants that can be seen in the Negev and many visitors flock there to look at the flowering tulips, irises, alliums and other species that may bloom in select locations in profusion in good years. However, in some years, when the rains fail they do not appear at all.

6.5.2 The term geophyte includes those plants, which have storage organs usually located below ground. The classification encompasses those plant species with bulbs (e.g. *Narcissus, Tulipa*, and *Allium* species), corms (e.g. *Gladiolus*, *Freesia* and *Crocus* species), tubers (e.g. potatoes), rhizomes (e.g. *iris* species), tuberous roots (e.g. *Dahlia*, *Anemone* and *Ranunculus* species) and hypocotyls (e.g. *Cyclamen* species). However most of the geophytes found in the Negev have bulbs.

6.5.3 Geophytes are classified according to Raunkiaer's life-form system as having their perennating buds under the soil and are protected by dry leaves and *'sustained by food reserves in a storage organ'*. (Danin, 1983, page 24) During the dry season, the parts above ground dry out and are shed. (Danin, 1983, page 24)

6.5.4 The geophytes have been one of the life-forms that have been seen by a number of researchers in the Negev to have potential for commercial use, not only in the Negev for pot plants, but for the cut flower market as well. Studies have been made by Prof. Gutterman, for example in his article '*Geophytes of the Negev as a Genetic Source for Ornamental Garden Plants, Cut Flowers and Pot Plants*', (1997, Acta Horticulturae) and others.

6.5.5 The list of geophytes studied are noted in the following table and are described individually below.

Table 6.0 H List of Geophytes

NO.[218]	GEOPHYTES	COMMENTS & FLOWERING PERIOD [219]
23	*Allium aschersonianum*	Perennial bulb – February to March
24	*Allium erdelii*	Perennial bulb – February to April
25	*Allium papillare*	Perennial bulb – March to April
26	*Allium rothii*	Perennial bulb – February to March
27	*Asphodeline lutea*	Perennial with fleshy roots – February to May
28	*Asphodelus aestivus*	Perennial with fleshy roots – January to April
29	*Colchicum tunicatum*	Perennial bulb – September to October (Autumn)
30	*Dipcadi erythraeum*	Perennial bulb – February to May
31	*Gynandiris monophylla*	Perennial bulb – March to April
32	*Iris mariae*	Perennial with rhizome – February to March
33	*Iris petrana*	Perennial with rhizome – March to April
34	*Ixiolirion tataricum*	Perennial bulb – March to May
35	*Leontice leontopetalum*	Perennial with tuber – February to April
36	*Leopoldia longipes*	Perennial bulb – April to May
37	*Ornithogalum narbonense*	Perennial bulb – March to April

[218] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

[219] Ibid.

NO.[218]	GEOPHYTES	COMMENTS & FLOWERING PERIOD [219]
38	*Ornithogalum trichophyllum*	Perennial bulb – December to February
39	*Pancratium sickenbergeri*	Perennial bulb – September to October (Autumn)
40	*Ranunculus asiaticus*	Perennial with tuberous roots – February to May
41	*Sternbergia clusiana*	Perennial bulb – September to November
42	*Tulipa polychroma*	Perennial bulb – March to April
43	*Tulipa systola*	Perennial bulb – February to April
44	*Urginea maritima*	Perennial bulb – July to October
45	*Urginea undulata*	Perennial – August to September (Autumn)

Note: Analysis of plant species in grey is located in Appendix G2.

6.5.6 The following section notes the potential use for each native geophyte and the comparative evaluation of the native species matched to an exotic species. Note the section below includes the first 10 geophytes, (alphabetically ordered), whilst the remainder are included in Appendix G2. (Refer also to Appendix F3 for additional data.)

23. *Allium aschersonianum* – Family: Alliaceae / Liliaceae [220] (שום אשרסון - Shum Asherson – Asherson's garlic), Photographs G44 and G45.

Brief Description

6.5.7 This perennial species has a dark pink inflorescence [221] that reaches up to

[220] Order of Liliaceae: Herbs, mostly perennial, or rarely soft-wooded shrubs; roots from rhizome, corm or bulb, sometimes tuberous; stems erect or climbing. Useful Products: aloe asparagus.

100 centimetres. (Fragman-Sapir www.) It grows in wilderness and desert areas. (Feinbrun-Dothan and Danin, 1998, page 799)

6.5.8 Flowers: February – March (Feinbrun-Dothan and Danin, 1998, page 799)

Potential Suitable Uses

6.5.9 *Allium aschersonianum* has been cultivated and is available on the market. (Fragman-Sapir www.) Gardens, natural areas en masse, pots. The SEPASAL database notes that the stem and bulb can be used as a vegetable (RBGK www.)

Comparison of Matched Pair

6.5.10 The exotic plant chosen as a match for the native *Allium aschersonianum* is *Allium christophii*, the ornamental onion or Star of Persia, which has a similar ornamental onion flower head and stature.

Table 6. 23 *Allium aschersonianum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
23	N	*Allium aschersonianum*	G, ML, E	1.5	3	3	3	3	3	3	**19.5**
23	E	*Allium christophii*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.5.11 *Allium aschersonianum* is as attractive as *Allium christophii*. It could be

[221] Flowering; flower cluster or a characteristic arrangement of flowers on a stem.

used en-masse in gardens and in pots and elsewhere with no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species *Allium christophii* which is often used in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

24. ***Allium erdelii*** – Family: Alliaceae or Liliaceae (שום ארדל– Shum erdell – Erdel garlic), Photographs G37, G38 and G39.

Brief Description

6.5.12 A small single stemmed perennial allium with a head of white flowers and yellow stamens up to 30cm tall. Leaves lie on the ground and are largely inconspicuous.

6.5.13 Flowers: February – April (Feinbrun-Dothan and Danin, 1998, page 798) Grows: Steppes and wilderness areas. (Feinbrun-Dothan and Danin, 1998, page 798)

Potential Suitable Uses

6.5.14 A rather striking, white headed but small allium. It would be good almost anywhere in the garden and/or middle landscape as well as in pots and tubs, in pedestrian areas and in bedding.

Comparison of Matched Pair

6.5.15 The exotic plant chosen as a match for the native *Allium erdelii* is *Allium tuberosum*, Garlic chives originally from the Mediterranean region and Asia, which has a similar size and flower type and is used in many herb gardens.

Table 6. 24 *Allium erdelii* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
24	N	*Allium erdelii*	G, ML, E	1.5	3	3	3	3	3	3	**19.5**
24	E	*Allium tuberosum*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.5.16 *Allium erdelii* is an attractive small species. It is similar to *Allium tuberosum* and it could be used en-masse in gardens and in pots and elsewhere and for cut flowers with little to no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species *Allium tuberosum,* which is often used in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

25. *Allium papillare* (nippled) – Family: Alliaceae /Liliaceae (שום הפטמית- Shum hapetamot - Nippled garlic), Photographs G40 and G41.

Brief Description

6.5.17 A small bulb with clusters of small white flowers of the desert sands or loessal sands, the scabbard of the leaf and part of the blade of the leaf is covered in groups of hairs in the shape directed to the back. The perianth is toothed and at the head, along its length stands a protruding red artery. (Feinbrun-Dothan and Danin, 1998, page 798)

6.5.18 Flowers: March-April. (Feinbrun-Dothan and Danin, 1998, page 798)

Potential Suitable Uses

6.5.19 Although it is largely insignificant in small numbers, en masse the white garlic/onion like flowers would be visually pleasing as *Allium erdelii*. It appears that it could be used specifically in sandy areas in gardens, in the middle landscape and in natural areas as well as in pots, alongside roads etc.

Comparison of Matched Pair

6.5.20 The exotic plant chosen as a match for the native *Allium papillare* is *Allium tuberosum*, Garlic chives originally from the Mediterranean region and Asia, which has a similar size and flower type and is used in many herb gardens.

Table 6. 25 *Allium papillare* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
25	N	*Allium papillare*	G, ML, E	1.5	3	3	3	3	3	3	**19.5**
25	E	*Allium tuberosum*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.5.21 *Allium papillare* is an attractive small species, although it is smaller in stature. It is similar to *Allium tuberosum* and it could be used en-masse in gardens and in pots and elsewhere and for cut flowers with little to no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species *Allium tuberosum* which is often used in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

26. *Allium rothii* – Family: Alliaceae / Liliaceae (שום הנגב - Shum hanegev - Negev garlic), Photographs G42 and G43.

Brief Description

6.5.22 *Allium rothii* is a small perennial geophyte with a large bulb in the ground with a visually complex and striking large flower head with dark purple and cream flowers on a erect strong stalk about 20cm tall. It grows on sand and rocky areas.

6.5.23 Flowers: February to beginning of April. (Shmida, 1986, page 24)

Potential Suitable Uses

6.5.24 This a very attractive plant which could be used in gardens and elsewhere in the landscape as well as in pots en masse or in small pots as single specimens.

Comparison of Matched Pair

6.5.25 The exotic plant chosen as a match for the native *Allium rothii* is *Allium karataviense 'Ivory Queen'*, an ornamental allium available in nurseries, originally from central Asia. The matching species is similar is stature with similar dense globular flower heads.

Table 6. 26 *Allium rothii* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
26	N	*Allium rothii*	G, ML, E	1.75	3	3	3	3	3	3	**19.75**
26	E	*Allium karataviense 'Ivory Queen'*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer

to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.5.26 *Allium rothii* is as attractive as *Allium karataviense 'Ivory Queen'*. It could be used en-masse in gardens and in pots and elsewhere with no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species *Allium karataviense 'Ivory Queen'*, which is used in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

27. ***Asphodeline lutea*** (yellow) - Family: Liliaceae (עיריוני צהוב - Iryoni Tsahov -Yellow Asphodel), Photographs G46 and G47 - PROTECTED!

Brief Description

6.5.27 The yellow asphodel or Jacob's rod is a perennial geophyte with fleshy roots just below the ground, whose clusters of flowers grow 80-120cm tall. It has grassy glaucus leaves to 30cm and stiff dense flower spikes with yellow flowers as well as decorative seed spikes. (Wright, 1984, page 300) The flowers are sweetly scented. (Plants for a Future 'Asphodeline' www.)

6.5.28 Flowers: February-May. (Feinbrun-Dothan and Danin, 1998, page 770)

Potential Suitable Uses

6.5.29 The plant is tall, attractive, majestic even and en-masse would be good in gardens, amenity areas, the middle landscape and natural areas. Lord, (2003, Volume1, page 197), notes that the species of this family would be *'useful plants for the border, rockery, or for naturalizing'*. The author has seen the species growing in the herbaceous borders of 'Kenwood', Hampstead Heath in north London.

6.5.30 Flowers: Flowers for a long period from February to May and with a bonus of interesting seed heads.

Comparison of Matched Pair

6.5.31 The exotic plant chosen as a match for the native *Asphodeline lutea* is *Kniphofia stricta*, which is originally from South Africa. Many kniphofia species are available in Israel. *Kniphofia stricta* is similar to *Asphodeline lutea* due similar flower stems and strap like leaves.

Table 6. 27 *Asphodeline lutea* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
27	N	*Asphodeline lutea*	G, ML, E	2.25	3	3	3	3	3	3	**20.25**
27	E	*Kniphofia stricta*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.5.32 *Asphodeline lutea* is as attractive as *Kniphofia stricta*. It could be used en-masse in gardens and elsewhere with no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species *Kniphofia stricta*, which is used in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

28. *Asphodelus aestivus* (pertaining to summer) or **ramosus** - Family: Liliaceae (עירית גדולה- Irit Gedola - Big asphodel (W) Common Asphodel), Photographs G48 and G49.

<u>Brief Description</u>

6.5.33 An attractive and common Mediterranean perennial plant with strap like leaves and star shaped light pink flowers held on stalks up to 1 metre above the ground. Even desiccated plants have some visual interest with dried stalks and seed heads.

6.5.34 Flowers: January - April. (Feinbrun-Dothan and Danin, 1998, page 769)

Potential Suitable Uses

6.5.35 The plant is suitable in natural areas and in the middle landscape and potential broad and smaller scale garden use, in containers and alongside roads. It can tolerate poor soils and thus can be used in most places where the drainage is good.

Comparison of Matched Pair

6.5.36 The exotic plant chosen as a match for the native *Asphodelus aestivus* is *Tulbaghia violacea* 'Silver Lace', the wild garlic originally from the Cape in South Africa, which is similar in appearance with strap like leaves albeit *Tulbaghia violacea* has flowers on top of a stem and the Asphodelus has a raceme of flowers.

Table 6. 28 *Asphodelus aestivus* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
28	N	*Asphodelus aestivus*	G, ML, E	2.5	2	3	3	3	3	3	**19.25**
28	N	*Tulbaghia violacea* 'Silver Lace'	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.5.37 *Asphodelus aestivus* is slightly less attractive than *Tulbaghia violacea* 'Silver Lace'. However, it could be used en-masse in gardens and elsewhere with no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species, which is used in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

29. *Colchicum tunicatum* (with coats or envelopes) – Family: Liliaceae

סתבנית הקלפות (- Sitvanit haklipot – Sitvanit with skins), Photograph G50.

Brief Description

6.5.38 A small hysteranthous [222] perennial species with pink star shaped flowers with elongated petals.

6.5.39 Flowers: September – October. (Feinbrun-Dothan and Danin, 1998, page 773) The author has seen the plant flowering in August..

Potential Suitable Uses

6.5.40 Lord, (2003, Volume1, page 400) notes that the species belonging to this genus are *'great favourites of rock-garden enthusiasts… and that they also do well in containers'*. This is a delightful small autumn crocus type plant with pink flowers, which would be good in gardens and all other areas used en-masse as well as in pots.

Comparison of Matched Pair

6.5.41 The exotic plant chosen as a match for the native *Colchicum tunicatum* is *Colchicum autumnale*, the 'Naked lady', which is similar in appearance and also flowers pink in the autumn. As a garden favourite there are many other hybridised varieties available.

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[222] The term describes plants whose leaves emerge after the flowers have opened.

Table 6. 29 *Colchicum tunicatum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
29	N	*Colchicum tunicatum*	G, ML, E	2.25	2	3	3	3	3	3	**19.25**
29	E	*Colchicum autumnale*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.5.42 *Colchicum tunicatum* is as attractive at many of the species and hybridised autumn crocus available. *C. tunicatum* could be used en-masse in gardens and elsewhere with no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species, which is used in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

30. *Dipcadi erythraeum* (red) - Family: Liliaceae (כתרים אדמדמים - Kitraim adamdamim - Reddish Kitraim / Keter=crown), Photograph G51, PROTECTED!

Brief Description

6.5.43 Fragman-Sapir (*'Dipcadi erythraeum'*, www.) notes that it is *'this is one of the only bulbs penetrating the extreme desert (areas with less than annual 70 mm rain'*.) This perennial is rather inconspicuous and has a lilac tinged flower spike 15cm tall and bright green strap like leaves which lie limp on the sand.

6.5.44 Flowers: February-May. (Feinbrun-Dothan and Danin, 1998, page 784)

Potential Suitable Uses

6.5.45 The plant is rather inconspicuous and spindly, although interesting at closer inspection. The plant could be used en-masse on sand and areas with very good drainage, in amenity areas, as well as in sandy areas in the middle landscape and in natural areas as well as to help to stabilise sands.

Comparison of Matched Pair

6.5.46 The exotic plant chosen as a match for the native *Dipcadi erythraeum* are a number of *Fritillaria* species including *Fritillaria persica*, which may be found growing naturally in Israel, but is also available as seed and as a bulb in nurseries in Europe. The flower colour and spikes are similar, but the *Fritillaria* has a greater physical and visual presence.

Table 6. 30 *Dipcadi erythraeum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
30	N	*Dipcadi erythraeum*	G, ML, E	1.25	1	3	3	3	3	3	**17.25**
30	E	*Fritillaria persica*	G	3	3	0	0	-3	0	1	4

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.5.47 *Dipcadi erythraeum* is an interesting but rather less conspicuous compared to *Fritillaria persica*. It best used on sands and it could be used en-masse in gardens but its main benefits would be in the middle landscape and naturally sandy areas with no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species, may be used in gardens but with potential negative ecological effects if used outside of garden situations in the Negev and with the need for additional water.

31. ***Gynandriris monophylla*** (single leaved) - Iridaceae [223] (אחיאירוס קטן- Achi-irus katan or tsaharon katan or irus matsui - Small achi-irus), Photograph G52.

Brief Description

6.5.48 A small perennial iris with very intense purple flowers and thin cylindrical leaves. The plant stands up to 20 cm tall, mostly on rocky and stony ground in the northern Negev.

6.5.49 Flowers: February – March. (Shmida, 1986, page 190) March – April. (Feinbrun-Dothan and Danin, 1998, page 806)

Potential Suitable Uses

6.5.50 This is a delightful looking small iris which would look good anywhere en-masse, in the garden or in the middle landscape as well as in pots. It prefers stony ground but also grows on stabilised sand and would probably do well in rockeries and in gravel areas.

Comparison of Matched Pair

6.5.51 The exotic plant chosen as a match for the native *Gynandriris monophylla* is *Iris unguicularis* 'Bob Thompson', originally from Algeria and other Mediterranean areas, which is available in Israeli nurseries. The flowers and form of the two plants are similar.

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[223] Order of Iridaceae: Perennial herbs with the roots from underground rhizomes, corms, or bulbs; stems herbaceous, usually very ornamental and beautifully mottled or spotted.

Table 6. 31 *Gynandriris monophylla* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
31	N	*Gynandriris monophylla*	G, ML, E	1.25	3	3	3	3	3	3	**19.25**
31	E	*Iris unguicularis* 'Bob Thompson'	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.5.52 *Ginadriris monophylla* is as attractive as *Iris unguicularis*. It best used on stony soils and it could be used en-masse in gardens as well as in the middle landscape and natural areas with no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species, which is used in gardens but with potential negative ecological effects if used outside of garden situations in the Negev and with the need for additional water.

32. *Iris mariae* - Iridaceae (אירוס הנגב - Irus Hanegev - Negev iris), Photographs G53 and G54 – **PROTECTED!**

<u>Brief Description</u>

6.5.53 A very attractive perennial iris, which grows approximately 20cm tall with purple flowers and strap like leaves. It is endemic to the sands of the northern Negev. Ben Dov et al, (1993, page 91), notes that the species has a high salinity tolerance at a maximum of 15,000 μS/cm.

6.5.54 Flowers: February - March. (Feinbrun-Dothan and Danin, 1998, page 808)

Potential Suitable Uses

6.5.55 A most attractive plant that could easily be used en masse in natural sand areas, in pots, in gardens, alongside roads, pedestrian areas for amenity and can be used where salinity is high. (Ben Dov et al, 1993, page 91)

Comparison of Matched Pair

6.5.56 The exotic species chosen as a match for the native *Iris mariae* is *Iris germanica* or *Iris pallida*. The flowers and form of the two plants are similar to the native *Iris mariae* although *I. mariae* is less tall. However, there are numerous other hybrids that may be matched with *Iris mariae*.

Table 6. 32 *Iris mariae* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
32	N	*Iris mariae*	G, ML, E	2.5	3	3	3	3	3	3	**20.5**
32	E	*Iris germanica*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.5.57 *Iris mariae* is as attractive as any Iris species available. It is also saline tolerant. It best used on sandy soils and it could be used en-masse in gardens as well as in the middle landscape and natural areas with no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic iris species, which are used in gardens but with potential negative ecological effects if used outside of garden situations in the Negev and with the need for additional water.

Results and Discussion of the Values Assessed for Each Native Geophytic Species Compared to the Exotic matched Pairs

6.5.58 Further geophytes assessed are located in Appendix F3. They are matched in the following tables:

Table 6. 33 *Iris petrana* - Ratings for Use and Comparison of Matched Pair

Table 6. 34 *Ixiolirion tataricum* - Ratings for Use and Comparison of Matched Pair

Table 6. 35 *Leontice leontopetalum* - Ratings for Use and Comparison of Matched Pair

Table 6. 36 *Leopoldia longipes* - Ratings for Use and Comparison of Matched Pair

Table 6. 37 *Ornithogalum narbonense* - Ratings for Use and Comparison of Matched Pair

Table 6. 38 *Ornithogalum trichophyllum* - Ratings for Use and Comparison of Matched Pair

Table 6. 39 *Pancratium sickenbergeri* - Ratings for Use and Comparison of Matched Pair

Table 6. 40 *Ranunculus asiaticus* - Ratings for Use and Comparison of Matched Pair

Table 6. 41 *Sternbergia clusiana* - Ratings for Use and Comparison of Matched Pair

Table 6. 42 *Tulipa polychroma* - Ratings for Use and Comparison of Matched Pair

Table 6. 43 *Tulipa systola* - Ratings for Use and Comparison of Matched Pair

Table 6. 44 *Urginea maritima* - Ratings for Use and Comparison of Matched Pair

Table 6. 45 *Urginea undulata* - Ratings for Use and Comparison of Matched Pair

6.5.59 The following discussion relies on the detail information located in Appendix F3 and Appendix G2. The evaluation process is described in paragraphs 6.2.3 to 6.2.19.

6.5.60 Table 6.0 G illustrates the evaluations of all the native species against the exotic matched pair species.

Table 6.0 I Comparison of Values for the Native Versus the Exotic Species - Geophytes

Plant No.	Plant Species Name	Native Species Cumulative Value	Exotic Species Cumulative Value
23	*Allium aschersonianum*	19.5	3
24	*Allium erdelii*	19.5	3
25	*Allium papillare*	19.5	3
26	*Allium rothii*	19.75	3
27	*Asphodeline lutea*	20.25	3
28	*Asphodelus aestivus*	19.25	3
29	*Colchicum tunicatum*	19.25	3
30	*Dipcadi erythraeum*	17.25	4
31	*Gynandriris monophylla*	19.25	4
32	*Iris mariae*	20.5	3
33	*Iris petrana*	20.25	3
34	*Ixiolirion tataricum*	20.25	3
35	*Leontice leontopetalum*	15.5	5
36	*Leopoldia longipes*	19.5	4
37	*Ornithogalum narbonense*	20.5	3
38	*Ornithogalum trichophyllum*	17.25	No match

Plant No.	Plant Species Name	Native Species Cumulative Value	Exotic Species Cumulative Value
39	*Pancratium sickenbergeri*	20.5	6
40	*Ranunculus asiaticus*	20.25	3
41	*Sternbergia clusiana*	20.75	3
42	*Tulipa polychroma*	20.5	3
43	*Tulipa systola*	20.5	3
44	*Urginea maritima*	20.5	4
45	*Urginea undulata*	18.5	4

Note those native species that have not been matched are not considered to have value for garden use.

6.5.61 23 geophytic species were located in the Negev. Only 4, (18%) of these have low evaluations of 15.5 to 17.5 out of a total of 21. They are thus not considered suitable for garden areas but they do have the potential for use in middle landscape [224] areas and for environmental purposes in natural areas. Those native species that do not achieve a score above 19 [225] do so because their aesthetic qualities are not high and/or because they are poisonous and thus their garden use potentials are not clear-cut.

6.5.62 19 out of the 23 geophytes assessed, (83%) have a high score above 19 points as illustrated in the table below. 11, (58%), of these score above 20.

[224] The middle landscape is discussed in Chapter 4.

[225] An overall cumulative score (value) of nineteen (19) or above is considered to be a good score, which denotes the high quality and overall potential use of each individual native species with regard to the criteria of evaluation. A score of less than 19 does not however, preclude potential use of some species in specific locations and for specific purposes.

(The exotic species have extremely poor evaluations as it is considered that their use is largely confined to garden areas, they have greater demands for water and have the potential to diminish ecological and landscape character/quality values.)

Highest Scoring Native Geophytes

6.5.63 The geophytes with the highest scores of nineteen or above include:

Highest Scores Table 3 - Geophytes

Plant No.	Plant Species Name	Cumulative Value
23	*Allium aschersonianum*	19.5
24	*Allium erdelii*	19.5
25	*Allium papillare*	19.5
26	*Allium rothii*	19.75
27	*Asphodeline lutea*	20.25
28	*Asphodelus aestivus*	19.25
29	*Colchicum tunicatum*	19.25
31	*Gynandriris monophylla*	19.25
32	*Iris mariae*	20.5
33	*Iris petrana*	20.5
34	*Ixiolirion tataricum*	20.25
36	*Leopoldia longipes*	19.5
37	*Ornithogalum narbonense*	20.5
39	*Pancratium sickenbergeri*	20.5
40	*Ranunculus asiaticus*	20.25
41	*Sternbergia clusiana*	20.75
42	*Tulipa polychroma*	20.5

Plant No.	Plant Species Name	Cumulative Value
43	*Tulipa systola*	20.5
44	*Urginea maritima*	20.5

6.5.64 The geophytes are a group that illustrate considerable promise for use in a variety of situations and locations. However, as with geophyes in more temperate climates their use value is restricted to the winter/spring season, for example the *Allium* species or the autumn/winter season such as the *Sternbergia* species. At other times of the year the plants remain dormant underground. A more in depth analysis is included towards the end of the chapter.

6.6 Grasses - Analysis of the Individual Plant Species and Comparison of Matched Pairs

Introduction

6.6.1 The use of ornamental grass in landscape projects or in private gardens, in the past centred mainly on the use of bamboo [226], pampas grass (*Cortaderia selloana*) or some ornamental type *Festuca* species. The use of grasses has increased dramatically over the last years and many species are now available in the U.K. and elsewhere to use mainly as part of ornamental gardening schemes. Although grasses may be considered under the life-forms as annuals and perennials, they have been extracted from these categories as their physical characteristics and visual appearance are radically different from most other annuals and perennials.

6.6.2 Most grasses used in landscape projects are perennials, although in some cases annuals may well be used in environmental schemes.

6.6.3 Hickey for the National Council for the Conservation of Plants and Gardens, (NCPG, www.), notes that grasses are located *'in the family Gramineae which has been re-named by modern botanists as Poaceae'*. Of the 650 genera and 10,000 species widely distributed throughout the world, Israel has 121 species. Whilst Shmida and Darom (1986 and 1994) note approximately 11 notable species of grasses that can be found in the Negev [227], Feinbrun-Dothan and Danin, (1998) note 52 perennial species that may be found growing in the Negev, but many of these are found only in the northern Negev associated with the wetter Mediterranean region.

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[226] Bamboo is a grass in the family Gramineae (Poaceae) as are all grasses.

[227] This figure is approximate as some plants are considered as perennials and not grasses by the author and others in the literature. For example *Juncus* species is considered by Shmida and Darom as a grass where for this research it is considered a perennial rush.

6.6.4 The author located 4 perennial grass species, 3 of which have been analysed below and in Appendix F4. [228]

Table 6.0 J List of Grasses

NO.[229]	GRASSES	COMMENTS & FLOWERING PERIOD [230]
46	*Pennisetum setaceum* also known as (*P. asperifolium*)	Perennial - Mostly from Africa – Summer flowering
47	*Piptatherum miliaceum*	Perennial - February to July
48	*Stipa parviflora*	Perennial - April to June

6.6.5 The following section notes the potential use for each native grass and the comparative evaluation of the native species matched to an exotic species. (Refer also to Appendix F4 for additional data.)

46. *Pennisetum setaceum* (bristled) or ***asperifolium*** (rough leaved) - Family: Gramineae / Poaceae [231] (זיפנוצה מחוספסת- Zifnostah mechuspesset – Rough/uneven zifnostah), Photographs GR79 and GR80.

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[228] The taxonomic identity of the 4^{th} species is uncertain as the seed heads were not available when viewed at the end of summer. Only the remains of clumps , eaten by flocks remained on the ground. It is considered that this species was either *Stipagrostis hirtigluma, cilliata* or *plumosa.*

[229] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

[230] Information re flowering mainly from Feinbrun-Dothan and Danin, 1998. Note the flowering times are for the whole of Israel and not only the Negev. Should other references note earlier or extended flowering times these are included.

[231] Order of Gramineae: Annual or perennial herbs, rarely shrubs or trees; stems erect – grasses.

Brief Description

6.6.6 An attractive, very saline tolerant, (Ben-Dov et al, 1993, page 59), grass species with purple/white flower heads. The grass grows in clump form 1metre tall and 1 metre wide or more. It is native to parts of the Negev, but other sub-species have been introduced in landscape schemes. It has the ability to spread rapidly via wind born seeds. Ben-Dov et al, (1993, page 59) note that is very saline tolerant

6.6.7 Flowers: Principally in summer. (Feinbrun-Dothan and Danin, 1998, page 893). May – August. (Shmida, 1994, page 294)

Potential Suitable Uses

6.6.8 Ben-Dov et al, (1993, page 59) note that the species could be used for gardening, slope and sand dune stabilisation. The plant is well known in Mediterranean gardening and landscape schemes and is even available in the U.K. as a half hardy perennial. It is considered a high-risk invasive and noxious weed species in some countries such as Australia and in some states of the USA. (USDA, NRCS, Plants Profile, *'Pennisetum Setaceum'*, www.) The plant has many suitable applications, in gardens and the middle landscape, but care should be taken to retain the local genetic strain and not to introduce foreign/exotic strains which could alter the ecological character of a natural area. The Royal Botanical Garden's SEPASAL database notes that the plant is used for ornamental purposes as well as erosion control, and as a revegetator. (RBGK, SEPASAL, *'Pennisetum setaceum'* www.)

Comparison of Matched Pair

6.6.9 The exotic species chosen as a match for the native *Pennisetum setaceum* are those hybrids of *Pennisetum setaceum*, for example *P. setaceum 'rubrum'* that have been introduced and bred from plants from other Mediterranean and African regions where it is native.

Table 6. 46 *Pennisetum setaceum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
46	N	*Pennisetum setaceum*	G, ML, E	2.5	2	3	3	3	3	3	**19.5**
46	E	*Pennisetum setaceum hybrids*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.6.10 *Pennisetum setaceum* is an attractive grass with remarkable flower heads. It could be used en-masse in gardens, and elsewhere in the landscape with little or no maintenance, no additional water with positive ecological and landscape effects as opposed to the hybridised *Pennisetum setaceum* varieties such as *P. setaceum 'Rubrum'* that are used. It is considered that this use of the exotic grass hybrids even in gardens may have significant potential negative ecological effects as the seeds may be distributed far and wide.

47. *Piptatherum miliaceum* (millet like) - Family: Gramineae / Poaceae

(נשרן הדוחן– Nashran hadochan –Millet like nashran), Photographs GR81, GR82, GR83 and GR84.

Brief Description

6.6.11 A perennial grass that grows 60- 100 cm tall, green in winter / spring and dry looking during the summer. The plant is dense.

6.6.12 Flowers: February – July. (Feinbrun-Dothan and Danin, 1998, page 875)

Potential Suitable Uses

6.6.13 A lovely looking grass, but it is best in environmental projects and in the middle landscape and not for garden type landscape use, except as an ornamental grass in the winter /spring time when the grass stalks are green and have a satisfactory visual appearance. Good along roads and for soil stabilisation.

Comparison of Matched Pair

6.6.14 No exotic species has been chosen as a match for the native *Piptatherum miliaceum* as it is considered best used in the middle landscape and suitable natural areas.

Table 6. 47 *Piptatherum miliaceum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
47	N	*Piptatherum miliaceum*	ML, E	1	0	3	3	3	3	3	**16**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

48. *Stipa parviflora* (small flowered) - Family: Gramineae / Poaceae

(מלעניאל קטן פרחים– Malaniel katan-perachim – Small flowered malaniel), Photographs GR85 and GR86.

Brief Description

6.6.15 An attractive grass with green and brownish stems, upright and with coppery/purple seed heads that move elegantly in the wind.

6.6.16 Flowers: March to April. (Shmida, 1994, page 294) April - June. (Feinbrun-Dothan and Danin, 1998, page 874)

Potential Suitable Uses

6.6.17 An attractive grass, best used in natural areas, for environmental purpose, for example grazing as well as erosion control and in the middle landscape, but it could also be used in appropriate locations in gardens.

Comparison of Matched Pair

6.6.18 The exotic species chosen as a match for the native *Stipa parviflora* the grass *Muhlenbergia capillaris*, one of the many grasses that have been introduced and are available in Israel. The matching is due to their similar physical and visual characteristics and particularly large light pinkish seed heads.

Table 6. 48 *Stipa parviflora* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
48	N	*Stipa parviflora*	G, ML, E	2.25	2	3	3	3	3	3	**19.25**
48	E	*Muhlenbergia capillaris*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.6.19 *Stipa parviflora* is an attractive grass. It could be used en-masse in gardens, but it is probably best used in the middle landscape and natural areas with little or no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic *Muhlenbergia capillaris* species. It is considered that this use of the exotic grass hybrids even in gardens may have potential negative ecological effects as the seeds may be distributed far and wide.

Results and Discussion of the Values Assessed for Each Native Grass Species Compared to the Exotic matched Pairs

6.6.20 The following discussion relies on the detail information located in Appendix F5. The evaluation process is described in paragraphs 6.2.3 to 6.2.19.

6.6.21 Table 6.0 K illustrates the evaluations of all the native species against the exotic matched pair species.

Table 6.0 K Comparison of Values for the Native Versus the Exotic Species - Grasses

Plant No.	Plant Species Name	Native Species Cumulative Value	Exotic Species Cumulative Value
46	*Pennisetum setaceum*	19.5	5
47	*Piptatherum miliaceum*	16	No match
48	*Stipa parviflora*	19.25	4

Note those native species that have not been matched are not considered to have value for garden use. (Note there is no Highest Scores Table 4 for Grasses as there are only 3 species.)

6.6.22 3 grass species were located in the Negev. The *Piptatherum* species was considered to have a low evaluation and thus it is not likely suitable in garden situations but it does have the potential for use in middle landscape [232] areas and for environmental purposes in natural areas. Those native

[232] The middle landscape is discussed in Chapter 4.

species that do not achieve a score above 19 [233] do so because their aesthetic qualities are not high and thus their garden use potentials are not clear-cut. The other 2 species have scores above 19 and are considered suitable in certain garden situations as well as in suitable middle landscape and for appropriate environmental purposes in natural areas. (The exotic species have extremely poor evaluations as it is considered that their use is largely confined to garden areas, they have greater demands for water and have the potential to diminish ecological and landscape character/quality values.)

[233] An overall cumulative score (value) of nineteen (19) or above is considered to be a good score, which denotes the high quality and overall potential use of each individual native species with regard to the criteria of evaluation. A score of less than 19 does not however, preclude potential use of some species in specific locations and for specific purposes.

6.7 Parasites - Analysis of the Individual Plant Species and Comparison of Matched Pairs

Introduction

6.7.1 Parasitic plants are plants that use the nutrients and water of another plant, the host, often to the detriment of the host, to survive. Parasitic plants are unlikely candidates to be used in landscape projects, not least because as stated above they often, in the long term, threaten the longevity of the host species. However, in the Negev Desert, the parasitic species are rather spectacular and cannot go unnoticed by passers by as they add interest, and colour in the landscape. It is thus suggested here that they require discussion and analysis for potential suitable use, especially as they may have particular relevance within ecological systems where a chain of organisms respond and rely on one another for their well-being. They are also considered important for wildlife. In the case of Loranthus acaciae, the species provides nectar. In this instance the red flowers of the plant initially attract the Palestinian sunbird, (*Nectarinia osea*) to the plant, where it then actually sups nectar from the green flowers, whose sticky seeds stick to the birds beak. The plant is dispersed when the bird then tries to offload the sticky seed by rubbing its beak onto the stems of the same or another tree.

6.7.2 The author has identified three species of parasites growing in the Negev. The *Loranthus acaciae* species is characterised as being a hemiparasite [234] and is described by Zohary (1966, Text, Page 46) as being a *'perennial glabrous, green hemiparasite'*. The two *Cistanche* species are holoparasites

[234] A hemiparasite is a parasite 'that is photosynthetic (during at least one stage of its life cycle) that obtains water and nutrients from the host xylem. Some advanced hemiparasites (e.g. dwarf mistletoes) also obtain photosynthates from the host phloem. Hemiparasites can be either facultative (e.g. many Scrophulariaceae) or obligate (e.g. mistletoes)'. (Nickrent www.)

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Table 6.0 L List of Parasites

NO.[236]	PARASITES	COMMENTS & FLOWERING PERIOD [237]
49	*Cistanche salsa*	Perennial - March to May
50	*Cistanche tubulosa*	Perennial - March to April
51	*Loranthus acaciae*	On Acacia and Ziziphus species – All year round

6.7.3 The following section notes the potential use for each native parasite and the comparative evaluation of the native species matched to an exotic species where possible. (Refer also to Appendix F5 for additional data.)

49. ***Cistanche salsa*** (salty/briny referring to the lands it grows in) - Family: Orobanchaceae [238] (יחנוק המלחות- Yachnuk hameleichot – Yachnuk of salty lands), Photograph PA87.

Brief Description

6.7.4 A striking parasite with a single broad flower spike that emerges up to 35 cm tall direct from the ground, appearing pink at a distance, but the breakdown

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[235] These are 'nonphotosynthetic parasite(s) that obtain water and nutrients from the host xylem and photosynthates from the host phloem'. (Nickrent website).

[236] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

[237] Information re flowering mainly from Feinbrun-Dothan and Danin, 1998. Note the flowering times are for the whole of Israel and not only the Negev. Should other references note earlier or extended flowering times these are included.

[238] Order of Orobanchaceae: Herbs parasitic on roots, often covered with scales at the base, never green.

of colours of white, purple and yellow emerges on closer observation.

6.7.5 Flowers: March – May. (Feinbrun-Dothan and Danin, 1998, page 617)

Potential Suitable Uses

6.7.6 The plants are an oddity, but are quite attractive and could be used as focal points in the landscape at the beginning of summer. Used en-masse the site of pink spikes would be rather interesting. The potential use of the plant must be tempered by the fact that it needs a host, such as *Anabasis*, *Hammada scoparia* and *Atriplex* species and this association may cause the demise of the host. However this does not mean that it could not and should not be used in the middle landscape as well as in some garden situations. The Royal Horticultural Society notes that the parasitic species *Lathraea cladestina* was "plant of the month during April 2006 and that it can be planted. (Royal Horticultural Society, What's On, *'Plant of the Month: April'*, www.) *Cistanche salsa* is used in Chinese medicine and thus has some economic potential as well.

Comparison of Matched Pair

6.7.7 No exotic species has been chosen as a match for the native as no similar parasites are used or are likely to be used in gardens in the Negev.

Table 6. 49 *Cistanche salsa* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
49	N	*Cistanche salsa*	ML, E	2.25	1	3	3	3	3	3	**18.25**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

50. ***Cistanche tubulosa*** (with small pipes) - Family: Orobanchaceae

(יחנוק המדבר- Yachnuk hamidbar – Desert yachnuk), Photograph PA88.

Brief Description

6.7.8 A striking bright yellow form of the *Cistanche*, growing to a height of 45 cm. The broad column of flowers emerges from ground in association, most commonly with *Atriplex halimus* as well as *Ochradenus baccatus, Tamarix nilotica* and *Nitraria retusa.* (Shmida, 1986, page 120)

6.7.9 Flowers: March – April. (Feinbrun-Dothan and Danin, 1998, page 617)

Potential Suitable Uses

6.7.10 The plants are an oddity, but are quite attractive and could be used as focal points in the landscape at the beginning of summer. Used en-masse the site of bright yellow spikes would be rather interesting. The potential use of the plant must be tempered by the fact that it needs a host, mainly *Atriplex* species and this association may cause the demise of the host. However this does not mean that it could not and should not be used in the middle landscape as well as in some garden situations. The Royal Horticultural Society notes that the parasitic species Lathraea cladestina was "plant of the month during April 2006 and that it can be planted. (Royal Horticultural Society, What's On, 'Plant of the Month: April', www.)

Comparison of Matched Pair

6.7.11 No exotic species has been chosen as a match for the native as no similar parasites are used or are likely to be used in gardens in the Negev.

Table 6. 50 *Cistanche tubulosa* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
50	N	*Cistanche tubulosa*	ML, E	2.25	1	3	3	3	3	3	18.25

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

51. *Loranthus acaciae* - Family: Lorathaceae [239] (הרנוג השיטים- Acacia harnug), Photographs PA89, PA90 and PA91.

Brief Description

6.7.12 A very attractive evergreen glabrous, green hemiparasite [240]. It is parasitic

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[239] Order of Loranthaceae: Shrubs parasitic on trees or very rarely erect terrestrial trees or shrubs; leaves mainly opposite or whorled, simple, entire, sometimes reduced to a scale. Flowers often brightly coloured. Useful Product: Mistletoe.

[240] Hemiparasites are parasitic plant that contains some chlorophyll and therefore is capable of photosynthesis and thus is only partially reliant on the host plant for survival. Holoparasites on the other hand are obligated in their survival for nutrients and water on the host plant. The UCLA Botanical Gardens website (UCLA, Botagard., www.) notes that the species is a holoparasite, but some of these do have leaves that photosynthesise. This means that as a holoparasite then *Loranthus acaciae* has leaves that photosynthesise but the plant is still reliant on a host and cannot survive on its own. The author has never seen a

mainly on the branches of *Acacia* species, but also *Ziziphus, Balanites, Tamarix, Nitraria, Atriplex, Ochradenus* and *Rhus.* It has evergreen leaves throughout the summer and bright orange-red attractive flowers.

6.7.13 Flowers: Flowers all year round. Eastern Sudanian. (Feinbrun-Dothan and Danin, 1998, page 103)

Potential Suitable Uses

6.7.14 Albeit that this species is a parasite, it has huge potential to be used as an attractive climber / creeper. It could be used in association with the host species to provide shade through its branch structure and glaucus leaves, being trained through trees to provide additional shade or along trellises and pergolas. It also has orange-red flowers all year round. It also has an ecological importance as its attractive red flowers attract the local Palestinian sunbirds that then feed on the nectar of the green flowers.

6.7.15 Its middle landscape and environmental use may be debatable, as the parasite eventually will kill the host species. In more managed situations this is unlikely to be the case as the hosts species is most likely to obtain additional water and nutrients through the maintenance regime.

Comparison of Matched Pair

6.7.16 Although no parasitic species provides a relevant matching species it is considered that the differences between the native species and an exotic species should be determined in this case as the *Loranthus* is such a good climbing plant. The exotic species thus chosen as a match for the native *Loranthus* acacia species is the climber *Lonicera japonica*, the Japanese honeysuckle that has similar evergreen, flowering (although white), and climbing characteristics

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specimen growing without its host species. A downside to planting the species in a garden situation is the potential and likely transference of the parasitic seed by the Palestinian sunbird to other host species in the natural environment.

Table 6. 51 *Loranthus acaciae* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
51	N	*Loranthus acaciae*	G	2.5	3	0	0	3	3	3	**14.5**
51	E	*Lonicera japonica*	G	3	3	0	0	-3	0	0	3

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.7.17 The *Loranthus acaciae* species is an appropriate choice as a climber especially to provide shade. It is best used in garden situations where additional water and nutrients can be given to the host species to prevent its demise. The use of *Lonicera japonica* is also not recommended outside of the garden. In areas where there is little water it will not survive. In areas such as along the few perennials streams that exist in the desert it may cause ecological damage.

Results and Discussion of the Values Assessed for Each Native Parasitic Species Compared to the Exotic matched Pairs

6.7.18 The following discussion relies on the detail information located in Appendix F5. The evaluation process is described in paragraphs 6.2.3 to 6.2.19.

6.7.19 Table 6.0 M illustrates the evaluations of all the native species against the exotic matched pair species.

Table 6.0 M Comparison of Values for the Native Versus the Exotic Species - Parasites

Plant No.	Plant Species Name	Native Species Cumulative Value	Exotic Species Cumulative Value
49	*Cistanche salsa*	18.25	No match
50	*Cistanche tubulosa*	18.25	No match
51	*Loranthus acaciae*	14.5	3

Note those native species that have not been matched are not considered to have value for garden use. (Note there is no Highest Scores Table 5 for Parasites as there are only 3 species.)

6.7.20 3 parasitic species were located in the Negev. The *Cistanche* species grow up from the ground in association with certain native shrubs and the *Loranthus* species attaches itself to *Acacia* trees and other tree species. Although the Cistanche species are attractive they are not considered highly suitable for garden situations as they are dependent on other plants for their survival and the other plants may not be suitable in garden locations. The *Cistanche* species are more suitable in the middle landscape [241] and for environmental purposes in natural areas. Although the *Loranthus* species does not achieve a high score of 19 [242] or above, which would suggest its use in gardens, it is most probably better used in garden type situations, where the host species can be managed, for example with fertilizers, so that it does not succumb to the demands of the parasite.

[241] The middle landscape is discussed in Chapter 4.

[242] An overall cumulative score (value) of nineteen (19) or above is considered to be a good score, which denotes the high quality and overall potential use of each individual native species with regard to the criteria of evaluation. A score of less than 19 does not however, preclude potential use of some species in specific locations and for specific purposes.

6.8 Perennials and Biennials - Analysis of the Individual Plant Species and Comparison of Matched Pairs

Introduction

6.8.1 Unlike perennials in temperate climates that flower in summer and die back in winter to escape the effects of the cold, perennials in the Negev grow during the winter, in the wet season and normally flower in the spring and early summer. There are, however, a few notable perennials that flower during the summer.

6.8.2 According to Raunkiaers life-form classification method, perennial plants are considered Hemicryptophytes, where the renewal bud is located *'at the soil surface at the top of a storage root or system of thick roots'*. (Danin, 1983, page 24) The dry leaves desiccate during the summer and protect the bud. (Danin, 1983, page 24) They are considered to be 'drought resistors'.

6.8.3 Perennial plants are an important group of plants for landscape architects. In the U.K. and other areas where there may be hard frosts, they survive by losing their foliage above ground and maintaining the necessary root system below ground to sprout again when the weather becomes more favourable, usually at the on set of spring. Apart from shrub and tree planting, the landscape architect uses perennial planting as one of the most appropriate ways of providing form, colour, smell and visual interest in the garden and other landscape areas. Over the last decade and more, perennial planting has become even more popular across the western world and plants are used in many different ways apart from the typical 'herbaceous border' which can be found in many English gardens, which comprise a wide variety of summer flowering perennials.

6.8.4 Biennials are included in this section as they have their perennating buds located in a similar way as do perennials and they resist the harsh drought conditions by storing surplus food in their roots, if only for one season.

6.8.5 Please also refer to the sections on Climbers, Geophytes, Grasses and Parasites for the analysis of perennials not analysed immediately below. The perennials that have been identified in the field, reviewed in the literature and analysed are noted in the following table and individually below.

Table 6.0 N List of Perennials and Biennials

NO.[243]	PERENNIALS	COMMENTS & FLOWERING PERIOD [244]
52	*Achillea santolina*	March to April
53	*Adiantum capillus veneris*	Grows only with water – All year
54	*Alhagi graecorum*	April to September (unusual summer flowering)
55	*Anemone coronaria*	December to April
56	*Centaurea aegyptiaca*	Perennial or biennial – April to May
57	*Cyperus conglomeratus*	February to June
58	*Diplotaxis harra*	May
59	*Echinops polyceras*	June to July
60	*Eremostachys laciniata*	February to April
61	*Erodium hirtum/crassifolium*	February to May
62	*Gypsophila arabica*	April to November (unusual summer

[243] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

[244] Information re flowering mainly from Feinbrun-Dothan and Danin, 1998. Note the flowering times are for the whole of Israel and not only the Negev. Should other references note earlier or extended flowering times these are included.

NO.[243]	PERENNIALS	COMMENTS & FLOWERING PERIOD [244]
		flowering)
63	*Juncus arabicus*	March to December (unusual summer flowering)
64	*Malva sylvestris*	Perennial, annual or biennial – February to April
65	*Pallenis spinosa*	April to June
66	*Paronychia argentea*	January to April
67	*Peganum harmala*	March to April
	Pulicaria desertorum/incisa	January to May (refer to Annuals)
68	*Reseda muricata*	March to April
69	*Reseda stenostachya*	February to December (unusual summer flowering)
70	*Scorzonaria papposa*	March to May
71	*Tragopogon collinus*	Perennial or biennial - February to April
72	*Verbascum sinaiticum*	Biennial only - April to July
73	*Zygophyllum album*	April to July

Note: Analysis of plant species in grey is located in Appendix G3

6.8.6 The following section notes the potential use for each native perennial and the comparative evaluation of the native species matched to an exotic species. Note the section below includes the first 10 perennials, (alphabetically ordered), whilst the remainder are included in Appendix G. (Refer also to Appendix F6 for additional data.)

52. *Achillea santolina* - Family: Compositae (אכילאה ערבתית– Achillea arvatit - Steppe achillea), Photographs P92 and P93.

Brief Description

6.8.7 This is an attractive perennial, which grows to 30cm tall with heads of small bright yellow flowers and soft grey green leaves and stems. The plant usually appears en – masse and provides an attractive natural ground cover.

6.8.8 Flowers: March – April (Feinbrun-Dothan and Danin, 1998, page 700)

Potential Suitable Uses

6.8.9 The plant can well be used en-masse as a groundcover in most situations including the garden. It is quite possible that it would remain green for longer periods if more water is applied. It has a deep root system which means it will search for water, but may be difficult to eradicate once established.

Comparison of Matched Pair

6.8.10 The exotic species chosen as a match for the native *Achillea santolina* species is *Achillea filipendula* that is available in nurseries in Israel, although it has larger flower heads and appears larger and more robust.

Table 6. 52 *Achillea santolina* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
52	N	*Achillea santolina*	G	2.5	3	3	3	3	3	3	**19.5**
52	E	*Achillea filipendula*	G	3	3	0	0	-3	0	0	3

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.8.11 *Achillea santolina* is an attractive perennial. It could be used en-masse in gardens especially on loessal soils, as well as in the middle landscape and natural areas with little or no maintenance, no additional water with positive ecological and landscape effects as opposed to the exotic species such as *Achillea filipendula* that may cause ecological damage and require additional water.

53. *Adiantum capillus - veneris* (Venus haired) – Family: Adiantaceae

(שערות שולמית מצויות– Saarot shulamut metsuyot – Shulamit's hair), P94.

Brief Description

6.8.12 Shmida, (1994, page 298), notes that the plant is a fern that increases through spores. It does not have flowers. Feinbrun-Dothan and Danin (1998, page 83), notes that the species is very common where there is water where there are springs and water falls throughout Israel.

6.8.13 Flowers: Throughout the whole year. (Feinbrun-Dothan and Danin, 1998, page 83)

Potential Suitable Uses

6.8.14 The species can only be used in wet or damp areas and required moisture in the air as well as in the soil, where there is some protection from the sun such as in rock crevices and also free from frost. It thus can only be used where there is an availability of water and in highly specialised garden situations for example around a fountain feature in a park or a courtyard etc.

Comparison of Matched Pair

6.8.15 An exotic matching pair has not been chosen, as this is one of the species located by the author in the desert growing in direct association with a perennial water source. Its use is highly specialised, in that it cannot be used away from water, although it is often used as a potted house plant especially in bathrooms and kitchens where humidity is higher.

Table 6. 53 *Adiantum capillus-veneris* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
53	N	*Adiantum capillus-veneris*	G, ML, E	1.25	1	1	1	3	3	-3	**7.25**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.8.16 The low score does not relate to the poor quality or characteristics of the species but that it is a niche plant and it can only be used in very specialised locations.

54. *Alhagi maurorum* – Family: Papilonaceceae [245] or Leguminosae (הגה מצוי– Hagah matsui – Common hagah), Photographs P95 and P96

6.8.17 The definition of this species is uncertain. Both Shmida and Feinbrun-Dothan and Danin name the species in Hebrew as (הגה מצוי(Hagah matsui). However, whereas Shmida, (1986, page 15, notes this species as *Alhagi maurorum*, Feinbrun-Dothan and Danin, (1998, page 335) note the species as *Alhagi graecorum*. In this case the author has decided to note the species as *Alhagi maurorum* as the specimens were located in an area as noted on

[245] Order of Papilionaceae or Fabaceae: Herbs, shrubs or trees; leaves simple or compound; flowers zygomorphic (of a flower or calyx or corolla: symmetrical about one plane only, usually the plane that bisects the flower vertically.)

Shmida's location diagram [246]. (1986, page 14)

Brief Description

6.8.18 A very spiny deciduous perennial with bright yellow green spines and interesting pineapple smelling, bright red flowers in the summer months. Greenness and flowering during the summer is unusual and a bonus. The plant is usually small to 500 mm.

6.8.19 Flowers: May - October and partially into December. (Shmida, 1994, page 14)

Potential Suitable Uses

6.8.20 This species may be considered a weed despite it being a source of food for camels. As it can reproduce from roots underground it can be highly invasive and very difficult to get rid of. It has large green spines and attractive small bright red / pinkish flowers during the summer and the autumn which is unusual, and is a bonus but it appears desiccated, burnt and unattractive at other times of the year. It also has other ethno-botanical, medicinal and commercial uses.

6.8.21 The best location for its use is on sands, which require stabilisation.

Comparison of Matched Pair

6.8.22 This species is not matched with an exotic species as it is considered that it should not be used in garden, or middle landscape situations and only in the most difficult saline and erosion prone conditions where no other plants can be used.

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[246] Steve Davis, from the Survey of Economic Plants for Arid and Semi-Arid Lands (SEPASAL) to the author, 19, July 2006, quotes Lewis where in 'Legumes of the World' that "the number of species is disputed and there may only be a single variable species." (E-mail to the author from S. Davis on 19 July 2006)

Table 6. 54 ***Alhagi maurorum*** **- Ratings for Use and Comparison of Matched Pair**

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
54	N	*Alhagi maurorum*	E	1.25 S -2 W/SP	0	1	1	3	0	3	**9.25 S** **6.25 W/SP**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. S=summer, W/SP=winter/spring. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

55. ***Anemone coronaria*** (crown) – Family: Ranunculaceae (כלנית מצויה– Kalanit metsua – Common kalanit), Photograph P97, PROTECTED.

Brief Description

6.8.23 An extremely attractive perennial, flowering in springtime with mainly bright red, showy flowers on long stems. There are some 120 species of *Anemone* but only *Anemone coronaria* is used commercially in the cut flower trade. (Pathfast, *'Anemone'*, www.)

6.8.24 Flowers: January – March. (Zohary 1966, page 199) December – April. (Feinbrun-Dothan and Danin, 1998, page 192)

Potential Suitable Uses

6.8.25 The species can be used in most locations as well as in gardens, pots and for cut flowers.

Comparison of Matched Pair

6.8.26 *Anemone coronaria* has numerous hybrids for example *'Hollandia'* or *'de*

Caen' that are available on the market. These are similar to the species type found in the Negev but have more colour variety.

Table 6. 55 *Anemone coronaria* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
55	N	*Anemone coronaria*	G, ML, E	2.25	3	3	3	3	3	3	**20.25**
55	E	*Anemone coronaria 'Hollandia'*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.8.27 *Anemone coronaria* is a very attractive perennial species. It could be used en-masse in gardens, and elsewhere in the landscape with little to no maintenance, no additional water with positive ecological and landscape effects as opposed to the hybridised varieties which may be used in gardens but with potential negative ecological effects if used outside of garden situations and potentially with the need for additional water.

6.8.28 ***Caralluma nevegensis / Caralluma europaea*** (Refer to the section on Succulents below.)

56. *Centaurea aegyptiaca* (Egyptian) – Family: Compositae (דרדר מצרי- Dardar Mitsri (Egyptian Centaury / Thistle), Photograph P98 and P99.

Brief Description

6.8.29 A very spiky but interesting perennial/dwarf shrub with grey leaves and spiky bulbous, flowers similar to an artichoke or thistle. It is very dense and creates a large spiky mound.

6.8.30 Flowers: April-May. (Feinbrun-Dothan and Danin, 1998, page 731) Shmida, (Shmida, 1986, page 170) notes some flowering from January – August with the peak in April.

Potential Suitable Uses

6.8.31 Thorny but interesting plant with a good form, colour and interesting thistle like flower heads. It would be good in dry/desert type landscape projects including gardens such as in rockeries, in gravels, amongst rocks, as well as in the middle landscape, alongside roads, natural areas, as a good groundcover and low hedge. Not to be used for children's areas due to the spiky flowers.

Comparison of Matched Pair

6.8.32 The most appropriate match appears to be small cacti that are used in the Negev such as *Opuntia acicularis,* the Bristly prickly pear due to its similar size, thorniness and grey-green colouration. This is not a perfect match as cacti are usually fleshy without leaves, but they both are low growing and have thorns. (*Centaurea cineraria*, the grey 'dusty miller' was discarded as an imperfect match.)

Table 6. 56 *Centaurea aegyptiaca* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
56	N	*Centaurea aegyptiaca*	G, ML, E	2.25	2	3	3	3	3	3	**19.25 †**
56	E	*Opuntia acicularis*	G	3	3	0	0	-3	0	1	**4 †**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.8.33 Despite being spiky *Centaurea aegyptiaca* is an attractive perennial species, but probably kept away from immediate human contact in garden situations. Thus it could be used in similar ways that small cacti like the *Opuntia* are used as ground cover and accents and barriers. It could thus be used en-masse in gardens, and elsewhere in the landscape with little to no maintenance, no additional water with positive ecological and landscape effects as opposed to *Opuntia acicularis* which may be used as effectively in gardens but with potential negative ecological effects if used outside of garden situations.

57. ***Cyperus conglomeratus*** (clustered, often spherically) – Family: Cyperaceae [247] (גומה מגובה - Gomeh megubav- Heaped Gomeh) Photographs P100 and P101.

Brief Description

6.8.34 A good looking sedge with splayed yellow-green spiky stems with globules of yellow-green flowers towards the top up to 500 mm tall and similarly in diameter. It reminds the author of *Juncus* species found in wet areas of the UK.

6.8.35 Flowers: February – June. (Feinbrun-Dothan and Danin, 1998, page 913)

Potential Suitable Uses

6.8.36 This is a very a good-looking clumpy plant that grows on sand. It may require some availability to water as most Cyperaceae grow in moist conditions. Its form is in contrast to most other desert plants with its open system of green stems and inflorescences balanced towards the end of the stems. The plant would be particularly good on sands and thus requires good drainage. It would be suitable for natural, sandy roadsides, the middle

[247] Order of Cyperaceae: Perennial or annual herbs, found usually in damp or marshy habitats. Flowers small and inconspicuous. Useful products: papyrus (*Cyperus papyrus*) - leaves of many species used for mats.

landscape and garden areas in small or larger groups.

Comparison of Matched Pair

6.8.37 The exotic species matched pair for the native *Cyperus conglomerates* species is *Cyperus alternifolius,* a sedge that is available in Israel that originates from Madagascar. This sedge however, is taller than the native sedge.

Table 6. 57 *Cyperus conglomeratus* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
57	N	*Cyperus conglomeratus*	G, ML, E	2.5	2	3	3	3	3	2	**19.5**
57	E	*Cyperus alternifolius*	G	3	3	0	0	-3	0	0	3

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.8.38 *Cyperus conglomerates* is an extremely attractive perennial species. It could be used en-masse on sandy soils in gardens, and elsewhere in the landscape with little to no maintenance, perhaps with some additional water with positive ecological and landscape effects as opposed to the hybridised varieties which may be used only in gardens but with potential negative ecological effects if used outside of garden situations and with the need for substantial amounts of additional water.

58. *Diplotaxis harra* - Family: Brassicaceae / Cruciferae (טורים זיפניים - Turayim Zifaniyim - Pungent Column), Photographs P102 and P103.

Brief Description

6.8.39 A strange but good looking annual with succulent type but hairy leaves with long flower stalks to 35cm with yellow flowers and seed pods. It is very drought hardy.

6.8.40 Flowers: January – May (Feinbrun-Dothan and Danin, 1998, page 260) February – May (Zohary 1966, page 307)

Potential Suitable Uses

6.8.41 It is best used on rocky ground with less than 70mm rainfall. It can be used for soil binding and natural insect repellent amongst edible crops and perhaps amongst other 'ornamental' and horticultural plants and can be biennial if more water is provided. (It may also be good to deter insects in green houses.) It can also last throughout the summer with additional water.

6.8.42 The plant is somewhat inconspicuous and small but it has lovely small yellow flowers. Growing in stony gravels it can be used almost like an alpine plant as is done with similar plants in the U.K.

Comparison of Matched Pair

6.8.43 A less than perfect match for the native *Diplotaxis harra* species are any number of small alpine type plants such as saxifrages.

Table 6. 58 *Diplotaxis harra* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
58	N	*Diplotaxis harra*	G, ML, E	1.75	2	3	3	3	3	3	**18.75**
58	E	*Saxifrage species*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer

to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.8.44 *Diplotaxis harra* is a small very drought tolerant species. It is best used on gravely soils in the middle landscape and natural areas and en-masse in gardens or in-between plants as insect and animal control with little to no maintenance, perhaps with no additional water with positive ecological and landscape effects as opposed to the *Saxifrage* species which may be used only in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

59. ***Echinops polyceras*** (many horned, horned like projection) – Family: Compositae (קיפודן בלנש- Kipodan Belansh (a kipod is a hedgehog) Photographs P104, P105 and P106 and Photographic Addendum AD8.

Brief Description

6.8.45 This is a very robust spiky perennial with low growing to about 400 mm blue-grey leaves, (with spikes) and pom-pom / globe like attractive light blue, spiky flower-heads.

6.8.46 Flowers: June – July and partially into August. (Shmida, 1986, page 263) June – July. (Feinbrun-Dothan and Danin, 1998, page 711)

Potential Suitable Uses

6.8.47 The species is very spiny and quite ugly when dormant. It would be good as a thorny boundary hedge or en – masse in natural areas and in the middle landscape. The species may also possibly be used in very particular desert type amenity landscapes where other plants are dominant but where the attractive flowers are a focus. It may remain green with additional water.

Comparison of Matched Pair

6.8.48 The exotic species matched pair for the native *Echinops polyceras* species is *Echinops 'Veitch's Blue'*. This species is similar in scale with similar leaves but a more intense flower colour.

Table 6. 59 *Echinops polyceras* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Natural Use Rating	Environmental / Disbenefit Rating	Ecological Benefit / Benefit Rating *	Landscape Character	Water Demand	Cumulative Value
59	N	*Echinops polyceras*	G, ML, E	0.25	1	3	3	3	3	3	**16.25 †**
59	E	*Echinops* 'Veitch's Blue'	G	3	3	0	0	-3	0	1	**4†**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.8.49 *Echinops polyceras* is probably not as aesthetically poor as noted in the scoring of 0.25 above and may potentially be used in select garden locations, but it will require maintenance. It is best used in the middle landscape and in natural areas with no additional water with positive ecological and landscape effects as opposed to the hybrid *Echinops* 'Veitch's Blue', which is commonly used in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

60. *Eremostachys lacianata* (slashed into narrow divisions with taper pointed incisions) – Family: Labiatae [248] צמר מפוצל (- Tsamar mefutsal - Divided Tsamar) Photographs P107, P108, and P109.

Brief Description

6.8.50 A herbaceous perennial with numbers of erect stems from the base with a height of 1.2 - 2 metres. The flowers stalks are bold and interesting with

[248] Order of Labiatae / Lamiaceae: Herbaceous or rarely woody, often odoriferous, stems usually quadrangular, leaves opposite or whorled. Useful products: mint salvia, marjoram, lavender etc.

large cut leaves at the base.

6.8.51 Flowers: March – Mid May. (Shmida, 1986, page 154) February - April. (Feinbrun-Dothan and Danin, 1998, page 563)

Potential Suitable Uses

6.8.52 The species is best located in the wetter regions. It is an attractive species with interesting long flower stems that remind the author of *Acanthus mollis*. It appears possible to use this as a flowering perennial in gardens. The leaves are noted to be poisonous to sheep and goats, (Shmida, 1986, page 154), and thus care must be used in locating this plant where children may be tempted to eat it. As it is poisonous to grazing animals and potentially to people, it is probably best used in the middle landscape.

6.8.53 The plant is noted as a 'rock garden plant' in Dr. Pavel Slaby's database on rock garden plants. (Slaby, *'Rock garden plants'*, www.) Halevy, (Acta horticulturae, www.) notes that the species as having potential in the cut flower market.

Comparison of Matched Pair

6.8.54 The exotic species matched pair for the native *Eremostachys lacianata* species is *Acanthus mollis*, Bears britches. This species is similar in scale with similar leaves and flower spikes and all parts of the plant are poisonous.

Table 6. 60 *Eremostachys lacianata* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
60	N	*Eremostachys lacianata*	G, ML, E	2.25	1	3	3	3	3	2	**17.25 ††?**
60	E	*Acanthus mollis*	G	3	3	0	0	-3	0	1	**4 ††**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.8.55 *Eremostachys lacianata* is a statuesque species as is *Acanthus mollis* and it should be possible to use it in wetter garden locations as well as in the middle landscape and in natural areas with no additional water with positive ecological and landscape effects as opposed to the hybrid *Acanthus mollis* which is commonly used in gardens but with potential negative ecological effects if used outside of garden situations and with the need for additional water.

61. *Erodium hirtum* (hairy) or ***crassifolium*** (thick leaved) – Family: Geraniaceae [249] מקור חסידה הסעיר (- Makor-Chasida HaSair - Hairy storks bill), Photographs P110 and P111.

6.8.56 Feinbrun-Dothan and Danin, (1998, page 388), note this plant with the Hebrew name הסעיר חסידה מקור (Makor-Chasida HaSair) as *Erodium*

[249] Order of Geraniaceae: Annual herbs or shrubs, rarely arborescent; leaves alternate or opposite, mostly lobate. Useful products: Chiefly cultivate d for their handsome flowers and scented leaves; geranium, pelargonium.

crassifolium whilst Shmida, (1986, page 198) notes the same plant as being *Erodium hirtum.* Whilst Shmida, (1986, page 198) notes that the species includes bulbs, Feinbrun-Dothan and Danin do not mention this fact. Photographs of the species, located on the Botanic Garden Jerusalem website shows roots with attached tubers. (Botanic Garden Jerusalem, *'Erodium crassifolium'*, www.)

Brief Description

6.8.57 A small geranium leafed type cranesbill looking like a small shrub up to 20cm tall with cut blue green leaves and intense mauve flowers which last for a day and then are replaced by an elongated seed.

6.8.58 Flowers: February – mid March. (Shmida, 1986, page 198) February – May. (Feinbrun-Dothan and Danin, 1998, page 388)

Potential Suitable Uses

6.8.59 The species mainly grows on gravels. It is very attractive and apart from soil stabilisation, road edge use and middle landscape utilisation it can indeed be used within a garden setting. The Permaculture Information Web site, (PIW, *'Erodium hirtum'*, www.) confirms this when it states that *'this plant might do well located in cultivated beds'*.

Comparison of Matched Pair

6.8.60 The exotic species matched pair for the native *Erodium hirtum* species is *Erodium reichardii.* This species of stork's bill is available in nurseries in Israel and is similar in size and inflorescence.

Table 6. 61 *Erodium hirtum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
61	N	*Erodium hirtum*	G, ML, E	2.75	3	3	3	3	3	3	**20.75**
61	E	*Erodium reichardii*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.8.61 The total score of 20.75 out of a possible 21 is significant as it indicates that *Erodium hirtum* which is a very attractive cranesbill could well be used in garden situations and the middle landscape and natural situations. The plant would require minimal maintenance, no additional water above 200mm, with positive ecological and landscape effects as opposed to the exotic species *Erdodium reichardii*, storksbill, which could only be used in gardens, with potential negative ecological effects if used outside of the gardens and the need for additional water.

Results and Discussion of the Values Assessed for Each Native Perennial and Biennial Species Compared to the Exotic matched Pairs

6.8.62 Further perennials assessed are located in Appendices F6 and G3. They are matched in Appendix G3 in the following tables:

Table 6. 62 *Gypsophila arabica*- Ratings for Use and Comparison of Matched Pair

Table 6. 63 *Juncus arabicus*- Ratings for Use and Comparison of Matched Pair

Table 6. 64 *Malva sylvestris*- Ratings for Use and Comparison of Matched Pair

Table 6. 65 *Pallenis spinosa*- Ratings for Use and Comparison of Matched Pair

Table 6. 66 *Paronychia argentea*- Ratings for Use and Comparison of Matched Pair

Table 6. 67 *Peganum harmala*- Ratings for Use and Comparison of Matched Pair

Table 6. 68 *Reseda muricata*- Ratings for Use and Comparison of Matched Pair

Table 6. 69 *Reseda stenostachya*- Ratings for Use and Comparison of Matched Pair

Table 6. 70 *Scorzonaria papposa*- Ratings for Use and Comparison of Matched Pair

Table 6. 71 *Tragopogon collinus*- Ratings for Use and Comparison of Matched Pair

Table 6. 72 *Verbascum sinaiticum*- Ratings for Use and Comparison of Matched Pair

Table 6. 73 Zygophyllum album- Ratings for Use and Comparison of Matched Pair

6.8.63 The following discussion relies on the detail information located in Appendix F6 and Appendix G3. The evaluation process is described in paragraphs 6.2.3 to 6.2.19.

6.8.64 Table 6.0 O illustrates the evaluations of all the native species against the exotic matched pair species.

Table 6.0 O Comparison of Values for the Native Versus the Exotic Species – Perennials and Biennials

Plant No.	Plant Species Name	Native Species Cumulative Value	Exotic Species Cumulative Value
52	*Achillea santolina*	20.5	3
53	*Adiantum capillus-veneris*	7.25	No match
54	*Alhagi maurorum*	9.25 - 6.25	No match
55	*Anemone coronaria*	20.25	4
56	*Centaurea aegyptiaca*	19.25	4
57	*Cyperus conglomeratus*	19.5	3
58	*Diplotaxis harra*	18.75	3
59	*Echinops polyceras*	16.25	4
60	*Eremostachys lacianata*	17.25	4
61	*Erodium hirtum*	20.75	4
62	*Gypsophila arabica*	19.75	4
63	*Juncus arabicus*	16.5	1
64	*Malva sylvestris*	16.5	4
65	*Pallenis spinosa*	18.5	No match
66	*Paronychia argentea*	17.25	3
67	*Peganum harmala*	16.25	4
68	*Reseda muricata*	20.25	3
69	*Reseda stenostachya*	20.25	3
70	*Scorzonera papposa*	20.5	4
71	*Tragopogon collinus*	20.5	4
72	*Verbascum sinaiticum*	13.25	No match

Plant No.	Plant Species Name	Native Species Cumulative Value	Exotic Species Cumulative Value
73	*Zygophyllum album*	20.25	6

Note: Those native species that have not been matched are not considered to have value for garden use. * Some plants have two values due to alterations in appearance through the year.

6.8.65 22 perennial and/or biennial species were located in the Negev. Only 2 of these, (9%) of these have very low evaluations of 6.25 to 9.25 out of a total of 21. With regards to *Alhagi maurarum* this nainly because it is considered a weed and because its appearance at times can be very poor. This is not the case with *Adiantum capillus-veneris.* The Maidenhair fern is a delightful little species, but it must grow where there is sahde and most importantly water and thus its use in most locations is highly restricted. The Maidenhair fern could be used in gardens and natural areas but only where there is a constant water supply, but its use in the middle landscape is minimised by its water requirements. The *Alhagi* species has very restricted use potential in all areas as it is considered a weed.

6.8.66 7 species, (32%) achieve a score of between 13.25 and 18.75, which is considered a low score. They are thus generally not considered suitable for garden areas but they do have the potential for use in middle landscape [250] areas and for environmental purposes in natural areas. Those native species that do not achieve a score above 19 [251] do so because their aesthetic qualities are not high and/or because they are poisonous and/or because they

[250] The middle landscape is dicussed in Chapter 4.

[251] An overall cumulative score (value) of nineteen (19) or above is considered to be a good score, which denotes the high quality and overall potential use of each individual native species with regard to the criteria of evaluation. A score of less than 19 does not however, preclude potential use of some species in specific locations and for specific purposes.

grow in wetter locations and thus their garden use potentials are not clear-cut.

Highest Scores Table 6 - Perennials

Plant No.	Plant Species Name	Cumulative Value
52	*Achillea santolina*	20.5
55	*Anemone coronaria*	20.25
56	*Centaurea aegyptiaca*	19.25
57	*Cyperus conglomeratus*	19.5
61	*Erodium hirtum*	20.75
62	*Gypsophila arabica*	19.75
68	*Reseda muricata*	20.25
69	*Reseda stenostachya*	20.25
70	*Scorzonera papposa*	20.5
71	*Tragopogon collinus*	20.5
73	*Zygophyllum album*	20.25

6.8.67 11 out of the 22 geophytes assessed, (50%) have a high score above 19 points as illustrated in the table above. 8, (73%), of these score 20 or above, which means that most have a high potential for garden use as well as for use in middle landscape and appropriate natural areas. (The exotic species have extremely poor evaluations as it is considered that their use is largely confined to garden areas, they have greater demands for water and have the potential to diminish ecological and landscape character/quality values.) A more in depth analysis is included towards the end of the chapter.

6.9 Dwarf Shrubs - Analysis of the Individual Plant Species and Comparison of Matched Pairs

Introduction

6.9.1 The dwarf shrubs and shrubs form the greatest percentage of plants investigated in the Negev. The term dwarf shrub is generally unknown in temperate climates and the author only became aware of it as part of the study of the literature. The term 'dwarf shrub' is used in this research as opposed to the term 'semi-shrub' or 'sub-shrub', which may equally be used.[252] The term used by the author is used by Feinbrun-Dothan and Danin. (1998, page 24) Michael Zohary, one of the key botanists of the region, also refers to the group as dwarf shrubs. Feinbrun-Dothan and Danin, (1998, page 24), state that the meaning of the Hebrew, בן־שיח (Ben Siach), is

> *'a low perennial plant, (20-50 cm) tall where the lower parts are woody and where the upper branches or parts of them dry out and die year upon year'.*[253]

6.9.2 Shmida (1986, page ix), refers to these plants as *'perennial plants parts of whom are woody growing to 50 cm tall'.*[254] In this respect, Shmida's characterisation of a dwarf shrub is similar to how the horticultural industry in the U.K. is likely to term a low growing shrub. However, the form and character of these dwarf shrubs is dependant on the die back of the branches during drought conditions and thus Feinbrun-Dothan and Danin's understanding of the type is preferred.

6.9.3 Dwarf shrubs thus relate directly to the plant life form type known as chamaephytes. Chamaephytes form part Raunkiaer's classification method.

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[252] The United States Department of Agriculture (USDA) uses the term 'sub-shrub'. (USDA website)

[253] Translation by the author.

[254] Ibid.

Danin, (1983, page 25), describes these as semi-shrubs, that have their renewal buds above the ground. Danin notes that *'branches which are dry are shed according to a predictable sequence'*. (Danin, 1983, page 25) He further states that the renewal buds are *'usually located at the base of the flower-bearing branches which become dry after seed dispersal;*, and *'hence, the dwarf size of the semishrubs is retained.'* (Danin, 1983, page 25) (Refer back to Chapter 3, Paragraph 3.5.5 where the different types of chamaephytes are described).

6.9.4 In general, shrubs form the foundation of the landscape architects planting palette as they can be used for many different functions. With the trees and unlike the annuals, geophytes and perennials they are always physically and visually present. It is thus fortuitous that there are nearly 200 dwarf shrub and shrub species that grow in the Negev. [255] The research has located 52 dwarf shrub species and 17 shrub species. It is notable that many species flower in the summer months although many flowers are rather inconspicuous.

6.9.5 The native dwarf shrubs that have been identified in the field, reviewed in the literature and analysed are noted in the following table and individually below.

Table 6.0 P List of Dwarf Shrubs

NO.[256]	DWARF SHRUBS	COMMENTS & FLOWERING PERIOD [257]

[255] Refer to cies demand more water than most native species. (Refer to Chapter 4, section { REF _Ref22183936 \r \h * ME', in Chapter 3.

[256] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

[257] Information re flowering mainly from Feinbrun – Dothan and Danin, 1998. Note the flowering times are for the whole of Israel and not only the Negev. Should other references note earlier or extended flowering times these are included.

NO.[256]	DWARF SHRUBS	COMMENTS & FLOWERING PERIOD [257]
74	*Achillea fragrantissima*	March-October (summer flowering unusual)
75	*Anabasis articulata*	October toNovember (autumn flowering, unusual)
76	*Anabasis setifera*	October to November (autumn flowering, unusual)
77	*Anvillea garcinii*	February to April
78	*Artemisia monosperma*	September to December (autumn flowering, unusual)
79	*Artemisia sieberi*	September to December (autumn flowering, unusual)
80	*Arthrocnemum machrostachyum*	May to September (summer flowering, unusual)
81	*Asteriscus graveolens*	Dwarf shrub or perennial – March to April
82	*Astragalus spinosus*	February to April
83	*Atriplex leucoclada*	Dwarf shrub or Annual – April to October (Summer flowering, unusual)
84	*Ballota undulata*	April to October (summer flowering, unusual)
85	*Chiliadenus iphionoides*	September to November (autumn flowering, unusual)
86	*Cleome droserifolia*	March to May
87	*Convolvulus lanatus*	April to May
88	*Convolvulus oleifolius*	March to May
89	*Echiochilon fruticosum*	March to June
90	*Echium angustifolium*	March to August (summer flowering,

NO.[256]	DWARF SHRUBS	COMMENTS & FLOWERING PERIOD [257]
		unusual)
91	*Fagonia arabica*	April to June
92	*Fagonia bruguieri*	March to April
93	*Fagonia mollis*	February to April
94	*Gymnocarpos decandrum*	January to April
95	*Halogeton alopecuroides*	March-July (early summer)
96	*Hammada scoparia*	October to November (autumn flowering)
97	*Haplophylum tuberculatum*	March to April
98	*Helianthemum kahiricum*	January to April
99	*Helianthemum ventosum*	March to May
100	*Helianthemum vesicarium*	January to May
101	*Heliotropium arbainense*	January to April
102	*Hekiotropium rotundifolium*	April to September (summer flowering, unusual)
103	*Limonium pruinosum*	March to May
104	*Moltkiopsis ciliata*	February to June
105	*Moricandia nitens*	December to April
106	*Noaea mucronata*	August to October (autumn flowering)
107	*Phagnalon rupestre*	March to June
108	*Phlomis brachyodon*	April to June

NO.[256]	DWARF SHRUBS	COMMENTS & FLOWERING PERIOD [257]
119	*Pituranthos tortuosus*	April to November (summer flowering, unusual)
110	*Pituranthos triradiatus*	June to November (summer flowering, unusual)
111	*Polygonum equisetiformis*	Dwarf shrub or perennial (all year, unusual)
112	*Prosopis farcta*	Dwarf shrub or shrub, Invasive! – April to August
113	*Pulicaria crispa*	January to April
114	*Reaumaria hirtella*	March to July
115	*Salvia dominica*	February to May
116	*Salvia lanigera*	Dwarf shrub or perennial – February to May
117	*Salsola tetrandra*	January to May
118	*Sarcopoterium spinosum*	February to April
119	*Scrophularia deserti*	Dwarf shrub or perennial – March to May
120	*Stachys aegyptiaca*	February to May
121	*Suaeda fruticosa*	September to May
122	*Teucrium polium (or) capiataum*	April to August (summer flowering, unusual)
123	*Verbascum fruticolosum*	Dwarf shrub or biennial or perennial – April to August (summer flowering, unusual)
124	*Zilla spinosa*	Dwarf shrub or shrub - March to June
125	*Zygophyllum coccineum*	February to April

NO.[256]	DWARF SHRUBS	COMMENTS & FLOWERING PERIOD [257]
126	*Zygophyllum dumosum*	February to April

Note: Analysis of plant species in grey is located in Appendix G4

6.9.6 The following section notes the potential use for each native dwarf shruband the comparative evaluation of the native species matched to an exotic species. Note the section below includes the first 10 dwarf shrubs, (alphabetically ordered), whilst the remainder are included in Appendix G4. (Refer also to Appendix F7 for additional data.)

74. *Achillea fragrantissima* – Family: Compositae (אחלית ריחני - Achillea reichanit - "Smelly achillea), Photographs DS136 and DS137.

Brief Description

6.9.7 *Achillea fragrantissima* is a dwarf-shrub with grey green leaves growing 50 - 100cm tall. It starts to flower at the beginning of March, and the peak is during April to May. The abundance of flowers is dependent on the amount of water the plant gets at growing time. (Shmida, 1986, page 132)

6.9.8 Flowers: March (partially) – May and then sporadically - September. (Shmida, 1986, page 132) April-July. (Feinbrun-Dothan and Danin, 1998, page 699)

Potential Suitable Uses

6.9.9 A good-looking small shrub with clusters of flowers and in the autumn seed heads, which when touched smells sweet. The species could be used in the garden on its own or in groups, as part of shelterbelts, in the middle landscape and natural areas. It appears to be attractive throughout the year. Ben Dov et al, (1993, page 55), note that the species has a high saline tolerance and that it is useful for gardening and at the coast and that it does not require more than 200mm water per annum.

Comparison of Matched Pair

6.9.10 The exotic species chosen as a match for the native *Achillea fragrantissima* species is *Helichrysum* species such as *Helichrysum angustifolium (italicum)* originally from southern Europe that is available in nurseries in Israel, due to its similar form and size. The flower of *Helichrysum angustifolium* are however larger.

Table 6. 74 *Achillea fragrantissima* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
74	N	*Achillea fragrantissima*	G, ML, E	2.75	3	3	3	3	3	3	**20.75**
74	E	*Helichrysum angustifolium*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.9.11 *Achillea fragrantissima* is an attractive dwarf shrub. *Helechrysum angustifolium* may be more spectacular in appearance but its use should be limited to gardens where it will require additional water. *Achillea fragrantissima* may be used in gardens as well as in the middle landscape and natural areas with little or no maintenance, no additional water with positive ecological and landscape effects. In contrast *Helechrysum angustifolium* may cause ecological damage and alter landscape character and require additional water if used elsewhere.

6.9.12 ***Agathophora alopecuroides***. (Refer to Plant number 95, *Halogeton alopecuroides* in Appendix G4.)

75. *Anabasis articulata* (jointed) – Family Chenopodiaceae (יפרוק המדבר- Yafruk hamidbar - Desert yafruk [258]), Photographs DS138, DS139 and DS140.

Brief Description

6.9.13 This is a very hardy shrub, growing on most types of soil with grey green fleshy stems and no leaves and very attractive bracts coloured white / cream through to pink and vermillion in September and October. It can grow 1m tall with a 1.5 metre spread, although normally it is about 0.5m tall and a 1 metre spread.

6.9.14 Aronson, (Pasternak, 1990, page 71), notes that the species has a maximum salinity tolerance of 32,000 µS/cm. According to Ben Dov et al, (1993, page 10), this equates to a very high salinity tolerance.

6.9.15 Flowers: September – January with core flowering October and November. (Shmida, 1986, page 312) October – November. (Feinbrun-Dothan and Danin, 1998, page 180)

Potential Suitable Uses

6.9.16 Undoubtedly a desert species with advantages as it grows on a variety of soils and a very high salinity tolerance. Its cream/yellow/pink/vermillion bracts are superb and the species could well be used in a variety of landscape situations and potentially in garden situations extensive groundcover and informal hedging and in the middle landscape as part of a shelterbelt and in natural areas as it supports other ecological components (desert rodents).

6.9.17 In spring time the plants can appear "burnt" and rather unattractive.

Comparison of Matched Pair

6.9.18 *Rosmarinus officinalis 'prostratus'* is an appropriate match for the native *Anabasis articulata* due to is similar scale, colour and sprawling nature. It also flowers well into the autumn when the *Anabasis* flowers and fruits.

[258] The Hebrew word יפרוק "yafruk" comes from the root for jointed.

Table 6. 75 ***Anabasis articulata*** **- Ratings for Use and Comparison of Matched Pair**

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
75	N	*Anabasis articulata*	G, ML, E	2.25 S 0.75 SP	2	3	3	3	3	3	**19.25 S** **17.75 SP**
75	E	*Rosmarinus officinalis 'prostratus'*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.9.19 *Anabasis articulata* is an attractive dwarf shrub, although it does not appear so during spring. *Anabasis articulata* may however, be used in gardens as well as in the middle landscape and natural areas with little or no maintenance, no additional water with positive ecological and landscape effects. In contrast *Rosmarinus officinalis 'prostratus'* may cause ecological damage and alter landscape character and require additional water if used elsewhere other than garden locations.

76. *Anabasis setifera* (bristle bearing) – Family: Chenopodiaceae

יפרוק זיפני (- Yafruk zifani - Bristly yafruk [259]), Photographs DS141, DS142 and DS143.

<u>Brief Description</u>

6.9.20 An attractive bright green xerohalophytic shrub, 500mm tall and with a 1.5 metre spread. It is significant as it grows in very hot conditions, which

[259] Refer to footnote RGEFORMAT |4.6}, particularly pa above.

receive 100mm of rainfall per annum and it is mostly found on gravels and it is a colonizer.

6.9.21 Flowers: July – November and partially in December and January. (Shmida, 1986, page 312) August – November. (Feinbrun-Dothan and Danin, 1998, page 180)

Potential Suitable Uses

6.9.22 A perfect plant for roadside embankments where it has naturalised and also on gravels and gravel slopes and as a colonizer. It can take extreme heat and very little water (100mm).

Comparison of Matched Pair

6.9.23 *Rosmarinus officinalis* appears to be an appropriate match for the native *Anabasis setifera* due to is similar scale, colour and sprawling nature.

Table 6. 76 *Anabasis setifera* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
76	N	*Anabasis setifera*	G, ML, E	2.25	2	3	3	3	3	3	**19.25**
76	E	*Rosmarinus officinalis*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.9.24 *Anabasis setifera* is an attractive dwarf shrub when it is green and it may however, be used in larger gardens as well as in the middle landscape and natural areas with little or no maintenance, no additional water with positive ecological and landscape effects. In contrast *Rosmarinus officinalis* may cause ecological damage and alter landscape character and require additional water if used elsewhere other than garden locations.

77. *Anvillea garcinii* – Family: Compositae (אנוילֵיאה מדברית - Anvillea midbarit - Desert Anvillea), Photographs DS144 and DS145.

Brief Description

6.9.25 An attractive grey leaved dwarf shrub with intense yellow – orange flowers growing up to 1 metre tall but usually around 400mm and with a spread of up to 1m. It appears evergreen as it still had its leaves in September when analysed although it can also appear leafless and dry in extreme drought conditions. It grows in extreme desert areas receiving less than 100mm of rainfall.

6.9.26 Flowers: Starting January and ending May but mainly February – April. (Shmida, 1986, page 131) February – April (Feinbrun-Dothan and Danin, 1998, page 687)

Potential Suitable Uses

6.9.27 This species has very good potential in the garden as well as in the middle landscape and in habitat areas. It requires very little water (100mm) and its grey leaves, and many yellow flowers and shape make it very attractive. It could be used in groups as a low groundcover or as individual specimens in pots.

Comparison of Matched Pair

6.9.28 There is no perfect exotic match for *Anvillea garcinii*. However, the much used *Santolina chamaecyparissus*, appears to be appropriate due to is similar scale, and overall grey hue and flowers that bloom in spring. They both have yellow flowers, although the *Santolina* flowers are smaller and more numerous.

Table 6. 77 *Anvillea garcinii* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
77	N	*Anvillea garcinii*	G, ML, E	2.5	3	3	3	3	3	3	**20.5**
77	E	*Santolina chamaecyparissus*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.9.29 *Anvillea garcinii* is an attractive dwarf shrub when it is in leaf and flower and it may be used in gardens as a groundcover as well as in the middle landscape and natural areas with little or no maintenance, no additional water above 100-200 mm with positive ecological and landscape effects. In contrast *Santolina chamaecyparissus* may cause ecological damage and alter landscape character and require additional water if used elsewhere other than garden locations

78. *Artemisia monosperma* (with a single seed) – Family: Compositae (לענה חד זרעית- Laana Chad zarit - Single seeded wormwood), Photographs DS146 and DS147 and Photographic Addendum AD9.

<u>Brief Description</u>

6.9.30 This is a very durable dwarf shrub of sands growing to 1 metre tall and 1 metre spread. The small leaves vary in colour between light green and dark green depending on the time of year. The species is green in the summer, when most other species appear dry and dusty. Flowers are light yellow in autumn.

6.9.31 Ben Dov et al, (1993, page 43), notes that *Artemisia monosperma* does not require more than 200mm water per annum and that it is very highly tolerant of saline conditions at a maximum of 25,000 μS/cm.

6.9.32 Flowers: September – October and partially into November. (Shmida, 1986, page 324) September – December. (Feinbrun-Dothan and Danin, 1998, page 705)

Potential Suitable Uses

6.9.33 Ben Dov et al, (1993, page 43), note that the species should be good for landscape purposes for slope and sand stabilisation and for use along coastal areas. The author agrees that this is a good species for most amenity areas as well as the middle landscape and natural sand areas. It is green when everything else appears dead. The species can appear rather ragged at times, at the end of the summer and thus it appears that it would be good to prune it down for winter. Furthermore, old specimens appear more open and splayed, which is not attractive and thus pruning may help to maintain a more acceptable form and appearance.

Comparison of Matched Pair

6.9.34 The exotic species *Hyssopus officinalis*, Hyssop from the Mediterranean region is an appropriate match for the native *Artemisia monosperma* due to is similar scale and rising stems and also because it used as a herb. *Hyssopus officinalis* does have more significant small blue flowers.

Table 6. 78 *Artemisia monosperma* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
78	N	*Artemisia monosperma*	G, ML, E	2.5	3	3	3	3	3	3	**20.5**
78	E	*Hyssopus officinalis*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.9.35 At most times *Artemisia monosperma* is an attractive dwarf shrub. It may be used on sands in gardens en-masse as well as on sands in the middle landscape and natural areas with little or no maintenance, no additional water with positive ecological and landscape effects. In contrast *Hyssopus officinalis* may cause ecological damage and alter landscape character and require additional water if used elsewhere other than garden locations.

79. *Artemisia sieberi* (formerly herba-alba – white herb) – Family: Compositae (לענת המדבר- Laanat hamidbar - Desert wormwood) Photographs DS148, DS149 and DS150.

Brief Description

6.9.36 A small round deciduous dwarf shrub, with olive green leaves in the spring and small yellow flowers that grow 300 mm tall with a 400 mm spread. The species is found mostly on stony, rocky, gravely soils, but also in some areas on sand. The species appears dry during the summer but greens up in the autumn winter and spring.

6.9.37 Flowers: September - October. (Shmida, 1986, page 182) September – December. (Feinbrun-Dothan and Danin, 1998, page 705)

Potential Suitable Uses

6.9.38 Ben Dov et al, (1993, page 55), notes that the plant could be used in gardens, and in coastal situations and that it does not require more than 200mm of water per annum and that it has high salinity tolerance of a maximum of 15,000 µS/cm. It is very good on stony soils and could be good in various garden type situations (and perhaps with summer water it would remain green?) It would be excellent in the middle landscape, and could be good for civil engineering/roadside projects.

Comparison of Matched Pair

6.9.39 The exotic species *Santolina chamaecyparissus*, Lavender cotton, provides an appropriate match for the native *Artemisisa sieberi* due to is similar scale, and grey-green foliage.

Table 6. 79 *Artemisia sieberi* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
79	N	*Artemisia sieberi*	G, ML, E	2.25 A/W/SP 0.25 S	3	3	3	3	3	3	**20.25 A/ SP/W 18.25 S**
79	E	*Santolina chamae-cyparissus*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. A/SP/W=autumn/winter/spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.9.40 *Artemisia sieberi* is an attractive dwarf shrub except during the summer months when it appears dry and inconspicuous. It may be used on stony soils in gardens en-masse as well as in the middle landscape and natural areas with little or no maintenance, no additional water with positive ecological and landscape effects. Additional water during the summer may help to retain leafage. In contrast *Santolina chamaecyparissus* may cause ecological damage and alter landscape character and require additional water if used elsewhere other than garden locations.

80. ***Arthrocnemum macrostachyum*** (with large flower spike) – Family: Chenopodiaceae (בן מלח מכחיל- Ben melach machchil - Bluish ben melach), Photographs DS151 and DS152.

Brief Description

6.9.41 A dwarf, shrub found by the author growing in the Dead Sea which has a saline content at least 6 times that of sea water. Aronson, (Aronson in Pasternak, 1990, page 71), notes that the species is a hydrohalophyte, (growing in salt marshes), and that it can tolerate salinity up to 90,000 μS/cm, and that it can be used as a salt tolerant ornamental. The author notes that this is almost twice the amount of salts in seawater [260]. A number of articles note that the species is also drought tolerant. (Danin, 1981, page 6, www.) and (Instito Veneto Di Scienze, Lettere Ed Arte www.)

6.9.42 The species has fern like feathery blight blue-green jointed stems and no leaves and very small yellowish flowers at the joints during the summer. It grows 1 metre tall and supposedly with a maximum spread, of 2 metres. (Shmida, 1986, page 316)

6.9.43 Flowers: May – September and November. (Shmida, 1986, page 316) May – September. (Feinbrun-Dothan and Danin, 1998, page 170)

Potential Suitable Uses

6.9.44 Ben Dov et al, (1993, page 54), note that plant can be used in gardens and that it has decorative branches, and that it is tolerant of salt laden winds and thus can be used at the coast. The species could also be utilised to desalinate soils. It has the potential to be used in gardens with an additional 50 mm of water above 200 mm, in the middle landscape or natural areas which would receive 250 mm water or above.

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[260] The conductivity of seawater varies around the world and at different depths. Ben Dov et al (1993, page 10), use the level of 50 Ece (dS/m) which is equivalent 50, 000 μS/cm to denote the conductivity of seawater.

Comparison of Matched Pair

6.9.45 Due to its fern-like grey foliage and scale, the exotic species *Ruta graveolens 'Jackmans Blue'*, (Common rue), appears to provide an appropriate match for the native *Arthrocnemum macrostachyum.*

Table 6. 80 *Arthrocnemum machrostachyum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N)ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
80	N	*Arthrocnemum macrostachyum*	G, ML, E	2.25	3	3	3	3	3	2	**19.25**
80	E	*Ruta graveolens 'Jackmans Blue'*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.9.46 *Arthrocnemum machrostachyum* is an attractive dwarf shrub with exceptional saline tolerance. It may be used gardens en-masse as well as in the middle landscape and natural areas with little or no maintenance, but with an additional 50 mm of water 1 with positive ecological and landscape effects. In contrast *Ruta graveolens 'Jackmans Blue'* will require more water and may cause ecological damage and alter landscape character and require additional water if used elsewhere other than garden locations.

81. *Asteriscus graveolens* (heavy /strong smelling) – Family: Compositae (כוכב ריחני- Kochav reichani - Fragrant star), Photographs DS153 and DS154.

Brief Description

6.9.47 A dwarf roundish shrub growing 400 mm tall with a spread of 500 mm with mid green leaves and numerous bright yellow flowers

6.9.48 Ben Dov et al, (1993, page 56), notes that the species is fleshy suitable for gardens and that it has a high saline tolerance of a maximum 15, 000 μS/cm. It grows in areas receiving less than 100mmm rainfall per annum.

6.9.49 Flowers: All year but core flowering February to April. (Shmida, 1986, page 130) March - April. (Feinbrun-Dothan and Danin, 1998, page 688)

Potential Suitable Uses

6.9.50 An extraordinary small shrub, very drought hardy, saline tolerant and with great potential garden use and everywhere else in the landscape. With additional watering it could perhaps flower all year round. This is one of the best!

Comparison of Matched Pair

6.9.51 The author has not located a perfect match for this species. However, due to its similar scale and use in Israel, the exotic species *Cistus salvifolius* (Sageleaf rockrose), appears to provide an appropriate match for the native *Asteriscus graveolens*. Being of different families the flowers are different. The flowers of the *Cistus* are large and paper like, whilst the flowers of the *Asteriscus* are smaller and more daisy like.

Table 6. 81 *Asteriscus graveolens* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
81	N	*Asteriscus graveolens*	G, ML, E	2.25	3	3	3	3	3	2	**19.25**
81	E	*Cistus salvifolius*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. Refer

to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.9.52 *Asteriscus graveolens* is a very attractive dwarf shrub with a good saline tolerance. It may be used gardens en-masse as well as in the middle landscape and natural areas with little or no maintenance, no additional water with positive ecological and landscape effects. In contrast *Cistus salvifolius* will require more water in all areas and may cause ecological damage and alter landscape character if used elsewhere other than garden locations.

82. *Astragalus spinosus* (spiny / thorny) – Family: Papilionaceae [261] (קדר משולחף- Keder meshulchaf - Bladder keder), Photographs DS155 and DS 156.

Brief Description

6.9.53 This species is one of the spiniest ever recorded by the author. The species grows 400mm tall with a maximum 1200mm with small green leaves and distinctive off-white seed pods

6.9.54 Flowers: February - March. (Shmida, 1986, page 162) February - April. (Feinbrun-Dothan and Danin, 1998, page 308)

Potential Suitable Uses

6.9.55 A wicked looking but interesting species with numerous spines and bladder like pods giving an interesting texture. Difficult to use in garden / amenity situations, but it would create an impenetrable low hedge where required, and could well be used in the middle landscape and in suitable natural areas. The dry appearance at the end of summer also limits its use to the middle landscape and habitat creation / enhancement.

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[261] Papilionaceae - Order of Papilionaceae or Fabaceae: Herbs, shrubs or trees; leaves simple or compound; flowers zygomorphic (of a flower or calyx or corolla: symmetrical about one plane only, usually the plane that bisects the flower vertically.)

Comparison of Matched Pair

6.9.56 The species is best used in the middle landscape and natural locations and not in gardens and thus the matching of species has not occurred.

Table 6. 82 *Astragalus spinosus* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
82	N	*Astragalus spinosus*	ML, E	2.5 SP 0.5 S	0	3	3	3	3	3	**17.5 SP†** **15.5 S†**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.9.57 ***Atriplex halimus***. (Refer to the section on Shrubs, below.)

83. *Atriplex leucoclada* (white / pale branched / shooted) – Family: Chenopodiaceae (מלוח מלבין - Maluach Malvin – maluach = salty, lavan = white), Photographs DS157 and DS158.

Brief Desription

6.9.58 A low growing (500mm) grey leafed dwarf shrub with a spread of up to 1.4 metres. It is a xerophyte and halophyte and can sustain salinity levels way and above sea water levels. This is noted by Aronson, (Pasternak, 1990, page 72) where the maximum salinity that the plant can tolerate is 79, 000 µS/cm. Aronson furthermore notes that the plant is suitable for fodder. (Pasternak, 1990, page 72)

6.9.59 Flowers: October - November. (Shmida, 1986, page 319) April- October.

(Feinbrun-Dothan and Danin, 1998, page 164)

Potential Suitable Uses

6.9.60 This is a good looking salt bush, which could be used in appropriate desert type gardens as a grey leaved ground cover, but its most appropriate use is in the middle landscape, alongside roads, for soil stabilisation and for razing in natural areas.

Comparison of Matched Pair

6.9.61 Due to its grey foliage and scale, the exotic species *Ruta graveolens 'Jackmans Blue'*, (Common rue), appears to provide an appropriate match for the native *Atriplex leucoclada*.

Table 6. 83 *Atriplex leucoclada* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
83	N	*Atriplex leucoclada*	G, ML, E	2.25	2	3	3	3	3	3	**19.25**
83	E	*Ruta graveolens 'Jackmans Blue'*	G	3	3	0	0	-3	0	0	**3**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.9.62 *Atriplex leucoclada* is a dwarf shrub with exceptional saline tolerance with an overall grey attractive appearance. It may be used as a groundcover in gardens en-masse as well as in the middle landscape and natural areas with little or no maintenance, with no additional water with positive ecological and landscape effects. In contrast *Ruta graveolens 'Jackmans blue'* will require more water and may cause ecological damage and alter landscape character if used elsewhere other than garden locations.

6.9.63 *Atriplex semibacatta* (Refer to plant number in the section on Exotic Species and Foreign Escapees below.)

Results and Discussion of the Values Assessed for Each Native Dwarf Shrub Species Compared to the Exotic matched Pairs

6.9.64 Further dwarf shrubs assessed are located in Appendices F7 and G4. They are matched in Appendix G4 in the following tables:

Table 6. 84 *Ballota undulata* - Ratings for Use and Comparison of Matched Pair

Table 6. 85 *Chiliadenus iphionoides* - Ratings for Use and Comparison of Matched Pair

Table 6. 86 *Cleome droserifolia* - Ratings for Use and Comparison of Matched Pair

Table 6. 87 *Convolvulus lanatus* - Ratings for Use and Comparison of Matched Pair

Table 6. 88 *Convolvulus oleifolius* - Ratings for Use and Comparison of Matched Pair

Table 6. 89 *Echiochilon fruticosum* - Ratings for Use and Comparison of Matched Pair

Table 6. 90 *Echium angustifolium* - Ratings for Use and Comparison of Matched Pair

Table 6. 91 *Fagonia Arabica* - Ratings for Use and Comparison of Matched Pair

Table 6. 92 *Fagonia bruguieri* - Ratings for Use and Comparison of Matched Pair

Table 6. 93 *Fagonia mollis* - Ratings for Use and Comparison of Matched Pair

Table 6. 94 *Gymnocarpos decandrum* - Ratings for Use and Comparison of Matched Pair

Table 6. 123 *Verbascum fruticolosum* - Ratings for Use and Comparison of Matched Pair

Table 6. 124 *Zilla spinosa* - Ratings for Use and Comparison of Matched Pair

Table 6. 125 *Zygophyllum coccineum* - Ratings for Use and Comparison of Matched Pair

Table 6. 126 *Zygophyllum dumosum* - Ratings for Use and Comparison of Matched Pair

6.9.65 The following discussion relies on the detail information located in Appendix F7 and Appendix G4. The evaluation process is described in paragraphs 6.2.3 to 6.2.19.

6.9.66 Table 6.0 Q illustrates the evaluations of all the native species against the exotic matched pair species.

Table 6.0 Q Comparison of Values for the Native Versus the Exotic Species – Dwarf Shrubs

Plant No.	Plant Species Name	Native Species Cumulative Value *	Exotic Species Cumulative Value
74	*Achillea fragrantissima*	20.75	3
75	*Anabasis articulata*	19.25 - 17.75	4
76	*Anabasis setifera*	19.25	4
. 77	*Anvillea garcinii*	20.5	3
78	*Artemisia monosperma*	20.5	3
79	*Artemisia sieberi*	20.25 - 18.25	3
80	*Arthrocnemum macrostachyum*	19.25	3
81	*Asteriscus graveolens*	19.25	4
82	*Astragalus spinosus*	17.5 - 15.5	No match
83	*Atriplex leucoclada*	19.25	3

Plant No.	Plant Species Name	Native Species Cumulative Value *	Exotic Species Cumulative Value
84	*Ballota undulata*	20.25 - 18.25	5
85	*Chiliadenus iphionoides*	15.25 - 12.25	No match
86	*Cleome droserifolia*	20.25	5
87	*Convolvulus lanatus*	20.5	4
88	*Convolvulus oleifolius*	20.5	4
89	*Echiochilon fruticosum*	20.5	4
90	*Echium angustifolium*	20	4
91	*Fagonia arabica*	20.5	5
92	*Fagonia bruguieri*	19.25	5
93	*Fagonia mollis*	19.25	5
94	*Gymnocarpos decander*	18.25 - 16.25	5
95	*Halogeton alopecuroides*	19.25	5
96	*Hammada scoparia*	16.25 - 15.0	No match
97	*Haplophyllum tuberculatum*	19	3
98	*Helianthemum kahiricum*	20.75 - 16.0	3
99	*Helianthemum ventosum*	20.75 - 16.0	3
100	*Helianthemum vesicarium*	20.25 - 16.0	3
101	*Heliotropium arbainense*	20.5	5
102	*Heliotropium rotundifolium*	20.5	5
103	*Limonium pruinosum*	20.5	5
104	*Moltkiopsis ciliata*	19.5	5
105	*Moricandia nitens*	20.5 - 16.0	5
106	*Noaea mucronata*	14.5 - 14.0	No match

Plant No.	Plant Species Name	Native Species Cumulative Value *	Exotic Species Cumulative Value
107	*Phagnalon rupestre*	18.5	3
108	*Phlomis brachyodon*	20.75	4
109	*Pituranthos tortuosus*	20.5 - 20.25	3
110	*Pituranthos triradiatus*	20.5	4
111	*Polygonum equisetiforme*	20.5	4
112	*Prosopis farcta*	11.5	No match
113	*Pulicaria crispa*	17.25	3
114	*Reaumuria hirtella*	16.5 - 16.25	3
115	*Salvia dominica*	20.75	5
116	*Salvia lanigera*	20.5	5
117	*Salsola tetrandra*	18.5	5
118	*Sarcopterium spinosum*	20.5 - 16.0	5
119	*Scrophularia desertii*	20.5 - 16.0	5
120	*Stachys aegyptiaca*	20.5 - 19.75	5
121	*Suaeda fruticosa*	18.25	5
122	*Teucrium polium*	20.5	5
123	*Verbascum fruticulosum*	15.75	No match
124	*Zilla spinosa*	20.5 - 18.0	4
125	*Zygophyllum coccineum*	20.25	4
126	*Zygophyllum dumosum*	20.25 - 19.25	4

Note: Those native species that have not been matched are not considered to have value for garden use. * Some plants have two values due to alterations in appearance through the year.

6.9.67 53 dwarf shrub species were located in the Negev. Only 1 of these, (1.9%)

namely *Prosopis farcta* has a very low score of 11.5 out of a total of 21. This is mostly because it is considered a weed. However, it may have potential for use in certain natural areas for environmental purposes, but probably not in the middle landscape where it may have the capacity to spread. Many of the dwarf shrubs have been scored twice with lower and higher scores, as in some cases their apperance changes as the seasons change. This is mostly because the species can lose their leaves towards the middle and end of summer. 16 species, (30%) conform to this group of plants. At one time of the year they have a lower evaluation, whilst at another time this evaluation increases to high. The 3 *Helianthemum* species fall into this category. It is, however, known that some of these species, but not all will retain their leaves when and should enough water become available. This means that it is more than likely that the group that has achieved the higher scores, above 19 will increase.

6.9.68 40 species, (75%) achieve a score of 19 [262]or above out of 21. This includes those 16 dwarf shrubs, which have also achieved lower scores mentioned above.

Highest Scores Table 7 - Dwarf Shrubs

Plant No.	Plant Species Name	Cumulative Value
74	*Achillea fragrantissima*	20.75
75	*Anabasis articulata*	19.25
76	*Anabasis setifera*	19.75

[262] An overall cumulative score (value) of nineteen (19) or above is considered to be a good score, which denotes the high quality and overall potential use of each individual native species with regard to the criteria of evaluation. A score of less than 19 does not however, preclude potential use of some species in specific locations and for specific purposes.

Plant No.	Plant Species Name	Cumulative Value
77	*Anvillea garcinii*	20.5
78	*Artemisia monosperma*	20.5
79	*Artemisia sieberi*	20.25
81	*Asteriscus graveolens*	19.25
83	*Atriplex leucoclada*	19.25
84	*Ballota undulata*	20.25
86	*Cleome droserifolia*	20.25
87	*Convolvulus lanatus*	20.5
88	*Convolvulus oleifolius*	20.5
89	*Echiochilon fruticosum*	20.5
90	*Echium angustifolium*	20
91	*Fagonia arabica*	20.5
92	*Fagonia bruguieri*	19.25
93	*Fagonia mollis*	19.25
95	*Halogeton alopecuroides*	19.25
97	*Haplophyllum tuberculatum*	19
98	*Helianthemum kahiricum*	20.75
99	*Helianthemum ventosum*	20.75
100	*Helianthemum vesicarium*	20.25
101	*Heliotropium arbainense*	19.5
102	*Heliotropium rotundifolium*	20.5
103	*Limonium pruinosum*	20.5
104	*Moltkiopsis ciliata*	19.5

Plant No.	Plant Species Name	Cumulative Value
105	*Moricandia nitens*	20.5
108	*Phlomis brachyodon*	20.75
109	*Pituranthos tortuosus*	20.25
110	*Pituranthos triradiatus*	20.5
111	*Polygonum equisetiforme*	20.5
115	*Salvia dominica*	20.75
116	*Salvia lanigera*	20.5
118	*Sarcopterium spinosum*	20.5
119	*Scrophularia desertii*	20.5
120	*Stachys aegyptiaca*	20.5
122	*Teucrium polium*	20.5
124	*Zilla spinosa*	20.5
125	*Zygophyllum coccineum*	20.25
126	*Zygophyllum dumosum*	20.25

6.9.69 31, (53%) out of the 53 dwarf shrubs achieve highest evaluation between 20 and 21 and thus they have the greatest potential for suitability for use in gardens as well as in the middle landscape as well as for environmental use in appropriate natural locations.

6.9.70 A more in depth analysis is included towards the end of the chapter.

6.10 Shrubs - Analysis of the Individual Plant Species and Comparison of Matched Pairs

Introduction

6.10.1 This section notes the combined information, (field data and literature review) regarding the shrub species that the author located in the Negev Desert. Shmida, (1986) in the preliminary pages, (ט״), in *'Handbook of Wildflowers of Israel – Desert Flora'*, notes that a shrub is a perennial plant, parts of which are woody and that grow 50 – 400 cm tall.

6.10.2 Shrubs, as well as trees are classified as phanerophytes according to Raunkiaer's system. (Refer to Chapter 3) According to Danin's interpretation of Raunkiaer, the phanarophytes include the larger shrubs and trees where the renewal buds are located some way above the ground. (Danin, 1983, page 25) Danin, (1983, page 25) notes that unlike the dwarf shrubs, the chamaephytes that shed branches, phanerophytes do not shed their branches and foliage is replaced seasonally and any branch loss, *'depends on the water regime'*.

6.10.3 In this research, shrubs have been separated from dwarf shrubs according to two main characteristics. In the first instance, as described above, dwarf shrubs remain smaller due to their ability to lose branches in arid areas when drought is severe and secondly dwarf shrubs are usually less than 1.5 metres tall. However, in the context of the Negev, some dwarf shrubs noted above may well be considered in the shrub category as in certain optimum conditions, when they have enough water, they do not lose branches and foliage, and thus their growth is uninhibited and they grow taller. This includes for example, *Zygophyllum dumosum*, described in plant number 126, Appendix G4. Some shrubs, may be smaller than a number of dwarf shrubs, but they are included in the shrub category as they do not lose limbs in times of extreme drought. Furthermore, some shrubs may also be classified as trees, but generally in the context of the Negev, the author is in agreement with Shmida who states that trees grow greater than 4 metres tall, (Shmida, 1986, page,ט״), and they usually have a recognisable enlarged stem or stems in the form of a trunk.

6.10.4 The eighteen native shrubs that have been identified and analysed in the field, reviewed in the literature and assessed for potential suitable use are as noted in the table and individually below.

Table 6.0 R List of Shrubs

NO.[263]	SHRUBS	COMMENTS & FLOWERING PERIOD [264]
127	*Atriplex halimus*	April to October (summer flowering, unusual)
128	*Calligonum comosum*	February to April
129	*Calotropis procera*	March to November (summer flowering, unusual)
130	*Capparis aegyptiaca*	January to July
131	*Capparis cartilaginea*	February to April
132	*Colutea istria*	March to April
133	*Ephedra aphylla*	March to May
134	*Haloxylon persicum*	Shrub or tree – February to April
135	*Iphiona scabra*	March to August (summer flowering, unusual)
136	*Lycium shawii*	November to June (part summer flowering)

[263] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

[264] Information re flowering mainly from Feinbrun-Dothan and Danin, 1998. Note the flowering times are for the whole of Israel and not only the Negev. Should other references note earlier or extended flowering times these are included.

NO.[263]	SHRUBS	COMMENTS & FLOWERING PERIOD [264]
137	*Nitraria retusa*	April to May
138	*Ochradenus baccatus*	All year and December to May
139	*Retama raetem*	February to April
140	*Rhamnus disperma*	March to April
141	*Suaeda monoica*	April to October (summer flowering unusual)
142	*Thymelea hirsuta*	March to July
143	*Traganum nudatum*	February to April
144	*Vitex agnus-castus*	June to September

Note: Analysis of plant species in grey is located in Appendix G5

6.10.5 The following section notes the potential use for each native shrub and the comparative evaluation of the native species matched to an exotic species. Note the section below includes the first 10 shrubs, (alphabetically ordered), whilst the remainder are included in Appendix G. (Refer also to Appendix F9 for additional data.)

127. ***Atriplex halimus*** (of the sea and / or referring to salt) – Family: Chenopodiaceae (מלוח קפח- Maluach kipeach - Tall saltbush), Photographs S275, S276, S277 and S278.

Brief Description

6.10.6 A grey leafed large xerohalophytic shrub growing up to 2.5 metres tall and with a spread or 3 metres or more. Aronson, (Aronson in Pasternak, 1990, page 72), notes the species being able to tolerate salinity levels up to 56, 000 µS/cm which is equivalent to sea water, and Ben Dov et al, (1993, page 42), note the species can be used in gardens, for soil and sand dune stabilisation and that it is tolerant of coastal saline winds.

6.10.7 Flowers: Partially April – May and then mainly August – September and then partially into October and November. (Shmida, 1986, page 318) April – October. (Feinbrun-Dothan and Danin, 1998, page 163)

Potential Suitable Uses

6.10.8 *'The plant makes a superb wind-resistant low-growing hedge that can be allowed to grow untrimmed or can be trimmed.* (Permaculture Web, *'Atriplex halimus'*, www.) Furthermore the plant is successful along the coast and it is tolerant of heavy pruning, *'and can regrow even when cut back into old wood'* (and) *'the plant draws salt out of the soil and so has been used in soil-reclamation projects to de-salinate the soil'*. (Permaculture Web, *'Atriplex halimus'*, www.)

6.10.9 The species is thus suitable for a number of middle landscape and natural environmental purposes including combating soil erosion on a variety of soils sand dunes stabilisation, as well as a revegetator and for desalinisation of soils. In garden situations, it is most probable that the species could be used as a clipped hedge, which will help control the often unruly appearance of the species. With water it should retain its foliage all year round.

Comparison of Matched Pair

6.10.10 Due to its size, and use as a large hedge and general grey appearance *Leucophyllum frutescens,* which is the natural form of the *Leucophyllum* found in Texas and introduced around the world is considered an acceptable match for the native *Atriplex halimus.* The *Leucophyllum,* does however have showy pink flowers whereas the *Atriplex's* flowers are visually insignificant. *Leucophyllum* species are used extensively in the Negev.

Table 6. 127 ***Atriplex halimus*** **- Ratings for Use and Comparison of Matched Pair**

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
127	N	*Atriplex halimus*	G, ML, E	2.5 S	3	3	3	3	3	3	20.5 S
127	E	*Leucophyllum frutescens*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.10.11 *Atriplex halimus* has excellent potential to be used in larger garden areas as a large background shrub and pruned as a clipped hedge with little or no additional water. It will also be an asset in the middle landscape and many natural areas as well, without additional water and little or no maintenance. In contrast, *Leucophyllum frutescens* requires additional water wherever it is used and its use outside of garden locations may greatly effect ecological and landscape quality.

128. *Calligonum comosum* (bearing a tuft of hair) – Family: Polygonaceae שבטות מצויץ (- Shavtoot metsuyats -Fringed shavtoot), Photographs S279 and S280.

Brief Description

6.10.12 This is a large shrub which can grow 3 metres tall and with a spread up to 4 metres with a tangle of green stems and small pinky white, (Shmida, 1986, page 44) to yellow flowers in the form of small furry "bottle brushes". The species grows mainly *on sands deeper than 1 metre.*

6.10.13 Flowers: Commencing January and then mainly February – March and partially into April. (Shmida, 1986, page 44) February – April. (Feinbrun-

Dothan and Danin, 1998, page 116)

Potential Suitable Uses

6.10.14 This is an interesting mop headed shrub, which can appear tangled and unattractive. However, because of its interesting and striking character it could be used in some larger garden type situations, as a pruned specimen or in groups or potentially as a clipped hedge. It is very good on deep sand and would be good as a wind break on dunes for halting sand movement and as a general shelterbelt species. Zohary (1966, page 68) notes that it is *'an excellent sand binder'*. It is also good in natural areas as it is browsed and useful to wildlife and in middle landscape areas as it requires very little water and it is very robust.

6.10.15 Ben Dov et al, (1993, page 47), note that this species could be used in garden situations, for sand dune stabilisation and that it does not require additional water above 200mm per annum and that it tolerates a maximum salinity of 15,000 µS/cm and is thus highly saline tolerant.

Comparison of Matched Pair

6.10.16 Due to its size and rather unruly appearance and use as a medium large shrub, *Eremophila polyclada,* the Flowering Lygnum from central Australia is considered an acceptable match for the native *Calligonum comosum.* However, the *Eremophylla* has larger white flowers whilst the *Calligonum* has smaller yellow flowers.

Table 6. 128 *Calligonum comosum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
128	N	*Calligonum comosum*	G, ML, E	2.25 S	2	3	3	3	3	3	19.25 S
128	E	*Eremophila polyclada*	G	3	3	0	0	-3	0	3	**6**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.10.17 *Calligonum comosum* has some potential to be used in larger garden areas as a large background shrub on sands. It will also be more useful on sand in the middle landscape and many natural areas as well, without additional water and little or no maintenance. In contrast, *Eremophila polyclada* may diminish ecological and landscape quality wherever it is used as it has the ability to spread through the landscape as witnessed by the author in the northern Negev.

129. *Calotropis procera* (tall) - Family: Asclepidaceae [265]
פתילת המדבר גדולה (- Petilat midbar gedola or Tapuach sedom - Large desert petilah or Sedom apple), Photographs S281, S282 and S283, PROTECTED!

Brief Description

6.10.18 The Sodom apple is a tree like shrub growing up to 3 and 4 metres tall with a similar spread, with visible upright branching, grey-green / light-green leaves, large roundest green fruits like a large unripe apple and large clusters

[265] Order of Asclepediaceae: Milkweed family - Climbing, twining or erect shrubs or shrublets, herbs or rarely trees.

of purple white flowers. Ben Dov et al, (1993, page31), note that the species has a very high saline tolerance up to 25,000 μS/cm and that it does not require more than 200mm of rainfall per annum, that it can be used in gardens, and that it is tolerant of sea side conditions. The latex of the plant can cause skin blistering. (RBGK, SEPASAL, *'Calotropis procera'*, www.)

6.10.19 Flowers: All year. (Shmida, 1986 page 246) May – November. (Feinbrun-Dothan and Danin, 1998, page 512)

Potential Suitable Uses

6.10.20 Calotropis is a strange looking plant that has a height and stature that is unlike anything else growing in the Negev. As an open canopied large shrub with large leaves and striking flowers it has the potential to be used in smaller gardens as a specimen and small shade tree, if shaped and in large garden type situations as a specimen and also in groups. It probably should not be used in children's areas as the latex from the plant can cause skin blistering and be detrimental to the eyes. (Jones and Sacamano, 2000, page 83) In the middle landscape it has the potential to be used in as part of shelterbelt planting, windbreaks, and also in appropriate natural areas. It has many ethno-botanical uses as well.

6.10.21 Jones and Sacamano, (2000, page 83), note that the plant has the potential to be used as an *'accent or silhouette against a wall, especially where water for landscaping is limited'*. They further note that it does not require water after establishment, that any soil is suitable, that it requires little maintenance and that it can become invasive in some situations. (Jones and Sacamano, 2000, page 83)

Comparison of Matched Pair

6.10.22 Some of the smaller growing and immature *Eucalyptus* species such as *Eucalyptus grossa,* the Course flowered mallee from Australia that are used as specimen trees or in groups in residential areas, appear to offer an appropriate match for *Calotropis procera* with its large blue-green waxy leaves, interesting flowers, fruits and open branching.

Table 6. 129 Calotropis procera - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
129	N	*Calotropis procera*	G, ML, E	2.5 S	2	3	3	3	3	3	19.5 †
129	E	*Eucalyptus grossa*	G	3	3	0	0	-3	0	3	**6**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.10.23 *Calotropis procera* has the potential to be used in larger garden areas as well as more intimate locations as a specimen shrub. It is probably more useful in the middle landscape and appropriate natural areas as well, without additional water and little or no maintenance. *Eucalyptus grossa* like many other *Eucalyptus* species can be used and are used in garden areas, but their use beyond the garden should be restricted due to the high probability of the species spreading with potential negative effects on ecological and landscape quality as witnessed by the author in the northern Negev.

130. *Capparis aegyptiaca* (Egyptian) – Family: Capparaceae (צלף מיצרי - Tsalaf mitsri - Egyptian caper bush), Photographs S284, S285, S86, S287.

Brief Description

6.10.24 Zohary, (1966, page 242), notes that '*this variety is the common caper in Palestine*', i.e. *Capparis spinosa.* Shmida, (1986, page 72), also notes that this species is the same as *Capparis spinosa*, var. *arvensis* A very drought tolerant evergreen species that grows with as an upright shrub or hanging from cliffs, with roundish bright green leaves in spring which take on a blue, grey green blush in summer growing up to 2 metres tall with a spread of up to 4 metres. Ben Dov et al, (1993, page 42), notes that *Capparis spinosa*, as not requiring more than 200mm of rainfall per annum, that it has high salinity tolerance, i.e. up to 15,000 µS/cm and that it can be used in garden situations.

6.10.25 Flowers: March – August and then partially through to and into November. (Shmida, 1986, page 72) May – August. (Zohary 1966, page 242) January – July. (Feinbrun-Dothan and Danin, 1998, page 218)

<u>Potential Suitable Uses</u>

6.10.26 This is one of the best overall species and its potential in gardens is good as a ground cover and as a clipped hedge as noted by the SEPSAL database. (RBGK, SEPASAL, *'Capparis spinosa'*, www.) It does have hooks, but these do not appear to be too dangerous and thus it should be possible to use them where children are likely to play. The species would be good in the middle landscape to combat erosion and in shelterbelt and windbreak areas and for other purposes.

6.10.27 The species is also good in appropriate natural areas to combat erosion and provide food and shelter for wildlife.

<u>Comparison of Matched Pair</u>

6.10.28 The *Bougainvillea* species such as *Bougainvillea spectabilis* originally from the Amazon rainforests is considered an appropriate match for *Capparis aegyptiaca.* This is because the species are large and generally sprawling and are used as large shrubs in the Negev with significant colourful bracts as well as spines. *Capparis aegyptiaca* has attractive flowers that are not as intense as the *Bougainvillea spectabilis* but the shape and entangled branching of the matched pair is similar.

Table 6. 130 *Capparis aegyptiaca* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
130	N	*Capparis aegyptiaca*	G, ML, E	2.5 SP 3 S	3	3	3	3	3	3	20.5 † SP 21 † S
130	E	*Bougainvillea spectabilis*	G	3	3	0	0	-3	0	2	**5†**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.10.29 *Capparis aegyptiaca* is a species has excellent potential to be used in larger garden areas as well as more intimate locations as a specimen shrub, with little maintenance and no additional water above 200mm per annum. The species' potential worth is evidenced by reaching the ultimate cumulative score of 21. It would also be very useful in the middle landscape and appropriate natural areas as well, without additional water and little or no maintenance. *Bougainvillea* is ubiquitous in garden and other areas of the Negev. However, although it is drought tolerant it does require additional water and its use beyond the garden should be restricted due to the potential negative effects on ecological and landscape quality and its demand for water.

131. *Capparis cartilaginea* (referring to the cartilage in the leaves) or ***sinaica*** (of the Sinai) – Family: Capparaceae (צלף סחוסי - Tsalaf schoosi (Cartilagenaous caper bush), Photographs S288, S289 and S290.

Brief Description

6.10.30 A similar species to *Capparis aegyptiaca* or *Capparis spinosa*, but *C.*

cartilaginea's leaves are a brighter and more yellow-green and have cartilage inside when cut. This evergreen species grows mainly on sands and gravels and reaches a height mainly of 2 metres with a 4 metre spread. The author has seen species which are usually lower at approximately 1.2 metres. The species grows in the hottest desert areas mainly in gravely wadis. The flowers are large and "blousy" and the species has thorns.

6.10.31 Ben Dov et al, (1993, page 42), note that the species does not require more than 200mm rainfall per annum and that it is very highly saline tolerant at a maximum of 25,000 µS/cm and that it can be used in garden situations.

6.10.32 Flowers: May – August and then partially into October. (Shmida, 1986, page 72) February - April. (Feinbrun-Dothan and Danin, 1998, page 217) (Zohary 1966, page 244)

Potential Suitable Uses

6.10.33 This is an attractive shrub, with bright green waxy foliage, which is extremely hardy in hot desert conditions. Some specimens can appear leggy, when it is presumed water has been very scarce and the branch structure becomes more evident. This is in areas receiving less than 50mm per annum and thus with some additional water the plant's appearance should improve.

6.10.34 The species has the potential to be used as an evergreen hedge, clipped or informal, or massed as an overall groundcover, and moisture conserver as *Capparis aegyptiaca*. It has the potential also to be good in the middle landscape, where it would require little or no maintenance and in the natural landscape mainly on well drained sands and gravels.

Comparison of Matched Pair

6.10.35 With its evergreen waxy leaves, white flowers and thorns and its use as a hedge or sprawling shrub, the exotic species *Carissa macrocarpa,* the Natal plum from South Africa is considered an appropriate match for the native *Capparis cartilaginea.*

Table 6. 131 *Capparis cartilaginea* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
131	N	*Capparis cartilaginea*	G, ML, E	2.5 S	3	3	3	3	3	3	20.5 S†
131	E	*Carissa macrocarpa*	G	3	3	0	0	-3	0	1	4†

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.10.36 *Capparis cartilaginea* is a species that has excellent potential to be used in larger and smaller gardens to cover large areas and especially as hedging, with little maintenance and no additional water above 200mm per annum. The species' potential worth is evidenced by reaching the ultimate cumulative score of 20.5, all year round. It would also be very useful in the middle landscape and appropriate natural areas as well, without additional water and little or no maintenance. *Carissa macrocarpa,* the Natal plum is ubiquitous in gardens and other areas of the Negev. However, although it is reasonably drought tolerant it does require additional water and its use beyond the garden should be restricted due to the potential negative effects on ecological and landscape quality and its demand for water.

132. *Colutea istria* – Family: Papilionaceae / Leguminosae - Papilionoideae (קרקש צהוב - Karkash tsahov - Yellow karkash), Photographs S291, S292, S293, S94 and S295, PROTECTED!

<u>Brief Description</u>

6.10.37 An evergreen shrub growing up to 3 metres tall with a similar spread with small green leaves and bright yellow flowers on upright and arching purplish / reddish whip like stems. The plant produces attractive seed pods which stay on the plant for long periods providing interest towards the end of summer. Ben Dov et al, (1993, page 36), note that the species does not require more than 200mm rainfall per annum and that it highly tolerant of saline conditions to a maximum of 15,000 μS/cm and that it can be used in gardens for slope as well as sand dune stabilisation.

6.10.38 The SEPASAL database, (RBGK, SEPASAL, *'Colutea istria'*, www.), notes that the species grows in areas receiving less than 90mm of rainfall per annum.

6.10.39 Flowers: March - April (Shmida, 1986, page 118) The author has seen it flowering in summer and at the end of summer.

Potential Suitable Uses

6.10.40 This is a very attractive tall, open shrub, probably better, whose appearance would likely improve with some additional water during the summer months. The database, (Plant for a Future, *'Colutea Istria'*, www.), notes that the species can be used in a *'woodland garden, sunny edge, in dappled shade'* and as a *'hedge'* and that it is used for land reclamation in the Negev. The species has great potential to be used as a flowering hedge and in larger garden areas as a tall shrub as well as top create shelterbelts and windbreaks and for other environmental purposes in the middle landscape and other natural areas with a bit more water, good amenity and natural planting. This is one of the best larger shrub species growing in very harsh conditions.

Comparison of Matched Pair

6.10.41 The *Senna* species are commonly used in desert landscapes in the Negev and appear to provide a good match for the native *Colutea istria. Senna artemisiodes ssp sturtii,* formerly known as *Cassia sturtii,* dense senna with its yellow flowers, and similar size from central Australia is available in the Negev.

Table 6. 132 *Colutea istria* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
132	N	*Colutea istria*	G, ML, E	3 S 1.25 SP	3	3	3	3	3	3	21 S 19.25 SP
132	E	*Senna Artemisiodes ssp sturtii*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.10.42 *Colutea istria* is a species that has excellent potential to be used in larger and smaller gardens as a colourful shrub, with little maintenance and no additional water above 200mm per annum. The species' potential worth is evidenced by reaching the ultimate cumulative score of 21 during the summer. It would also be very useful in the middle landscape and appropriate natural areas as well, without additional water and little or no maintenance. *Senna* species are iubiquitous in gardens and other areas of the Negev. However, although it is reasonably drought tolerant it does require additional water and its use beyond the garden should be restricted due to the potential negative effects on ecological and landscape quality and its demand for water.

133. ***Ephedra aphylla*** (without leaves) – Family: Ephedraceae (שרביטן ריסני - Sharvitan Risani – Ciliate [266] sharvitan), Photographs S296, S297 and S298.

Brief Description

6.10.43 Shmida, (1986, page 149), notes that this a rare shrub without leaves, with green branches, that grows 70 – 200 cm tall mainly in rocky areas. The author has noted specimens 3 metres tall with a 4 metre spread. The flower is without a corolla and out of the flower protrude stamens, giving the flower head a cream colour. (Shmida, 1986, page 149)

6.10.44 Flowers: Principally March – May and then partially to October and then fully again from November – January. (Shmida, 1986, page 149) March - May. (Feinbrun-Dothan and Danin, 1998, page 93)

Potential Suitable Uses

6.10.45 Strange in form and appearance, this mop headed shrub with long wispy stems, without noticeable leaves, is a striking green feature in the landscape. It is evergreen throughout the summer and it appears that en – masse it would be a good shelterbelt and windbreak plant. It also has potential to be used as a boundary hedge and as a striking specimen feature in gardens. In the desert it appears to provide shelter as well as food for small birds.

Comparison of Matched Pair

6.10.46 Shmida, (1986, page 149), notes that the species has branching characteristics of broom. This is more or less true, of the exotic species *Eremophila polyclada,* native to central Australia and used in the Negev. Both the *Ephedra* and the *Eremophila* have tangled stems although the *Eremophyla* has larger white flowers and the *Ephedra* smaller yellow flowers.

Table 6. 133 ***Ephedra aphylla*** **- Ratings for Use and Comparison of**

[266] In botany – Referring to the hairs along the margin or edge of a structure, such as a leaf, usually forming a fringe.

Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
133	N	*Ephedra aphylla*	G, ML, E	2.5 SP, S	2	3	3	3	3	3	19.5 SP, S
133	E	*Eremophila polyclada*	G	3	3	0	0	-3	0	3	**6**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.10.47 *Ephedra aphylla* as a tangled matrix of leafless stems may be located in some garden locations as a specimen and as a background feature and boundary hedge with little maintenance and no additional water above 200 mm per annum. It would also be very useful in the middle landscape and appropriate natural areas as well, without additional water and little or no maintenance. *Eremophila polyclada* is drought tolerant but its use beyond the garden should be restricted due to the potential negative effects on ecological and landscape quality and its demand for water.

134. *Haloxylon persicum* (Referring to Persia) – Family: Chenopodaciae (פרקרק פרסי- Perakrak parsi - Persian perakrak), Photographs, S299 and S300.

Brief Description

6.10.48 Shmida, (1986, page 316), notes that this is a shrub or tree growing only in the sands of the Arava valley, growing to 1.7 - 3 metres tall. The author has only noted smaller species that do not have any great height. Shmida, (1986, page 316), notes that the plant is minus leaves and the young branches are green which carry out the function of photosynthesis. (Shmida, 1986, page

316) The branches are jointed and part of them drop down like jumbled weeping branches. (Shmida, 1986, page 316)

6.10.49 Flowers: Mainly August - November and partially February - March. (Shmida, 1986, page 316) February – April and fruiting November. (Zohary, 1966, page 166) February – April. (Feinbrun-Dothan and Danin, 1998, page 174)

Potential Suitable Uses

6.10.50 A species that has successfully been used particularly to control the movement of sand. (Refer to Morell, www.) This species in the Negev is largely located in the harsh confines of the Arava where it is low growing, but it is also found in other countries where it grows into an upright and potentially attractive tree. At present its best use is in natural areas of sand to combat soil movement and in the middle landscape where it requires very little maintenance. However, it is considered that with some additional water and maintenance and pruning the species could perform as a tree in garden situations and in the middle landscape, acting also as a larger shelterbelt and windbreak species.

Comparison of Matched Pair

6.10.51 The species is not generally suitable for most garden situations and thus a matching species has not been considered.

Table 6. 134 *Haloxylon persicum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
134	N	*Haloxylon persicum*	ML, E	0 to 2	0 to 1	3	3	3	3	3	15 to 18

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

135. *Iphiona scabra* (rough or scurfy) – Family: Compositae (אפיונה מחוספסת- Ephyonah mechoospesset – Rough Iphiona), Photographs S301 and S302.

Brief Description

6.10.52 Feinbrun-Dothan and Danin, (1998, page 685), note that this species is a sticky shrub with dense projecting hairs. It has lateral / secondary thorns only by the leaves. The species has yellow flowers. The author noted these species growing mainly in dry rocky and stony wadis.

6.10.53 Flowers: March – August. (Feinbrun-Dothan and Danin, 1998, page 685)

Potential Suitable Uses

6.10.54 The author has only viewed this species during the height of summer when parts of the plants were desiccated, but the yellow flowers were apparent. It is likely that the species would remain green throughout the summer with additional water and then its appearance would improve. The main potential function would be in the middle landscape on gravely soils but it doe have potential as groundcover in background garden areas. The plant has spines on the stems and foliage that is not that conducive to touching and therefore is probably best kept away from children's areas.

Comparison of Matched Pair

6.10.55 *Iphiona scabra* is does not have the merit to make a good garden plant and thus the matching process has not been carried out.

Table 6. 135 *Iphiona scabra* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
135	N	*Iphiona scabra*	ML, E	-0.5	0 to 1	3	3	3	3	3	15.0 to 16.5†

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

136. *Lycium shawii* (after Henry Shaw, 1800 - 1889) – Family: Solanaceae (עטד ערבי- Atad aravi -Arabian atad), Photographs S303, S304, S305, S306 and S307.

Brief Description

6.10.56 This is an extremely thorny shrub with arched, tangled branches growing 1 – 2 metres tall with small fleshy elongated leaves. (Shmida, 1986, page 272) The species has small tubular flowers that vary in colour from white to purple. *Lycium* in the Negev is mostly a plant of wadis and channels and because of the thorns many grow the plant as a partitioning hedge. (Shmida, 1986, page 272) Ben Dov et al, (1993, page 48), notes that *Lycium shawii*, has a very high salinity tolerance, up to a maximum of 25, 000 µS/cm, that it does not require additional water above 200mm and that it can be used in garden situations, for soil stabilisation as well as sand dune stabilisation. The SEPASAL database, (RBGK, SEPASAL, *'Lycium shawii'*, www.), notes that the species spiny / thorny and that it grows in areas receiving 0 – 100mm rainfall.

6.10.57 Flowers: Mainly December – April and then partially throughout the rest of the year. (Shmida, 1986, page 272) November – June. (Feinbrun-Dothan and Danin, 1998, page 588) The author has noted the species flowering at most times of the year.

<u>Potential Suitable Uses</u>

6.10.58 This is one of the most spiny / thorny species that the author has come across and is similar in it density of spines to species of *Pyracanthos* familiar to most landscape architects and gardeners in more temperate climates. The species loses its leaves in summer and its appearance is very poor, but when it is green it shows the potential to be used as an impenetrable informal and possible formal hedge. It may be possible that with additional water during the summer the species may retain its leaves and then it may be possible to use it in some garden situations as a thorny impenetrable hedge and in the middle landscape. However, if its deciduous character is not related to drought then the potential use of the shrub is limited in garden and middle landscape situations and it is more suited to environmental uses in saline areas for soil and sand dune stabilisation. It is also a very good plant for wildlife in natural areas.

6.10.59 Not to be used in children's areas because of numerous very sharp spines.

<u>Comparison of Matched Pair</u>

6.10.60 Garden use is restricted and thus the matching process has not been carried out.

Table 6. 136 ***Lycium shawii*** **- Ratings for Use and Comparison of Matched Pair**

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
136	N	*Lycium shawii*	ML, E	2.75 SP -2 S	0	3 1	3	3	3	3	17.75 † 11†

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.10.61 ***Nicotiana glauca***. (Refer to section 'Naturalised Species and Foreign Escapees', below.)

Results and Discussion of the Values Assessed for Each Native Shrub Species Compared to the Exotic matched Pairs

6.10.62 Further shrubs assessed are located in Appendices F8 and G5. They are matched in Appendix G5 in the following tables:

Table 6. 137 *Nitraria retusa* - Ratings for Use and Comparison of Matched Pair

Table 6. 138 *Ochradenus baccatus* - Ratings for Use and Comparison of Matched Pair

Table 6. 139 *Retama raetem* - Ratings for Use and Comparison of Matched Pair

Table 6. 140 *Rhamnus disperma* - Ratings for Use and Comparison of Matched Pair

Table 6. 141 *Suaeda monoica* - Ratings for Use and Comparison of Matched Pair

Table 6. 142 *Thymelea hirsute* - Ratings for Use and Comparison of Matched Pair

Table 6. 143 *Traganum nudatum* - Ratings for Use and Comparison of Matched Pair

Table 6. 144 *Vitex agnus-castus* - Ratings for Use and Comparison of Matched Pair

6.10.63 The following discussion relies on the detail information located in Appendix F8 and Appendix G5. The evaluation process is described in paragraphs 6.2.3 to 6.2.19.

6.10.64 Table 6.0 S illustrates the evaluations of all the native species against the exotic matched pair species.

Table 6.0 S Comparison of Values for the Native Versus the Exotic Species – Shrubs

Plant No.	Plant Species Name	Native Species Cumulative Value *	Exotic Species Cumulative Value
127	*Atriplex halimus*	20.5	5
128	*Colligonum comosum*	19.25	6
129	*Calotropis procera*	19.5	6
130	*Capparis aegyptiaca*	21 - 20.5	5
131	*Capparis cartilaginea*	20.5	4
132	*Colutea istria*	21 - 19.25	5
133	*Ephedra aphylla*	19.5	7
134	*Haloxylon persicum*	18 - 15	No match
135	*Iphiona scabra*	16.5 - 15	No match

Plant No.	Plant Species Name	Native Species Cumulative Value *	Exotic Species Cumulative Value
136	*Lycium shawii*	17.75 - 11.0	No match
137	*Nitraria retusa*	15.75 - 13.75	No match
138	*Ochradenus baccatus*	21	5
139	*Retama raetem*	21 - 20.25	5
140	*Rhamnus disperma*	19.5 - 18.25	5
141	*Suaeda monoica*	19.25 - 18.75	5
142	*Thymelea hirsuta*	20.5 - 19.25	4
143	*Traganum nudatum*	15.25	No match
144	*Vitex agnus-castus*	21	4

Note: Those native species that have not been matched are not considered to have value for garden use. * Some plant have two values due to alterations in appearance through the year.

6.10.65 18 shrub species were located in the Negev. None of these achieved very low scores. Some of the shrubs have been scored twice with lower and higher scores, as in some cases their appearance changes as the seasons change. This includes 6 species with lower scores of between 11.0 and 18.75. Another group includes 6 species with two high scores, which indicates that changes in appearance are marginal. Most of these shrub species, i.e. 13 species, (72%) have a high or seasonally high evaluation between 19 and 21 [267]. This evaluation indicates their potential for use in

[267] An overall cumulative score (value) of nineteen (19) or above is considered to be a good score, which denotes the high quality and overall potential use of each individual native species with regard to the criteria of evaluation. A score of less than 19 does not however, preclude

gardens as well as in the middle landscape as well as for environmental purposes in appropriate natural areas.

6.10.66 The shrubs with the highest scores of nineteen or above include:

Highest Scores Table 8 - Shrubs

Plant No.	Plant Species Name	Cumulative Value
127	*Atriplex halimus*	20.5
128	*Colligonum comosum*	19.25
129	*Calotropis procera*	19.5
130	*Capparis aegyptiaca*	21
131	*Capparis cartilaginea*	20.5
132	*Colutea istria*	21
133	*Ephedra aphylla*	19.5
138	*Ochradenus baccatus*	21
139	*Retama raetem*	21
140	*Rhamnus disperma*	19.5
141	*Suaeda monoica*	19.25
142	*Thymelea hirsuta*	20.5
144	*Vitex agnus-castus*	21

6.10.67 8, (44%) out of the 18 shrubs achieve highest evaluation between 20 and 21, and of these 5 (28% of the total shrubs) have a score of 21. They have the greatest potential for suitability for use in gardens as well as in the middle landscape as welll as for environmental use in appropriate natural locations.

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potential use of some species in specific locations and for specific purposes.

6.10.68 A more in depth analysis is included towards the end of the chapter.

6.11 Succulents - Analysis of the Individual Plant Species and Comparison of Matched Pairs

Introduction

6.11.1 Succulent plants usually have thick and enlarged water storing stems and / or leaves. It is not usually essential to differentiate succulent plants from the shrub or perennial species but the author noted that one of the species, namely *Carraluma nevegensis* or *europea* was so atypical that it needed to be located in a group on its own. This decision ties in with the fact that succulents are a "specialised" life-form, as noted by Hickey for the National Council for the Conservation of Plants and Gardens, (Hickey, NCCPG, www.), and that do not fit in with Raunkiaer's classification of life forms according to the location of the perrenating bud. (Refer to Chapter 3.) The succulents are able to survive drought conditions by being able to store moisture in *'fleshy tissue in their stems, roots or leaves'*.[268]

6.11.2 Feinbrun-Dothan and Danin, (1998, pages 120-122) note a limited number of succulent species growing in Israel and the Negev Desert. These species fall under the genera 'Aizoaceae' and are described in general, by Feinbrun-Dothan and Danin (1998, page 120) as being *'herbs or, now and again, low shrubs'*[269]

6.11.3 The succulent species assessed by the author are noted in the table and individually below.

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[268] Hewitt, (1993, Page 10 notes that succulents include the cacti family and that most succulents *'have very shallow, but extensive root systems'*. (Page 11).

[269] Translation from Hebrew into English by the author.

Table 6.0 T List of Succulents

NO.[270]	SUCCULENTS	COMMENTS & FLOWERING PERIOD [271]
145	*Caralluma europaea* or *nevegensis* (Shmida, 1986)	Perennial succulent - October to April (Autumn, winter flowering, unusual))
146	*Mesembryanthemum nodiflorum*	Annual succulent – February to June

6.11.4 The following section notes the potential use for each native succulent and the comparative evaluation of the native species matched to an exotic species. (Refer also to Appendix F9 for additional data.)

145. *Caralluma negevensis* (from the Negev) or ***C. europaea*** variety ***judaica***, currently accepted as ***Apternathes europaea var. judaica*** – Family: Asclepidiaceae [272] (אצבוע הנגב- Etzboa hanegev - Negev etzboa (etzboa means finger) or אצבוע אירופי - Etsboa Iropi – European etsboa), Photographs SU331 and SU332, PROTECTED!

Brief Description

6.11.5 Shmida, (1986, page 28), notes this species as *Caralluma nevegensis*, and as

[270] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

[271] Information re flowering mainly from Feinbrun-Dothan and Danin, 1998. Note the flowering times are for the whole of Israel and not only the Negev. Should other references note earlier or extended flowering times these are included.

[272] Order of Asclepediaceae: Widely distributed family of twining, climbing or erect herbs and shrubs or shrublets of the order Gentianales; most with milky juice climbing, twining or erect shrubs or shrublets, rarely trees, most with milky juice.

a shrub while Feinbrun-Dothan and Danin, (1998, page 514), note the species as *Caralluma europaea variety judaica* as a perennial. In 1983, Danin, (page 30) writes about the species as being *C. nevegensis,* a succulent.

6.11.6 However, to further complicate matters, whilst the SEPASAL database, (RBGK, SEPASAL, *'Caralluma'*, www.) refers to the genus as *Caralluma,* it is apparent that the taxonomy of the species has changed and it is now accepted as *Apternathes europaea var. judaica.* (Meve and Heneidak, Botanical Journal of the Linean Society, 2005, page 432)

6.11.7 In this research, as the author is translating mainly from Shmida, the genus and species name, *Caralluma negevensis* is used, but it is realised that over time this taxonomic reference is likely to become redundant.

6.11.8 This is a small succulent, mainly growing in rock fissures, with succulent 'fingers' growing to a length of approximately 5 –10 cm, with delightful yellow and purple striped star like flowers and thin elongated seedpods. Most flowering occurs in spring but also continues into the summer. (Shmida, 1986, page 28)

6.11.9 Ben Dov et al, (1993, page 87), note that the species dos not require more than 200mm rainfall per annum and that it can be used in gardens and it is tolerant of saline coastal winds.

6.11.10 Flowers: October – April. (Feinbrun-Dothan and Danin, 1998, page 514) Mainly April - May but also partially June – October. (Shmida, 1986, page 28)

Potential Suitable Uses

6.11.11 This plant is small and in the desert, as it protrudes out from rock fissures it is well camouflaged and hard to see. The plants really need to be grown where they can be viewed close-up as they are intriguing and the flowers are a visual delight. Its main use, potentially is thus in garden rockeries and in pots, and perhaps in gravels and in courtyards where its character can be appreciated on amore intimate level. This species has the potential to be sold in nurseries. This plant is not really useful in the middle landscape except to use it in rocky crevices to increase the numbers, which appear to be rather scant in the wild. Similarly, the species could be located in the wild from nurseries to help increase the wild populations.

Comparison of Matched Pair

6.11.12 *Caralluma nevegensis* is such a niche plant that its use is restricted and thus the matching process with an exotic species has not been carried out.

Table 6. 145 *Caralluma nevegensis / Apternathes europaea var. judaica* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
145	N	*Caralluma nevegensis*	G, ML, E	2.25	3	1	3	3	3	3	18.25

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

146. *Mesembryanthemum nodiflorum* (with flowers borne from the nodes – Family: Aizoaceae [273] אהל מצוי (- Ahal matsui - Common ahal), Photographs SU333 and SU334.

Brief Description

6.11.13 This plant is called the slender leaf ice plant in the USA. (Zohary 1966, page 77) This species is an annual with succulent leaves that change from a

[273] Order of Aizoaceae: Herbs or low shrubs, erect or prostrate, often fleshy, mainly South African and Mediterranean, often on sandy seashores or desert areas.

bright green to red over the growing season. The plant is creeping and low growing with spread of up to 30 cm. Aronson, (Aronson in Pasternak, 1990, page 65), notes that the species is a xerohalophyte. The flowers only open at midday and the plant is unusual as a desert annual as it flowers late June – early summer when most annuals are not active. (Danin, 1983, page 111)

6.11.14 It has been suggested that *M. nodiflorum* may form monotypic [274] stands by inhibiting the growth of other species by depositing salt onto the ground. (USGS, *'Mesembryanthemum nodiflorum'*, www.)

6.11.15 Flowers: Mainly March – June, but some commencing February and extending through May into June. (Shmida, 1986, page 82) March – May. (Feinbrun-Dothan and Danin, 1998, page 122) February – June. (Zohary 1966, page 77)

Potential Suitable Uses

6.11.16 Field observations by the author note that the plant is a *'small, lovely succulant creeping along the ground'* with *'bright yellow green fleshy leaves'* and *'orange red tips'* [275]. The plant could be used alongside roads, on gravels as a groundcover, embankments for soil stabilisation and in rockeries. A problem may arise that after plant death, the salt leaches from the decaying plant into the surrounding soil. This increased salinity may halt other, less salt-tolerant species from establishing. The species has the potential to be used as an annual groundcover in gardens where it can reseed itself and in pots where it can be reseeded, but it is probably best removed before it decays and deposits additional salts into the soil. In this way it may even desalinate the soil. Middle landscape and natural use is probably also to be discouraged as it may increase the salinity of the soils unless it is removed on an annual basis.

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[274] Consisting of only one type.

[275] Field notes of 16/4/2000.

Comparison of Matched Pair

6.11.17 An appropriate exotic species match for *Mesembryanthemum nodiflorum* is the annual *Mesembryanthemum criniflorum* although this species has larger and more colourful flowers.

Table 6. 146 *Mesembryanthemum nodiflorum* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
146	N	*Mesembryanthemum nodiflorum*	G	2.5 SP	3	0	0	0	3	3	11.5
146	E	*Mesembryanthemum criniflorum*	G	3	3	0	0	-3	0	3	**6**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.11.18 *Mesembryanthemum nodiflorum* should be used with care as it may salinate soils, although it will not require additional water, but maintenance would be required to remove dead saline plants. As it may salinate soils it is considered that it should not be used in the middle landscape or natural areas unless saline soils are required. The exotic *Mesembryanthemum criniflorum* is a better species to be used in gardens but should not be used in the middle landscape and / or natural areas as it may negatively affect ecological and landscape quality.

Results and Discussion of the Values Assessed for Each Native Succulent Species Compared to the Exotic matched Pairs

6.11.19 The following discussion relies on the detail information located in Appendix F9. The evaluation process is described in paragraphs 6.2.3 to 6.2.19.

6.11.20 Table 6.0 U illustrates the evaluations of all the native species against the exotic matched pair species.

6.11.21 Neither of the two succulents achieve scores of 19 or above [276]. *Mesembryanthemum nodiflrum* is considered unsuitable for use in most areas as it has the potential to salinate soils. Although *Caralluma nevegenis* is a very attractive succulent with delightful star shaped flowers, it is too small for widespread use, but it could be well be used in more intimate courtyards in plant pots and in rockeries.

Table 6.0 U Comparison of Values for the Native Versus the Exotic Species – Succulents

Plant No.	Plant Species Name	Native Species Cumulative Value	Exotic Species Cumulative Value
145	*Caralluma nevegensis*	18.25	No match
146	*Mesembryanthemum nodiflorum*	11.5	6

Note: Those native species that have not been matched are not considered to have value for garden use. (Note there is no Highest Scores Table 9 for Succulents as there are only 2 species.)

[276] An overall cumulative score (value) of nineteen (19) or above is considered to be a good score, which denotes the high quality and overall potential use of each individual native species with regard to the criteria of evaluation. A score of less than 19 does not however, preclude potential use of some species in specific locations and for specific purposes.

6.12 Trees - Analysis of the Individual Plant Species and Comparison of Matched Pairs

Introduction

6.12.1 This section notes the combined information, (field data and literature review) regarding the tree species that the author located in the Negev Desert. Shmida, (1986) in the preliminary pages, (טי), in 'Handbook of Wildflowers of Israel – Desert Flora', notes that a tree is a perennial plant, parts of which are woody and that grow more than 4 metres tall. This description appears limited as it is possible to find mature trees in the Negev and in other deserts that are not quite 4 metres tall, and shrubs that may be larger than 4 metres tall. The additional characteristics of trees is that they have established trunks, (single stem), or a number of trunks, (multi-stem), and a canopy of leaves supported by branches.

6.12.2 As noted above in Chapter 3, shrubs as well as trees are classified as Phanerophytes according to Raunkiaer's system. According to Danin's interpretation of Raunkiaer, the Phanerophytes include the larger shrubs and trees where the renewal buds are located some way above the ground. (Danin, 1983, page 25) Danin, (1983, page 25) notes that unlike the dwarf shrubs, the chamaephytes that shed branches, phanerophytes do not shed their branches and foliage is replaced seasonally and any branch loss, *'depends on the water regime'*.

6.12.3 It is this water regime, amongst other climatic, edaphic factors and human factors that determine the number of species and the number of trees of a particular species that may be found in the Negev Desert. It is not surprising to realise that compared to other smaller life forms, the number of native tree species in the Negev is comparatively small, at 1.4% of the total species found in the desert [277]. As larger life forms it is readily understood that they require more water compared to smaller life forms, and thus some trees may

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[277] Please refer to ragraphs 4.6.7 to 4.6.9' for a breakdown of the native plant species growing in the Negev.

only be found near perennial water and others may have extensive root systems that reach down to water tables well below the surface, whilst others grow in areas where additional seasonal water will flow and collect, thus providing an adequate water supply for perennial life.

6.12.4 Trees are generally important in most climatic zones as often the largest life forms with the greatest biomass. They alter the physical environment, creating and altering microclimatic conditions thus providing protection for other floristic forms as well as providing protection and sustenance for many species of wildlife as well as man. The tree's ability to create shade is on of the most important attributes it has for both man an wildlife and this is even more acute in hot desert areas where the provision of shade, can create a great difference in solar as well as terrestrial radiation and thus a great improvement in thermal comfort for people as well as other biotic life.

6.12.5 A comparative investigation of the shade created by the native trees compared to two commonly used foreign species, was carried out by the author and is located in Chapter 8. This research was published as a peer reviewed article in the Journal of Arid Environments, in 2003. (Kotzen, 2003)

6.12.6 Apart from illustrating the effectiveness of native trees to modify microclimate, the research has identified a key characteristic of the native trees of the Negev and possibly of most desert trees. This is that they have broad canopies as opposed to tall canopies and that broad canopied trees create more shade than tall canopied trees. This is particularly evident at mid-day when the shade of the tree is at its minimum as the sun is at its zenith. (Kotzen, 2003 and Chapter 8 below)

6.12.7 Twelve native tree species have been identified and have been assessed in the desert and in the literature out of nineteen species that grow in the desert. They are as noted in the Table and individually below.

Table 6.0 V List of Trees

NO.[278]	TREES	COMMENTS & FLOWERING PERIOD [279]
147	*Acacia gerrardii*	January to December
148	*Acacia raddiana*	June to December (summer flowering, unusual)
149	*Acacia tortilis*	April to December (summer flowering, unusual)
150	*Balanites aegyptiaca*	Tree or shrub – February to August (summer flowering, unusual)
151	*Hyphaene thebaica*	March
152	*Moringa peregrina*	March to May
153	*Phoenix dactylifera*	Palm tree – April to May
154	*Pistacia atlantica*	February to April
155	*Populus euphratica*	February to April
156	*Tamarix aphylla*	July to November (summer / autumn flowering, unusual)
157	*Tamarix nilotica*	Tree or shrub - March to December (summer / autumn flowering, unusual)
158	*Ziziphus spina-christi*	March to October (summer flowering, unusual – however flowers malodorous)

[278] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

[279] Information re flowering mainly from Feinbrun-Dothan and Danin, 1998. Note the flowering times are for the whole of Israel and not only the Negev. Should other references note earlier or extended flowering times these are included.

6.12.8 The following section notes the potential use for each native tree and the comparative evaluation of the native species matched to an exotic species. Note the section below includes all the trees. (Refer also to Appendix F10 for additional data.)

147. ***Acacia gerrardii subsp. Nevegensis Zohary*** (named for William Tyrer Gerrard, 19th century botanist and the Israeli botanist, Zohary) – Family: Mimosaceae (שטת הנגב - Shitat hanegev - Negev acacia), Photographs T335, T336 and T337, PROTECTED!

Brief Description

6.12.9 The International Legume Database and Information Service, (ILDIS, '*Acacia gerrardii*' Benth., www.), notes that this species is now accepted as *Acacia iraqensis*. However, The SEPASAL database, (RBGK, SEPASAL, '*Acacia gerrardii*', www.), notes that the species is *Acacia gerrardi subspecies nevegensis*.

6.12.10 *A, gerrardii* subsp. *nevegensis* is a thorny species growing up to 6 metres tall with an 8 metre spread in broad dry wadis. The species has attractive pom-pom light yellow flower during the summer months.

6.12.11 Ben Dov et al, (1993, page 18), note that *A. gerrardii* subsp. *Nevegensis* does not require more than 200 mm of rainfall per annum and that it is highly tolerant of saline conditions, to a maximum of 15,000 μS/cm and that it can be used in gardens. The SEPASAL database, (RBGK, SEPASAL, '*Acacia gerrardii*', www.), notes that the species grows in areas receiving 20-100mm of rainfall per annum.

6.12.12 Flowers: Principally July – August and then partially through September – November. (Shmida, 1986, page 180) June – September. (Feinbrun-Dothan and Danin, 1998, page 292)

Potential Suitable Uses

6.12.13 In the wild this tree often looks tangled and rather unkempt and in its transition from the wild into the garden, the nursery stock would likely require some training and pruning. This however, is not dissimilar to many species in more temperate climatic zones which require training / pruning to acquire a sing stem or a particular acceptable form.

6.12.14 Jones and Sacamano, (2000, page 11), note that *'A. gerrardii is usually a 'small patio-size tree but can become a spreading shade tree under optimum conditions'*.

6.12.15 The field data, collected in the Negev, and as noted in Chapter 8 regarding the effectiveness of the species to improve microclimate illustrates that *A. gerrardii* reduced the direct beam solar radiation under the tree canopy by 87%, with a reduction in light intensity of 64,500 / 79,500 lux (average / maximum), with a 6.8 / 16.6 (average / maximum) reduction in ground temperature with a concomitant reduction in long wave radiation from the ground of 64 / 101 W/m^2 (average / maximum).

Comparison of Matched Pair

6.12.16 Numerous *Prosopis* species are used in the Negev and due to its similar size, *Prosopis nigra* the Black mesquite originally from Argentina and Paraguay is considered an appropriate match for the native *Acacia gerrardii* as well as for its uses as a shade, specimen and courtyard tree.

Table 6. 147 ***Acacia gerrardii subsp. nevegensis*** **- Ratings for Use and Comparison of Matched Pair**

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
147	N	*Acacia gerrardii*	G, ML, E	2.75 SP 3 S [280]	3	3	3	3	3	3	20.75 SP† 21 S†
147	E	*Prosopis nigra*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.12.17 *Acacia gerrardii* has successfully been used in the USA in gardens. The species has excellent potential to be used without additional water and minimal maintenance for shade and other purposes in gardens, as well as in the middle landscape as well as appropriate natural locations. The *Prosopis nigra* species has also been successfully been used in gardens. However, it cannot be used without additional water wherever it is located and it should not be used in the middle landscape or natural areas as it may have detrimental effects on ecological and landscape quality.

6.12.18 ***Acacia longifolia***. (Refer to the section on Naturalised Species and Foreign Escapees, below.)

[280] The field notes illustrate the value as 3.25 but the maximum used in the final assessment is 3.

148. ***Acacia raddiana*** (after the Italian botanist Raddi [281]) – Family: Mimosaceae (שיטה סלילנית- Shitah selalinit - Coiled acacia), Photographs T338, T339, T340, T341 and T342. PROTECTED!

Brief Description

6.12.19 A thorny umbrella shaped tree, typically noted in the east African savanna but growing in the Negev in large and small wadis, 6 metres tall with an 8 metre spread. Some specimens may be larger.

6.12.20 The flowers are small yellow-white pompoms. Principal flowering is June – October and isolated individuals flower almost the whole year round. (Shmida, 1986, page 178) Ben Dov et al, (1993, page 19), note that *A. raddiana* does not require more than 200 mm of rainfall per annum and that it is highly tolerant of saline conditions, to a maximum of 15,000 µS/cm and that it can be used in gardens.

6.12.21 Diallo et al, (Environmental Microbiology, April 2004, page 410), in an article on soils note that the root system of *A. tortilis ssp. raddiana* comprises *'a plagiotropic [282] tap root (at a depth of 30 cm from the soil surface) bearing abundant lateral roots along its length'*, and that the roots fix nitrogen in the soil.

6.12.22 Flowers: June - Oct. (Feinbrun-Dothan and Danin, 1998, page 292) Principally June – November but partially April – May and December. (Shmida, 1986, page 178)

Potential Suitable Uses

6.12.23 This tree species varies considerably in form either being single stemmed or multi-stemmed and it is good for shade, for wildlife - pods and flowers for insects, birds and it has numerous other uses. The species has good potential to be used in garden areas as well as in the middle landscape and natural areas where the temperatures do not fall consistently below zero.

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[281] Giuseppe Raddi, 1770 – 1829.

[282] Having the longer axis inclined away from the vertical line.

6.12.24 The field data, collected in the Negev, and as noted in Chapter 8 regarding the effectiveness of the species to improve microclimate illustrates that *A. raddiana* reduced the direct beam solar radiation under the tree canopy by 86%, with a reduction in light intensity of 65,625 / 80,500 lux (average / maximum), with a 7.9 / 18.6 (average / maximum) reduction in ground temperature with a concomitant reduction in long wave radiation from the ground of 74 / 115 W/m^2 (average / maximum).

Comparison of Matched Pair

6.12.25 Numerous *Prosopis* species are used in the Negev and due to its similar size, *Prosopis alba* the White mesquite originally from Argentina and P is considered an appropriate match for the native *Acacia gerrardii* as well as for its uses as a shade, specimen and parkland tree.

Table 6. 148 *Acacia raddiana* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
148	N	*Acacia raddiana*	G, ML, E	2.75 SP 3 S [283]	3	3	3	3	3	3	20.75 SP† 21 S†
148	E	*Prosopis alba*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

[283] The field notes illustrate the value as 3.25 but the maximum used in the final assessment is 3.

6.12.26 *Acacia raddiana* has successfully been used in the Negev in garden fringe areas. The species has excellent potential to be used without additional water and minimal maintenance for shade and other purposes in gardens, as well as in the middle landscape as well as appropriate natural locations. The *Prosopis alba* species has also been successfully been used in gardens. However, it cannot be used without some additional water wherever it is located and it should not be used in the middle landscape or natural areas as it may have detrimental effects on ecological and landscape quality.

149. ***Acacia tortilis*** (referring to the twisted pods) – Family: Mimosaceae שיטת הסוכך (- Shitat hasocheich - Umbrella acacia), Photograph T343, T344, T345, PROTECTED!

Brief Description

6.12.27 A vase / funnel shaped tree growing to 5 metres tall and a spread of 8 metres in the Negev, mainly in the hot dry wadis of the Arava and wadis connecting into the Arava. The leaves of *A. tortilis* are distinguished by having short rough hairs and this is a main feature to differentiate between *A. tortilis* and *A. raddiana.* (Shmida, 1986, page 178)

6.12.28 Danin, (1983, page 117), notes that *A. tortilis* is more drought tolerant than *A. raddiana* and requires higher temperatures throughout its life-cycle than *A. raddiana*. Danin, (1983, page 117), notes that the roots of some large specimens at Ein Yahav, reach down to water 12 metres below the ground surface.

6.12.29 Flowers: Mainly May – July and also partially through to October. (Shmida, 1986, page 178) April – December. (Feinbrun-Dothan and Danin, 1998, page 292)

Potential Suitable Uses

6.12.30 This is a multipurpose thorn tree but its shape is not generally as good as *A. raddiana* for creating a shade canopy. This is a result of the general multi stem character of the species and its dense funnel shape. Although it may be used as large background shrub or in some cases specimen shrub in some garden situations it is best used in middle landscape and appropriate natural locations. Ben Dov et al, (1993, page 19), note that *A. tortilis* does not require more than 200 mm of rainfall per annum and that it is highly tolerant of saline conditions, to a maximum of 15,000 μS/cm and that it can be used in gardens. However, its garden use should consider than on shallow soils its lateral roots lie near the surface and these can cause problems to paving and other areas.

6.12.31 The field data, collected in the Negev, and as noted in Chapter 8 regarding the effectiveness of the species to improve microclimate illustrates that *A. tortilis* reduced the direct beam solar radiation under the tree canopy by 90%, with a reduction in light intensity of 69,275 / 76,000 lux (average / maximum), with a 6.3 / 12.6 (average / maximum) reduction in ground temperature with a concomitant reduction in long wave radiation from the ground of 74 / 101 W/m^2 (average / maximum). The species has the potential to be used in garden situations but probably as a specimen tree or in background situations. It has the potential to be used for many different purposes in the middle landscape and in natural areas including use as a living hedge and for shelterbelts and windbreaks and it can be used on sand dunes.

Comparison of Matched Pair

6.12.32 *Acacia tortilis* is not considered a good garden species, although it may be possible to use it as a large background shrub and specimen tree. An exotic matching species has thus not been considered.

Table 6. 149 ***Acacia tortilis*** **- Ratings for Use and Comparison of Matched Pair**

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
149	N	*Acacia tortilis*	G, ML, E	2.5 SP 3 S [284]	1	3	3	3	3	3	18.5 SP† 19 S†

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

150 ***Balanites aegyptiaca*** (Egyptian) – Family: Zygophyllaceae (זקום מצרי- Zakum mitsri - Egyptian zakum), Photographs T346, T347, T348 and T349, PROTECTED!

Brief Description

6.12.33 This is a thorny tree with arched branches that can grow up to 8 metres tall with a similar spread.

6.12.34 The height of flowering is in spring, the flowers are small and the colour is a green -cream. It also flowers sparsely throughout the summer and then fully in the autumn. (Shmida, 1986, page 174)

6.12.35 Ben Dov et al, (1993, page 28), note that *Balanits aegyptiaca* does not require more than 200 mm of rainfall per annum and that it is highly tolerant of saline conditions, to a maximum of 15,000 μS/cm and that it can be used in gardens.

[284] The field notes illustrate the value as 3.25 but the maximum used in the final assessment is 3.

6.12.36 Flowers: March – May and then sparsely through to October and then fully to December. (Shmida, 1986, page 174) February – August and then to December. (Feinbrun-Dothan and Danin, 1998, page 396)

Potential Suitable Uses

6.12.37 This species can be trained into a very good shade tree as well as a climber. The species has numerous ethno-botanical functions, so much so that in Africa it often protected by local people. It can be used in numerous middle landscape and natural situations, for example as a living hedge, shelterbelt and windbreak.

Comparison of Matched Pair

6.12.38 *Ceratonia siliqua,* the Carob tree that is ubiquitous in Mediterranean areas and often used in the Negev, is considered an appropriate match fro the native *Balanites aegyptiaca* in terms of scale, rugged appearance and densely knit branches with glossy leaves, providing a good shade. Both also have interesting, but dissimilar fruits with agricultural value.

Table 6. 150 *Balanites aegyptiaca* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
150	N	*Balanites aegyptiaca*	G, ML, E	3 SP 3 S [285]	3	3	3	3	3	3	21 SP† 21 S†
150	E	*Ceratonia siliqua*	G	3	3	0	0	-3	0	2	5

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.12.39 The ultimate cumulative value of 21 [286] illustrates that *Balanites aegyptiaca* is almost a perfect species for use in garden situations except that it does have thorns. However, once the foliage is above head height the thorns are no longer a problem. It has successfully been used in the Negev as a shade tree and a specimen tree within a parkland setting. The species has excellent potential to be used without additional water and minimal maintenance as well as in the middle landscape as well as appropriate natural locations. The *Ceratonia siliqua* species has also been successfully been used in gardens. However, it cannot be used without additional water wherever it is located and it should not be used in the middle landscape or natural areas as it may have detrimental effects on ecological and landscape quality.

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[285] It should be noted that a naturally growing specimen was not located but the assessment was executed on a specimen growing within a garden situation. The summer assessment value was in fact 3.25. but the maximum used in the final assessment is only 3.

[286] Ibid.

6.12.40 ***Calotropis procera.*** (Refer to plant number , in the section, Shrubs, above.)

6.12.41 ***Ficus sycomorus.*** (Refer to the section Naturalised Species and Foreign Escapees, below.)

151. ***Hyphaene thebaica*** (of or from Thebes, now Luxor in Upper Egypt) – Family: Palmae [287] דום מצרי (- Dom Mitsri - Egyptian doum palm), Photographs T353, T354, T355 and T356, PROTECTED!

Brief Description

6.12.42 Feinbrun-Dothan and Danin, (1998, page 899), notes that the species is characterised by dioecious [288] trees with trunks that branch higher up to a height of 20 – 30 metres. Feinbrun-Dothan and Danin, (1998, page 899), note that the leaves resemble a fan, cut, and appearing like the palm of a hand. The fruit resembles a small coconut with a fibrous covering with a hard seed. (Feinbrun-Dothan and Danin, 1998, page 899) It has very extensive roots.

6.12.43 Ben Dov et al, (1993, page 28), note that *Hyphaene thebaica* does not require more than 200 mm of rainfall per annum and that it is highly tolerant of saline conditions, to a maximum of 15,000 μS/cm and that it can be used in gardens.

6.12.44 Flowers: March. (Feinbrun-Dothan and Danin, 1998, page 899),

Potential Suitable Uses

6.12.45 This is a characterful species, which changes its appearance as it matures. In

[287] Order of Palmae: Mainly tropical trees and shrubs and vines usually having a tall columnar trunk bearing a crown of very large leaves; coextensive with the order Palmales - Stems stout or slender, often along river banks. Useful Products: Coconut and date palm amongst many others.

[288] Characterized by species in which the male and female reproductive organs occur on different individuals; sexually distinct.

the early years it is compact and characterised by large dense leaf clusters, whilst in maturity it produces slender trunks, which often fork, with the leaves and fruits held aloft. It has good potential to provide shelterbelts and windbreaks at a young age and specimen species in larger gardens throughout its lifespan. The literature states that it is drought tolerant but requires some water. Ben Dov et al, (1993, page 28), note however, that it does not require more than 200mm per annum. The species has good potential as a specimen palm in garden locations as well as in the middle landscape, on sand and in suitable natural areas.

<u>Comparison of Matched Pair</u>

6.12.46 Because of its significant height and visual presence, the Mexican fan palm, *Washingtonia robusta* that is often used in the Negev, provides and appropriate exotic match for the native *Hyphaene thebaica*.

Table 6. 151 *Hyphaene thebaica* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
151	N	*Hyphaene thebaica*	G, ML, E	3 SP 3 S [289]	3	3	3	3	3	3	21 SP† 21 S†
151	E	*Washingtonia robusta*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten.

[289] It should be noted that a naturally growing specimen was not located but the assessment was executed on a specimen growing within a garden situation. The summer assessment value was in fact 3.25. but the maximum used in the final assessment is only 3.

SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.12.47 The cumulative value of 21 illustrates that *Hyphaene thebaica* is a species that can well be used in appropriate situations especially as a specimen palm or palm group within a parkland setting. The species has excellent potential to be used without additional water and minimal maintenance as well as in the middle landscape as well as appropriate natural locations. The *Washingtonia robusta* species has also been successfully been used in gardens. However, it cannot be used without additional water wherever it is located and it should not be used in the middle landscape or natural areas as it may have detrimental effects on ecological and landscape quality.

152 ***Moringa peregrina*** (foreign or exotic or wandering, straggling in growth) – Family: Moringaceae [290] (מורינגה רתמית- Moringa ratmit - Rotem like moringa), Photographs T357, T358, T359 and T360, PROTECTED!

Brief Description

6.12.48 Growing in hot desert areas, around springs, watercourses and oases Shmida, (1986, page 246), notes that this is a tree with a number of stems reaching 4 - 6 metres tall. The young branches hang downwards and it resembles *Retama raetem* and therefore the name, 'Moringa retamit". (Shmida, 1986, page 246)

6.12.49 The flower of the *Moringa* is pink and large and very different from other flowers of trees in the desert. (Shmida, 1986, page 246) The fruit - is a long pod (length 20 – 30 cm).

6.12.50 Flowers: Principally March - April and also partially all year except July – September. (Shmida, 1986, page 246) March – May. (Feinbrun-Dothan and Danin, 1998, page 274)

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[290] Order of Moringaceae: Trees commonly stout-trunked with gummy bark, and with a large mucilage canal in the centre of the pith. Useful Products: *Moringa oleifera* (horseradish tree) has edible fruits, the seeds supply 'oil of ben' or 'watchmaker's oil' used in perfumery and light lubricants, and the roots are a source of edible condiment.

Potential Suitable Uses

6.12.51 The species is very similar at a distance to *Retama raetem* and also some *Tamarix* species. However, larger specimens of *Moringa peregrina* have tree trunks and shade canopies, and unlike *Retama raetem, Moringa* has the ability to be pruned and trained into a shade tree. It has attractive flowers as well as interesting long seedpods and thus its potential for garden use is good for example as ornamental trees. The species also has good potential to be used as large shrub and to create shelterbelts and windbreaks in the middle landscape and in suitable natural areas. Although it located in the wild largely along watercourses, Ben Dov et al, (1993, page 28) note that it does not require additional water above 200mm per annum. The species also has great potential to be farmed as well.

Comparison of Matched Pair

6.12.52 The exotic species *Schinus molle,* the pink peppercorn tree, which is commonly use in the Negev is an appropriate exotic match for *Moringa peregrina* due to their similar scales and the appearance of the foliage which hangs as it is wispy and soft.

Table 6. 152 *Moringa peregrina* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
152	N	*Moringa peregrina*	G, ML, E	3	3	3	3	3	3	3	21
152	E	*Schinus molle*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.12.53 The cumulative value of 21 illustrates that *Moringa peregrina* is a species that has excellent potential to be used in appropriate situations especially in middle landscape and appropriate natural areas without additional water and minimal maintenance. In garden situations the species can be used as a background shrub but as a tree it will require shaping and pruning to reveal a crown and stems(s). *Schinus molle* has also been successfully been used in gardens in the Negev for many years. However, it cannot be used without additional water wherever it is located and it should not be used in the middle landscape or natural areas as it may have detrimental effects on ecological and landscape quality.

153. ***Phoenix dactylifera*** (furnished with fingers / finger like) – Family: Palmae (תמר מצוי - Tamar matsui - Common date palm), Photographs T361, T362, T363, PROTECTED!

<u>Brief Description</u>

6.12.54 Danin, (1983, pages, 119 - 120), notes that date palms are cultivated throughout the world and in Israel populations occur at desert springs, which is considered their natural habitat *'of the species first used for domestication 6000 years ago'* and that wild date palms have many trunks. The author notes that he has noted wild date palms that are not associated with oases but that are rather linked to small dry wadis. Danin, (1983, pages, 119 - 120), notes that the fruits are tasty and are dispersed by birds and humans and *'frequently wild date palms can be found growing on wet saline soils with a salt crust'*, but the roots penetrate the less saline layers below.

6.12.55 Ben Dov et al, (1993, page 83), note that *Phoenix dactylifera* does not require more than 200 mm of rainfall per annum and that it is extremely tolerant of saline conditions, and it is tolerant of seawater to a maximum of 50,000 μS/cm and that it can be used in gardens and it is tolerant of coastal; saline winds. Jones and Sacamano, (2000, page 252), note that *Phoenix dactylifera* can withstand periods of drought, which is confirmed by Ellison and Ellison, (2001, page 162)

6.12.56 Flowers: April - May. (Feinbrun-Dothan and Danin, 1998, page 900)

Potential Suitable Uses

6.12.57 This is an excellent palm tree for many purposes, but it appears that it does require water, although Ben Dov et al (1993, page 83), note that it does not require more than 200mm per annum. From experience, the author notes that large specimens can require up to 120 litres per day. However, it can be as a large shrub type plant, probably without any additional water above 200mm, but it is unlikely bear fruit. As a shrub it can be used in the middle landscape and in natural areas as a shelterbelt and windbreak. In order to produce the best fruit high temperatures in the 40 degrees centigrade are required.

Comparison of Matched Pair

6.12.58 *Phoenix dactylifera* is a commonly used garden species in the Negev and thus there is no particular need to match it with an exotic species. However, it can be done with the Canary Island palm, *Phoenix canariensis*, which has a similar palm leafed canopy but a much fatter trunk.

Table 6. 153 *Phoenix dactylifera* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
153	N	*Phoenix dactylifera*	G, ML, E	2.75 SP 3S	3	3	3	3	3	3	20.75 SP 21S
153	E	*Phoenix canariensis*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.12.59 The cumulative values of 20.75 for spring and 21 for summer illustrates that *Phoenix dactylifera* is a species that has excellent potential to be used in a variety of appropriate situations including gardens and the middle landscape and appropriate natural areas without additional water and minimal maintenance. In garden situations its aesthetic character will need to be tested without any additional water above 200mm. Like *Phoenix canariensis,* the native *Phoenix dactylifera* has been used to provide shade, avenues and as specimen trees. However, *Phoenix canariensis* does not provide edible fruits it and it definitely cannot be used without additional water wherever it is located and it should not be used in the middle landscape or natural areas as it may have detrimental effects on ecological and landscape quality.

154. ***Pistacia atlantica*** (from Atlas mountains where first identified) – Family: Anarcadiaceae [291] (אלה אטלנטית- Eilah atlantit – Atlantic eilah) Photographs T364, T365, T366, T367 and T368, PROTECTED!

<u>Brief Description</u>

6.12.60 Shmida, (1986, page 298), notes that this is a large tree with a central trunk reaching a height of 3 - 6 metres. Shmida, (1986, page 298), and that *Pistacia atlantica* is the prettiest of trees found in the desert. The author notes that the trees are mostly semi-evergreen and retain some leaf throughout the year. Sometimes the gall-nuts resemble coral/sandlewood, and so it is easy to recognise it even when it has shed its leaves. (Shmida, 1986, page 298) Ben Dov et al, (1993, page 15), note that *Pistacia atlantica* does not require more than 200 mm of rainfall per annum and that it is highly tolerant of saline conditions, to a maximum of 15,000 μS/cm and that it can be used in gardens.

6.12.61 The SEPASAL database, (RBGK, SEPASAL, *'Pistacia atlantica*, www.), notes that the species is not frost tolerant. The author notes that this information is not correct as the species is definitely frost tolerant as it grows

[291] Order of Anarcadiaceae: Trees or shrubs, often with resinous bark, mainly in the tropics. Useful Products: pistachio nuts, cashew nuts, mango.

in the mountains of the Negev where temperatures drop below freezing in the winter and where it snows.

6.12.62 Flowers: March – April. (Shmida, 1986, page 298) February – April. (Feinbrun-Dothan and Danin, 1998, page 419)

Potential Suitable Uses

6.12.63 Jones and Sacamano, (2000, page 259), note that these are *'handsome large trees for shade, parks and public places'* and that they are extremely drought tolerant.

6.12.64 This tree species resembles closely many of the round canopied trees found in more temperate climates. It has a good form and shape, large canopy with attractive trunks, flowers, fruit and galls and thus has makes a good specimen and shade tree. It also has the potential to be used as a formal, clipped hedge. The species is very drought tolerant and can be used in the middle landscape as well as in natural areas, where it provides shade for other species and wildlife.

6.12.65 The field data, collected in the Negev, and as noted in Chapter 8 regarding the effectiveness of the species to improve microclimate illustrates that *Pistacia atlantica* reduced the direct beam solar radiation under the tree canopy by 89%, with a reduction in light intensity of 54,500 / 70,000 lux (average / maximum), with a 8.6 / 20.4 (average / maximum) reduction in ground temperature with a concomitant reduction in long wave radiation from the ground of 106 / 128 W/m^2 (average / maximum).

Comparison of Matched Pair

6.12.66 Although being far more spectacular with its flame red flowers, *Albizzia lebbeck*, the Siris tree [292], appears to be an appropriate exotic species match

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[292] *Albizzia lebbeck* and another exotic species *Delonix regia*, which would also have made an appropriate match were used as exotic control species in the research investigating the quality of the shade produced by the native trees of the Negev. The study was first published in the

for *Pistacia atlantica* due to its similar size, leaf shape, open branching structure, its deciduous character and because it is often used in the Negev.

Table 6. 154 *Pistacia atlantica* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
154	N	*Pistacia atlantica*	G, ML, E	3 SP, S	3	3	3	3	3	3	21 SP,S
154	E	*Albizzia lebbeck*	G	3	3	0	0	-3	0	1	**4**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.12.67 The cumulative values of 21 for both the spring and summer illustrates the quality of *Pistacia atlantica* as a species that has excellent potential for use in a variety of appropriate situations including gardens and the middle landscape and appropriate natural areas without additional water and minimal maintenance. Unlike *Albizzia lebbeck* the native *Pistacia atlantica* has not been used to provide shade, avenues and as specimen trees as it could do. In contrast to the native species *Albizzia lebbeck* cannot be used without additional water wherever it is located and it should not be used in the middle landscape or natural areas as it may have detrimental effects on ecological and landscape quality.

Journal of Arid Environment, (Kotzen, 2003) and forms the basis of Chapter 8.

155. ***Populus euphratica*** (from the Euphrates) – Family: Salicaceae [293]

צפצפת הפרת (- Tsiftsafat haprat), Photographs T369, T370, T371, T372, PROTECTED!

Brief Description

6.12.68 Shmida, (1986, page 298), notes that this is a tree that grows alongside perennial rivers and springs; 3 - 6 metres tall (The author notes that the large group at "Ein Avdat" grow taller at 8 – 10 metres) They have both long straight leaves that resemble a lancet and also broad short leaves. (Shmida, 1986, page 298) *Populus* are deciduous in the winter, and it flowers and sprouts in the spring. (Shmida, 1986, page 298)

6.12.69 Ben Dov et al, (1993, page 26), note that *Populus euphratica* requires and additional 100mm of water above the 200 mm of rainfall per annum and that it is highly tolerant of saline conditions, to a maximum of 15,000 μS/cm and that it can be used in gardens.

6.12.70 Flowers: February – April. (Shmida, 1986, page 298) (Feinbrun-Dothan and Danin, 1998, page 96)

Potential Suitable Uses

6.12.71 This is an attractive tree, taller than most that grow in the Negev and if it flourishes with as little as 300mm of water per annum as noted by Ben Dov et al (1993, page 26), then its uses may be numerous in garden situations in groups and specimen trees. (The author notes that the xerophytic character of this species will require testing as he has only noted it growing where there is natural perennial water supply.) If pruned and shaped it is possible to use this as a deciduous hedge as well. *Populus* species are known to have invasive roots and thus care should be taken by locating trees at least 12 metres away from drains and building foundations as noted by the Plants for

[293] Order of Salicaceae: Two genera of trees or shrubs having hairy catkins, namely *Salix* and *Populus*. *Populus* are wind pollinated, and Salix species, insect pollinated. Useful Products: Baskets, cricket bats.

a Future database, (Plants for a Future, *Populus euphratica'*, www.). The species is also very saline tolerant. Ben Dov et al (1993, page 26) note that it is tolerant up to 15,000 μS/cm whilst the author has taken samples around trees where the level was greater than 20,000 μS/cm. The species is also noted for biomass production and thus it may be useful to plant it in areas, which are saline and wet in natural areas. The SEPASAL database, (RBGK, SEPASAL, *'Populus euphratica'*, www.), notes that the species is used on saline soils and used to create shelterbelts. In the middle landscape, it will only be suitable in areas, which receive 300mm of rainfall per annum, or in areas where rainfall is less but where additional water may be directed and collected. (Refer to Chapter 9 on creating micro-landscape conditions

Comparison of Matched Pair.

6.12.72 The Rosewood tree, *Tipuana tipu* that originates in Bolivia has been used all over the world, as well as the Negev as a shade tree. It is used as thee exotic species match for the native *Populus euphratica* although the *Tipuana* species can grow larger and it has yellow flowers. Both species, however, have an open foliage canopy and are winter deciduous and have attractive bark.

Table 6. 155 *Populus euphratica* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
155	N	*Populus euphratica*	G, ML, E	2.5 SP, S	3	1	1	3	3	2	15.5 SP,S
155	E	*Tipuana tipu*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.12.73 The cumulative value of 15.5 the spring and tends to disguise the potential of the species as a good garden specimen avenue or shade tree. The low cumulative value does indicate that the tree is not appropriate in most locations and that it will require additional water in all situations. In fact it would be a poor choice in the middle landscape and natural areas unless the area receives 300 mm or more water per annum. The exotic *Tipuana tipu* also requires water wherever it is used and it is suggested it should not be used outside garden areas, in the middle landscape or natural areas as it may have detrimental effects on ecological and landscape quality.

156. ***Tamarix aphylla*** (without leaves) – Family: Tamaricaceae

אשל הפרקים (- Eshel haprakim - Jointed tamarix), Photographs T373, &374, T375, T376, T377 and T378, PROTECTED!

Brief Description

6.12.74 Shmida, (1986, page 266), notes that *Tamarix aphylla* grows mostly in the form of a tree 4 – 8 metres tall. The author notes that some trees grow to 10 metres tall and with an equal spread. With some older trees, the author notes that the branches can sag to the ground and root from there and thus the tree can expand from its original centre.

6.12.75 Aronson, (Aronson, in Pasternak, 1990, page 91), notes that the species is tolerant of a maximum of 56,000 μS/cm, which is seawater, that it is useful for fuel wood, in carpentry and soil stabilisation and Ben Dov et al (1993, page 27), note that the species can be used in gardens, for soil and sand dune stabilisation and it is tolerant of coastal conditions, that it requires 300mm of water per annum and that it is tolerant of saline conditions up to 25,000 μS/cm.

6.12.76 Flowers: Mainly August – November but also partially February – March and August. (Shmida, 1986, page 266) July - November. (Feinbrun-Dothan and Danin, 1998, page 447)

Potential Suitable Uses

6.12.77 Jones and Sacamano, (2000, page 317), note that this is an admirable tree adapted to harsh desert conditions, but because of its drawbacks it is best suited to *'outlying low-maintenance areas'*. However, they do note that because of its hardiness, it may be used in some ' *'close-up'* situations where conditions are harsh and other species would not survive. Jones and Sacamano, (2000, page 317), furthermore note that the tree can be used for shade, as a screen against wind and dust and for visual screening, soil stabilisation, revegetation and the species may be pruned into a dense hedge 1 to 3 metres tall or even taller.

6.12.78 Jones and Sacamano, (2000, page 317), note that the problems include; invasive roots which can affect underground pipes, foundations and paving; saline leaf litter which *'can affect nearby gardens'*, brittle branches which can be affected by storms, old trees have heavy branches which may cause damage when they fall, and twigs and branches washed down by floods will root when buried.

6.12.79 The SEPASAL database, (RBGK, SEPASAL, *'Tamarix aphylla*, www.), notes that the species is evergreen that it is fast growing and that environmentally it is used on sands, for shade as shelterbelts, as ornamental hedging, as a soil moisture conserver and a soil conditioner, structure improver, as a street tree and in firebreaks.

6.12.80 On the whole the author notes that this is a very good specimen which can be utilised for a number of environmental and landscape purposes, but in garden / public areas it will need to be maintained and pruned when it gets too large.

6.12.81 The field data, collected in the Negev, and as noted in Chapter 8 regarding the effectiveness of the species to improve microclimate illustrates that *Tamarix aphylla* reduced the direct beam solar radiation under the tree canopy by 89%, with a reduction in light intensity of 63,250 / 72,000 lux (average / maximum), with a 15.4 / 22.4 (average / maximum) reduction in ground temperature with a concomitant reduction in long wave radiation from the ground of 95 / 141 W/m^2 (average / maximum).

Comparison of Matched Pair

6.12.82 *Tamarix aphylla* is an evergreen tree that is sometimes used in gardens in the Negev. So too are numerous Australian *Eucalyptus* species that are of a similar size and form to the *Tamarix.* Of these it is considered that the drought tolerant species *Eucalyptus campaspe* is an appropriate match.

Table 6. 156 *Tamarix aphylla* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
156	N	*Tamarix aphylla*	G, ML, E	2.5 SP 2.75 S	3	3	3	3	3	3	20.5 SP 20.75 S
156	E	*Eucalyptus campaspe*	G	3	3	0	0	-3	0	3	**6**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.12.83 The cumulative values of 20.5 for spring and 20.75 for summer out of a total of 21 illustrates the overall potential of the species. The tree requires some maintenance in gardens to pick up leaf litter, which can leach salts into the soil and pruning at long intervals to reduce heavy boughs but without any additional water above 200 mm per annum. The tree is also an asset in the middle landscape, where it has been used to good effect as well as in appropriate natural areas. The exotic *Eucalyptus campaspe* similarly does not require additional water but it should not be used outside garden areas, in the middle landscape or natural areas as it may have detrimental effects on ecological and landscape quality.

157. ***Tamarix nilotica*** (of the Nile) – Family: Tamaricaceae (אשל היאור- Eshel hayeor - Nile tamarix), Photographs T379, T380, T381, T382 and T383, PROTECTED!

Brief Description

6.12.84 Shmida, (1986, page 263), notes that this is a shrub or tree with scaly saline leaves growing 2 - 4 metres tall with lengths of mostly pinky whitish flowers. (Shmida, 1986, page 263) Height of flowering is April - June, however flowering continues throughout the year. (Shmida, 1986, page 263) Aronson, (Aronson in Pasternak, 1989, page 92), notes that the species is tolerant of salinity up to 8000 μS/cm and that it can be used as fuel and as a salt tolerant ornamental. In an abstract to an article on the ability of *Tamarix nilotica* to absorb metals from soils, Soltan et al, (Soltan, Chemistry and Ecology, www.), note that the species can be used in the phytoremediation process to clean up soils.

6.12.85 Flowers: Mainly March - June but partially February and June to December. (Shmida, 1986, page 263) March – December. (Feinbrun-Dothan and Danin, 1998, pages 450)

Potential Suitable Uses

6.12.86 This creates a good dense shrub. Good on saline soils in gravels and sands. Potentially it could make a good screen and hedge in gardens as well as in middle landscape locations, (potentially formal and informal) and the racimes of flowers are very attractive during the hot dry summer months. It is likely, however, that the species would require some additional water as it is normally located where there is water. The amount of water required is uncertain and would require testing. With pruning it may potentially be shaped as a small tree.

Comparison of Matched Pair

6.12.87 Due to its family resemblance, similar form and pink flowers *Tamarix chinensis*, the salt cedar originally from eastern Europe and Asia is considered an acceptable match for the native *Tamarix aphylla*. Both species are evergreen and have attractive inflorescences throughout the summer months although *Tamarix nilotica* may be a little taller.

Table 6. 157 *Tamarix nilotica* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
157	N	*Tamarix nilotica*	G, ML, E	2.75 SP, S	3	1	3	3	3	1	16.75 SP, S
157	E	*Tamarix chinensis*	G	3	3	0	0	-3	0	2	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.12.88 Despite this species' attractiveness its only receives a cumulative score of 16.7. This is because it is largely dependant on greater amounts of water. It thus has the potential to be utilised in garden situations as a large shrub or screen or as a small tree but it would require additional water. The amount of water is not known and should be tested. The tree could also be an asset in the middle landscape and natural areas but only where there is perennial or underground water. Again the required amount should be tested. The exotic *Tamarix chinensis* also requires additional water wherever it is used, but it should not be used outside garden areas, in the middle landscape or natural areas as it may have detrimental effects on ecological and landscape quality.

158. *Ziziphus spina-christi* (crown of thorns) – Family: Rhamnaceae (שיזף מצוי - Shizaf matsui - Common ziziphus), Photographs T384, T385, T386, and T387.

Brief Description

6.12.89 Shmida, (1986, page 174), notes that this is a thorny tree with zigzag growing trunks. Shmida, (1986, page 174), notes it gets 3 - 6 metres tall, in contrast to *Ziziphus lotus* which only grows into a shrub. (The author notes a very large old exceptional specimen which is much greater in size, (12 metres tall with and equivalent spread growing close to the cross roads at Ein Hatzeva.) *Ziziphus spina-christi* has many stems and the branches are arched and fall downwards at the circumference of the tree. (Shmida, 1986, page 174) The leaves are simple and the shape elliptical and the thorns resemble hooks, arranged along the young stems and make it hard for the leaves to be eaten. (Shmida, 1986, page 174) It flowers a number of times a year and in cooler parts it is deciduous and that flowering and fruiting mostly take place during the summer and the fruits are eaten by various animals. (Danin, 1983, page 123)

6.12.90 Flowers: All year. (Shmida, 1986, page 174) March – October. (Feinbrun-Dothan and Danin, 1998, page 426)

Potential Suitable Uses

6.12.91 This is a remarkable tree, with a good form, leaves, flowers and fruit that provides a good shade and according to Ben Dov et al, (1993, page 26) it has a high saline tolerance and it does not require more than 200mm of water per annum and that it is highly tolerant of saline conditions up to 15,000 µS/cm.

6.12.92 The Agro Forestry Tree database, (*'Zizyphus spina-christi'*, www.), notes that the species is useful for erosion control *'because it develops a very deep taproot and spreading lateral roots'*, and it can be used for stabilizing sand dunes and other unstable soils. The database, (Agro Forestry Tree database, *'Zizyphus spina-christi'*, www.), also notes that Christ's thorn is planted around towns and villages for shade and it makes useful windbreaks and shelterbelts and as a soil improver, it improves soil quality by increasing available Phosphorus.

6.12.93 The fruits are small and are eaten very ripe or dry, tasting of sweet apples. However, on the negative side, local people in the Negev comment that the flowers smell of faeces ad the young branches have spiky hooks, which may make it difficult to use in children's areas. The species has many uses in the middle landscape for shelterbelts / windbreaks, revegetation, stabilization of soils including dunes and soil improvement and it is an important source of food for animals in natural areas. It is also a very good tree for bees and honey production.

6.12.94 The field data, collected in the Negev, and as noted in Chapter 8 regarding the effectiveness of the species to improve microclimate illustrates that *Ziziphus spina-christi* reduced the direct beam solar radiation under the tree canopy by 84%, with a reduction in light intensity of 61,333/ 70,000 lux (average / maximum), with a 8.4 / 16.6 (average / maximum) reduction in ground temperature with a concomitant reduction in long wave radiation from the ground of 97 / 146 W/m^2 (average / maximum).

Comparison of Matched Pair

6.12.95 The exotic species *Parkinsonia aculeata*, the Jerusalem thorn is commonly used in desert landscapes and provides and appropriate match to the native *Ziziphus spina-christi* in terms of scale and a certain 'ragged' desert type form and visual quality.

Table 6. 158 *Ziziphus spina-christi* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
158	N	*Ziziphus spina-christi*	G, ML, E	3 [294]S P, S	3	3	3	3	3	3	21 SP, S
158	E	*Parkinsonia aculeata*	G	3	3	0	0	-3	0	3	**5**

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten.

[294] The tree scored 3.25 both in the spring and summer seasons but the final scoring method only allows for a maximum of 3 points.

SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.12.96 A cumulative score of 21 illustrates that this species is a good all round specimen. It could be used in gardens with little or no additional water above 200mm per annum as a small patio tree, for shade, as a specimen and in groups for shelterbelts and screening. It is also possible to use the species in the middle landscape and appropriate natural areas without additional water and maintenance. It thus has the potential to be utilised in garden situations as a large shrub or screen or as a small tree but it would require additional water. The exotic *Parkinsonia aculeata* is often used in garden areas with minimal amounts of water and maintenance but its use in the middle landscape or natural areas should be restricted as it may have detrimental effects on ecological and landscape quality.

Results and Discussion of the Values Assessed for Each Native Annual Species Compared to the Exotic matched Pairs

6.12.97 The following discussion relies on the detail information located in Appendix F10. The evaluation process is described in paragraphs 6.2.3 to 6.2.19.

6.12.98 Table 6.0 W illustrates the evaluations of all the native species against the exotic matched pair species.

Table 6.0 W Comparison of Values for the Native Versus the Exotic Species – Trees

Plant No.	Plant Species Name	Native Species Cumulative Value *	Exotic Species Cumulative Value
147	*Acacia gerrardii*	21 – 20.75	5
148	*Acacia raddiana*	21 – 20.75	5
149	*Acacia tortilis*	19 – 18.5	No match
150	*Balanites aegyptiaca*	21	5

Plant No.	Plant Species Name	Native Species Cumulative Value *	Exotic Species Cumulative Value
151	*Hyphaene thebaica*	21	5
152	*Moringa peregrina*	21	5
153	*Phoenix dactylifera*	21 – 20.75	5
154	*Pistacia atlantica*	21	4
155	*Populus euphratica*	15.5	5
156	*Tamarix aphylla*	20.75 – 20.5	6
157	*Tamarix nilotica*	16.75	5
158	*Ziziphus spina-christi*	21	5

Note: Those native species that have not been matched are not considered to have value for garden use. * Some plant have two values due to alterations in appearance through the year.

6.12.99 12 tree species were located in the Negev. None of these achieved very low scores. Some of the trees have been scored twice with lower and higher scores, as in some cases their appearance changes as the seasons change. 3 tree species achieve lower scores of between 15.5 and 18.5. For *Acacia tortilis* this is because of its shape and its limited potential for use in garden locations. For *Populus euphratica* this is because the tree will only grow withan ample supply of perennial water and similarly *Tamarix nilotica* will only grow where there is water available. 9 out of the 12 tree species evaluated, (77%) have a high eveluation between of over 19 and 21 [295]. This

[295] An overall cumulative score (value) of nineteen (19) or above is considered to be a good score, which denotes the high quality and overall potential use of each individual native species with regard to the criteria of evaluation. A score of less than 19 does not however, preclude potential use of some species in specific locations and for specific purposes.

evaluation iundicates their potential for use in gardens as well as in the middle landscape as well as for environmental purposes in appropriate natural areas. 8 of the 9 highest scoring tree species, (89%) achieve a constant or seasonal score of 21 as illustrated in the tables immediately above and below:

Highest Scores Table 10 - Trees

Plant No.	Plant Species Name	Cumulative Value
147	*Acacia gerrardii*	21
148	*Acacia raddiana*	21
149	*Acacia tortilis*	19
150	*Balanites aegyptiaca*	21
151	*Hyphaene thebaica*	21
152	*Moringa peregrina*	21
153	*Phoenix dactylifera*	21
154	*Pistacia atlantica*	21
156	*Tamarix aphylla*	20.75
158	*Ziziphus spina-christi*	21

6.13 Naturalised and Adventive Species and Foreign Escapees - Analysis of the Individual Plant Species and Comparison of Matched Pairs

Introduction

6.13.1 This section analyses the species that the author located in the Negev Desert that when reviewed in the literature turned out to be foreign escapees, adventive [296] species, some of which that have become naturalised [297] in a particular area. The term naturalised does not in any way mean that the species are now part of 'nature.' Conversely it is a fundamental principal of this research thesis that most of these species should not be encouraged and where possible they should be eradicated as they have proven to be invasive and are likely to be detrimental to local biodiversity, with additional changes to landscape character and landscape quality. However, in some cases they may be useful in garden locations. These few species located by the author during the field trips have thus been singled out and removed from the main sections relating to the life forms discussed above.

6.13.2 Note that in this section, matching with a foreign species is not used as the species are themselves foreign having been introduced into the Negev.

Table 6.0 X List of Naturalised Species and Foreign Escapees

NO.[298]	NATURALISED	COMMENTS & FLOWERING PERIOD [299]

[296] Not native and not fully established; locally or temporarily naturalized.

[297] Naturalised plant species refer to species that have escaped from cultivation, (from gardens, forest plantations and various other means), and can reproduce without the help from people.

[298] The number allocated to the plant species is relevant only to this research. The number relates to the alphabetical order of the plant.

	SPECIES & FOREIGN ESCAPEES	
159	*Verbesina encelioides*	Annual – Summer (unusual)
160	*Atriplex semibacatta*	Perennial – February to December
161	*Nicotiana glauca*	Shrub – May to October – summer flowering (unusual)
162	*Acacia longifolia*	Tree – April to May
163	*Ficus sycamorus*	Tree - Summer flowering (unusual)

6.13.3 The following section notes the potential use for each naturalised or adventive species or foreign escapee (Refer also to Appendix F11 for additional data.)

Annuals

159. *Verbesina encelioides* – Family: Compositae (ורבזינה זהובה – Verbezina zehubah – Golden verbesina) Photograph A27.

Brief Description

6.13.4 This is an erect naturalised annual 30 cm to 1.5 metres tall with bright yellow flowers. The plant is toxic to livestock and is considered a weed in many states of the USA.

Flowers: Summer (Feinbrun-Dothan and Danin, 1998, page 691)

Potential Suitable Uses

6.13.5 Although very attractive, this plant is not native and it has the ability to spread rapidly. It is toxic to livestock and should not be used in any

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[299] Information re flowering mainly from Feinbrun-Dothan and Danin, 1998. Note the flowering times are for the whole of Israel and not only the Negev. Should other references note earlier or extended flowering times these are included.

circumstances. In fact it should be eradicated where found.

Comparison of Matched Pair

6.13.6 This species is not matched with an exotic species as it is an exotic introduced species itself.

Table 6. 159 *Verbesina encelioides* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
159	N	*Verbesina encelioides*	none	2.25	0	0	0	0	0	3	5.25 ††

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

Perennials

160. *Atriplex semibaccata* (half berry like/pulpy) – Family: Chenopodiaceae (מלוח הענבות- Maluach ha-anavot- Berry saltbush), Photographs FO/P388 and FO/P389.

Brief Description

6.13.7 A low growing grey foliaged species. Feinbrun-Dothan and Danin, (1998, pages 162 - 163), note that the species is a perennial and that the leaves are alternate and the covering of the fruit ripens with juiciness, red in colour, looking like a berry; the fruit dries flat and dark. Zohary, (1966, page 1150) , notes that this species is an annual.

6.13.8 Flowers: February – December. (Feinbrun-Dothan and Danin, 1998, page

Potential Suitable Uses

6.13.9 It is considered a weed in many countries and by many institutions.

6.13.10 Although this species is used for soil stabilization especially along roads it is non-native, (Australian in origin), it is invasive and thus should not be planted in any situation.

Comparison of Matched Pair

6.13.11 This species is not matched with an exotic species as it is an exotic introduced species itself.

Table 6. 160 *Atriplex semibaccata* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
160	N	*Atriplex semibaccata*	none	2.5	0	0	0	0	0	3	5.5

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

Shrubs

161. *Nicotiana glauca* (greenish or bluish grey) – Family: Solanaceae

טבק השיח (- Tabak hasiach – Shrub or Bush tobacco), Photographs, FO/S390 and FO/S391.

Brief Description

6.13.12 Shmida, (1994, page 94), notes that this is a shrub or tree that grows in Israel alongside roads and rubbish tips. Feinbrun-Dothan and Danin, (1998, page 593), notes that in Israel it only grows as a shrub. Shmida, (1994, page 94), notes that it grows very quickly and in a single year it can grow 2-3 metres and *Nicotiana glauca.* is one of the most successful invasive plants around the world. (Shmida, 1994, page 94) During the last century it has spread across the world, in Israel in the last 20 years. The Plant for a Future database, (*'Nicotiana glauca'*, www.), notes that all parts of the plant are poisonous.

6.13.13 Flowers: May – October. (Shmida, 1994, page 94) Throughout the summer. (Feinbrun-Dothan and Danin, 1998, page 593)

Potential Suitable Uses

6.13.14 Although this species has the potential to be used for a number of purposes including shelterbelts and even in gardens it should strictly be avoided and should never be used in any situation in the Negev as it is very invasive. In fact it is suggested that the existing invaders should be eradicated as the author has noted the spread of the species during field trips to the Negev.

Comparison of Matched Pair

6.13.15 This species is not matched with an exotic species as it is an exotic introduced species itself.

Table 6. 161 ***Nicotiana glauca*** **- Ratings for Use and Comparison of Matched Pair**

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
161	N	*Nicotiana glauca*	none	2.5	0	0	0	0	0	3	5.5††

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

Trees

162. ***Acacia longifolia*** (long leaved) or ***salicina*** (willow) – Family: Mimosaceae (שיטה ארוכת עלים - Shita Arucot - alim - Long leaved acacia) Photographs FO/T392 and FO/T393.

6.13.16 Shmida (1994, page 132), notes this species as *A. longifolia,* and the Flora of Israel database as *A. salicina.* (Flora of Israel, *'Acacia salicina'*, www.) The Flora of Israel database notes that the species has escaped in a few locations. (Flora of Israel, *'Acacia salicina'*, www.)

Brief Description

6.13.17 Shmida (1994, page 132), notes this species as a woody plant from Australia found often along roads and in groves and that it is a green tree with long dark green leaves growing 2 – 4 metres high. On the adult tree the outer branches hang downwards. (Shmida 1994, page 132) The leaves are simple and are equal on both sides with a length of 13 - 20cm ... and it is very and leathery withstanding dryness. (Shmida 1994, page 132) It flowers in spring with numerous yellow clusters round and yellow, with tens of flower seeds grouped in each one. (Shmida 1994, page 132)

6.13.18 The SEPASAL database, (RBGK, SEPASAL, *'Acacia salicina'*, www.), notes the species can be found in a variety of soils and habitats that it a nitrogen fixer, and that it has numerous environmental and ornamental uses including shelterbelts and as a street tree.

6.13.19 Flowers: April – May. (Shmida 1994, page 132)

Potential Suitable Uses

6.13.20 *Acacia longifolia (A. saligna)* should not be used in any situation.[300] It is suggested, by the author, that the existing specimens should be eradicated as

[300] The author has noted individuals of the species growing along roadsides as well as in far-flung protected wadis where it is presumed seeds or vegetative parts have been distributed by water and / or animals and / or the wind.

they pose a real threat to the local ecological system and to a diminution in landscape quality.

Comparison of Matched Pair

6.13.21 This species is not matched with an exotic species as it is an exotic introduced species itself.

Table 6. 162 *Acacia longifolia / saligna* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
162	N	*Nicotiana glauca*	none	2.5	0	0	0	0	0	2	4.5

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

163. *Ficus sycomorus* (referring to fig-mulberry leaves) – Family: Moraceae [301] (פיקוס השקמה- Ficus hashkema - Sycamore fig), Photographs T350, T351 and T352, PROTECTED!

Brief Description

6.13.22 Feinbrun-Dothan and Danin, (1998, page 98), note that the species may grow as a tree or a shrub and that it has greenish, simple and whole leaves. The un-ripe figs are grouped on the trunk of older branches of the tree like bunches of grapes, and they are minus seeds (in Israel). (Feinbrun-Dothan and Danin, 1998, page 98) They were planted in the past; found in East

[301] Order of Moraceae: Trees or shrubs, rarely herbs with milky juice: Useful products: Mulberry, rubber, jack-fruit.

Africa. (Feinbrun-Dothan and Danin, 1998, page 98)

6.13.23 In Israel it occurs on dunes and coastal towns, but it does not produce viable seeds, although it is easily propagated by cuttings. (Zohary, 1966, page 38)

6.13.24 It is sensitive to frosts, that when cultivated it requires space, as it is shady and spreading, that it tolerates pruning and lopping, that it is used for shade, dune fixation, soil improvement ... (The FAO Corporate Document Repository, *'Ficus sycomorus'*, www.)

6.13.25 Flowers: Throughout the summer. (Feinbrun-Dothan and Danin, 1998, page 98)

<u>Potential Suitable Uses</u>

6.13.26 This tree has been mentioned in the bible and has been in existence in Israel for thousands of years, having been introduced most probably from Egypt, where it grows as a native species. The specimens located by the author in the western Negev were all small (5 metres tall), whereas elsewhere in Africa the species can grow to three or four times this height.

6.13.27 It is suggested that because the species has been in the Negev for thousands of years and that it is unlikely that the species could spread and create ecological damage that it should be possible at least to use this species in wetter areas in the middle landscape and for a dense shade and as specimens in garden situations where more water is available. Feinbrun-Dothan and Danin, (1998, page 98) and Zohary, (1966, page 38) note that the tree produces fruits without viable seeds and thus the author suggests it could be planted. The species has many positive attributes and is also likely to benefit wildlife and it also has agricultural potential as it can produce six crops of figs per annum.

<u>Comparison of Matched Pair</u>

6.13.28 This species is not matched with an exotic species as it is an exotic introduced species itself.

Table 6. 163 *Ficus sycomorus* - Ratings for Use and Comparison of Matched Pair

Plant No. and Matching Pair No.	(N) ative or (E)xotic Pairing	Plant Species Names	Use Suitability (G)arden, (M)iddle (L)andscape, (E)nvironmental	Aesthetic Rating	Garden Use Rating	Middle Landscape Use Rating	Environmental / Natural Use Rating	Ecological Benefit / Disbenefit Rating	Landscape Character Benefit Rating *	Water Demand	Cumulative Value
163	N	*Ficus sycomorus*	G, ML	3	3	2	0	0	3	2	13

Note: Boxes in grey = native species. Boxes in white = potential or actual exotic introduced species noted being used. † = spiny. †† = poisonous if eaten. SP=spring, S=summer. Refer to Table 6.0 in the Introduction for additional notes and explanation of the ratings / value hierarchy.

6.13.29 It is considered that despite being a foreign species that *Ficus sycomorus* could be used in garden situations for shade, singly and in groups and in the middle landscape. However, all use is likely to require amounts of water above the baseline measure of 200 mm per annum.

Results and Discussion of the Values Assessed for Each Naturalised and Adventive Species and Foreign Escapees

6.13.30 The above analysis and Table 6.0 Y indicate the low scores achieved by the foreign species that have been deliberately or inadvertently been introduced into the Negev. The low scores illustrate that these species may and do create considerable potential negative effects and thus their potential use is extremely limited. The exception is *Ficus sycamorus,* which was introduced into Israel many thousands of years ago and has the potential for use in wetter garden and middle landscape areas.

Table 6.0 Y Comparison of Values for the Native Versus the Naturalised and Adventive Species and Foreign Escapees

Plant No.	Plant Species Name	Native Species Cumulative Value *	Exotic Species Cumulative Value

159	*Verbesina encelioides*	5.25	No match
160	*Atriplex semibaccata*	5.5	No match
161	*Nicotiana glauca*	5.5	No match
162	*Acacia longifolia*	4.5	No match
163	*Ficus sycomorus*	13	No match

Note: Those native species that have not been matched are not considered to have value for garden use.

6.14 Conclusions of the Suitability Analysis and Matching of the Native Negev Versus the Exotic Species

Introduction

6.14.1 The study of whether the native plants of the Negev may have potential for use in the Negev commenced with the analysis of each species. This assessment is partially contained in Appendix F, Appendix G, and above. The second part of the assessment was to ascertain potential use for each individual species relative to a matching exotic species, according to a set list of criteria. This assessment forms the major part of this chapter and Appendix G. The third and final part of the evaluation for potential use, which follows below includes the broad evaluation of the potential use according to the set list of criteria per life-form and then an overall cumulative evaluation of all the life-forms combined. This evaluation analyses the averages for each of the evaluative issues that have been used throughout the pair matching process. The methodology centres on adding together the scores for each issue, for each species in each life-form and then dividing the total by the number of plant species. Thus the main benefits and disbenefits are broadly quantified for each of the important qualities for each life-form group. This process is considered by the author not as important as identifying, the merit and potential use of each individual native species, but it does assist in providing an overall view of the potential worth, issue by issue, in using the native Negev plant species relative to exotic species. With regard to this process a number of points are noted:

1. In the case where two values have been recorded, for example a value for spring and a second for winter, the highest value has been used. This is considered appropriate as most plants, including the exotic matching species used are not aesthetically 'at their best' all year round, but the assessment has valued the exotic species when they are at their best. Thus the matching of the native species with the exotic species is more balanced;

2. The numbers of species added up for the native species versus the exotic

species is most times different. This is because in some cases a matching exotic species was not paired with the native species as the aesthetic qualities of the native species were considered not high enough to warrant potential garden use;

3. This process is a "broad brush" approach and distortions in the findings can occur where for example the low valuation for one species will lower the total evaluation for the life-form group. The merits and beneficial qualities on the one hand and negative qualities and disbenefits for each individual species is thus disguised and distorted;

4. The tables used below tabulate the overall evaluation for each life-form with regard to the key issues and note the number of species that have the potential for use within garden, middle landscape and environmental/natural areas of the landscape. The total number of species per life-form is noted and thus it is possible to calculate the percentage numbers that have the potential for use in the different broad landscape locations. This percentage may provide an indication of the overall potentials for the individual species that have not been seen and thus not assessed as part of this research. However, it is considered that this approach is too general and that each species needs to be considered on its own merits and not as a group.

Annuals

6.14.2 Nineteen native annuals have been evaluated and the overall valuations are as follows:

Comparative Table 1 Annuals

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use * ◊	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21 points
Native Annuals 19	8	19	19	1.73	1.53	2.74	2.74	2.84	2.74	2.95	17.3
Exotic Annuals 16 3	16	0	0	2.9	2.94	0	0	Minus2.81	0	1.44	4.56

Note: * = Record of the number of species considered suitable out of the number of species analysed. ◊ = In / with respect to the Negev. ‡ = Out of a total possible score of 3 points which is the highest and most positive score for each issue. -3 = the lowest score for each issue.

6.14.3 Out of the nineteen native annuals evaluated eight, which is 42% are considered to have a high potential for garden use as well as middle landscape and environmental/natural use. All nineteen have the potential for middle landscape as well as environmental uses in appropriate natural locations. The average aesthetic score of the native species is 1.73 as compared to an overall score of 2.9 for the exotic species disguises the individual assessment for the native species where half of the species have an aesthetic evaluation of a high score of 2.25 points or over and eight species have an overall score of 19 or over. In comparison, although the exotic species have overall high aesthetic values the cumulative score of 4.56 is poor compared to the native species. The poor valuation relates to not being suitable for use other than in garden locations and their potential to diminish ecological and landscape quality/values.

Climbers

6.14.4 Three native climbers have been evaluated and the overall valuations are as follows:

Comparative Table 2 Climbers

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use * ◊	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21 points
Native Climbers 3	3	3	3	2.0	3.0	3.0	3.0	3.0	3.0	3.0	20.0
Exotic Climbers 3	3	0	0	2.9	3.0	0	0	Minus 2.0	0	Minus 0.33	3.66

Note: * = Record of the number of species considered suitable out of the number of species analysed. ◊ = In / with respect to the Negev. ‡ = Out of a total possible score of 3 points which is the highest and most positive score for each issue. -3 = the lowest score for each issue.

6.14.5 Out of the three native climbers evaluated all three are considered to have potential for garden use as well as middle landscape and environmental/natural use. The average aesthetic score of the native species is 2.0 as compared to an overall score of 3.0 for the exotic species disguises the individual assessment of the native species where two of the three have an aesthetic evaluation of 2.25 points. This is similarly the case with the overall cumulative values. Yet two of the species have scores 19.5 and 20.5. Although the exotic species have overall high aesthetic values the cumulative score of 3.66 is poor compared to the native species. The poor valuation relates to not being suitable for use other than in garden locations and their potential to diminish ecological and landscape quality/values.

Geophytes

6.14.6 Twenty three native geophytes have been evaluated and the overall valuations are as follows:

Comparative Table 3 Geophytes

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use * ◊	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21 points
Native Geo-phytes 23	19	23	23	2.0	2.7	2.91	2.86	3.0	3.0	3.0	19.51
Exotic Geo-phytes 22	22	0	0	3.0	3.0	0	0	Minus 3.0	0	Minus 0.45	3.45

Note: * = Record of the number of species considered suitable out of the number of species analysed. ◊ = In / with respect to the Negev. ‡ = Out of a total possible score of 3 points which is the highest and most positive score for each issue. -3 = the lowest score for each issue.

6.14.7 Out of the twenty three native geophytes evaluated nineteen, which is 83% are considered to have potential for garden use as well as middle landscape and environmental/natural use. The average aesthetic score of the native species is 2.0 as compared to an overall score of 3.0 for the exotic species disguises the individual assessment of the native species where twelve of the twenty three have an aesthetic evaluation of 2.25 points or above. The overall cumulative score for all the geophytes is 19.51, which is a good score and illustrates that most of the geophytes show potential for use. However, eight species have a cumulative score between 19 and 20 and eleven species have a score above 20. Although the exotic species have overall high aesthetic values the cumulative score of 3.45 is poor compared to the native species. The poor valuation relates to not being suitable for use other than in garden locations and their potential to diminish ecological and landscape quality/values.

Grasses

6.14.8 Three native grasses have been evaluated and the overall valuations are as follows:

Comparative Table 4 Grasses

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21
Native Grasses 3	2	3	3	1.9	3.0	3.0	3.0	3.0	3.0	3.0	18.25
Exotic Grasses 2	2	0	0	3.0	3.0	0	0	Minus 3.0	0	1.0	3.66

Note: * = Record of the number of species considered suitable out of the number of species analysed. ◊ = In / with respect to the Negev. ‡ = Out of a total possible score of 3 points which is the highest and most positive score for each issue. -3 = the lowest score for each issue.

6.14.9 Of the three native grasses evaluated two are considered to have potential for garden use as well as middle landscape and environmental/natural use. The average aesthetic score of the native species is 1.9 as compared to an overall score of 3.0 for the exotic species. This disguises that fact that two of the species have been considered to have an aesthetic value of 2.5. The overall cumulative score for all the grasses is 18.25, but two of the three species received a good score of 19.25 and 19.5. Although the exotic species have overall high aesthetic values the cumulative score of 3.66 is poor compared to the native species. The poor valuation relates to not being suitable for use other than in garden locations and their potential to diminish ecological and landscape quality/values.

Parasites

6.14.10 Three native parasites have been evaluated and the overall valuations are as follows:

Comparative Table 5 Parasites

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21
Native Parasites 3	1	2	2	2.33	1.66	2.0	2.0	3.0	3.0	3.0	16.33
Exotic Parasites 1	1	0	0	3.0	3.0	0	0	Minus 3.0	0	0	3.66

Note: * = Record of the number of species considered suitable out of the number of species analysed. ◊ = In / with respect to the Negev. ‡ = Out of a total possible score of 3 points which is the highest and most positive score for each issue. -3 = the lowest score for each issue.

6.14.11 Of the three native parasites evaluated only one is considered to have potential for garden use and two others may well be used in appropriate middle landscape and environmental/natural locations. The average aesthetic score of the native species is quite high at 2.3 as is the overall score of 3.0 for the exotic species. Although the exotic species have overall high aesthetic values, the cumulative score of 3.66 is poor compared to the native species. The poor valuation relates to not being suitable for use other than in garden locations and their potential to diminish ecological and landscape quality/values. Although the native species have overall high aesthetic values the cumulative score of 17 is low, which suggests that their potential use is generally limited.

Perennials

6.14.12 Twenty two native perennials have been evaluated and the overall valuations are as follows:

Comparative Table 6 Perennials

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21
Native Pere-nnials 22	12	21	22	2.03	1.86	2.63	2.36	3.0	2.86	2.45	17.67
Exotic Pere-nnials 18	18	0	0	3.0	2.88	0	0	Minus3.0	0	0.72	3.61

Note: * = Record of the number of species considered suitable out of the number of species analysed. ◊ = In / with respect to the Negev. ‡ = Out of a total possible score of 3 points which is the highest and most positive score for each issue. -3 = the lowest score for each issue.

6.14.13 Of the twenty two native perennials twenty are considered to have potential for garden use, twenty one are considered for middle landscape use and all are considered suitable for use in appropriate environmental/natural locations. The average aesthetic score of the native species is quite high at 2.0. This could indeed be higher except that the score has been lowered by the inclusion of a small number of poor performing species. The lower than average scores for the perennials is due mainly to two species, namely *Alhagi maurorum* and *Verbascum sinaiticum* that are considered not aesthetically appropriate for use in garden locations. They have helped to lower the overall cumulative valuation to 17.67. This low overall cumulative score disguises the fact that 12 of the twenty have their own cumulative scores above 19 and thus have good potential for use. The overall cumulative value for the exotic perennials is 3.6. This poor valuation relates to not being suitable for use other than in garden locations and their potential to diminish ecological and landscape quality/values.

Dwarf Shrubs

6.14.14 Fifty three native dwarf shrubs have been evaluated and the overall valuations are as follows:

Comparative Table 7 Dwarf Shrubs

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21
Native Dwarf Shrubs 53	40	53	53	2.28	2.38	2.83	2.94	3.0	3.0	2.74	19.35
Exotic Dwarf Shrubs 47	47	0	0	3.0	3.0	0	0	Minus 3.0	0	1.0	4.0

Note: * = Record of the number of species considered suitable out of the number of species analysed. ◊ = In / with respect to the Negev. ‡ = Out of a total possible score of 3 points which is the highest and most positive score for each issue. -3 = the lowest score for each issue.

6.14.15 Forty out of fifty three dwarf shrubs analysed are considered to have a high potential for garden use. This is 75% of the dwarf shrubs investigated by the author. All except one of the dwarf shrubs analysed, i.e. *Prosopis farcta,* are considered to have the potential for middle landscape use and use in appropriate natural areas. The overall aesthetic value for the native dwarf shrubs is high at 2.29 out of a possible 3.0 and the overall cumulative value is 19.35 out of a possible score of 21. Thirty one of the species obtain a score over between 20 and 21 and nine species between 19 and 20. This high number of species illustrates that there is good potential for these dwarf shrubs to be used for various purposes in the Negev. However, this does not preclude the use of those that receive scores less than 19 as the use of each species needs to be considered on its own merits. The overall cumulative value for the exotic dwarf shrubs is 4.0. This poor valuation relates to not being suitable for use other than in garden locations and their potential to diminish ecological and landscape quality/values.

Shrubs

6.14.16 Eighteen native shrubs have been evaluated and the overall valuations are as follows:

Comparative Table 8 Shrubs

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21
Native Shrubs 18	13	18	18	2.29	2.11	2.94	3.0	3.0	3.0	2.88	19.25
Exotic Shrubs 13	13	0	0	3.0	3.0	0	0	Minus 3.0	0	2.0	5.08

Note: * = Record of the number of species considered suitable out of the number of species analysed. ◊ = In / with respect to the Negev. ‡ = Out of a total possible score of 3 points which is the highest and most positive score for each issue. -3 = the lowest score for each issue.

6.14.17 Thirteen out of the eighteen shrubs analysed, which is 72%, are considered to have potential for garden use. The five that are not considered as giving garden use potential are mainly extremely thorny and appear desiccated through the summer months. All the shrubs analysed are considered to have the potential for middle landscape use and use in appropriate natural areas. The overall aesthetic value for the native shrubs is high at 2.29 out of a possible 3.0 and the overall cumulative value is 19.25 out of a possible score of 21. This lower score is caused by the five aforementioned poorer quality species. This evidenced by the fact that eight of the species, obtain a score between 20 and 21 and five species between 19 and 20. Thus 72% of the native shrubs achieve a high cumulative score. This high number of species illustrates that there is good potential for the native shrubs to be used for various purposes in the Negev. However, this does not preclude the use of those that receive scores less than 19, as the use of each species needs to be considered on its own merits. The overall cumulative value for the exotic shrubs is 4.85. This poor valuation relates to not being suitable for use other than in garden locations and their potential to diminish ecological and landscape quality/values.

Succulents

6.14.18 Two native succulents have been evaluated and the overall valuations are as follows:

Comparative Table 9 Succulents

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21 points
Native Succu -lents 2	1	1	1	2.38	2.38	0.5	1.5	3.0	3.0	3.0	18.25
Exotic Succu -lents 1	1	0	0	3.0	3.0	0	0	Min us 3.0	0	3	6.0

Note: * = Record of the number of species considered suitable out of the number of species analysed. ◊ = In / with respect to the Negev. ‡ = Out of a total possible score of 3 points which is the highest and most positive score for each issue. -3 = the lowest score for each issue.

6.14.19 Only two native succulents have been evaluated, with a high average aesthetic value of 2.38. The poor overall cumulative average of 14.9 relates to the fact that *Mesembryanthemum nodiflorum* has the potential to salinate soils and thus it is considered an inappropriate species for most locations. *Caralluma nevegensis* is a delightful small species but its use is limited except in very specific garden situations. The cumulative value for the exotic succulent is 6.0. This poor valuation relates to not being suitable for use other than in garden locations and their potential to diminish ecological and landscape quality/values.

Trees

6.14.20 Twelve native trees have been evaluated and the overall valuations are as follows:

Comparative Table 10 Trees

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21
Native Trees 12	9	12	12	2.85	2.83	2.83	2.83	2.83	3.0	2.66	20
Exotic trees 11	11	0	0	3.0	3.0	0	0	Minus 3.0	0	2.09	5

Note: * = Record of the number of species considered suitable out of the number of species analysed. ◊ = In / with respect to the Negev. ‡ = Out of a total possible score of 3 points which is the highest and most positive score for each issue. -3 = the lowest score for each issue.

6.14.21 Nine of the twelve of the native trees analysed, which is 75% are considered to have potential for garden use, for middle landscape use and use in appropriate natural areas. The overall aesthetic value for the native trees is high at 2.85 out of a possible 3.0 and the overall cumulative value is 20 out of a possible score of 21. This score would have been higher were it not for the *Populus euphratica* and *Tamarix nilotica* species that require additional water. Eight of the twelve trees scored between 20.75 and 21, and one tree scored between 19 and 20. This indicates that the native trees generally have very good potential for a variety of purposes in the Negev. (This potential is investigated relative to alterations in microclimate in Chapter 7.) However, this does not preclude the use of those that receive scores less than 19, as the use of each species needs to be considered on its own merits relative to its location. The overall cumulative value for the exotic shrubs is 5.0. This poor valuation relates to not being suitable for use other than in garden locations and their potential to diminish ecological and landscape quality/values.

Cumulative Analysis

6.14.22 The following tables illustrate the cumulative scores for all the native and exotic species together.

Cumulative Table 1 Native Species

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21
Native Annuals 19	8	19	19	1.73	1.53	2.74	2.74	2.84	2.74	2.95	17.3
Native Climbers 3	3	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0	3.0	20.0
Native Geophytes 23	19	23	23	2.0	2.7	2.91	2.86	3.0	3.0	3.0	19.51
Native Grasses 3	2	3	3	1.9	3.0	3.0	3.0	3.0	3.0	3.0	18.9
Native Parasites 3	1	2	2	2.33	1.66	2.0	2.0	3.0	3.0	3.0	17
Native Perennials 22	12	21	22	2.03	1.86	2.63	2.36	3.0	2.86	2.45	17.67
Native Dwarf Shrubs 53	40	53	53	2.28	2.38	2.83	2.94	3.0	3.0	2.74	19.35
Native Shrubs	13	18	18	2.29	2.11	2.94	3.0	3.0	3.0	2.88	19.19

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21
18											
Native Succulents 2	1	1	1	2.38	2.38	0.5	1.5	3.0	3.0	3.0	18.25
Native Trees 12	9	12	12	2.85	2.83	2.83	2.83	2.83	3.0	2.66	20
Total Number of Species 158	**109**	**155**	**156**	**2.18**	**2.35**	**2.54**	**2.62**	**2.97**	**2.96**	**2.85**	**18.72**

Cumulative Table 2 Matched Exotic Species

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21
Exotic Annuals 16	16	0	0	2.9	2.94	0	0	Minus 2.81	0	1.44	4.56
Exotic Climbers 3	3	0	0	2.9	3.0	0	0	Minus 2.0	0	Minus 0.33	3.66
Exotic Geophytes 22	22	0	0	3.0	3.0	0	0	Minus 3.0	0	Minus 0.45	3.45
Exotic Grasses 2	2	0	0	3.0	3.0	0	0	Minus 3.0	0	1.0	3.66
Exotic	1	0	0	3.0	3.0	0	0	Minus	0	0	3

Total Number of Species	Number Suitable for Garden Use * ◊	Number Suitable for Middle Landscape Use * ◊	Number Suitable for Environmental/Natural Use *	Average Aesthetic Rating ‡	Average Garden Use Rating ◊ ‡	Average Middle Landscape Use Rating ◊ ‡	Average Environmental Use Rating ◊‡	Ecological Benefit / Disbenefit Average Rating ◊ ‡	Average Landscape Character Benefit Rating ◊ ‡	Average Demand for Water ◊ ‡	Average Cumulative Value out of a possible total of 21
Parasites 1								3.0			
Exotic Perennials 18	18	0	0	3.0	2.88	0	0	Minus 3.0	0	0.72	3.61
Exotic Dwarf Shrubs 47	47	0	0	3.0	3.0	0	0	Minus 3.0	0	1.0	4.0
Exotic Shrubs 13	13	0	0	3.0	3.0	0	0	Minus 3.0	0	2.05	5.08
Exotic trees 11	11	0	0	3.0	3.0	0	0	Minus 3.0	0	2.09	5
Exotic Species Total 146	**135**	**0**	**0**	**2.98**	**2.98**	**0**	**0**	**Minus 2.88**	**0**	**0.84**	**4.00**

6.15 Cumulative Values Discussion

6.15.1 The above tables provide total cumulative numbers and averages for each issue for all the life-forms combined. The tables enable a comparative overall evaluation between the native species and the exotic species. The author notes that the comparisons are relative only to the 158 [302] native species located by the author in the Negev and their matching exotic pair. It should thus be noted that the results would differ, had a different number of

[302] 163 plants found growing in natural locations in the Negev. However 5 of these species are not native and therefore the total native species considered is 158.

species been located by the author in the Negev. The conclusions are as follows:

Number of Species Suitable for Garden Use and Garden Use Ratings

6.15.2 The cumulative analysis illustrates that 109 out of the 158 [303], which is 69% of the native species located by the author in the Negev are suitable for use in garden locations [304]. This number is obviously smaller than the 100% of the exotic plant species that were located in garden locations, but it is considerable.

6.15.3 The cumulative average garden use rating for the all the native species rating is 2.35 out of 3, whilst for the exotic species it is 2.98. The difference in the scores is due to the fact that the cumulative score for the native species takes account of those species with poor, minor and moderate garden use potential. However, the exotics are scored high because they have the suitable characterstics of garden plants. Some but not all of the native species have similar garden plant qualities. [305]

Number of Species Suitable for Middle Landscape Use and Middle Landscape Use Ratings

6.15.4 155 out of 158 [306] native Negev plant species, which is 98% are considered suitable for use in the middle landscape. The average middle landscape use rating is 2.54 out of 3. In contrast, none of the exotic species, which is 0%,

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[303] Ibid.

[304] Potential uses for each individual species are noted for each species in the life-form sections above.

[305] These characteristics are analysed for each species in Chapter 6 above and in Appendix F and Appendix G.

[306] 163 plants found growing in natural locations in the Negev. However 5 of these species are not native and therefore the total native species considered is 158.

and which have a zero average middle landscape use rating are considered suitable for middle landscape use as they are likely to diminish ecological and landscape values and demand considerable amounts of water.

6.15.5 Native plant use in the middle landscape would thus be greatly advantageous in the creation of habitat. This should increase ecological values and diminish water requirements.

Number of Species Suitable for Environmental Use in Natural Landscape Areas and Environmental Use Ratings

6.15.6 156 out of 158 [307] native Negev plant species, which is nearly 99% are considered suitable for use for environmental works in natural areas. The average environmental use rating is 2.62 out of 3. In contrast, none of the exotic species, which is 0%, and which have a zero average natural use rating are considered suitable for natural area use. They are likely to diminish significantly ecological and landscape values and should never be used in this context.

Aesthetic Ratings

6.15.7 The cumulative average aesthetic rating for the native species is 2.18 out of a maximum of 3.0 as compared to the cumulative rating for the exotic species which is 2.98. The average of 2.18 is moderate. This does not, however, indicate that all the native species are aesthetically mediocre but rather that there are a number of species that are poorer in aesthetic quality. The exotic garden species are located in garden locations due to each species' individual physical and aesthetic characteristics. Thus, each native species needs to be similarly judged with regard to its individual characteristics. [308]

Ecological Benefits / Disbenefits

6.15.8 The cumulative average ecological benefit for the native species is 2.97 out

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[307] Ibid.

[308] These characteristics are analysed for each species in Chapter 6 above and in Appendix F and Appendix G.

of a maximum of 3.0 as compared to the cumulative disbenefit rating for the exotic species, which is -2.88. The use of the native species is considered positive as it will increase habitat and thus be greatly beneficial to ecological values and wildlife in general. In contrast the use of exotic species in inappropriate areas is negative altering existing ecological conditions and values.

Landscape Character Benefits / Disbenefits

6.15.9 The cumulative average landscape benefit for the native species is 2.96 out of a maximum of 3.0 as compared to the cumulative rating for the exotic species, which is 0.0. The use of the native species is considered highly positive in the middle landscape and natural areas. Some native species are also considered to have a positive effects in garden locations, by creating a local 'sense of place'. In contrast, the use of exotic species is inappropriate in the middle landscape and natural areas by altering landscape character and thus landscape quality/value.

Demand for Water

6.15.10 The cumulative average demand for water for the native species is 2.85 out of a maximum of 3.0 as compared to the cumulative rating for the exotic species, which is 0.84. The native Negev species have the distinct advantage in requiring less water than most of the exotic species used in the Negev.

Cumulative Values for all Issues

6.15.11 The overall cumulative value for the native Negev plants is 18.73, whilst the overall cumulative value for the exotics is 4.00 out of a total of 21. The large divergence between these figures illustrates the overall advantages with regard to the potential use of the native Negev species with regard to the assessment criteria. As noted in paragraph 6.2.16, at the beginning of the chapter it is considered that any native species with a cumulative score of 18 to 19 has good overall potential for use in the Negev. A score of 19 to 21 denotes a species with high qualities and that is likely to be suitable for garden use.

6.15.12 The overall score of 18.73 indicates that the native Negev plants as a whole [309], are less than suitable for garden use but it suggests that they are suitable for use in the middle landscape and general areas. However, as stated above 69% of the native Negev plants reach a score of 19 to 21 and thus show potential also for garden use.

6.16 Summary and Conclusions

6.16.1 The analysis shows that most of the native species could be used in the Negev and that they are superior to the use of exotic species in the middle landscape and natural areas. In some cases their aesthetic and physical qualities make them equal or superior to the exotic species that are used in gardens.

6.16.2 On the whole the use of native species is very beneficial. Their use not only meet Ian Thompson's criteria of being beneficial to the ecology and community as well as having aesthetic merit, but their use can also have economic benefits. Their use also fulfils the contemporary principle of the triple bottom line (3BL), which is includes 'economy, ecology and society'. [310] Thus the native species would not only have ecological and societal merit which are keystones of Thompson's criteria, but by requiring less water and maintence their use would be economically expedient as well.

6.16.3 The analysis of the individual Negev species and matched pairs established the following points with regard to garden, middle landscape and natural/environmental use:

Gardens

- The use of exotic species for garden use is well established in the Negev and the variety and aesthetic qualities cannot be undermined with regard to the 'delight' they generate for people. However these garden species can have ecological effects beyond the garden boundary

[309] Referring to the 158 species reviewed by the author.

[310] Also termed as 'People, Planet and Profit.

and they require considerable amounts of water.

- Over two-thirds of the native Negev Desert species located by the author were analysed to have some suitable garden use. Many of them have similar aesthetic values to the exotic species but are considerably superior with regard to water demand, with little or no effect on ecological values, if used appropriately.

- The use of some native species in garden locations would be positive in acknowledging the *genius loci* and creating a specific and local sense of place. This is in contrast to the use of exotic plant species where the sense of place is more generic and non-specific.

Middle Landscape

- In the middle landscape, native species are considerably better than exotic species. Ninety nine percent, of the native species located by the author may be suitable for use in middle landscape areas, whereas no exotic plant species are suitable for use in middle landscape areas for the following reasons:

- Whereas the exotic species may cause significant ecological negative effects, the native species would have significant positive ecological effects;

- Whereas the exotic species may create a degradation in landscape character and thus landscape quality/value, the native species are likely to create positive landscape effects;

- The native species should not require additional water in the middle landscape, whereas the exotic species require additional water supplies.

- The native species should require little or no maintenance, whereas the exotic species would require maintenance.

Natural Areas – Environmental Use

- No exotic species should ever be used in natural areas. This is because the effects on ecological and landscape values could be extremely negative.

- Most exotic species would not survive without irrigation, which is mostly unfeasible in natural areas., which are usually remote.
- All the native Negev plants could be used in appropriate natural locations for environmental purposes, such as revegetation, soil stabilisation, ecological and landscape enhancement etc.
- Native species should mostly not require any additional water supply.

6.16.4 The testing of the hypothesis with regards to potential suitable use, (relative to life-form, physical and aesthetic characteristics and relative to a matched exotic species, where possible), for each of the 163 species located by the author has been undertaken in Chapter 6. The next chapter, Chapter 7 concentrates on the important attribute, particularly in hot desert environments, of desert trees to create shade. The shade characteristics of native species is quantified and assessed relative to two exotic control species.

6.16.5 The following chapter, Chapter 7 follows on directly from this chapter in antesting the hypothesis on whether the shade created by the native trees of the Negev, makes them suitable for the creation of shade and microclimate modification. Following this Chapter 8 investigates various aspects of microlandscape manipulation, which should help plant establishment and continued growth.

7. CHAPTER 7 AN INVESTIGATION OF SHADE UNDER SIX DIFFERENT TREE SPECIES OF THE NEGEV DESERT TOWARDS THEIR POTENTIAL USE FOR ENHANCING MICRO-CLIMATIC CONDITIONS IN LANDSCAPE ARCHITECTURAL DEVELOPMENT

7.1 Introduction

7.1.1 Chapter 7 continues the testing of the hypothesis from Chapter 6 whether the native Negev plants are suitable for use. The focus in Chapter 7 however, is on the ability of the native Negev trees to create adequate shade. This study has been separated out from Chapters 5 and 6 for two reasons. In the first instance, this part of the research was carried out with a single objective, which was to ascertain whether the trees of the Negev could be used as effectively for shade as exotic species. The other aspects of using the trees, for example as shelterbelt species or for aesthetic purposes is included in Chapter 6. The second reason is the study was published as a research paper on its own and it appears that it is more useful to retain the logic and overall methodology as set out in the original paper. [311]

The Objectives of the Research and the Paper

7.1.2 Trees are planted for a variety of reasons in the landscape. In temperate as well as in arid regions trees are used to provide shade and for visual as well as environmental purposes. As in all biomes, in the Negev Desert in southern Israel, the indigenous trees are important ecological and landscape elements. For example, in terms of ecological and wildlife importance the Acacia trees, *Acacia tortilis* and *Acacia raddiana,* of the Arava [312], and other

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[311] Kotzen Benz, 2003, *'An investigation of shade under six different tree species of the Negev Desert towards their potential use for enhancing micro-climatic conditions in landscape architectural development'*, Journal of Arid Environments 55, pages 231-274.

[312] The Arava is the Hebrew name given to the low lying areas of the Great Rift Valley which extends from Eilat in the south towards the

low lying wadis support the visually striking parasite *Loranthus acaciae*. This clambering woody creeper with intense red flowers in turn feeds the endemic Palestinian Sunbird, *Nectarinia osea*. The beak of the Palestinian Sunbird is particularly suited to supping nectar from the green flowers of the parasite although it is attracted initially to the plant by the red flowers. (Shmida and Darom, 1986, page 4) These trees as well as that of other species are also visually important as they help to create and enhance landscape character and landscape quality.[313] They are also significant in environmental terms in that they help to stabilise soils, improve soils through the deposition of organic material and provide food and shelter for wildlife, and not least because they alter microclimate by creating shade. The creation of this shade benefits some desert fauna such as birds, insects, reptiles, various flora, as well as people who may be passing by.

7.1.3 It would appear logical then to suggest that in the development of desert regions, native tree species would be used for visual and other purposes and to create shade and to temper microclimate. But this is not often the case in the Negev Desert. Most trees that are planted in settlement areas are not native and the native tree species are not generally exploited in developments for landscape architectural and environmental purposes. Although the Jewish National Fund does use some native tree species in some environmental improvement schemes, past and present plantings include numerous foreign specimens including *Eucalyptus, Prosopis, Ficus* and many other species from around the world. Furthermore, influential

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Dead Sea in the north. It is bounded by Jordan to the east, and mountains and hills to the west.

[313] The use of the term landscape character refers to the visual character of the landscape, which is determined by physical conditions including such items as soils, topography, slope, enclosure, vegetation, surface water etc. The term landscape quality refers to the value of the landscape, e.g. high, medium, low which relates directly back to the Landscape Character, which is determined by the landscape features and elements themselves.

research on the use of plants, including trees for landscape purposes, generally ignore the local species and promote the use of alien species or treat foreign and native species in the same manner. Thus for example, although the publication *'Plants for Desert Landscaping'* suggests that some native trees, but not all can be used in the local Negev landscape there is no mention of the alterations in visual character created by using foreign tree species. (Ben Dov et al. 1993) In a further publication on *'Water-Wise Gardening - List of Recommended Plants'* there is no mention of native species although non-native species such as *Eucalyptus* are recommended for planting in the Negev in a further publication by Ben Dov, Forti, Pauker and Pasternak. (Ben Dov et al, 1997). As mentioned previously, it must be stated in the strongest terms that the Negev Desert is not a small part of Australia and the relatively large-leafed and tall Eucalyptus trees do not fit in with the landscape in many situations. (Appendix I, Figure 1)

7.1.4 Foreign tree species are also utilised despite the fact that they are often more water demanding, may be ecologically damaging as well as being detrimental to the landscape character and to the landscape quality of the region. There are many other faunal and floral examples world-wide where introduced species have created problems. This is discussed in Chapter 4. In South Africa, for example, Botha notes in Veld and Flora magazine (Botha, 2001, page 59), that the cost of removing introduced foreign species is greater than the land value on more than half the farms they are found on. In the United Kingdom, Japanese Knotweed, *Polygonum cuspidatum* is so problematic and invasive that it has to be registered by law within development sites. The introduction of alien species or invasive alien plants is a recognised world-wide phenomenon and is of world-wide concern, as is evidenced by the establishment of the Global Invasive Species Programme in Cape Town with funds from the World Bank. (Montgomery, The Garden, 2003, page 30) In southern Israel, in the Negev, landscape and ecological damage has been identified at first hand where foreign grasses have been introduced onto experimental plots and these have spread across the surrounding land. Furthermore, in the Negev, the ecological and landscape damage can in particular be seen by the spread of *Nicotiana glauca,* a species of tobacco plant, known as Tree Tobacco in the U.S.A. This plant, which is native to Bolivia, Paraguay and Argentina is considered to be a real problem in the northern Negev by the local and national authorities and is even recognised as a problem plant throughout the Mediterranean. (Epedemie www.) [314] Its success in the Negev is due to its drought resistance of and tolerance to a wide range of environmental conditions. It outperforms native vegetation where it often forms mono specific stands. (Appendix J, Figure 2) Apart from the ecological and visual damage it is causing it is toxic to livestock and could indeed be deadly to other animals as well as people. (Epedemie website) Yet, despite its noxious character it is still advocated as being useful in some publications, for example by Jones and Sacamano. (Jones and Sacamano, 2000, page 224) Another tree, *Acacia longifolia,* which also originates from Australia, has found its way into remote areas of the Negev where it does not belong. It may be found scattered across most of northern Israel and may be found in the northern Negev as well. (Shmida and Darom, 1994, page 132) Appendix J, Figure 3 shows the species established within a remote part of a wadi near 'Sde Boqer' within a protected nature reserve. It is likely that the seeds of the plant have been distributed by winter floodwaters into the wadi. (Appendix A, Figure 36) The reasons for the use of foreign trees and other plant species are not at all clear cut. As discussed in Chapter 4 and briefly reiterated here, the explanation is likely to be related to the non-culturalisation of the plants by the local community whereby nature and the desert is kept at arms length as it were. Plato states in the 'Republic' that

> *'the virtue and beauty and rightness of every manufactured article, living creature, and action is assessed only in relation to the purpose for which it was made or naturally produced'.* (Porteous, 1996, page 51)

7.1.5 This non-culturalisation is possibly because the plants of the Negev have not yet been seen to have a purpose beyond the natural, as they have not yet

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[314] The website is part of a research project on invasive exotic species, funded by the European commission.

been objectified or 'acquired' by the local people or scientists. Nor have they acquired a social or human significance within the local society and therefore they are not considered worthy of use. In contrast, for example, by extracting plants from the wild from places like China, or South Africa and Australia, numerous western plant hunters have elevated those plants seen to have specific aesthetic and other merits beyond the natural into the cultural realm and perhaps towards their intended purpose as Plato suggests. In the west, exotic, foreign plants are thus readily accepted because they have been collected and acquired and they have been subjected to a trans-location process of culturalisation, which has not happened to the local plants. Until now, the local Negev plants have not been given other than a natural purpose

7.1.6 In the quest for a more sensitive and more sustainable approach to landscape, environmental development and planting in the region, it is thus suggested that some native plants and indeed trees could well be used in proposed and existing developments. These could be utilised specially in areas where the local and neighbouring ecological and landscape quality and character need to be retained. These native trees would appear to fit in best with the local environment whilst at the same time improving localised microclimates for the benefit of wildlife and increasing comfort for people. The benefits of their use would also include a reduction in irrigation and water use in areas that have very little water and in a region where water use and demand creates a political issue. Jad Isaac states that water is a

> *'highly politicized issue in the Middle East, and many alarm bells are ringing because of this inseparability of water and politics'*. (Isaac, web site, page 1)

7.1.7 As part of this investigation two non-native specimen's were investigated as comparisons to six native species. Whereas the native species require no additional water in their particular local environment, the *Delonix regia* and *Albizia lebbeck* specimens require considerable amounts of water to survive. On 'Kibbutz Revivim' where these trees were located, trees are generally supplied with between 120 - 200 litres each per week over an approximate period of 40 weeks.[315] [Water is given less frequently in the wetter winter months.] This means that each tree will receive approximately 4800 - 8000 litres (4.8 - 8 cubic metres) per annum. These are considerable amounts when considering the economic and political costs of water use.) An additional benefit would be a reduction in the general maintenance requirements.

7.1.8 In development projects trees are used for various purposes, but an important consideration are their effects on microclimate and in particular their ability to create shade. In order to help promote the use of native tree species, this investigation has been conceived in order to progress beyond the empirical knowledge that the native trees of the Negev create shade and therefore alter microclimate. This investigation uses microclimatic data that has been collected under trees during three field trips to the region during the summers of 1999, 2000 and 2002.[316] This field data was then used with other climatic data from the relevant literature to demonstrate beyond doubt that the native trees of the Negev significantly alter microclimate through their shade output and thus some of the trees are suitable to be used in the landscape for shade purposes.

The Negev Desert and its Trees

7.1.9 There are eleven medium to large sized native tree species that grow unattended by man in the Negev Desert. These include *Acacia gerrardii, Acacia raddiana, Acacia tortilis, Balanites aegyptiaca*, Cordia *sinensis, Moringa peregrina, Phoenix dactylifera, Pistacia atlantica, Populus*

[315] Information from Gil Raviv, Gardener, Kibbutz Revivim, September 2001.

[316] Measured solar radiation data was only collected during the 2002 field trip as previously equipment to record this data was unavailable to the author. This and other equipment was kindly made available by Arup Research and Development, The Ove Arup Partnership, London U.K.

euphratica, Tamarix aphylla and *Ziziphus spina-christi.* Of these eleven species, only seven grow in areas where it appears that perennial ground water is more limited, and where rainfall is between 200 mm and 0 mm per annum. These are: *Acacia gerrardii, Acacia raddiana, Acacia tortilis, Phoenix dactylifera, Pistacia atlantica, Tamarix aphylla* and *Ziziphus spina-christi.*

7.1.10 The investigation of microclimate was undertaken under a specimen of each of six of these seven species. *Phoenix dactylifera,* the date palm, was not assessed. This is because where it is found unattended in the desert 'wilderness' it has a bushy character, without a canopy, unlike the more commonly seen palms whose clear stems have been created by the removal of the palm leaves by man. These nurtured palms may require substantial amounts of water and in landscape schemes in arid areas they may need up to 120 litres of water per day.

7.1.11 The species and their geographical distribution in the Negev, (Appendix J, Figure 4), are as follows: *Acacia gerrardii* is found scattered in the Negev Highlands, the southern Negev and the Arava. *Acacia raddiana* is located in all the Negev regions. *Acacia tortilis* is found mainly in the Arava and in the wadis of the southern Negev where frost doesn't occur. Scattered individuals of *Pistacia atlantica* are established predominantly in the south western parts of the Negev Highlands. *Tamarix aphylla* is found throughout the Negev regions, but mostly in the north and west. *Ziziphus spina-christi* is located thinly spread in the north and all other areas of the Negev.

Trees and Micro-climatic Modification

7.1.12 There are four main ways to modify microclimate in the landscape including desert landscapes. The first looks to the modification of wind. The second is to modify relative humidity. The third is to modify received solar radiation and the final method is to modify terrestrial radiation from the ground and other surfaces.

7.1.13 Trees can have some effect on all four factors, but are most important when it comes to modifying solar radiation and terrestrial radiation from the ground through the creation of shade. Solar radiation is radiation from the sun whilst terrestrial radiation is emitted by objects on earth. (Brown and Gillespie, 1995, page 97)

Trees and Solar Radiation

7.1.14 Trees are an important way of reducing localised solar radiation especially in desert areas. In desert areas, the low atmospheric humidity combined with the absence of clouds permits *'a high proportion of the solar radiation to reach the ground, both in the visible range and in the infra-red'*. (Nielsen, 1979, page 1)

7.1.15 Solar energy arrives on earth over a range of wavelengths: ultraviolet, visible and solar infrared. Ultraviolet wavelengths (10^{-8}m) are too short for our eyes to see and many of these photons are consumed by ozone in the stratosphere. (Brown and Gillespie, 1995, page 46) However, the reduction in ozone in the stratosphere, which has resulted from man's use of chemicals such as chlorofluorocarbons has increased the amount of ultraviolet radiation reaching the earth's surface and for humans and other animals, it can well affect the skin and eyes.. (Brown and Gillespie, 1995, page 47) Most of the solar energy we receive, though, is in the form of visible light and solar infrared. The visible wavelengths or energy, which we term light (10^{-7}m), and which we use to see, is also absorbed by the leaves of plants for photosynthesis. Solar infrared (10^{-5}m) is beyond the red end of the visible light spectrum. Leaves cannot use this for photosynthesis and they therefore reject it via reflection or transmission. However, solar infrared does affect energy budgets. With solar energy a single layer of leaves will generally absorb 80% of incoming visible radiation, whilst reflecting 10% and transmitting 10%. With infrared approximately 20% is absorbed with 50% being reflected and 30% transmitted. More layers of leaves will be more efficient at reducing solar radiation under a tree.. (Brown and Gillespie, 1995, page 47) (Appendix J, Figure 5)

7.1.16 The canopy of a tree creates shade. The shade indicates a reduction in downward energy flow, particularly of visible light and solar infrared. This shade is created by two elements, namely major and minor branching/limbs as well as leaf cover. The percentage of limbs and leaf cover varies from tree species to tree species, from tree to tree within the species and the density of leaf cover also varies from season to season. Thus the amelioration of solar radiation created by a tree is subject to a number of variables.

7.1.17 The solar constant which is the measurement of energy received at the earth's atmosphere is considered to be 1360 W/m^2. (Duffie and Beckman, 1974, page 4). Approximately 50% of this energy passes through the atmosphere and the other 50% is partially absorbed and dispersed and thus approximately 680W/m^2 would reach the ground. In September at 'Sde Boqer' in the Negev, the average 30 day total direct beam radiation on a horizontal plane, (i.e. radiation that passes directly through the atmosphere to reach the earth's surface), averages out over a 12 hour period at 611W/m^2. The maximum observed daily total averages out at 841W/m^2, whilst the maximum observed hourly total averages out at 980W/m^2. (Faiman et al, 1999) In fact, solar radiation can be higher than 1000 W/m^2 as indicated by measurements taken by the author during mid September 2002 when the highest recorded energy level recorded by the author was 1054 W/m^2.[317] The average measured solar radiation received between 08:00 and 15:00 between the 15th and 20th of September 2002, measured by the author was in fact 738W/m^2.[318] Approximately half of this energy is visible light and the other half is solar infrared. (Brown and Gillespie, 1995, page 47). This energy that reaches the ground is absorbed, transmitted or reflected by the ground. Radiation that is reflected will affect energy budgets and thermal

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[317] The measurement of 1054 W/m^2 was recorded at 12:00 hours on 19/09/2002. Similar energy peaks were recorded on the previous day as well.

[318] The average solar radiation has been calculated by averaging the recorded data taken at 08:00, 10:00, 12:00 and 14:00 between the 15th and 20th of September 2002. It should be noted that these readings were taken at different locations and altitudes in the Negev but the location were within 100km of each other.

comfort as will the absorbed radiation. The amount of absorbed energy, which is then emitted, as terrestrial radiation, is a function of the temperature of the object. (Brown and Gillespie, 1995, page 98) By blocking incoming solar radiation the branches and leaves of a tree directly reduces the energy reaching the ground, thereby reducing temperature and long wave radiation from the ground. This reduction in solar radiation and terrestrial radiation is indeed important when one considers that the

> *'combined heat load from air, sun and ground may become so great that it exceeds by a factor of 10 the metabolic heat production of a man'.*
> (Nielsen, 1979, page 1)

7.2 Materials and Methods of the Field Observations and Desk Top Study

General Methods: Timing, Locations and Measurements

7.2.1 Field observations were carried out during the first two weeks of September 1999 and the second and third weeks of September 2000 and 2002. These periods are at the end of summer and are prior to the autumn and winter rains. This means that the trees would have endured a long hot summer period without any rainfall since the winter, and that the density of the tree canopy would not be affected dramatically by any new dense foliage growth. The microclimatic effects under the tree were thus measured when the tree canopy was least effective. (In springtime and the beginning of summer, after the winter rains, leaf cover is considerably more extensive and the microclimatic changes should thus be greater.) The period was also chosen as it is usually hot with maximum day temperatures in the mid to high 30° centigrade.

7.2.2 The trees that were assessed were all mature specimens except for the *Ziziphus spina-christi* as a mature specimen of this species could not be readily found growing in accessible and/or natural conditions. The location of the individual tree specimens was chosen according to prior knowledge gained through previous surveys of where these specimens were available in natural/semi-natural conditions. (Appendix J, Figure 6) The *Acacia* *gerrardii* and *Acacia raddiana* specimens were assessed in a wadi on the edge of the 'Maktesh Ramon', (Ramon Crater), between the hills called 'Har Afor' and 'Har Marpek', at an elevation of approximately 500m above sea level at 30° 35' N, 34° 54' E. *Acacia tortilis* was assessed at 'Nachal Hazeva' in the Arava valley, near Route 90 at approximately -105 metres below sea level at 30° 49' N, 35° 15' E. The *Pistacia atlantica* specimen was assessed at a location near 'Bor Hemet', (Hemet's Well), south east of the town of 'Mizpe Ramon', along Route 171, at an elevation of approximately 850 metres above sea level in the hills of the Negev Highlands, at 30° 35' N, 34° 42' E. The *Tamarix aphylla* specimen was studied in a loessal valley of the northern Negev, directly north of the 'Mashabim' road junction on Route 40 and immediately opposite the road junction to 'Kibbutz Mashabe Sade' at 31° 0.5' N, 34° 46' E at approximately 350 metres above sea level. *Ziziphus spina-christi* was assessed on the route to 'Maale Akrabim' in the hills overlooking the 'Arava' at 30° 55' N and 35° 9' E, approximately 450 metres above sea level.

7.2.3 During 2002, the shade of two exotic tree species were assessed in order to make a comparison between the shade of these species and the shade of the six Negev trees. These trees, a *Delonix regia* specimen and a *Albizia lebbeck* specimen are located on 'Kibbutz Revivim', at 31° 0.5' N, 34° 46' E at approximately 280 metres above sea level. They were chosen because both species are well used in arid developments. (Appendix J, Figure.6) The trees are semi-mature in size and they were found growing in uncultivated but irrigated ground. (There would have been little point in recording data of trees growing within turf or other planted areas.)

7.2.4 The micro climatic assessment of the trees was undertaken between 31 August 1999 and 6 September 1999 and between the 11th and the 19th of September 2000 and the 15th and 20th September 2002. The measurements were taken at 2 hourly intervals commencing at 08:00 with the last measurement taken at approximately 15:00. Each set of measurements took approximately one hour to accomplish. Measurements were taken under the tree canopies along the main compass points, namely: north, south, east and west, although some measurements e.g. lux and tree dimensions were taken at the intermediate points, namely south east, south west, north east and north west as well. The measurements were taken immediately within the tree canopy as well as adjacent to the tree trunk. Thus 8 measurements were taken under the canopy of each tree for each microclimatic issue, four times a day. Where necessary, measurements were also taken outside of the tree canopy to compare with the measurements within the canopy. (Appendix J, Figure .7)

7.2.5 Although trees will decrease short wave solar radiation under the canopy, trees will increase long wave radiation *'as trees and other shading objects are better emitters of long wave radiation than the sky'*. (Brown and Gillespie, 1995, page 59) However, the net result is a decrease in total radiant energy input as the additional long wave radiation is 'usually overwhelmed by the large decrease achieved' in solar radiation. (Brown and Gillespie, 1995, page 54) As this study is considering the differences between radiation in the shade, compared to that in the sun, long wave radiation from the trees is not considered an important consideration although long wave radiation emitted from the ground is considered to be important and has thus been investigated.

Solar Radiation

7.2.6 Solar Radiation was calculated according to two methods. In the first instance a mathematical model was used which illustrates a pattern in the reduction of solar radiation caused by the tree canopy. This methodology thus only gives a general understanding of the reduction of solar radiation by the trees, as the variables are numerous.

7.2.7 In the second instance, particular solar radiation data was recorded underneath and beyond the trees during 2002 using a pyranometer and data logger. This data is thus specific to the individual trees investigated at particular moments in time. Using the two methods allows for a partial comparison of the calculated data to the real data collected during the 2002 field trip.

Mathematical Modelling

7.2.8 With regard to calculating solar radiation mathematically, at ''Sde Boqer' in the Negev, the average 30 day total beam radiation on a horizontal plane averages out at $611 W/m^2$ and the maximum averages out at $841 W/m^2$, whilst the maximum observed hourly total averages out at $980W/m^2$.[319] Although the maximum averages and maximum daily totals are over $200\text{-}350W/m^2$ higher than the average 30 day total of $611W/m^2$, the average of $611W/m^2$ has been used to calculate changes in solar radiation under the trees, as the change in energy in W/m^2, caused by the tree canopy, should remain the same.

7.2.9 Approximately 50% of this $611W\ m^2$ of incoming radiation is light, and the other 50% is solar infrared which cannot be seen. Leaves generally transmit approximately 10% of visible light and 30% of infrared. (Faiman D. et al.) (Appendix J, Figure 5). As far as visible light is concerned, if the canopy of a tree has approximately 60% branching,[320] (as did the *Pistacia atlantica* specimen), this means that 60% of 50% of the beam radiation, i.e. of $611W/m^2$, is intercepted, absorbed and/or reflected. Thus this causes 40% of 50% of $611W/m^2$, which is $122.2W/m^2$ to reach the ground. If the density of the canopy is further extended by the leaves of a tree canopy by say 10%, (in

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[320] The approximate density of branching and leaf cover has been calculated by projecting a positive colour image onto graph paper, which is defined overall by one centimetre square grid. (Appendix I, Figure 7) This grid is further broken up into 10ths so that each one centimetre grid is divided into 100 millimetre squares. The branching and leafs are then marked in separate colours on the this fine grid and the coloured grids are then counted as a percentage of the whole to determine the percentage of branching and leaves in contrast to open sky. (It is noted that this method only approximates the percentages and that different parts of the tree and indeed different trees within the species have variations in leaf and branch percentages.)

a dry period), then this should reduce that part of the direct visible energy from the sun passing through the leaves by approximately 90% for one layer of leaves. (Brown and Gillespie, 1995, page 48) We thus have to subtract this radiation, which is being blocked by the leaves. This makes the energy received on the ground equal to 40% of 50% of beam radiation minus 90% of 10% of the visible radiation intercepted by leaves which as far as visible light is concerned is half of the 611W/m^2, which is 305.5W/m^2. In other words the visible radiation is 611W/m^{2}x50% x 40% minus 90% of 10% of 305.5W/m^2. Similarly, infrared radiation can be calculated as 40% x 50% of 611W/m^2 minus 70% of 10%, (the amount of infrared blocked by the leaf is 70%), of 305.5W/m^2 of infrared as follows:

{40/100(50/100x611) - 90/100(10/100x305.5)}visible light +
{40/100(50/100X611) - 70/100(10/100x305.5)}infrared

={122.75 - 27.5} + {122.2 - 21.4}

=94.7+ 100.8

=195.5W/m2

7.2.10 196W/m^2 is thus the approximate direct beam energy received by one square metre under a tree at 'Sde Boqer' in September with 60% branching and 10% leaf cover on a hot cloudless summer's day. The average energy falling on one square metre beyond the tree's canopy is approximately 611W/m^2 and thus the calculated beam radiation energy on one square metre under the tree is approximately 32% of the direct beam radiation on one square metre beyond the canopy zone. This means that 68% of the direct beam radiation is blocked. A person under a tree would however receive more energy because of terrestrial long wave radiation emitted from other objects, notably from the sky, the tree's branches and leaves, and particularly terrestrial long wave radiation from the ground. However, the reduction in direct beam solar radiation of nearly 70% is highly significant.

Data Collection

7.2.11 It is evident from the direct solar radiation data collection that reductions in solar radiation can be greater than the 68% highlighted above. Indeed, up to

95% reductions may be found in areas of shade caused by greater branching density and particularly in the areas in the shade of or close to the tree trunk. Solar radiation was measured under the trees using a pyranometer. (During the September 2002 data collection, solar radiation data was collected in W/m^2 using a Kipp & Zonen pyranometer and a Solrad CM3/C20 data logger.)

Ground Temperature and Long Wave Radiation from the Ground

7.2.12 Radiated heat from the ground is an important addition to the microclimate and heat budget. Solar beam and other diffuse radiation heats up the ground and this in turn emits long wave radiation which heats up objects as well as people above the ground. As discussed above, the canopy of a tree may significantly reduce the solar radiation reaching the ground below the tree and the temperature of the ground will thus be reduced in the shaded areas. Therefore there will be concomitant reductions in long wave radiation from the ground under the tree when compared to the long wave radiation emitted from the hotter ground beyond the tree canopy, i.e. in the direct sun.

7.2.13 The temperature of the ground and the resulting long wave radiation is however affected by the soil makeup and the colour of the ground (albedo). Brown and Gillespie (Brown and Gillespie, pages 51 and 52), illustrate how the Stefan and Boltzmann equation can be used to calculate the energy output from the temperature of the ground. This equation states that Energy $= S \times (T+273)^4$. When energy is measured in Watts per square metre the linking number S as 5.67×10^{-8} is used. (T = ground temperature.) For 'real life' results the theoretical findings should be tempered by including emissivity factors for the kind of ground. Taking an emissivity value of 90% for dry sandy soils, which is typical of the soils found in the desert regions where the study took place, Energy $= (0.9)\, S \times (T+273)^4$. (Brown and Gillespie, pages 48 to 53) Brown and Gillespie point out that the emissivity factor for surfaces in the landscape are mostly greater than 0.9. (Brown and Gillespie, page 52)

7.2.14 Thus for example if the ground temperature is 30^0C then using the Stefan and Boltzmann equation the calculation will be as follows:

$$Energy=(0.9)(5.67 \times 10^{-8}) \times (30+273)^4$$

$$=(0.9)(478)$$

$$=430W/m^2$$

7.2.15 (During the 1999 and 2000 field trips, ground temperature was measured using a 'Protimeter' with a fast response surface thermometer featuring a low thermal mass stainless steel ribbon. Measurements were taken in degrees centigrade. Variations within 1/10th of a degree were measurable within a range of -50°C to 100°C. Ground temperature in 2002 was measured using a HI 98704 Portable microprocessor K-J-T and a Thermocouple Thermometer by Tempcon Instrumentation Ltd.)

Shade and Lux

7.2.16 The intensity of light and shade was measured as shade denotes a diminution in solar radiation light waves. The diminution in visible solar energy from the sun caused by obstruction by an object, which is shade, is an important comfort factor for people. People also seek and use shade because the light intensity and glare is reduced which eases strain on the eyes. This reduction also has an effect on reducing the reflection of light from the ground, further reducing glare and increasing human comfort. If glare is present, *'the eye strains to see objects through the glare'*. (Texas Association of Retinitis Pigmentosa web site) The physical reactions caused are to the eye and the surrounding muscles and over time this can cause eye-fatigue as well as *'diminish visual functioning at the time'* (Texas Association of Retinitis Pigmentosa web site)

7.2.17 The shade characteristics of each tree depends on the form of the canopy and branching of the species, as well as the individual characteristics of the individual tree within the species, where it is growing, the amount of leaf cover and the angle of the sun. (Appendix J, Figures 7, 8 and 9)

7.2.18 (During 1999 and 2000, a hand held incident light meter was used to measure lux. (Sekondia Flashmate L-308811) This was held at chest height, approximately 1.5 metres above the ground. The light was recorded and then recalculated as lux using the unit's calculation tables. During 2002 a

Megatron Lux-DA10 light meter was used.)

Air Temperature

7.2.19 Robert Brown and Terry Gillespie state that although, thermal comfort is due to the influence of air temperature as well as solar radiation, air is usually efficiently mixed so that although there are differences in temperature with height above the ground there are virtually no horizontal differences. (Brown and Gillespie, page 140) Brown and Gillespie state furthermore that any differences are likely to be dissipated very quickly by air movement. Air temperature under and beyond the tree canopy was recorded but is thus not included, as the temperature differences are nominal.

7.2.20 (Air temperature was measured using a double insulated and aspirated 'Protimeter Condensator II' instrument, with a probe built within a low thermal conductivity carbon fibre tube, in degrees centigrade. The Protimeter instrument measures variations within 1/10th of a degree were within a range of -20°C and 60°C. The measurements were checked against a maximum/minimum thermometer, which was placed in the shade on the north side of each tree.)

Relative Humidity

7.2.21 Relative humidity is also an important microclimatic factor but as with air temperature any differences in humidity are quickly dissipated by air movement and thus do not form part of this study. *'The humidity in any part of a landscape is very likely to be nearly identical to the humidity anywhere else in the landscape'*. (Brown and Gillespie, page 69 and 139)

7.2.22 (Relative humidity was recorded as part of the data collection. Relative humidity was measured using the double insulated and aspirated 'Protimeter Condensator II' instrument with a probe built within a low thermal conductivity carbon fibre tube. Variations within 1/10th of 1% were measurable within a range of 1% to 99%.)

Sun Position and Angles and Tree Canopy and Shade Characteristics

7.2.23 Approximate sun angles and positions were recorded for each set of measurements throughout the day. The approximate tree canopy and shape were also measured and plotted as well as the approximate shade pattern at each time of measurement. (Appendix J, Figures 8 and 9) This allows for an understanding of the effects of microclimate change under and beyond the canopy of the tree. For example, some ground temperature measurements under the tree canopy are similar to those beyond the tree canopy. This can result from two factors:

- Either the angle of the sun is low and the sun's rays pass under the tree canopy onto the ground below the tree canopy and/or
- The canopy of the tree is not uniformly dense and gaps in the canopy allow the energy of the sun to pass directly onto areas of ground below the canopy of the tree. (Appendix J, Figure 8) The shade characteristics of each tree thus depends on the form of the canopy and branching of the species, as well as the individual characteristics of the individual tree within the species, where it is growing, the amount of leaf cover and the angle of the sun.

7.2.24 At 08:00 winter time and 09:00 summer time, the altitude of the sun above the horizon was approximately 35° above the eastern horizon with an azimuth of 90°. (Note azimuth notation is as follows: north = 360°, east = 90°, south = 180° and west = 270°.) At 10:00 winter time and 11:00 summer time, the altitude of the sun was approximately 55° above the horizon in an east south easterly direction with an azimuth of approximately 110°. At 12:00 winter time and 13:00 summer time the altitude of the sun was approximately 70° above the horizon in the south east with an azimuth of approximately 140°.

7.2.25 At 14:00 winter time and 15:00 summer time the sun's altitude was approximately 75° above the horizon in a southerly direction with an azimuth of approximately 200°. The effect of the elevation of the sun means that the tree's shadow is more elongated when the sun is lower in the sky and is smaller and more compact as the sun rises higher above the horizon. This affects the extent of shade and the microclimatic influence under and away from the tree, although in this particular study the influences were only recorded within the canopy of the tree. However, it must be noted that due to the angle of the sun as well as gaps in the canopy some parts of the areas under the tree would be in direct/partial sunlight. (Appendix J, Figure 8 and 9)

Other Information

7.2.26 Information regarding the dimensions and form of the tree and surface soil makeup were recorded. Wind speed measurements were also recorded during the 1999 and 2000 field trips using an AVM 500 velocity meter using a thermistor bead heated element. Photographs of the tree, its canopy, its branching and leaf characteristics and its shade were taken at 14:00 hours in 1999 and at other times of the day during the 2000 and 2002 surveys.

7.3 Results of the Study

7.3.1 The following results are noted in nine tables, i.e. one for each tree specimen, one each for the two control species and a summary table of all the results. (See Tables in Appendix J, Tables 1 to 9) (For the form of tree canopy and shade for each individual specimen see Appendix J, Figures 6 and 7.)

Solar Radiation

Mathematical Modelling Method

7.3.2 By utilising the data regarding the canopy densities of the trees with the mathematical model for calculating solar radiation, we see an average 55% reduction in solar radiation under the investigated native trees in the Negev Desert. The average reduction for the two control specimens was 57%, which is similar to the reductions for the six native species. The greatest reductions were found under the *Pistacia atlantica* and *Tamarix aphylla* specimens as they had the greatest density of branching and leaf cover. The reductions in solar radiation were in the order of 415W/m^2, which is 68% of the incoming direct beam solar radiation.

7.3.3 The densities of the branch and leaf cover for each specimen of the species were assessed to be approximately as follows: (See Appendix J Figures 6 and 7)

Acacia gerrardii:	50% branches, 5% leaf cover.
Acacia raddiana:	50% branches, 1% leaf cover.
Acacia tortilis:	50% branches, 1% leaf cover.
Pistacia atlantica:	60% branches, 10% leaf cover.
Ziziphus spina-christi:	20% branches, 25% leaf cover.
Tamarix aphylla:	20% branches, 60% leaf cover.

Control Specimens

Delonix regia:	5% branches, 70% leaf cover.
Albizia lebbeck:	5% branches, 60% leaf cover.

7.3.4 It must be noted that the above percentages are approximate only, as the density of branching and leaf cover will not only vary amongst individual specimens within the given species but this density varies within the canopy of the tree itself. The density of branching and leaf cover has been assessed by the method described in the section on Materials and Methods immediately above.

7.3.5 The reductions in solar radiation for each specimen has been calculated using the average figure of 611W/m^2 beam radiation for Sde Boqer in September, combining this with the density of branch and leaf cover as described in the section on Methods and Materials above.

Data Collection Method

7.3.6 Using the data collected on site with the pyranometer, the average solar radiation measured in the deepest shade for the six trees is 10.5% of the average solar radiation measured beyond the influence of the tree canopies. This means that there is an average reduction of approximately 90% in the deepest shade. This was similarly the case with the two 'exotic' control specimens. The greatest reductions were identified with *Pistacia atlantica* as this tree had the largest trunk girth of 2.23 metres, which created a very dense shade. Lesser reductions are found with the specimens investigated with less robust trunks as well as in areas under the trees where branching and leaf cover is less dense.

The Results

Native Specimens

Acacia gerrardii (See Appendix J, Table 1 and Figure 7)

Mathematical Modelling Method

7.3.7 With 50% branching and 5% leaf cover, visible radiation is reduced to 139W/m^2 and infrared radiation to 142W/m^2, which gives an approximate total of 281W/m^2, which reaches the ground. This is approximately 46% of the beam solar radiation received per square metre beyond the canopy of the tree. Thus in theory, 1 m^2 under the tree would receive approximately 54% less direct beam solar radiation as 54% is blocked by the branches and the leaves.

Data Collection Method

7.3.8 Analysis of the solar radiation data collected shows an average maximum radiation of 816W/m^2 beyond the influence of the tree and an average of 105W/m^2 within the shadiest parts of the tree. This means that there is an average 87% reduction. Or in other words the radiation reaching the shadiest parts of the ground under the tree is 12% of the total average direct beam radiation beyond the canopy of the tree.

Acacia raddiana (See Appendix J, Table 2 and Figure 7)

Mathematical Modelling Method

7.3.9 With 50% branching and 1% leaf cover, visible radiation is reduced to 150W/m^2 and infrared radiation to 151W/m^2, which gives an approximate total of 301W/m^2, which reaches the ground. This is approximately 49% of the beam solar radiation received per square metre beyond the canopy of the tree. Thus in theory, 1 m^2 under the tree would receive approximately 51% less direct beam solar radiation as 51% is blocked by the branches and the leaves.

Data Collection Method

7.3.10 Analysis of the solar radiation data collected shows an average maximum radiation of 825W/m^2 beyond the influence of the tree and an average of

119W/m^2 within the shadiest parts of the tree. This means that there is an average 86% reduction. Or in other words the radiation reaching the shadiest parts of the ground under the tree is 14% of the total average direct beam radiation beyond the canopy of the tree.

Acacia tortilis (See Appendix J, Table 3 and Figure 7)

Mathematical Modelling Method

7.3.11 As the *Acacia tortilis* specimen had similar branching and leaf cover percentage as the *Acacia raddiana* specimen, i.e. 50% branching and 1% leaf cover the reductions are similar and indicate approximately 51% less direct beam solar radiation. Visible radiation is reduced to 150W/m^2 and infrared radiation to 151W/m^2, which gives an approximate total of 301W/m^2, which reaches the ground.

Data Collection Method

7.3.12 Analysis of the solar radiation data collected shows an average maximum radiation of 788W/m^2 beyond the influence of the tree and an average of 78W/m^2 within the shadiest parts of the tree. This means that there is an average 90% reduction. Or in other words the radiation reaching the shadiest parts of the ground under the tree is 10% of the total average direct beam radiation beyond the canopy of the tree.

Pistacia atlantica (See Appendix J, Table 4 and Figure 7)

Mathematical Modelling Method

7.3.13 With 60% branches and 10% leaf cover, visible radiation is reduced to 95W/m^2 and infrared radiation to 101W/m^2, which gives an approximate total of 196W/m^2, which reaches the ground. This is a significant 32% of the solar radiation received per square metre beyond the canopy of the tree. In other words, 1m^2 under the tree would receive 67% less direct beam solar radiation as 67% is blocked by the branches and the leaves.

Data Collection Method

7.3.14 Analysis of the solar radiation data collected shows an average maximum radiation of 735W/m^2 beyond the influence of the tree and an average of

80W/m^2 within the shadiest parts of the tree. This means that there is an average 89% reduction. Or in other words the radiation reaching the shadiest parts of the ground under the tree is 11% of the total average direct beam radiation beyond the canopy of the tree.

Tamarix aphylla (See Appendix J, Table 5 and Figure 7)

Mathematical Modelling Method

7.3.15 With 20% branches and 60% leaf cover, visible radiation is reduced to 79W/m^2 and infrared radiation to 116W/m^2, which gives an approximate total of 195W/m^2, which reaches the ground. This is a significant 32% of the solar radiation received per square metre beyond the canopy of the tree. In other words, 1m^2 under the tree would receive 68% less solar beam radiation as 68% is blocked by the branches and the leaves. (In fact, this may be more as the dense needle shaped character of the leaves and the close bunching of the needles of the Tamarix may act more like branching than normal leaves in their transmission of solar radiation, giving an even greater decrease in solar radiation.)

Data Collection Method

7.3.16 Analysis of the solar radiation data collected shows an average maximum radiation of 709W/m^2 beyond the influence of the tree and an average of 79W/m^2 within the shadiest parts of the tree. This means that there is an average 89% reduction. In other words the radiation reaching the shadiest parts of the ground under the tree is 11% of the total average direct beam radiation beyond the canopy of the tree.

Ziziphus spina-christi (See Appendix J, Table 6 and Figure 7)

Mathematical Modelling Method

7.3.17 With 20% branches and 25% leaf cover, visible radiation is reduced to 175W/m^2 and infrared radiation to 191W/m^2, which gives an approximate total of 366W/m^2, which reaches the ground. This is 60% of the solar radiation received per square metre beyond the canopy of the tree. In other words, 1m^2 under the tree will receive 40% less direct beam solar radiation as the branches and the leaves block 40%.

Data Collection Method

7.3.18 Analysis of the solar radiation data collected shows an average maximum radiation of 780W/m^2 beyond the influence of the tree and an average of 128W/m^2 within the shadiest parts of the tree. This means that there is an average 84% reduction. Or in other words the radiation reaching the shadiest parts of the ground under the tree is 16% of the total average direct beam radiation beyond the canopy of the tree.

The Results

Control Specimens

Delonix regia (See Appendix J, Table 7 and Figure 7)

Mathematical Modelling Method

7.3.19 With 5% branches and 70% leaf cover, visible radiation is reduced to 98W/m^2 and infrared radiation to 141W/m^2, which gives an approximate total of 238W/m^2, which reaches the ground. This is 39% of the solar radiation received per square metre beyond the canopy of the tree. In other words, 1m^2 under the tree will receive 61% less direct beam solar radiation as 61% is blocked by the branches and the leaves.

Data Collection Method

7.3.20 Analysis of the solar radiation data collected shows an average maximum radiation of 694W/m^2 beyond the influence of the tree and an average of 88W/m^2 within the shadiest parts of the tree. This means that there is an average 87% reduction. Or in other words the radiation reaching the shadiest parts of the ground under the tree is 13% of the total average direct beam radiation beyond the canopy of the tree.

Albizia lebbeck (See Appendix J, Table 8 and Figure 7)

Mathematical Modelling Method

7.3.21 With 5% branches and 60% leaf cover, visible radiation is reduced to 125W/m^2 and infrared radiation to 162W/m^2, which gives an approximate total of 287W/m^2, which reaches the ground. This is 47% of the solar radiation received per square metre beyond the canopy of the tree. In other words, $1m^2$ under the tree will receive 53% less direct beam solar radiation as 5 3% is blocked by the branches and the leaves.

Data Collection Method

7.3.22 Analysis of the solar radiation data collected shows an average maximum radiation of $706W/m^2$ beyond the influence of the tree and an average of $119W/m^2$ within the shadiest parts of the tree. This means that there is an average 83% reduction. Or in other words the radiation reaching the shadiest parts of the ground under the tree is 17% of the total average direct beam radiation beyond the canopy of the tree.

Lux and Shade

7.3.23 The data recorded under the canopies of the 6 individual native tree specimens of the different species shows that there is a significant difference in the light intensity, measured in lux, between the shade and areas under and beyond the canopy of the trees which are in full sunlight. This difference is comparable to the differences measured under the two control species. The average difference between lux in direct sunlight and lux in the deepest shade for the native species for the 2002 field trip is 62331 lux, between 0800-16:00. Similarly, the average difference between lux in direct sunlight and lux in the deepest shade for the control species is 57250 lux, between 0800-16:00. The deepest shade measured over the field trips was 4000 lux, whilst the brightest sunshine was measured at 104,800 lux.

7.3.24 The average maximum difference in lux for all 6 species over the day, between the sun and the shade is a significant 74666lux. (The average maximum difference for the control species is 69500 lux.) The measurement of lux in the full sun in mid September ranged from 72 000 to 104 000 lux depending on location and time of day. The light intensity measured within full shade ranged from 5520 to 18000 lux. The difference in light quantity is thus very considerable.

7.3.25 Even under the species such as the *Ziziphus spina-christi* and the *Acacia* species where branch and leaf cover of the canopy were only in the order of

45% to 50%, the lux measurements in the deepest shade were more than 10 times less than areas in the sun.

7.3.26 The average differences between lux beyond the influence of the tree canopy, i.e. in the direct sunlight and lux in the deepest shade below the trees canopy for each species specimen is as follows:

Native Species		All tables in Appendix J
Acacia gerrardii	64500 lux	(See Tables 1 and 9)
Acacia raddiana	65625 lux	(See Tables, 2 and 9)
Acacia tortilis	64533 lux	(See Tables 3 and 9)
Pistacia atlantica	54750 lux	(See Tables 4 and 9)
Tamarix aphylla	63250 lux	(See Tables 5 and 9)
Ziziphus spina-christi	61333 lux	(See Tables 6 and 9)
Control Species		
Delonix regia	57875 lux	(See Tables 7 and 9)
Albizia lebbeck	56625 lux	(See Tables 8 and 9)

Ground Temperature and Long Wave Radiation from the Ground

7.3.27 Taking the data from the 2002 field surveys, the Stefan and Boltzmann equation has been used to calculate the energy output from the temperature of the ground as illustrated in the 'Materials and Methods' section above.

Native Species

Acacia gerrardii (See Appendix J, Tables 1 and 9)

7.3.28 The average of the lowest ground temperatures between 08:00 and 15:00 within the tree canopy was 25.9^{0}C whilst the lowest ground temperature within the tree canopy over the whole period was 20.5 ^{0}C. The overall average ground temperature within the tree canopy was 30.7^{0}C. In contrast the average ground temperature recorded between 08:00 and 15:00 beyond the influence of the tree canopy was 37.4.8^{0}C, whilst the highest recorded ground temperature was 45.5^{0}C. This means that there is an average difference of 7.4^{0}C between ground temperatures of areas under the tree compared to areas beyond the tree canopy. However, the greatest difference in ground temperature within the tree canopy compared to beyond the tree canopy occurred during the period 14:00-15:00. This 16.6^{0}C difference occurred where the temperature beyond the tree canopy was 45.5^{0}C and the lowest within the tree canopy was 28.6^{0}C. (During 2000 the difference measured was even greater at 20.3^{0}C.)

7.3.29 Using the Stefan and Boltzmann equation the following conversions to energy are as follows. At 25.9^{0}C, (the average of the lowest ground temperatures), the average energy radiating from the ground under the tree is 407W/m^2. At 20.5^{0}C, (the lowest ground temperature recorded within the tree canopy over the whole period), the energy radiating from the coolest ground under the tree is 379W/m^2. At 37.9^{0}C, which is an average of the ground temperatures recorded beyond the tree canopy, the energy radiating from the ground beyond the influence of the tree is 476W/m^2, whilst at 45.5.9^{0}C which is the maximum temperature recorded beyond the tree canopy the energy radiating from the ground is 525W/m^2. Between 08:00 and 15:00, the average difference in long wave energy from the ground under the canopy, (average 30.7^{0}C/434W/m^2), compared to beyond the canopy, (average 37.9^{0}C/476W/m^2), is 42W/m^2, whilst the difference between the most protected parts under the canopy, averaging at 25.9^{0}C/407W/m^2, and the areas in full sun, averaging at 37.9^{0}C/476W/m^2, is 69W/m^2. However, the greatest difference in long wave energy from the ground between areas beyond and within the tree canopy which was recorded between 14:00 and 15:00 when the outside ground temperature was at its highest (45.5^{0}C/525W/m^2) to the lowest, (28.9^{0}C/424W/m^2) in the shade at the same time results in a diminution in energy under the tree of 101 W/m^2.

<u>Acacia raddiana</u> (See Appendix J, Tables 2 and 9)

7.3.30 The average of the lowest ground temperatures recorded between 08:00 and 15:00 within the tree canopy was 26.9^{0}C whilst the lowest ground temperature recorded within the tree canopy over the whole period was

22.0^{0}C. The overall average ground temperature within the tree canopy was 31.3 ^{0}C. In contrast the average ground temperature between 08:00 and 15:00 recorded beyond the influence of the tree canopy was 39.2^{0}C, whilst the highest recorded ground temperature recorded beyond the tree was 47.9^{0}C. This means that there is an average difference of 7.9^{0}C between ground temperatures of areas under the tree compared to areas beyond the tree canopy. However, the greatest difference in ground temperature within the tree canopy compared to beyond the tree canopy occurred during the period 14:00-15:00. This 18.6^{0}C difference occurred where the temperature beyond the tree canopy was 47.9^{0}C and the lowest within the tree canopy was 29.3^{0}C.

7.3.31 Using the Stefan and Boltzmann equation the following conversions to energy are as follows. At 28.6^{0}C, (the average of the lowest ground temperatures), the average energy radiating from the ground under the tree is 413W/m^2. At 22.0^{0}C, (the lowest ground temperature recorded within the tree canopy over the whole period), the energy radiating from the coolest part of the ground is 386W/m^2. At 39.2^{0}C, which is an average of the highest ground temperatures recorded beyond the tree canopy, the energy radiating from the ground beyond the influence of the tree is 485W/m^2, whilst at 47.9^{0}C, which is the maximum recorded ground temperature beyond the tree canopy the energy radiating from the ground is 541W/m^2. Between 08:00 and 15:00, the average difference in long wave energy from the ground under the canopy, (average 31.3^{0}C/438W/m^2), compared to the ground beyond the canopy, (average 39.3^{0}C/489 W/m^2), is 51W/m^2 whilst the difference between the most protected parts under the canopy, (average 26.9/413W/m^2), and the areas in full sun, (average 39.2/485) is 72W/m^2. However, the greatest difference in long wave energy from the ground between areas beyond and within the tree canopy which was recorded between 14:00 and 15: 00 when the outside ground temperature was at its highest (47.9^{0}C/541W/m^2) to the lowest, (29.3^{0}C/426W/m^2) in the shade at the same time results in a diminution in energy under the tree of 115 W/m^2.

__Acacia tortilis__ (See Appendix J, Tables 3 and 9)

7.3.32 The average of the lowest ground temperatures between 08:00 and 15:00

within the tree canopy was 29.1°C whilst the lowest ground temperature within the tree canopy over the whole period was 28.1°C. The overall average ground temperature within the tree canopy was 36.0°C. In contrast the average ground temperature recorded between 08:00 and 15:00 beyond the influence of the tree canopy was 43.7°C, whilst the highest ground temperature recorded was 48.7°C. This means that there is an average difference of 7.7°C between the average ground temperatures of areas under the tree compared to the average temperatures of areas beyond the tree canopy. However, the greatest difference in ground temperature within the tree canopy compared to beyond the tree canopy occurred during the period 12:00-13:00. This 15.9°C difference occurred where the temperature beyond the tree canopy was 49.2°C and the lowest within the tree canopy was 33.3°C.

7.3.33 Using the Stefan and Boltzmann equation the following conversions to energy are as follows. At 31.8°C, (the average of the lowest ground temperatures), the average energy radiating from the ground under the tree is 425W/m^2. At 28.1°C, (the lowest ground temperature recorded within the tree canopy over the whole period), the energy emitted from the coolest part of the ground under the tree is 419W/m^2. At 43.7°C which is the average temperature recorded beyond the tree canopy, the average energy radiating from the ground beyond the influence of the tree is 513W/m^2, whilst at 49.2°C, which is the maximum recorded ground temperature beyond the tree canopy the energy emitted is 550 W/m^2. Between 08:00 and 15:00, the average difference in long wave energy of the ground under the canopy (average 36.0°C/465 W/m^2), compared to the ground beyond the canopy, (average 42.3°C/504 W/m^2) is 39W/m^2 whilst the difference between the most protected parts under the canopy, (average 29.1°C/425 W/m^2) and the areas in full sun beyond the tree canopy, (average 43. 7°C/513 W/m^2), is 88 W/m^2. However, the greatest difference in long wave energy from the ground between areas beyond and within the tree canopy which was recorded between 12:00 and 13:00 when the outside ground temperature was at its highest (49.2°C/550W/m^2) and the lowest, (28.1°C/419 W/m^2) in the shade at the same time results in a diminution in energy under the tree of 131

W/m^2.

__Pistacia atlantica__ (See Appendix J, Tables 4 and 9)

7.3.34 The average of the lowest ground temperatures between 08:00 and 15:00 within the tree canopy was 27.8^{0}C whilst the coolest ground temperature within the tree canopy over the whole period was 24.6^{0}C. The overall average ground temperature within the tree canopy was 33.5^{0}C. In contrast the average ground temperature recorded between 08:00 and 15:00 beyond the influence of the tree canopy was 42^{0}C. This means that there is an average difference of 14.2^{0}C between the average ground temperatures of areas under the tree compared to the average temperature of areas beyond the tree canopy. However, the greatest difference in ground temperature within the tree canopy compared to beyond the tree canopy occurred during the period 12:00-13:00. This 20.4^{0}C difference occurred where the temperature beyond the tree canopy was 50.2^{0}C and the lowest temperature within the tree canopy was 29.8^{0}C.

7.3.35 Using the Stefan and Boltzmann equation the following conversions to energy are as follows. At 27.8^{0}C, (the average of the lowest ground temperatures), the average energy radiating from the ground under the tree is 418W/m^2. At 24.6^{0}C, (the lowest ground temperature recorded within the tree canopy over the whole period), the energy emitted from the coolest part of the ground under the tree is 400W/m^2. At 42^{0}C, which is the average temperature recorded beyond the tree canopy, the average energy radiating from the ground beyond the influence of the tree is 502W/m^2, whilst at 50.2^{0}C, which is the maximum recorded ground temperature beyond the tree canopy the energy emitted is 557W/m^2. Between 08:00 and 15:00, the average difference in long wave energy of the ground under the canopy, (average 33.5^{0}C/450W/m^2), compared to the ground beyond the canopy, (average 42^{0}C/502W/m^2), is 52 W/m^2, whilst the difference between the most protected parts under the canopy, (average 27.8^{0}C/418W/m^2), and the areas in full sun beyond the tree canopy, (average 42^{0}C/502W/m^2), is 84W/m^2. However, the greatest difference in long wave energy from the ground between areas beyond and within the tree canopy which was recorded between 12:00 and 13:00 when the outside ground temperature was at its highest, (50.2^{0}C/557W/m^2), and the lowest, (29.8^{0}C/429W/m^2), in the shade, at the same time results in a diminution in energy under the tree of 128W/m^2.

__Tamarix aphylla__ (See Appendix J, Tables 5 and 9)

7.3.36 The average of the recorded lowest ground temperatures between 08:00 and 15:00 within the tree canopy was 28.5^{0}C whilst the lowest ground temperature within the tree canopy over the whole period was 23^{0}C. The overall average ground temperature within the tree canopy was 33.8^{0}C. In contrast the average ground temperature recorded between 08:00 and 15:00 beyond the influence of the tree canopy was 43.8^{0}C, whilst the highest recorded ground temperature was 51.4^{0}C. This means that there is an average difference of 10^{0}C between ground temperatures of areas under the tree compared to areas beyond the tree canopy. However, the greatest difference in ground temperature within the tree canopy compared to beyond the tree canopy occurred during the period 12:00-13:00. This 22.4^{0}C difference occurred where the temperature beyond the tree canopy was 51.4^{0}C and the lowest within the tree canopy was 29^{0}C.

7.3.37 Using the Stefan and Boltzmann equation the following conversions to energy are as follows. At 28.5^{0}C, (the average of the lowest ground temperatures), the average energy radiating from the ground under the tree is 422W/m^2. At 23^{0}C, (the lowest ground temperature recorded within the tree canopy over the whole period), the energy radiating from the coolest ground under the tree is 392W/m^2. At 43.8^{0}C, which is an average of the ground temperatures recorded beyond the tree canopy, the energy radiating from the ground beyond the influence of the tree is 514W/m^2, whilst at 51.4^{0}C which is the maximum temperature recorded beyond the tree canopy the energy radiating from the ground is 565W/m^2. Between 08:00 and 15:00, the average difference in long wave energy from the ground under the canopy, (average 33.8^{0}C/452W/m^2), compared to beyond the canopy, (average 43.8^{0}C/514W/m^2), is 62W/m^2, whilst the difference between the most protected parts under the canopy, averaging at 28.5^{0}C/422W/m^2, and the areas in full sun, averaging at 43.8^{0}C/514W/m^2, is 92W/m^2. However, the greatest difference in long wave energy from the ground between areas beyond and within the tree canopy which was recorded between 12:00 and 13: 00 when the outside ground temperature was at its highest ($51.4^0C/565W/m^2$) to the lowest, ($29^0C/424W/m^2$) in the shade at the same time results in a diminution in energy under the tree of $141W/m^2$.

__Ziziphus spina-christi__(See Appendix J, Tables 6 and 9)

7.3.38 The average of the recorded lowest ground temperatures between 10:00 and 15:00 within the tree canopy was 35.7^0C whilst the lowest ground temperature within the tree canopy over the whole period was 33.4^0C. (Lower were recorded at 08:00 but the tree and its surroundings fell within the shadow of a nearby hill.) The overall average ground temperature within the tree canopy was 41.6^0C. In contrast the average ground temperature recorded between 10:00 and 15:00 beyond the influence of the tree canopy was 50^0C, whilst the highest recorded ground temperature was 53.8^0C. This means that there is an average difference of 8.4^0C between ground temperatures of areas under the tree compared to areas beyond the tree canopy. However, the greatest difference in ground temperature within the tree canopy compared to beyond the tree canopy occurred during the period 14:00-15:00. This 16.6^0C difference occurred where the temperature beyond the tree canopy was 53.8^0C and the lowest within the tree canopy was 37.2^0C.

7.3.39 Using the Stefan and Boltzmann equation the following conversions to energy are as follows. At 35.7^0C, (the average of the lowest ground temperatures), the average energy radiating from the ground under the tree is $463W/m^2$. At 33.4^0C, (the lowest ground temperature recorded within the tree canopy over the whole period), the energy radiating from the coolest ground under the tree is $450W/m^2$. At 50^0C, which is an average of the ground temperatures recorded beyond the tree canopy, the energy radiating from the ground beyond the influence of the tree is $555W/m^2$, whilst at 53.8^0C which is the maximum temperature recorded beyond the tree canopy the energy radiating from the ground is $582W/m^2$. Between 10:00 and 15:00, the average difference in long wave energy from the ground under the canopy, (average $41.6^0C/500W/m^2$), compared to beyond the canopy, (average $50^0C/555W/m^2$), is $55W/m^2$, whilst the difference between the most protected parts under the canopy, averaging at 35.7^{0}C/463W/m^2, and the areas in full sun, averaging at 50^{0}C/555W/m^2, is 92W/m^2. However, the greatest difference in long wave energy from the ground between areas beyond and within the tree canopy which was recorded between 14:00 and 15: 00 when the outside ground temperature was at its highest (53.8^{0}C/582W/m^2) to the lowest, (37.2^{0}C/472W/m^2) in the shade at the same time results in a diminution in energy under the tree of 110W/m^2.

Control Species

Delonix regia (See Appendix J, Tables 7 and 9)

7.3.40 The average of the recorded lowest ground temperatures between 08:00 and 15:00 within the tree canopy was 28.2^{0}C whilst the lowest ground temperature within the tree canopy over the whole period was 21.9^{0}C. The overall average ground temperature within the tree canopy was 33.4^{0}C. In contrast the average ground temperature recorded between 08:00 and 15:00 beyond the influence of the tree canopy was 44.4^{0}C, whilst the highest recorded ground temperature was 53.1^{0}C. This means that there is an average difference of 12.1^{0}C between ground temperatures of areas under the tree compared to areas beyond the tree canopy. However, the greatest difference in ground temperature within the tree canopy compared to beyond the tree canopy occurred during the period 14:00-15:00. This 22.5^{0}C difference occurred where the temperature beyond the tree canopy was 53.1^{0}C and the lowest within the tree canopy was 30.6^{0}C.

7.3.41 Using the Stefan and Boltzmann equation the following conversions to energy are as follows. At 28.2^{0}C, (the average of the lowest ground temperatures), the average energy radiating from the ground under the tree is 420W/m^2. At 21.9^{0}C, (the lowest ground temperature recorded within the tree canopy over the whole period), the energy radiating from the coolest ground under the tree is 386W/m^2. At 44.4^{0}C, which is an average of the ground temperatures recorded beyond the tree canopy, the energy radiating from the ground beyond the influence of the tree is 518W/m^2, whilst at 53.1^{0}C which is the maximum temperature recorded beyond the tree canopy the energy radiating from the ground is 577W/m^2. Between 08:00 and

15:00, the average difference in long wave energy from the ground under the canopy, (average 33.4^{0}C/450W/m^2), compared to beyond the canopy, (average 44.4^{0}C/518W/m^2), is 68W/m^2, whilst the difference between the most protected parts under the canopy, averaging at 28.1^{0}C/419W/m^2, and the areas in full sun, averaging at 44.4^{0}C/518W/m^2, is 99W/m^2. However, the greatest difference in long wave energy from the ground between areas beyond and within the tree canopy which was recorded between 12:00 and 13: 00 when the outside ground temperature was at its highest (53.1^{0}C/577W/m^2) to the lowest, (30.6^{0}C/434W/m^2) in the shade at the same time results in a diminution in energy under the tree of 143W/m^2.

Albizia lebbeck (See Appendix J, Tables 8 and 9)

7.3.42 The average of the recorded lowest ground temperatures between 08:00 and 15:00 within the tree canopy was 30^{0}C whilst the lowest ground temperature within the tree canopy over the whole period was 23.6^{0}C. The overall average ground temperature within the tree canopy was 35.5^{0}C. In contrast the average ground temperature recorded between 08:00 and 15:00 beyond the influence of the tree canopy was 44.4^{0}C, whilst the highest recorded ground temperature was 53.1^{0}C. This means that there is an average difference of 8.7^{0}C between ground temperatures of areas under the tree compared to areas beyond the tree canopy. However, the greatest difference in ground temperature within the tree canopy compared to beyond the tree canopy occurred during the period 14:00-15:00. This 20^{0}C difference occurred where the temperature beyond the tree canopy was 53.1^{0}C and the lowest within the tree canopy was 33.1^{0}C.

7.3.43 Using the Stefan and Boltzmann equation the following conversions to energy are as follows. At 30^{0}C, (the average of the lowest ground temperatures), the average energy radiating from the ground under the tree is 430W/m^2. At 23.6^{0}C, (the lowest ground temperature recorded within the tree canopy over the whole period), the energy radiating from the coolest ground under the tree is 395W/m^2. At 44.4^{0}C, which is an average of the ground temperatures recorded beyond the tree canopy, the energy radiating from the ground beyond the influence of the tree is 518W/m^2, whilst at 53.1^{0}C which is the maximum temperature recorded beyond the tree canopy the energy radiating from the ground is 577W/m^2. Between 08:00 and 15:00, the average difference in long wave energy from the ground under the canopy, (average 35.5^{0}C/463W/m^2), compared to beyond the canopy, (average 44.4^{0}C/518W/m^2), is 57W/m^2, whilst the difference between the most protected parts under the canopy, averaging at 30^{0}C/430W/m^2, and the areas in full sun, averaging at 44.4^{0}C/518W/m^2, is 88W/m^2. However, the greatest difference in long wave energy from the ground between areas beyond and within the tree canopy which was recorded between 14:00 and 15: 00 when the outside ground temperature was at its highest (53.1^{0}C/577W/m^2) to the lowest, (33.1^{0}C/448W/m^2) in the shade at the same time results in a diminution in energy under the tree of 129W/m^2.

Averages of differences in Ground Temperature and Long Wave radiation from the Ground of all the Specimens of the Species

(See Appendix J, Table 9)

7.3.44 The average reduction in surface ground temperature difference under the canopy compared to beyond the canopy of all six native tree specimens is 8.9^{0}C whilst the maximum reduction achieved is 17.9^{0}C. The average reduction in surface ground temperature difference under the canopy compared to beyond the canopy for the two control specimens is 10.4^{0}C whilst the maximum reduction achieved is 21.3^{0}C.

7.3.45 Long wave radiation energy reductions for all six specimens averages out at 85W/m^2, whilst the average of the greatest differences measured for all the six tree specimens is 116W/m^2. Long wave radiation energy reductions for the two control specimens averages out at 93W/m^2, whilst the average of the greatest differences measured for all the six tree specimens is 138W/m^2.

7.3.46 From the above it can be seen that the native trees effect an average change in ground temperature under the trees of approximately 9^{0}C, whilst the exotic control specimens reduce the temperature by an average of 10^{0}C. These are similar figures and the discrepancy of 1^{0}C or 10% may relate to changes in temperature around the tree and the measurement locations.

7.3.47 Similarly, with long wave radiation from the ground, it is evident that the native trees effect an average change in radiation under the trees of approximately $85W/m^2$, whilst the exotic control specimens reduce the temperature by an average of $93W/m^2$. Again, these are similar figures and the discrepancy of less than $10W/m^2$ or 10% may relate either to changes in temperature around the tree and/or the measurement locations.

7.4 Discussion

7.4.1 The major issues regarding the amelioration of microclimate under trees in the Negev Desert are the modifications in short wave solar radiation, long wave radiation from the ground and lux. The tree canopy reduces solar radiation levels, which reduces the energy reaching the ground that results in reduced long wave radiation from the ground and a diminution of light intensity.

Solar Radiation

7.4.2 Although the final energy input under the canopy of a tree is more than the solar beam radiation, (as the scope of this study does not consider long wave terrestrial radiation, diffuse and reflected radiation from the sky and other objects), it becomes clear that a tree canopy in the desert has a considerable effect on solar radiation under the tree.

7.4.3 The average calculated solar radiation received under the canopy the six native tree species is in the order of $274W/m^2$, which is approximately 45% of the solar energy received beyond the tree. (See Table 9) Compared to the $611W/m^2$ received beyond the influence of the tree canopy, the average reduction in solar direct beam energy is $337W/m^2$. Calculations for the two control specimens indicate an approximate reduction of 349 W/m^2 and thus the received radiation is approximately 43% of the direct beam solar energy received beyond the tree. Thus it can be noted that the calculated reductions in direct beam solar energy for both the native as well as exotic specimens is similar.

7.4.4 Field data collection and analysis also indicates large reductions in direct beam solar radiation. The average reduction for the six native specimens is 678 W/m^2/87%. For the control specimens this is 597 W/m^2/85%. A comparison between the percentage reductions between the native specimens and the control specimens shows the effect as being very similar. It must be noted that the higher reductions found through the data collection as opposed to the calculated mathematical modelling method is due to the fact that much greater reductions in direct beam solar radiation were created by the tree trunks, which could not be calculated using the mathematical method.

7.4.5 The reductions in direct beam solar energy is highly significant and although all trees would reduce solar radiation, the study shows that the native trees of the Negev have a marked impact, being almost equal to the alien, exotic species and therefore should be considered when a reduction in solar radiation is required.

Quality of Shade and Lux

7.4.6 The reduction in lux within the shade under the six specimens of desert trees shows a notable amelioration in light intensity and glare which offers relief from the full intensity of the sun. The reduction in light energy and infrared energy by the canopy causes reductions in ground temperatures in the shade as well. Even in the hottest and driest season, when the trees of the Negev have the least amount of leaves, the trees produced significant amounts of shade. The reduction in lux, an average of 63081 lux across all six specimens and an average maximum of 74667 lux [321], also raises the comfort levels for people by reducing glare. This indicates beyond doubt that the native trees of the Negev should be considered when a reduction in light intensity is required. (See Table 9)

Ground Temperature

7.4.7 The reduction in ground temperature resulting from shade and the diminution of solar radiation means that the ground itself radiates less heat energy. This results in a zone within the shaded area, which is more comfortable for humans and for wildlife. All trees produce shade and thus

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[321] Recorded during the 2002 field trip. Greater reductions were recorded during the 1999 trip with an average reduction of 73887 lux and an average maximum reduction of 85667 lux.

there will always be a reduction in ground temperature in the shaded zone. The six native species show a significant average reduction in ground temperature of approximately 9°C, and an average maximum reduction of approximately18 °C, an average reduction in radiation of 85W/m^2 and an average maximum reduction of 116 W/m^2. The control species show similar results, where the average reduction in ground temperature is approximately 10°C and an average maximum reduction of approximately 21 °C. The average reduction is 93W/m^2 and the average maximum reduction is 138 W/m^2. The study indicates that the six trees of the Negev are definitely suitable to create shade and alter ground temperatures and long wave radiation from the ground. (See Table 9)

Other Observations Relating to Shade

7.4.8 It is evident that most of the native trees of the Negev have canopies that are broader/wider as opposed to being taller. In effect this means that the shade that is created is greater when the canopies are wider rather than taller. In fact, it can be shown that during the hottest parts of the day, in summer, i.e. when more shade is likely to be required, that broad canopied trees create significantly more shade. Figures 10 and 11 in Appendix J, illustrate how broad/wide canopied trees generally provide more shade than a tall canopied tree. The Figures indicate generally how broad shaped canopies create more shade over the whole day especially at midday during the summer months. When the sun is high in the sky the shade is concentrated directly around the tree canopy and thus not only does a broad shaped tree provides significantly more shade over the whole day but it does so during the hottest parts of the day when it is most needed.

Using Native Trees in Landscape and Environmental Projects

7.4.9 As illustrated above, the six trees that have been identified all provide significant amounts of shade for them to be used as microclimate modifiers. With regard to other landscape and environmental uses the *Acacia gerrardii, Acacia tortilis, Pistacia atlantica and Tamarix aphylla* species have already been identified as being useful landscape trees. (Jones and Sacamano, 2000, pages 11, 18, 259 and 317) Analysis of the *Acacia raddiana* and *Ziziphus* *spina-christi* species in the field over a five-year study period also indicates that these trees would be suitable for landscape use [322]. The *Acacia gerrardii* species can be used as a 'spreading shade tree' and its

> *'toughness under dry conditions makes it valuable for revegetation, medians and parking and street shade'.* (Jones and Sacamano, 2000, page 11)

7.4.10 *Pistacia atlantica* is considered to be a

> *'handsome large tree for shade, parks and public spaces', and for 'roadsides or medians where there is adequate space'.* (Jones and Sacamano, 2000, page 259)

7.4.11 The *Tamarix aphylla* is a very useful species despite some drawbacks. It can be used for

> *'shade, screening wind, dust and blowing sand'*, and for *'soil stabilisation and revegetation'*, as well as *'sheared into a dense hedge 4 to 10 feet (1 to 3m) tall or taller'.* (Jones and Sacamano, 2000, page 317)

7.4.12 The *Acacia tortilis* species is considered to be an *'excellent umbrella-form shade tree'.* (Jones and Sacamano, 2000, page 19) Observations and analysis in the field also suggests that *Acacia tortilis* species may well be suitable for providing shade in public as well as private gardens and for use as a street tree. Similarly the *Ziziphus* species may well be used as large tree to provide shade as well as a street tree. It could also be used in public as well as private gardens [323]. However, the smell of the flowers of *Ziziphus spina-christi* may be offensive to some people. [324]

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[322] Unpublished Ph.D., research by the author. The research is titled 'The Assessment of Plant Species for Landscape Design Use in the Negev Desert of Israel'.

[323] Ibid.

[324] Some people consider that the flowers smell like faeces.

7.5 Summary and Conclusions

7.5.1 The use of native tree species in some zones of the Negev is preferable to the use of introduced foreign species. This is particularly the case where the landscape character and quality of the area needs to be retained and where ecological damage and diminution in value may be caused through the introduction of foreign species. Native trees also have the noted ability of being able to survive local desert conditions without additional water. Thus, where trees are required it may be possible to use the six specimens discussed, taking into account the physical characteristics of the trees, their size, rooting characteristics, visual and tactile character and the landscape design objectives required. As illustrated above, the trees have the ability to alter solar radiation, long wave radiation from the ground surface and light intensity to a significant degree. When it comes to the provision of shade all six trees provide a dense enough shade to significantly reduce solar radiation, ground radiation and glare and thus they could and should be used for various developments in the Negev.

7.5.2 The hypothesis that states that the native Negev trees are suitable for use in the Negev has thus been confirmed especially with regard to the provision of appropriate shade, which benefits people as well as wildlife.

7.5.3 The penultimate chapter, Chapter 8 notes microlandscape methods, that are very rarely addressed in landscape design in arid areas and that would enhance the establishment and wellbeing of all planting, native and exotic in desert areas.

8. CHAPTER 8 MICRO-LANDSCAPE STRATEGIES FOR PLANT SURVIVAL AND ESTABLISHMENT IN THE NEGEV

8.1 Introduction

8.1.1 The previous chapter, Chapter 7 established that the native trees of the Negev are suitable for creating shade and with Chapter 6, the hypothesis on whether the native plants of the Negev are suitable for use is robustly tested. However, plant use depends on the ability for plants to be established and survive and plant establishment and survival in the Negev Desert as well as in other natural environments may rely not only on the genetic characteristics of the individual species and climate but also on a number of micro-landscape conditions. These micro-landscape conditions, which form the core focus of Chapter 8 have been observed and noted by the author in the field in the Negev and related information has been collected as part of the literature review of the Negev plants and the Negev Desert in general.

8.1.2 It is suggested that this information could benefit the establishment and wellbeing of the native plants, or for that matter any plants introduced into the Negev and other hot, dry desert environments. It appears from the author's own experience that these issues are not common knowledge amongst landscape architects working in desert environments, as very little has been published. Thus it is considered worthwhile for this research and for others that these micro-landscape conditions as a means towards more sustainable development in the Negev are discussed. The rationale behind this argument is that development would become more sustainable as plant establishment and survival are improved through less wastage, and by minimising water input and maintenance, thus also minimising costs.

8.1.3 The investigation of these issues is considered a significant but not central part of this thesis and is not intended to be definitive. Nor can the issues be absolutely verified until further research is undertaken and the conditions tested.

8.1.4 The first concern for any planting is the availability of water to the plant's roots. The second most important issue is the thermal conditions, which need to be within a range that is conducive to plant establishment and continued wellbeing.

8.1.5 There are, however, three other main issues, that affect plant establishment and plant survival in the Negev are soils, topography/landform and aspect. These conditions have a considerable affect on the amount of water that becomes available to the native plants as well as the thermal region above and below ground level. This is evidenced by the fact that vegetation patterns are different in every physiographic unit in the same climatic zone. [325] Indeed, Evenari et al (1982, Page 232), suggest that it is the water regime for each habitat that is responsible for the *'wide variation in plant cover.'* Thus the overall climate may not be the only decisive factor that alters vegetation in the region but landscape forms, soil characteristics and other features, which help to determine water availability and useful changes in microclimate

8.1.6 Landform also has an effect on aspect and determines for example the amount of direct solar radiation plants are subjected to at different times of the day. There are also two other issues that affect plant growth; plant physiology and man's positive impacts on the landscape, including water-harvesting methods. But man also creates negative impacts. These issues also require consideration.

8.2 Soils

Introduction

8.2.1 Soil are an important consideration for all planting. If the soil is incorrect for the plant species then the plant will not perform adequately and may even die. Different types of soil also have the ability to retain water, or create run-off, leach water and even to distil saline water.

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[325] Dan Joel, 'The Soil Pattern of the Arid Regions of Israel and its Effect on present and Potential Land Use' in Golany 1979, page 216.

Water and Soils

8.2.2 Avinoam Danin, (1983, Page 12) states that water availability to plants is partly due to soils and lithology. As stated in Chapter 3, sands cause good rainwater infiltration but the water holding capacity is low. This deeper infiltration means that there is less evapotranspiration and therefore in low rainfall areas a high infiltration rate is considered beneficial. (Balba, 1996, Page 121) Finer soils at the lower part of the root zone are considered to be beneficial because if the soil is too sandy then water will disappear below the root zone and not be available for some plants. On the other hand, less infiltration occurs with more silt and clay, but these soils have a greater holding capacity. With chalk and loess there is a loss of water due to runoff and only 30-50% of rainfall is available to plants. [326]

8.2.3 Mainly loessal soils and sands are used for agriculture in the Negev. However, loess tends to form impermeable crusts on the surface during rains. [327] Furthermore, loessal soils in the Negev can have a high clay content which does not allow for easy water penetration. Loess is thus a good growing medium and allows water to leach salts below the root zone but it has its own problems in causing crusts and therefore inhibiting water percolation. From an investigation of habitats in the Negev highlands, Evenari et al, (1982, Page 235), state that loessal soils have the potential to be wetted up to a depth of 5metres but up to 180 mm of rainwater only wets the soil up to 30-50cm deep. But loessal soils can hold residual water and where water run-off is directed naturally or by man to a topographical depression it can penetrate to deeper layers. 500-600 mm of water can be stored in the upper 3 metres of soil and made available to plants for subsequent plant growth and these areas *'therefore becomes an excellent plant habitat.'* (Evenari et al, 1982, Page 235) An addition of stony material would also be an advantage in order to facilitate water percolation.

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[326] Ibid., page 15.

[327] Kally Elisha, *' Water Supply to Arid Areas'*, in Golany 1979, page 418.

8.2.4 Salt can accumulate in loessal soils over time through evaporation and care must be taken when planting that the soils do not and have not accumulated these salts. The salts originate from the small quantities, which are in the rain. (Danin, 1983, page 15)

8.2.5 Compared to loessal soils, Danin, (1983, page 16) notes that in hard-bedded limestone, dolomite, fissured granite and metamorphic rocks, 60-90% of rainfall is available to plants as rainfall infiltrates via fissures and soft interbeds. Where smooth faced outcrops of massive rocks are found, several times the amount of rainfall is available at the foot of outcrops and in soil pockets. (Danin, 1983, page 16) This results from a smooth flow of water, with little or no percolation until it reaches the fissure sand interbeds. Smooth faced rocks can therefore also be used in some locations to increase water supply to plants.

Stones in Soil

8.2.6 Evenari et al, (1982, page 260), notes that on hilltops and slopes in the Negev highlands, the stoniness of soils shows that there is a dramatic increase of water content by weight, which is double that in other areas. Evenari et al, (1982, page 260), found that 9-12% water by weight was found below the stones where usually the water content was 4-6%. Of particular importance to planting is the fact that moisture below 6-8% is unavailable to plants, as roots are *'unable to extract the moisture surrounding the soil.'* (Evenari et al, 1982, page 260) Evenari et al further notes (1982, page 235) that in gravelly wadi soils, water penetrates deeply but availability is reduced to 80-100mm in total per tree or shrub with deep roots over 5 metres.

8.2.7 Soil salinity is also an important factor where *'high salinity may decrease the plant's capacity to keep itself supplied with water'* (Evenari et al, 1982, page 26) In this regard it is extremely interesting and important to note that stones in soil do not only allow for better water percolation but they also make desalinised water available to plant roots thus enhancing plant survival. Miller and Donahue (1990, page 140), point out that this occurs in course materials such as sands and gravels when after drainage, plant roots may be located mostly in soil air. The relative humidity however is close to 100% whether the soil is dry or moist and *'slight temperature fluctuations allow water vapor to condense on roots'*. This is distilled water, containing no salts and thus can readily be absorbed by plants. (Miller and Donahue 1990, page 140) *'Thin salt water films continue to supply a source of evaporating water and some nutrients'*. (Miller and Donahue 1990, Page 140) (Figure 49)

8.2.8 Evenari et al (1982, page 266) furthermore point out that the ruderals such as Salsola enermis can inhabit spots of disturbed soil such as on roads, pipelines etc. in enormous numbers. These ruderal plants are taken over by other plants after 2-3 years but the source of water for these is often the water pockets under stones. These ruderal/waste-ground plants are important initiators of soil stability and can be used as such. They are strikingly green in the summer when much else is dry.

8.2.9 The advantages of stony soils in general should be recognised, as they are an important part of plant survival. If run-off rather than infiltration is required, stone removal would be facilitate water flows. Thus Evenari et al, (1982, page 260) state that *'the stoniness of desert soils ... is of the greatest biological importance'*.

Soil pH

8.2.10 (Refer specifically to Appendix C.)

8.2.11 The majority of the soils, (83%) analysed as part of this research and as measured by the author fall within the range of being alkaline to very alkaline. 34% of the plants assessed were found growing in alkaline soils between pH 7.5 – 8.0 and 64% were located in very alkaline soils with a pH above 8.0. Of these 17% grew in soils pH 8.5 – pH 9.0.

8.2.12 The Negev plants generally prefer these alkaline soils and thus this should be factored in to any proposals using native plant species. Soils and plant species choice have to be matched accordingly

Soil salinity/conductivity

8.2.13 (Refer specifically to Appendix C.)

8.2.14 Many natural desert soils are saline. The conductivity tests undertaken by the author show that most of the plants assessed, i.e. 136 (approximately 65%) were growing in soils with a conductivity of between 101 - 600 μS/cm, (micro Siemens per centimetre), which is considered to be a low to medium salinity hazard. (Willens in Cochrane and Brown, 1978, page 51) However, 14% were found in very saline soils with conductivity measurements ranging above 2250 μS/cm and even above 20 000μS/cm. Measurements above 2250μS/cm indicate a very high salinity hazard for plants. (Willens in Cochrane and Brown, 1978, page 51)

8.2.15 Salinity greatly affects plant survival and growth and in the Negev many plants are tolerant of saline conditions, but others are not. Thus soils and plants have to be matched accordingly.

Soil Temperature - Albedo of Soils

8.2.16 Miller and Donahue, (1990, page 70) note that light soils reflect more heat. This is an important fact for microclimate modification in the landscape as non-reflected heat is absorbed heat, which has a bearing on thermal comfort for humans as well as plant establishment and survival.

8.2.17 The ratio of the intensity of the light reflected from an object or a surface to that of the light it receives from the sun is called 'albedo'. This albedo varies greatly over natural as well as artificial surfaces. Thus, for example, a dark moist cultivated soil will have an albedo of only 5-15%, whilst a dry sandy soil will have an albedo of 25-35%. Asphalt for example has an albedo of only 5%. (Brown Gillespie, 1995, page 49) From empirical observations at certain sites in the Negev, this absorption of solar radiation appears to indicate that in a very similar area, plants tend to grow in areas where the ground is lighter and thus less absorptive of radiation. (Appendix A, Figure 3) When measured with a fast response surface thermometer during investigations of microclimate under trees in the Negev, (refer to Chapter 7), dark surfaces had a higher temperature in the same conditions than lighter surfaces. However, it must be noted that other factors such as minor variations in the soil makeup and structure as well as a more advantageous water regime due to soil texture and/or slopes may be responsible for differences in soil temperature.

Soil Temperature - Air in Soils

8.2.18 Konya, (1980, page 12) notes that air in soil is a very good insulator. Thus although the topmost surface of the soil may be very hot, areas lower down are significantly cooler. This means that the soil temperature in the plant root zone can be reduced in soils that have more air within. Sandy soils have the most air but as mentioned above they are problematic because they do not retain water. On the other hand clay soils have the least air but they do manage to retain water. The answer to creating more air in clay soils and to provide water retentive abilities in sandy soils is the introduction of organic material. It is thus suggested that in landscape schemes that organic material is added to both sandy and clay soils in order to improve water retention and additional air and thus insulation for plant roots.

Creating the Best Soil Mix

8.2.19 In order to ascertain the best possible soil mixture, a number of crucial issues require attention:

- In the first instance, a mix of loessal and gravely soils appears to provide the best balance of water penetration and water holding capacity;
- Secondly stones in the soil allow for the production of desalinised water which becomes available to plant roots. Stones in the loessal soils also alleviate the problem of accumulated salts from rainfall, which concentrate over time through evaporation. (Danin, 1983, page 15);
- Adding organic matter to the soil is the final consideration as organic matter holds water and reduces soil temperatures within the root zone.

Soil Tillage

8.2.20 The over-tilling of soil is also an important consideration. Where soils have been disturbed, for example with road building in the Negev, the expected range of native vegetation has been reduced and those that thrive on the absence of competition for water and nutrients flourish. This is due to leached upper soils, which are replaced with saline lower soils and thus native saline tolerant species such as *Salsola inermis*, and other *Salsola* and *Atriplex* species have become dominant. (Danin, 1983, page 18) (See Appendix A, Figure 41)

8.3 Aspect

8.3.1 Yaacov Orev notes that wind-facing slopes get more rain than flat slopes. [328] This can be as much as high as 15% on a 10% slope. [329] Thus a 10% slope would get 115 mm of rainfall if the rainfall were 100 mm. In environmental terms, this means it is better to improve wind-facing slopes before flat areas although flat areas may initially appear more promising. It also suggests that if water harvesting is being considered then wind-facing slopes should provide considerably more water than other slopes.

8.3.2 The lie of the ground and its aspect to the moving sun is also an important micro-landscape / microclimatic factor, which has an effect with regard to the heating of soils by the sun and thus to plant establishment, growth and thus plant survival. South facing slopes are warmer and the angle of incidence, i.e. the angle of which sunlight hits the ground affects how much radiation hits the ground and therefore how much energy is absorbed. This is illustrated in Figures 50 and 51 after Miller and Donahue (1990, Figure 2-10, page 70) and Brown and Gillespie. (1995, page 48)

8.4 Topography Water and Water Harvesting

8.4.1 The harvesting of run-off is an important consideration for all planting strategies in the Negev. This is evidenced by the success of *Eucalyptus* and *Acacia* tree planting where water is directed to these plantations from higher lying areas, (Figures 24 and 25), and at Avdat Farm where Nabatean water

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[328] Orev Yaacov, 'Revegetation of the Arid Range', in Golany 1979, Page 288.

[329] Ibid.

harvesting techniques are used to grow fruit trees and annual crops such as wheat and cotton. (Figure 52)

8.4.2 Michael Evenari experimented with topographical modifications at Avdat following the precedents set by the Nabateans in the Avdat region. He took 2.5ha catchments and divided them into 17 micro-catchments ranging in size from $16m^2$ to $1000m^2$. (Evenari et al 1982, page 21) Winter rainwater was directed into these micro-catchments. These are called *"negarim"* in Hebrew from the root *"neger"* which means run-off. (Figure 27) Evenari's experiments show a An average yield of *Atriplex halimus* a native type of salt bush, was 660kg/ha of fresh matter and 400kg/ha dry matter which is equal to 160-170 feed units p/ha. Without micro catchments the yield was very much less with only 20-50 feed units per ha, which is approximately 12.5% to 30% of the plant matter with micro-catchments. (Evenari et al 1982, page 21) The use of negarim also had the advantage of leaching out soluble salts. Salt dropped from 1.02% to 0.08 to 0.12%. (Evenari et al 1982, page 21) The experiment shows a significant increase of biomass in the microcatchments and although the yields are not high enough to provide the basis for agriculture, the method is certainly useful for landscape and environmental works.

8.4.3 Rainfall is a precious commodity in the Negev, but the Nabateans and Evenari have shown that although it arrives in small quantities per annum, when it does rain substantial amounts of water can be collected. Thus the collection of and redistribution of rainfall must be part of any planting strategy.

8.4.4 The following calculations have been prepared to illustrate the amounts of water that could be collected if water harvesting is undertaken. Dudley Stamp, (1961, page 23), points out that 1 inch of rainfall equates to 100 tons of water per acre. This means that 2.54 cm of rainfall equates to approximately 100 X1016 kg of water as a UK ton is approximately 1016kg. Thus 2.54cm of rain equals 101,600 litres of water as 1kg is equal to 1 litre and thus 1cm or rain (10mm) is equal to 40 000 litres per acre. Taken over 1 hectare of ground this equates to 88 000 litres per hectare as there are 2.2 acres per hectare. Thus 10mm of rain provides 8.8 litres per m^2. If rainfall is

100mm per annum then in theory at 100% run-off each square metre could supply 88 litres of water, 10 m^2 will provide 880 litres and 1 ha will provide 880 000 litres which is 880 cubic metres. These totals are considerable even when run-off may be low. Run-off can be significantly increased and indeed doubled by reducing permeability by reducing stones, which slow down water flow. This technique was used by Nabatean farmers and later experiments emulated this process at Avdat Farm. (Dudley Stamp, 1961, page 23) (Refer to Figures 10, 27, 39 and 52)

8.4.5 As discussed under the sub heading 'Disturbed Habitats' in Chapter 4, many plants found in the Negev may be concentrated along roadsides in ditches, as water concentrates in these areas. In order to deliver as much water as possible to the plants run-off needs to be maximised. It is suggested that landscapes can be profiled, sloped with ridge and furrows in order to direct water to the plants and hold it there. (See Figure 54)

8.4.6 It is suggested by the author that an impervious road surface, (refer to Figure 39), is similar to areas of 'smooth faced rock outcrops' in the Central Negev Highlands, (discussed in paragraph 8.2.5 above), where most of the specimens of *Pistacia atlantica* are found to be growing. Danin (1983, page 102), states that the amount of water available to plants in these areas depends on:

- the mass of the substrate associated with the roots (rhizosphere);
- the size of the catchment area;
- the annual rainfall; and the amount of water, which eventually reaches the rhizosphere.

8.4.7 Furthermore, Danin notes that the smooth faced rock types *'contribute much more runoff than other substrates' and that 'runoff may start after the first millimetre of rain'*. (Danin, 1983, page 102),

8.4.8 With additional water, plants cannot only survive but they can grow larger. This is evidenced by the group of dwarf shrubs that grow larger in the presence of more water. (Evenari et al, 1982, page 251)

8.4.9 All trees in the desert appear to grow only where their roots have access to underground water. This means landscape planting initially requires some type of irrigation and then micro-landscape alterations to provide additional water e.g. Nabatean micro-catchments. (Figure 27)

8.5 Plant Physiology

8.5.1 In temperate climatic conditions, landscape architects often use the rule of thumb that a plant's root system is very similar in area to the canopy of branches and leaves above ground. In the Negev and other deserts this is not the case. As mentioned in Chapter 5 even small xerophytic plants can have more extensive root systems compared to similar species in temperate climates where water is more readily available. *Tulipa systola,* (Photographs G72 and G73, Appendix H3),and the small hairy storksbill, *Erodium hirtum* , (Photographs P110 and P11, Appendix H5) may have roots extending 30-40cm for the tulip and 40-50cm for the storksbill. (Evenari et al, 1982, page 259) Adams et al (1978, Page 56) notes that *Retama raetem,,* (Photographs S312-316, Appendix H7), can have a root system of 40 square metres, and *Tamarix aphylla* can have roots that extend way beyond the tree's profile above ground., (Figure 53, Appendix A, and Photographs T373 and T378, Appendix H10) This suggests that plants with extensive root systems can also be used on higher ground as their roots will seek out water well below ground level. (Figure 43, Diagram 2) Adams et al (1978, page 56) notes that

> *'it is thus very important to note that when considering the use of a plant it is not just the leaf canopy that should be considered, for in the arid environment, the roots play a highly significant role: "canopies" operate both below and above ground level'.*

8.5.2 Although Adams et al identify the particular problems of introducing foreign species amongst existing species and potential root system conflicts with regard to water, combining native species can also be problematic if they do not coexist naturally. It is therefore important to identify the plant associations where plants grow satisfactorily together and therefore do not have competing root systems. Usually this coexistence also means that plants form part of an established habitat and thus their coexistence is ecologically sound. Thus the concept of habitat associations as advocated by

Jens Jensen mentioned in Chapter 4, can be used as a core principle to inform planting designs and therefore this should also form an important part of the database of the characteristics of native plant use.

8.5.3 In Israel, in the Mediterranean phytogeographic region winter annuals form only 28% of species. However in the Negev, annuals form 59% of the species found .[330] This shows that winter annuals are particularly adapted to desert conditions. This is partially because their roots tend to be shallow and limited in extent and can regulate their size according to water conditions. In general, the use of annuals by landscape architects is fairly limited except in more rural schemes. However, because of their success in surviving drought, annuals may be seen to be an important part of the landscape architect's palette in desert areas. But it must be noted that most of these annuals only flower in the winter and spring and they disappear or appear dead during the hot summer months. Thus their use would need to be linked into overall planting strategies where other plants are used as well.

8.6 Influence of Man

8.6.1 It is well known that man's activities on the land can cause erosion. In the Negev this be caused by removing vegetation for many reasons as well as by over grazing of flocks. Erosion occurs particularly when the rainfall pattern is characterised by short intense storms. Where the ground is denuded through over grazing and loss of vegetation, a puddling effect is caused which results in low infiltration rates. This then affects plant growth and accelerates erosion. [331] This means that in desert areas, especially on slopes, the removal of vegetation is a serious issue as serious erosion can be caused in a short space of time. Thus on development sites, all natural

[330] Evenari M., Shanan, L. and Naphtali T., 1982, 'The Negev: The Challenge of a Desert', Harvard University Press, page 281.

[331] Schechter Joel, 1979, 'Research Challenges of Arid Zones: The Israeli Example', Golany Gideon, Editor, 1979, 'Arid Zone Settlement Planning, The Israeli Experience', Pergamon Press, Oxford, page 53.

vegetation should be retained as far as possible to avoid the potential of erosion and also that measures may have to be taken to avoid erosion where plants are removed.

8.7 Summary and Conclusions

8.7.1 The following table is used to provide a summary list of the author's author's suggested measures to enhance plant establishment and survival in the Negev and in other hot desert areas.

Table 8. 1 List of Micro-landscape Measures to Assist Plant Survival in the Negev (Refer to Figure 43, Appendix A)

Where	What	Why
Loessal Soil	Introduce stones / gravels.	Improves percolation and soil wetting.
Gravely soils	Introduce loess.	To aid water wetting and retention capability.
Saline soils	Introduce stones / gravels.	Saline water evaporates and eventually condenses as distilled water on stones where it becomes available to plant roots.
Sandy soils	Add Organic matter Add silt or clay.	Retention of water in root zone. Silts and clays have higher moisture retention capabilities.
Sandy soils	Add silt or clay.	Silts and clays have higher moisture retention capabilities.
Clay soils	Add Organic matter.	Retention of water in root zone.
Clay soil	Add sand and stones.	To decrease run-off and

Where	What	Why
		increase percolation.
All soils	Tilling at soil surface to create air pockets above root zone.	Air acts as an insulator and keeps root zone below cooler.
All soils	Do not till too deep.	Tilling too deep may bring saline soil to the surface which has accumulated over the years.
All soils	Check pH.	Most Negev species prefer alkaline soils.
All soils	Check salinity and use appropriate species.	Many Negev soils are saline. Many Negev species have some saline tolerance and some have a high tolerance.
All locations	Pit plant / no till cultivation.	Conserves soil moisture as opposed to tilling soil, which increases evapotranspiration.
Slopes	Use slopes to collect water.	Water that cannot penetrate soil on slopes at any one time can be directed to areas where it can pool and collect and percolate or be stored. A further benefit is that additional water also tends to leach out salts.
Slopes	Plant on wind facing slopes.	Wind facing slopes can receive as much as 15%

Where	What	Why
		more water on a 10% slope.
Flat topography	Create ridge and furrows and direct water run-off to strategically placed plants.	A sloping landscape can help to direct runoff to plants.
Flat topography	Create ridge and furrows or small 'barkhan' [332]shaped forms aligned east-west with south and north facing slopes. (Figure 46)	A slope facing away from the sun receives less radiation and thus is cooler and more conducive to plant survival
Light soils versus dark soils	Light soils are more likely to be better for planting than dark soils.	Light soils reflect more light and heat. Dark soils retain more heat and become overly hot for planting.
All areas – planting mixed species	Ensure rooting characteristics of each species is compatible with each other. It is probably best to use species that grow together in natural conditions.	One species' roots may dominate another and thus it may not perform or survive
All Areas – Use annuals	Where applicable use annuals even though they survive only over the winter into springtime. Use also with other plants	Annuals form 59% of plants growing in the Negev and thus are very successful as drought survivors. Because they

[332] A barkhan is a crescent shaped sand dune.

Where	What	Why
	such as perennials and shrubs.	die off at the end of spring they need to be used with other life forms as well.
All areas	Retain native vegetation and pit plant minimising loss of vegetation and effects on soil surface.	Loss of vegetation causes erosion and puddling effect where water runoff is enhanced.
Natural and Middle Landscape areas	Create small depressions in ground imitating porcupine diggings. [333] (Figures 58 and 59, Appendix A)	Depressions in ground collect detritus (mulch) and wind-blown and water-driven seeds. Greater amounts of water also accumulates in holes facilitating seed establishment and greater potential for survival.

[333] Prof. Yitzchak Gutterman and colleagues have been studying the phenomenon of seed collection in porcupine diggings for over 10 years and have noted the seeds and species that collect in these diggings. (Summary of article by Gutterman and Herr, 1981 www.springerlink.com/content/r022q1230821340h) A later article notes that there are changes over time *'in terms of species richness, biomass and that such changes take place in 3 stages. During the initial growing season (stage 1), species richness, plant density and plant biomass are lower than in the surrounding non-disturbed area, followed by progressive plant succession. Subsequently, a maximum level is attained when a dig becomes 50–60% filled in (stage 2). As the extent of filling exceeds 60%, a decrease in species richness, plant density and plant biomass is observed (stage 3)'*. (Summary of article by Gutterman, and

8.7.2

8.7.3 Confirmation that the native plants of the Negev are suitable for use in the Negev has been established in chapters 6 and 7. However, the establishment and sustainable management of the plants could be improved through the introduction of micro-landscape measures suggested above in Chapter 8.

8.7.4 The following chapter, Chapter 9 is the final chapter of this thesis. The chapter reiterates and summarises the main issues of the thesis.

Golani Garsani 1990,
www.springerlink.com/content/x2p4k5r1711666u)

9. CHAPTER 9 CONCLUSIONS, SUMMARY OF CONTRIBUTIONS AND FUTURE RESEARCH

9.1 Introduction

9.1.1 Following the testing of the hypothesis in chapters 6 and 7 and the discussion on the manipulation of micro-landscape conditions in Chapter8, the final chapter of this dissertation, Chapter 9 has four aims:

- to summarise the *research findings*. This includes the conclusions from the collection and analysis of field data and the conclusions from the literature review;
- to review *other issues* relating to sustainable landscape development in the Negev;
- to provide a *summary of the contributions* made by the research; and
- to make *recommendations* for future research.

9.2 Research Findings

9.2.1 The main aim of this research was to test the truth or falsity of the hypothesis that *'the indigenous xerophytic and halophytic plants of the Negev are suitable for use in landscape design in the Negev Desert in Israel'*.

9.2.2 The objective behind the formulation of the hypothesis was to ascertain whether or not the native Negev plants could help towards creating more sustainable landscape development in the region. The issue of establishing more sustainable development is exceptionally pressing in the Negev Desert, because water is very scarce. This creates a potential for regional conflict. Furthermore, landscape character, landscape quality and ecological values are being diminished by the introduction and use of exotic plant species.

9.2.3 The formulation of the hypothesis also raised a number of issues and additional questions, which have been addressed as part of the research and which are summarised in section 9.3 below.

9.2.4 The hypothesis is tested using the natural / quasi experimental method, which centres on the systematic collection and analysis of the field and literature data, as well as the matching of native and exotic species pairs in a relevant systematic way. A full-scale experiment where plants could be grown alongside one another and assessed was not practical due to the many years it would require to gather and grow the plants and also because of financial and logistical constraints. The data collection, analysis and matched pair comparison methodology, which was used has great advantages as it has kick-started the process towards more sustainable planting in the Negev.

9.2.5 Chapter 1, (paragraph 1.2.5), concluded that the suitability of plants for use in the Negev relates to the principle of being 'fit for purpose' and that context and the local environmental conditions are an important factor in assessing suitability. Contextual factors are an important aspect of the field studies and the literature review. The investigations and analysis confirm that the native Negev plants are definitely 'fit for purpose' both physically and climatically.

9.2.6 Most of the species also fit the Vitruvian model for appropriate design by having 1) commodity, 2) firmness and 3) delight. They can 1) be used for various purposes, 2) they are extremely tolerant of arid conditions, and 3) they are aesthetically pleasing. They also conform to Ian Thompson's adaptation of the Vitruvian model or a) ecology, b) community, and c) delight. Most species a) enhance biodiversity and wildlife, b) they are functional in desert areas by providing shade, windbreaks against desert dust, enhancement of wildlife etc. which provides value to local communities, and c) and they are pleasing in their wildlife enhancement as they are pleasing to look at. (Refer to Chapter 1, paragraphs1.2.7 to 1.2.9 and Chapter 5, paragraphs 5.2.20 and 5.2.21.)

9.2.7 The use of the native Negev plants also meets the contemporary ideal for performance as expressed in the 'triple bottom line' (3BL).[334] 3BL is

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[334] The phrase triple bottom line was coined by John Elkington of the consultancy 'SustainAbility' in 1994. (Wikipedia, *'Triple Bottom Line'*,

usually articulated as 'People, Planet, Profit', or the reversed version 'Economy, Ecology and Society.' The economic incentive has been and always will be an important aspect of development, and it has been illustrated in the comparison of native versus the exotic species that the use of native species would ensure economic benefits. This is because they require less or no water supply, they can happily grow in the native soils without expensive additives such as soil conditioners and fertilizers and in many situations they require little or no maintenance.

9.2.8 Chapter 6, and the associated appendices, notably F and G, have comprehensively examined the physical and aesthetic characteristics of the native species and their potential uses. The analysis and matching of pairs undertaken in Chapter 6 shows that the hypothesis is confirmed for most of the 163 species that were investigated [335]. More than 65% of the native Negev species researched, show potential suitability for use in garden areas, and 98% show potential for use in the middle landscape and 99% for environmental purposes in natural areas. The ecological benefits of using the native species is in great contrast to the potential and actual ecological damage caused by the introduction of exotic species. The benefits in maintaining and enhancing the landscape character and landscape quality of the Negev are also great. The economic and socio-political benefits of using native plants, which require little or no additional water also strongly points to their suitability for use. Although many of the native species do not stand up to the qualities of the exotic garden plant species, 65% of them do, and they can also be used to enhance ecological values in gardens and reduce water use. The hypothesis therefore receives strong support, even if it cannot be definitively proven until plant trials are undertaken.

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www.) The term is usually used in regard to measuring business, organizational and societal success.

[335] According to Ross Koning (Koning, R., *'The Scientific Method'*, www.) a hypothesis cannot be proved, as proof exists only when the chance for error is zero.

9.2.9 With regards to the study of the six Negev tree species in Chapter 7 [336], the hypothesis has also been undoubtedly confirmed. This comprehensive scientific study published as a peer-reviewed article is based on the analysis and mathermatical modelling of microclimatic data collected under and beyond the trees over a 3 year period. It proves that the native trees have excellent shading abilities and on the whole provide more shade than the exotic control specimens. These native trees are thus considered suitable for use to provide shade for people as well as wildlife and are thus most suitable for use in landscape design projects in the Negev. The research has also proven that broad canopied trees, which are the form most found in hot dry desert regions, create more shade than taller canopied trees that are mostly found in more temperate regions.

9.3 Other Issues

9.3.1 The hypothesis raised a number of important issues. They are phrased as questions and answered within the framework of the literature review. The questions are as follows:

1. Why is the research important, and how and to what effect are plants used in the Negev?
2. What are the characteristics of the Negev Desert and its plants?
3. Why are the native plants not used and what plants do others suggest for use?
4. Is the existing landscape paradigm suitable and what is an appropriate alternative?
5. Is the landscape architect an appropriate person to determine plant use?

9.3.2 Summaries of the answers to the questions are as follows:

<u>Why is the research important, and how and to what effect are plants used in</u>

[336] Published as a peer reviewed article. (Kotzen, 'Journal of Arid Environments' 2003.)

the Negev?

9.3.3 The landscape character, landscape quality and ecological value of the Negev Desert are under increased pressure from development in the Negev. The landscape character and thus the landscape quality/value of the different heterogeneous areas of the Negev are also being changed by the introduction of foreign, exotic species. The introduction of exotic species also has the potential to cause ecological damage as well as having significant detrimental financial implications as demonstrated in other arid and non-arid countries around the world, including the U.S.A. the U.K., Australia and South Africa.

9.3.4 Water is also a significant issue in the region and it has been suggested that the next wars in the region will be fought over water. Exotic species are mostly used and exotic species demand more water than most native species. (Refer to Chapter 4, section 4.6, particularly paragraphs 4.6.7 to 4.6.9.)

9.3.5 The use of native plant species will not only reduce the negative potential landscape and ecological effects, but also enhance them. Water use would also be reduced. The use of the native species as opposed to exotic species is also economically superior. Thus using native Negev plants in the Negev is considered more sustainable than using exotic species.

What are the characteristics of the Negev Desert and its plants?

9.3.6 The Negev Desert is a heterogeneous region with hot, dry and semi arid areas with a variety of geomorphological types within 4 main phytogeographical regions. Soils and geology affect the amount of rainfall received by plants and this affects species spread and survival. The potential suitable use of the Negev plants is intimately linked to their life-form and the different ways plants manage drought. Of particular importance is the group of sub shrubs / dwarf shrubs [337], which remain small as they discard limbs and foliage when necessary. How the Negev plants overcome drought conditions is also important.

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[337] Raunkaier's system terms this group chamaephytes.

9.3.7 In order to understand the potential for using native desert plants, a more appropriate hierarchical system is required. This has been achieved by combining the normal hierarchy used by landscape architects with the life-forms found in desert environments. The hierarchy thus includes a category of dwarf shrubs, which is not usually used in more temperate climates.

9.3.8 Understanding the Negev soils and their water retention characteristics is also vital for the landscape designer and can help in the creation of micro-landscape conditions, which will promote plant establishment and growth. The research has identified salinity levels located at each species as well as contributing to the understanding of micro-landscape conditions, in Chapter 8, which will help to promote better plant establishment and longevity and more sustainable water use.

Why are the native plants not used and what plants do others suggest for use?

9.3.9 Very few native Negev plants are used or have been suggested for use by researchers in the Negev. Publications by those working in the field concentrate on the introduction of foreign species and xeriscaping [338]. Little recognition is given to the native species and any differentiation in their potential use compared with the exotic species. Furthermore, the ideology behind the planting is to turn the desert green and the trend is to treat all landscapes as gardens.

9.3.10 The discussion in this thesis has concluded that the reasons centre on the fact that the Israeli's living in the Negev respond to the desert as well as the native plants as being part of a hostile natural environment. In contrast, the exotic garden species that are used have at some stage been extracted from the wild and have thus been culturalised. It is hoped that this research, in part, will help to 'culturalise' these native plants and help shift the perceptions of local people so that they will consider their native plants

[338] Using drought tolerant plant species, water saving irrigation techniques, mulching to reduce evaporation of water from soils etc.

suitable for a variety of uses, including garden use in the Negev.

Is the existing landscape paradigm suitable and what is an appropriate alternative?

9.3.11 The formulation of an alternative paradigm for landscape planting is a key to planting in the Negev and other desert environments and perhaps for all planting regimes no matter where in the world they are designed and implemented.

9.3.12 An alternative landscape paradigm is urgently required in the Negev to replace the existing paradigm where plants are used, mainly in the context of creating gardens. John Dixon Hunt's, (2000), analysis of the landscape into three categories or natures is rejected for a more appropriate model with four main categories and two sub-categories. The significance of this alternative paradigm is that it creates finer distinctions. It separates out pristine Wilderness from wilderness areas that are affected by man, settlement areas from agricultural areas and most importantly within these main categories it defines the two sub-categories of garden and the middle landscape. Garden areas are intensive, high cost and high maintenance and may include exotic plants. In contrast, middle landscape areas are extensive, lower cost and only use native plants. They may be described as being habitat. The distinction between the garden and the middle landscape is a fulcrum for defining plant use in the Negev. The individual plants are thus suggested for use in natural areas and/or in the middle landscape and/or in garden locations.

9.3.13 Greater use of the alternative paradigm would have significant advantages. The use of the alternative paradigm should promote more sustainable development in the Negev and elsewhere, with large-scale diminutions in water supply, maintenance and costs. Furthermore, and most significantly ecological and landscape values would be retained and enhanced.

Is the landscape architect an appropriate person to determine plant use?

9.3.14 Part of the reason why the native plants are not considered suitable for use in the studies undertaken in the Negev and with regard to plant usage is because landscape architects have not been involved. The research illustrates that landscape architects have particular and possibly exclusive abilities to combine science with aesthetics and spatial organisation. Landscape architects can manage change in the landscape and in doing so enrich the human environment (community), enhance biodiversity, (ecology) and provide delight. All this is achieved in a sustainable and economically positive manner.

9.4 Summary of Contributions

9.4.1 This section notes the contributions of the research with regard to sustainable landscape development in the Negev. The author has aimed to:

1. Provide a comprehensive review of the potentials for using the native Negev plants. (This has not been done prior to this research and it has been done by a landscape architect who has the ability to combine the physical characteristics of the plants with aesthetic and other such as spatial criteria);
2. Provide an alternative paradigm for plant use in the Negev, which is relevant to other desert as well as more temperate areas;
3. Create a database of species' physical and aesthetic characteristics, locations and potential uses. This information will be made available to the Royal Botanical Gardens at Kew for potential inclusion in the SEPASAL database [339];
4. Undertake and aesthetic analysis of the 163 species. (This has not been done by a landscape architect prior to this research);
5. Provide scientific data and proof of microclimatic modification by 6 of the native trees, thus expediting their use for shade creation. (This is the first research of this kind undertaken on native trees in the Negev);
6. Measure pH and salinity/conductivity data for various species in various

[339] Survey of Economic Plants for Arid and Semi-Arid Lands established and run by the Centre for Economic Botany, Kew.

locations in the Negev with data in Appendix C;

7. Apply the accepted RHS standard for identifying and recording colour in plants in the Negev. (The Royal Horticultural Society system was extensively used to record leaf, stem and flower colour);

8. Prove in Chapter 7 that broad canopied trees found in desert areas are more suitable for creating shade than taller trees, which are most often found in more temperate climatic zones;

9. Bring together empirical data and literature on micro-landscape conditions, which could benefit plant establishment and survival; and

10. Create a photographic resource of the 163 species. Many of the photographs illustrate the species better than the images currently available.

9.5 Recommendations for Further Research

9.5.1 The most important investigation to follow this research would be the field trialling of the native Negev species, which have been analysed to have the best potential for use in garden and middle landscape locations. Trials would include the investigation of the species located by the author as well as others not previously analysed but that appear suitable from the literature. Field experiments should include water demands, appropriate soils, salinity tolerances, growth characteristics, longevity etc.

9.5.2 Sustainable landscape design in the Negev as well as in other arid areas would also benefit from the trials of the micro-landscape conditions suggested by the author.

9.6 Final Conclusions

9.6.1 The rigorous investigation of 163 native Negev species and the physical and theoretical context of plant use in the Negev has provided a necessary and important step towards sustainable landscape development in the Negev. One of the recommendations set out at the Kew International Conference on Economic Plants for Arid Lands, in 1985, was that *'many arid land problems could be solved by using arid land plants'*. (Wickens, 1985, page

IX) This dissertation demonstrates that the native Negev plants could and should be used to help tackle some of the problems, which relate particularly to water conservation and the retention and enhancement of landscape and ecological values that are being threatened in the Negev with increased development. In light of the proposed envisaged increase in development in the Negev, the use of native Negev plants will help to create more sutainable development in the Negev which will benefit local people, local landscape and ecological conditions. Furthermore, reductions in water use brought about by using native species, compared to exotic species will benefit the State of Israel as well as the region where water use is a source of conflict.

GLOSSARY

Abiotic – Lifeless.

Achene - A dry, indehiscent, one-seeded fruit, formed from a single carpel and with the fruit distinct from the fruit wall.

Adventive – referring to species that have been introduced but that have not become naturalised.

Aizoaceae - Order of Aizoaceae: Herbs or low shrubs, erect or prostrate, often fleshy, mainly South African and Mediterranean, often on sandy seashores or desert areas.

Allelopathic - Allelopathy involves a plant's secretion of biochemical materials into the environment to inhibit germination or growth of surrounding vegetation.

Alluvium - Alluvium is young sediment—freshly eroded rock particles that have come off hillsides and been carried by streams. In other words, alluvium is transported down slope by water.

Anarcadiaceae - Order of Anarcadiaceae: Trees or shrubs, often with resinous bark, mainly in the tropics. Useful Products: pistachio nuts, cashew nuts, mango.

Anthelmintic - An agent or drug that destroys or causes the expulsion of parasitic intestinal worms.

Angiosperm – Flowering plant.

Annual – A plant that completes its life cycle in one growing season.

Anticlines - An arch-shaped fold in rock in which rock layers are upwardly convex. The oldest rock layers form the core of the fold, and outward from the core progressively younger rocks occur.

Arava – The rift valley, on the eastern boundary of Israel with Jordan, which runs from Eilat in the south to the Dead Sea in the north.

Asclepiadaceae - Order of Asclepiadaceae: Widely distributed family of twining, climbing or erect herbs and shrubs or shrublets of the order Gentianales; most with milky juice climbing, twining or erect shrubs or shrublets, rarely trees, most with milky juice.

Batha - Low arid and often spiny semi-shrub lands in the eastern Mediterranean Basin are termed 'phrygana' in Greece and batha in Israel.

Berberidaceae - Order of Berberidaceae: Mostly shrubs or under shrubs - many beautiful garden plants.

Biennial – A plant that completes its life cycle in two years. During the first year it grows vegetatively and the surplus food produced is stored in its perennating organ, usually the root. In the following year these food reserves are used for the production of leaves, flowers, and seeds, after which the plant dies.

Biome - A large community of plants and animals, characterised by its particular type of dominant vegetation and its associated animals, e.g. tundra.

Biogenic – Produced by living organisms.

Biotic - Of or relating to living organisms.

Bisaccate - Having two little bags, sacs, or pouches.

Boraginaceae - Order of Boraginaceae: Herbs, numerous in the Med. Some beautiful garden plants.

Brassicaceae - Order of Brassiacaceae / Cruciferae: Annual or perennial herbs, rarely somewhat shrubby, with watery juice; useful products:cabbage, turnip, mustard, radish and wallflower.

Calyx - The sepals of a flower considered as a group.

Canescent - Covered with short, fine whitish or greyish hairs or down; hoary and/or turning white or greyish.

Caprines – Goats.

Capparaceae - Order of Capparaceae: Trees, shrubs, or more rarely herbs, fruit a drupe or berry - caper berry fruit of Capparis spinosa.

Caryophyllaceae: Order of Caryophyllaceae: Herbs, annual or perennial; leaves opposite, simple, entire... Useful products: many beautiful garden plants; dianthus gypsophila etc.

Caesalpiniaceae - Order of Caesalpiniaceae: Trees, shrubs, rarely herbs, fruit a legume or indehescent, often winged. Useful products: Senna = Cassia angustifolia, and tamarind.

Chalcolithic - Of or relating to the period of human culture preliminary to the Bronze Age, characterized by the use of copper and stone tools.

Chalk - A soft, white, porous form of limestone composed of the mineral calcium carbonate. Chalk is formed in shallow waters by the gradual accumulation of the calcite mineral remains of micro-organisms over millions of years

Chamaephytes - Plant whose buds are close to the ground.

Corolla - The petals of a flower considered as a group or unit and usually of a color other than green; the inner whorl of the perianth.

Chert - is a very hard sedimentary rock that is usually found in nodules in limestone. Chert is light grey to dark grey in colour. It probably formed from the remains of ancient sea sponges or other ocean animals that have been fossilised. Silica has replaced the tissue forming the sedimentary rock. Flint is a very dark form of chert. It breaks like obsidian with conchoidal fractures making it widely used by ancient people to make arrowheads, spearheads, and knives.

Cilia – Plural of cilium.

Cilium - One of the hairs along the margin or edge of a structure, such as a leaf, usually forming a fringe.

Ciliate - In botany – Referring to the hairs along the margin or edge of a structure, such as a leaf, usually forming a fringe.

Cistaceae - Order of Cistaceae: Some herbs but mainly shrub, mainly Mediterranean or North American. Useful products: Garden shrubs.

Colluvium - A heterogeneous mixture of material that as a result of gravitational action has moved down a slope and settled at its base.

Compositae - Order of Compositae: Herbs, shrubs, flowers crowded into heads or single flowers male ormaleand female, outer ones often ligulate (rayed), the inner tubular, or all ligulate: bellis, aster, dahlia.

Convolvulaceae - Order of Convolvulaceae: Herbaceous or woody, often climbing, juice usually milky plants such as Ipomoea and Convolvulus species. Useful Products: Sweet potato - Ipomoea batata.

Chenopodiaceae - Order of Chenopodiaceae: Annual or perennial herbs or shrubs, often glaucus, stems sometimes jointed. Useful Products: Beetroot, spinach, beet.

Chorotype – Phytogeographical territory or phytochoria

Colluvium - A heterogeneous mixture of material that as a result of gravitational action has moved down a slope and settled at its base.

Conglomarate – Order of Cruciferae or Brassicaeae: Annual or perennial herbs, rarely somewhat shrubby, with watery juice. Useful products: Cabbage, turnip, mustard, radish and wallflower.

Convolvulaceae - Order of Convolvulaceae: Herbaceous or woody, often climbing, juice usually milky. Useful Products: Sweet potato -Ipomoea batata, flowering plants – Ipomoea and Convolvulus.

Coumarins - A fragrant crystalline compound, $C_9H_6O_2$, extracted from several plants, such as tonka beans and sweet clover, or produced synthetically and widely used in perfumes.

Cyanobacteria - A photosynthetic bacterium of the class Coccogoneae or Hormogoneae, generally blue-green in colour and in some species capable of nitrogen fixation.

Cyperaceae - Order of Cyperaceae: Perennial or annual herbs, found usually in damp or marshy habitats. Flowers small and inconspicuous. Useful products: papyrus (Cyperus papyrus) - Leaves of many species used for matsCyanobacteria were once thought to be algae. Also called blue-green alga.

Deobstruent - Clears obstructions from the natural ducts of the body.

Diaspore - Seed production/dispersal. From the Greek meaning scattering, to sow, scatter like seed.

Dioecious - Characterized by species in which the male and female reproductive organs occur on different individuals; sexually distinct.

Divaricate - Branching or spreading widely from a point or axis, as branches.

Dolomite - is named for the French mineralogist Deodat de Dolomieu, is a common sedimentary rock-forming mineral that can be found in massive beds several hundred feet thick. They are found all over the world and are quite common in sedimentary rock sequences. These rocks are called appropriately enough dolomite or dolomitic limestone

Ecotone – A transitional zone between two ecological communities containing the characterstic species of each

Eocene - The Eocene epoch is part of the Tertiary Period in the Cenozoic Era, and lasted from about 54.8 to 33.7 million years ago. The oldest known fossils of most of the modern orders of mammals appear in a brief period during the Early Eocene and all were small, under 10 kg.

Edaphic - Pertaining to, or affected by the state or condition of the soil.

Ephedraceae - Order of Ephedraceae: Upright shrubs, climbing or hanging from cliffs.

Erg – Erg deserts are extensive accumulations of sand often referred to as a 'sand sea'.

Equidae - The Equidae family include horses, asses and Zebra.

Eremic - Pertaining to sandy deserts.

Evapotranspiration - Is the combined evaporation from the soil and transpiration from a plant.

Exosmosis - Biological term for when water flows from a cell or organism into a surrounding solution.

Flexuous - Crooked (not straight). Bending or winding alternately from side to side; sinuous.

Furanocoumarins - Toxic compounds found primarily in species of the Apiaceae (Umbelliferae) and Rutacea. They come in a variety of flavours and have adverse affects on wide variety of organisms, ranging from bacteria to mammals.

Garigue – In Mediterranean areas - Deforestation over many years resulting in dominant open rocky ground dominated by dwarf shrubs usually less than 50 cm tall often with flowering bulbs.

Geraniaceae - Order of Geraniaceae: Annual herbs or shrubs, rarely arborescent; leaves alternate or opposite, mostly lobate. Useful products: Chiefly cultivate d for their handsome flowers and scented leaves; geranium pelargonium

Geological - Relating to the structure/history/composition of the earth

Geomorphology - refers to the branch of geology which is concerned with the structure, origin and development of the topographical features of the earth's crust.

Glabrous - Smooth; having a surface without hairs, projections, or any unevenness.

Filamentous - A chainlike series of cells, as in many algae,

Gramineae - Order of Gramineae / Poaceae: Annual or perennial herbs, rarely shrubs or trees; stems erect – grasses.

Gynodioecious - Having bisexual flowers on some plants and only female flowers on other plants of the same species.

Halophyte - A plant that grows in saline soils

Hammada – Extensive, nearly level desert surface areas comprising bare bedrock or bedrock veneered by pebbles, smoothly scoured and polished.

Hemiparasite - A parasitic plant that contains some chlorophyll and therefore is capable of photosynthesis and thus is only partially reliant on the host plant for survival.

Heterogeneous - Consisting of dissimilar elements, parts, or ingredients -- opposed to Homogeneous - Of the same or similar nature or kind

Hydrophytes - A plant that only grows in water or very moist soil.

Hygrochastic - Of a fruit, which opens by the absorption of water.

Hypoglycemia - Is the clinical syndrome that results from low blood sugar.

Hysternathous – Of leaves that develop only after the flowers have opened

Indehiscent - Said of fruits, fruit-bodies etc., which do not open to disperse their contents.

Indurate / Indurated - Hard, hardened.

Inflorescence – Flowering; flower cluster or a characteristic arrangement of flowers on a stem.

Infructescence – The fruiting stage of an inflorescence.

Involucre - A group of bracts enveloping a condensed inflorescence. Protecting bracts.

Iridaceae - Order of Iridaceae: Perennial herbs with the roots from underground rhizomes, corms, or bulbs; stems herbaceous, usually very ornamental and beautifully mottled or spotted.

Isohyet – An isohyet is a line joining places of equal precipitation on a map.

Isotherm – An isotherm is a line of equal or constant temperature on a graph, plot, or map.

Juncaceae - Order of Juncaceae: Perennial or annual herbs, rarely shrub like, often with hairy roots; rhizome erect or horzontal. leaves mostly in basal tuft, cylindrical to flat and grass like.

Kibbutz – A collective farm or settlement in modern Israel.

Kibbutzim – Plural of kibbutz

Labiatae - Order of Labiatae: herbaceous or rarely woody, often odoriferous, stems usually quadrangular, leaves opposite or whorled. Useful products: mint, salvia, marjoram, lavander etc.

Landscape Character – Definitions given to homogenous areas of landscape with similar natural and man-made physical and visual characteristics, including landform, landuse, vegetation patterns etc.

Landscape Quality – Quantifying landscape areas in terms of their considered value in terms of a hierarchy such as high quality, medium quality, low quality determined by various factors including its rarity, integrity, intrusive elements, tranquillity etc.

Lignification - Becoming woody as a result of the deposition of lignin in the cell walls.

Lignified – with woody tissue

Ligulate - Said of a corolla which has very short tube and which is prolonged above into a flattened group of united petals.

Liliaceae - Order of Liliaceae: Herbs, mostly perennial, or rarely soft-wooded shrubs; roots from rhizome, corm or bulb, sometimes tuberous; stems erect or climbing. Useful Products: aloe asparagus.

Lisan Lake - The Lisan Lake, stretched from the northern Arava Valley to the Sea of Galilee. About 15,000 years ago it dried up, leaving behind what is known now as the Dead Sea.

Loess - Is a German word from löss, meaning pour, dissolve or loosen. It refers to windblown deposits predominantly silt sized (6-90%).

Loranthaceae - Order of Loranthaceae: Shrubs parasitic on trees or very rarely erect terrestrial trees or shrubs; leaves mainly opposite or whorled, simple, entire, sometimes reduced to a scale. Flowers often brightly coloured. Useful Product: Mistletoe.

Malvaceae - Order of Malvaceae: Herbs or shrubs, rarely small trees, often with fibrous stems. Useful products: cotton, hibiscus and many fibre plants.

Mannitol - This is a sugar alcohol. It is used reduce acutely raised intracranial pressure in the cranium.

Maquis – In Mediterranean areas – Deforestation over many years resulting in dominant plants of evergreen shrubs and shrubby trees to 5m tall creating dense thickets.

Marl - Marl is a sedimentary rock containing clay and calcium carbonate.

Menispermaceae - Order of Menispermaceae: Twining or rarely erect shrubs or small trees.

Mesophyte - Any plant growing in surroundings with an average supply of water.

Mimosaceae - Order of Mimosaceae: Trees or shrubs, very rarely herbs. Fruit a legume or indehiscent; seeds with scanty or no endosperm – includes many trees used in desert landscapes: Prosopis, Mimosa, Acacia, Albizzia species.

Monotypic - Consisting of only one type.

Moraceae - Order of Moraceae: Trees or shrubs, rarely herbs with milky juice. Useful products: Mulberry, rubber, jack-fruit.

Moringaceae - Order of Moringaceae: Trees commonly stout-trunked with gummy bark, and with a large mucilage canal in the centre of the pith. Useful Products: Moringa oleifera (horseradish tree) has edible fruits, the seeds supply 'oil of ben' or 'watchmaker's oil' used in perfumery and light lubricants, and the roots are a source of edible condiment.

Morphology - A branch of biology that deals with the form and structure of animals and plants

Moshav – An Israeli cooperative settlement of small farms, or small holdings.

Moshavim – Plural of moshav.

Nabateans - A trading people of ancient Arabia with settlement oasis

Neolithic - The cultural period that lasted in SW Asia from about 9000 to 6000BC and in Europe from about 4000 to 2400 BC and was characterised by primitive crop growing and stock rearing and the use of polished stone and flint tools and weapons.

Neogene - The Neogene Period is a unit of geologic time consisting of the Miocene (23 to 5.3 million years before the present), Pliocene (5.3 million to 1.8 million years before present), Pleistocene (up until 10, 000 years ago), and Holocene (10, 000 years ago until the present day) epochs. The Neogene Period follows the Paleogene Period.

Obovoid - Egg-shaped and solid.

Orobanchaceae - Order of Orobanchaceae: Herbs parasitic on roots, often covered with scales at the base, never green

Ottoman – The Ottoman empire ruled by the Turks from the 13th century to its dissolution after Word War 1.

Ovoid - Shaped like an egg; ovate.

Paleolithic - The period of the emergence of primitive man and the manufacture of unpolished chipped stone tools, about 2.5 million to 3 million years ago until about 12 000 BC. Lower Paleolithic is the earliest of the 3 periods during the Paleolithic era commencing 3 million years ago and ending about 70 000 years ago with the emergence of Neanderthal Man.

Palmae - Order of Palmae: Mainly tropical trees and shrubs and vines usually having a tall columnar trunk bearing a crown of very large leaves; coextensive with the order Palmales - Stems stout or slender, often along river banks. Useful Products: Coconut and date palm amongst many others.

Papaveraceae - Order of Papaveraceae: Annual to perennial herbs with coloured juices, rarely shrubs or small trees, flowers mostly solitary visited by insects for pollen, fruit capsular. Useful Products: Opium poppy.

Papilionaceae - Order of Papilionaceae: Herbs, shrubs or trees; leaves simple or compound; flowers zygomorphic (of a flower or calyx or corolla: symmetrical about one plane only, usually the plane that bisects the flower vertically.)

Pappus - A modified calyx, (the sepals of a flower considered as a group),composed of scales, bristles, or featherlike hairs in plants of the Compositae family, such as the dandelion and thistle.

Pedicel - A small stalk or stalk-like part bearing a single flower in an inflorescence.

Pedogenic - relating to pedogenisis (soil development)

Perennation - The survival from season to season, generally with a period of reduced activity between each season.

Perianth - The outer envelope of a flower, consisting of either the calyx or the corolla, or both.

Perennial – A perennial plant living for three or more years.

Phenology - The study of the timing of recurring biological phases, the causes of their timing with regard to biotic and abiotic forces, and the interrelation among phases of the same or different species.

Phenotype - The physical constitution of an organism as determined by the interaction of of its genetic constitution and the environment.*

Phloem — The tissue that carries organic nutrients, particularly sucrose.

Physiognomic – the appearance of something

Physiographic - means the same as geomorpholical which refers to the branch of geology which is concerned with the structure, origin and development of the topographical features of the earth's crust.

Phytogenic – Having a plant origin e.g. coal.

Phreatophytes - a plant having very long roots that reach down to the water table or the layer above it.

Phytochoria – Phytogeographical territory or Chorotype.

Plagiotropic - Having the longer axis inclined away from the vertical line.

Plumbaginaceae - Order of Plumbaginaceae: Herbs, shrubs or climbers with bracts often sheathing, dry and membraneous, mainly along Mediterranean shores and mountains. Useful products: Some medicinal uses but mainly horticultural value.

Polygamous - Having both hermaphroditic and unisexual flowers on the same plant or on separate plants of the same species.

Polygonaceae - Order of Polygonaceae: Herbs, shrubs, or climbers, rarely trees. Useful products: Rhubarb (Rheum rhaponticum), Buckwheat (Fagopyrum esculentum.)

Polyisoprene – Natural rubber.

Procumbent - Trailing along the ground but not rooting.

Psammophile – Sand loving plant.

Puberulent – Covered with minute hairs or very fine down; finely pubescent.

Raceme - Clusters of flowers along the main stem in which the flowers at the base open first.

Ranunculaceae - Order of Ranunculaceae: Perennial and annual herbs with radical and alternate leaves, or shrubs or climbers. Useful products: many beautiful garden plants.

Reg – Desert pavements of loose stones.

Relict – An organism or species of an earlier time survivingin an environment that has undergone considerable change.

Rendzina - A dark soil that develops under grass on limestone and chalk.

Resedaceae - Order of Resedaceae: Annual or perennial herbs with watery juice, rarely woody. Useful products: fragrant garden plants, e.g. Reseda oderata (Mignonette).

Rhamnaceae - Order of Rhamnaceae: Mainly trees or shrubs, sometimes twining or climbing, comprising about 55 genera and 900 species. Useful products: Alder Buckthorn.

Roasaceae - Order of Rosaceae: Trees, shrubs or herbs. Useful products: some of the most

Rhizosphere - The soil zone that surrounds and is influenced by the roots of plants.

Rutaceae - Order of Rutaceae: Shrubs or trees, rarely herbs; leaves simple or compound, mostly gland dotted. Useful products: Lemon - Citrus limon, Orange - Citrus sinensis, Buchu - Barosma betulina.

Sabkha - A saline depression.

Salicaceae - Order of Salicaceae: Two genera of trees or shrubs having hairy catkins, namely Salix and Populus. Populus are wind pollinated, and Salix species, insect pollinated. Useful Products: Baskets, cricket bats.

Scabrous - Having or covered with scales or small projections and rough to the touch

Scape - The stem-like, flowering stalk of a plant with leaves clustered around the base of its stem.

Scrophulariaceae - The Scrophulariaceae are mostly herbs or sometimes small shrubs comprising about 190 genera and 4,000 predominately temperate species. The fruit type is usually a capsule. Useful products: mainly horticultural, Foxglove -Digitalis purpurea.

Segetal – field weeds.

Semishrub – Or dwarf shrub, referring to shrubs whose height is curtailed during hot summer s in desert regions where the outer parts of the plant are discarded.

Semi-steppe batha - Batha that has developed at the limits of the Mediterranean region beside the steppe and characteristically comprising plants that are different to the Mediterranean type of batha. (Feinbrun – Dothan and Danin, 1998, page 24)

Spadix - A fleshy club like spike bearing minute flowers, usually enclosed within a sheathlike spathe.

Steppe – Landscape with plants with dwarf shrubs that grow scattered across the whole area. (Feinbrun – Dothan and Danin, 1998, page 40)

Succulent - Plants having thick fleshy leaves or stems and/or a plant that is able to exist in arid conditions by using water stored in its fleshy tissues.*

Solanaceae - Order of Solanaceae: Herbaceous or woody plants: Useful products: Potato, tomato, capsicums, tobacco, deadly nightshade.

Sterols - Any of a group of solid, cyclic, unsaturated alcohols, with a complex structure that includes four carbon rings; cholesterol is an example. Steroids are derived from sterols.

Stomatitis – Infections of the mouth.

Striatulate - The meaning of this word is uncertain but it appears to mean striated.

Synanthropic – Ecologically associated with humans.

Tamaraceae - Order of Tamaricaciae: Trees or shrubs with slender branches and small scale like alternate leaves.

Taxonomy - The science of classifying living things. Wikipedia

Thermophelous - Of, relating to, or being an organism growing at a high temperature.

Thermophyte - A plant tolerant of, or thriving at, high temperatures.

Terete - Cylindrical and tapering.

Thymeleaceae - Order of Thymelaeaceae : Trees, shrubs, rarely herb, mainly from Southern Africa, Australia and the Mediterranean. Useful products: Mezereon bark.

Tisane – Herbal tea.

Tomentose - Covered with matted woolly hairs.

Umbel - Racemose inflorecence, characteristic of umbelliferous plants, in which the flowers arise from the same point in the main stem and have stalks of the same length, to give a cluster with the youngest flowers in the centre.*

Umbelliferae - Order of Umbelliferae: Herbaceous, very rarely woody, with furrowed and wide soft pith. Useful products: Celery - Apium graveolens, carrots, coriander.

Verbenacaceae - Order of Verbenacaceae: Woody or herbaceous plants mostly from the tropics and southern temperate regions including Lantana and Vitex species. Useful products: Teak wood and some beautiful garden plants.

Vilous - Covered with short soft hairs.

Viscid - Of a surface, sticky, coated with a thick, syrupy secretion.

Wadi – A valley or stream bed that remains dry most of the year.

Watersprout - Water sprouts are shoots that arise from a plant above ground level as opposed to suckers that arise from below ground level.

Xenophyte - A xenophyte is an alien plant, one that is not found naturally in the geographical area.

Xerohalophyte - An inland desert, (as opposed to coastal), salt tolerant plant species as described by Aronson. (Aronson in Pasternak, 1990, page 35)

Xerophyte - a plant structurally adapted for life and growth with a limited water supply especially by means of mechanisms that limit transpiration or that provide for the storage of water.

Xeriscaping - After the term Xeriscape, which refers to the efficient use of water and associated landscape design and practical methods in the landscape.

Xylem — In vascular plants, the xylem is the tissue that carries water up the root and stem.

Zygophyllaceae - Order of Zygophyllaceae: Shrubs or herbs woody at base, rarely trees; branches often jointed at the nodes: Fagonia, Peganum Zygophylum.

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RBGK, Royal Botanic Gardens, Kew (1999). Survey of Economic Plants for Arid and Semi-Arid Lands (SEPASAL) database. Published on the Internet, 'Tamarix aphylla' - http://www.rbgkew.org.uk/ceb/sepasal/internet - [Accessed: 04/10/2006; 10:00]

RBGK, Royal Botanic Gardens, Kew (1999). Survey of Economic Plants for Arid and Semi-Arid Lands (SEPASAL) database. Published on the Internet, 'Tamarix nilotica' - http://www.rbgkew.org.uk/ceb/sepasal/internet - [Accessed: 05/10/2006; 10:50]

RBGK, Royal Botanic Gardens, Kew (1999). Survey of Economic Plants for Arid and Semi-Arid Lands (SEPASAL) database. Published on the Internet, 'Teucrium polium' - http://www.rbgkew.org.uk/ceb/sepasal/internet - [Accessed: 25/08/2006; 12:45]

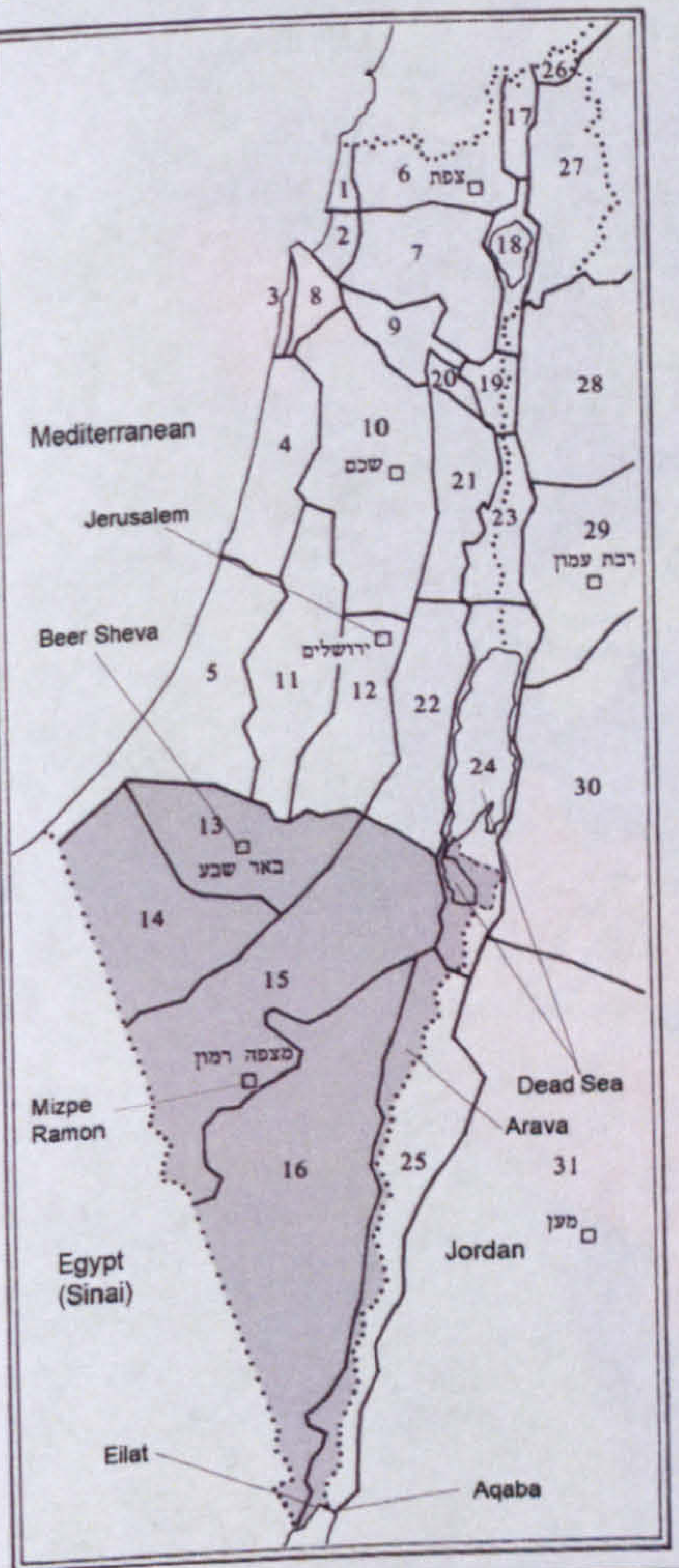
RBGK, Royal Botanic Gardens, Kew (1999). Survey of Economic Plants for Arid and Semi-Arid Lands (SEPASAL) database. Published on the Internet, 'Urginea maratima' - http://www.rbgkew.org.uk/ceb/sepasal/internet - [Accessed: 23/07/2006; 20:20]

RBGK, Royal Botanic Gardens, Kew (1999). Survey of Economic Plants for Arid and Semi-Arid Lands (SEPASAL) database. Published on the Internet, 'Varthemia iphioniodes' - http://www.rbgkew.org.uk/ceb/sepasal/internet - [Accessed: 10/08/2006; 09:15]

RBGK, Royal Botanic Gardens, Kew (1999). Survey of Economic Plants for Arid and Semi-Arid Lands (SEPASAL) database. Published on the Internet, 'Vitex agnus –

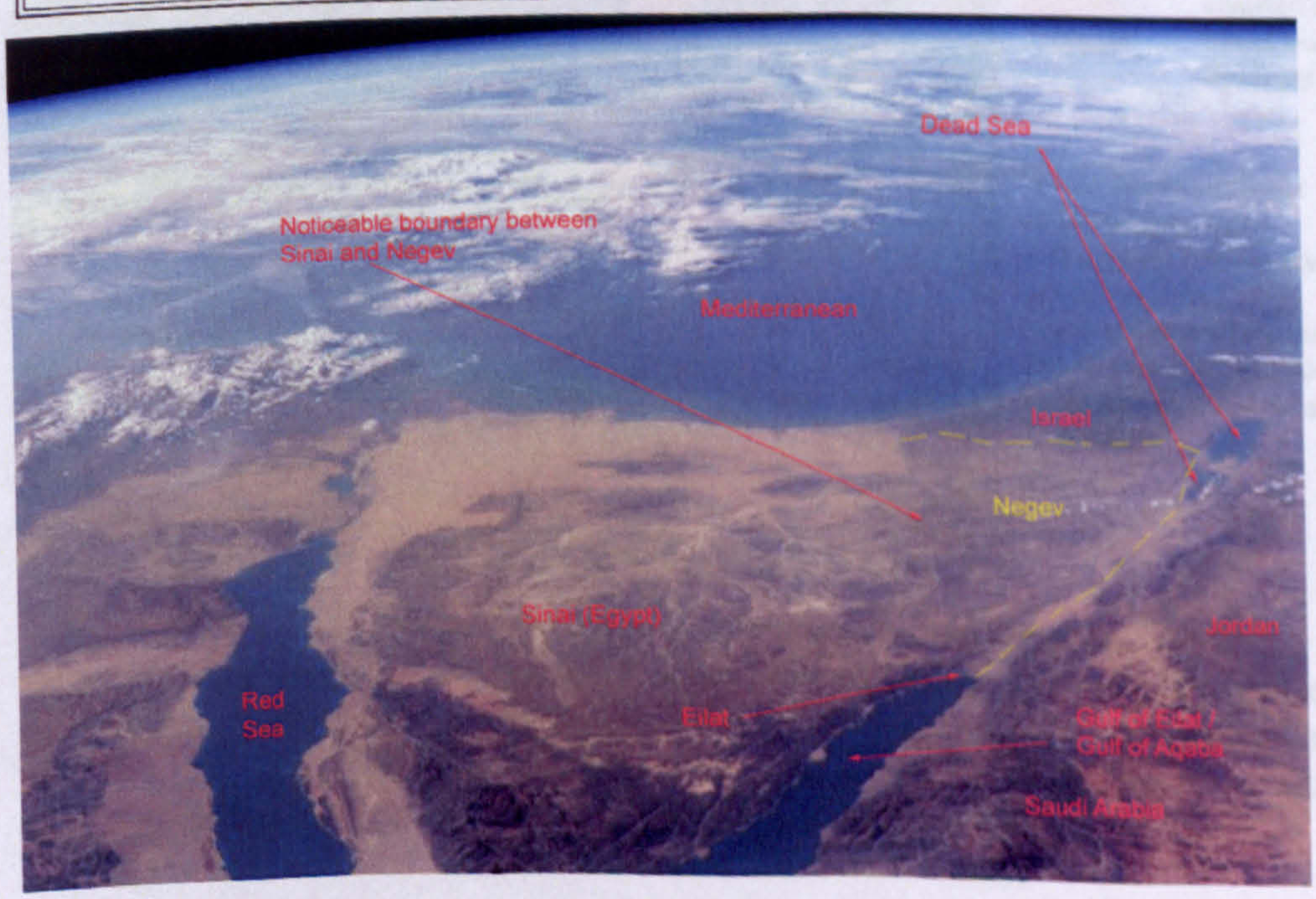
Appendix A - Figures

(Unless stated otherwise, photographs and illustrations are by the author.)



Left: Figure 1. Map of Israel showing the Negev and Negev districts marked in grey.
13 – Northern Negev, 14 – Western Negev, 15 – Negev Highlands, 16 – Southern Negev, 25 - Arava
(After Feinbrun-Dothan and Danin 1998, page 7.)

Below: Figure 1a. NASA photograph from the International Space Station showing the Negev and neighbouring countries and geographical features. The Negev's boundaries are shown approximately with a yellow dotted line. The Sinai boundary is evident because of the vegetation cover is greater in the Negev than in Sinai with uncontrolled grazing of flocks. (NASA, www, Photographic date 2003.)



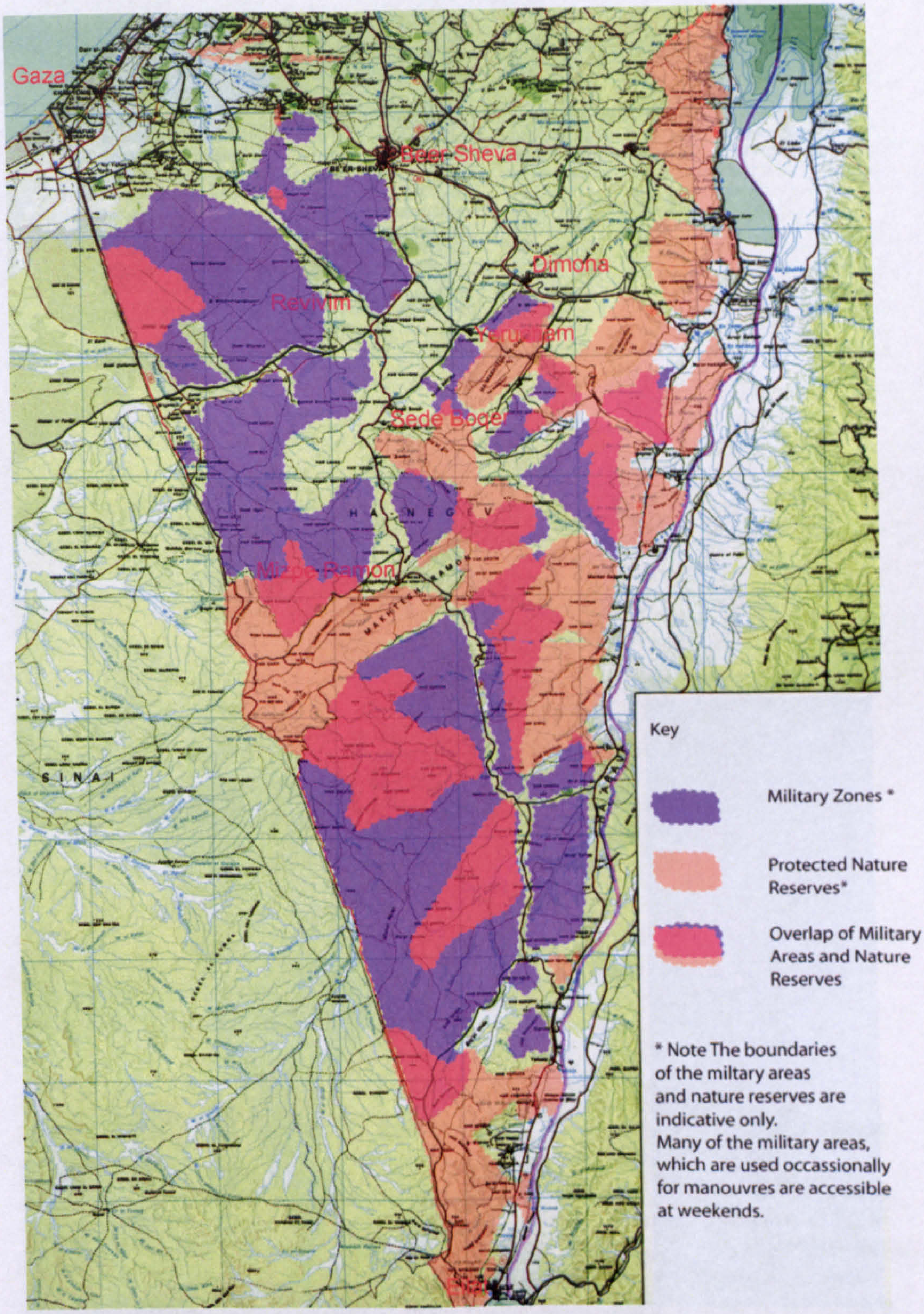


Figure 1b: Map of the Negev illustrating military exercise areas and protected nature reserves. (Some military areas are not accessible and others are only accessible at weekends. Base information from Stern et al 1986 and military exercise and nature reserve areas after 1:100 000 mapping published by the Israel Nature Protection Authority.

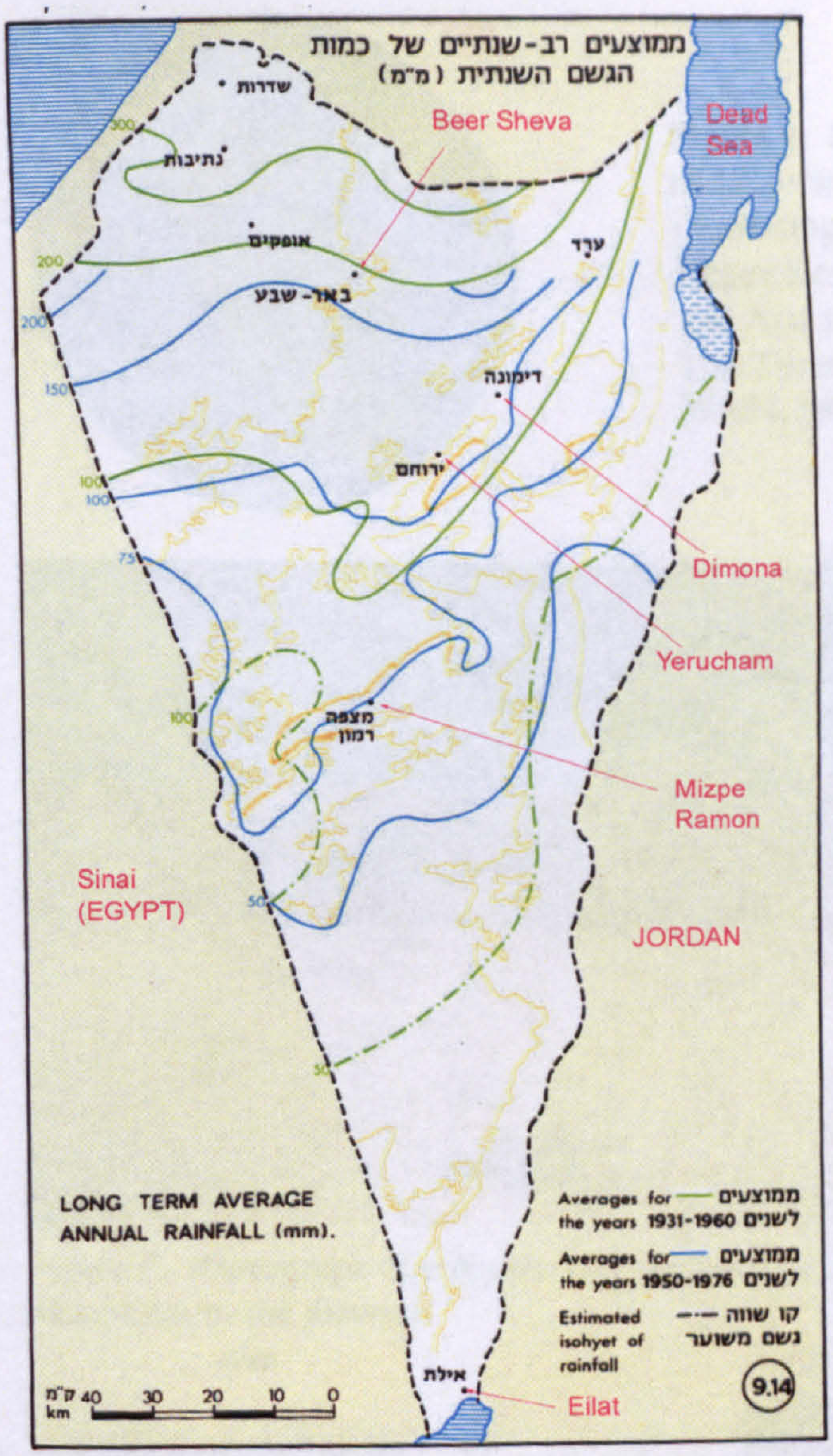


Figure 2. Map of the Negev showing long term annual rainfall as isohyets. (After Stern et al, 1986, page 65)

Figure 3. Photograph of area of *reg* and illustrating *Retama raetem* growing in light coloured soil as opposed to area dominated by dark rocks.

Figure 4. Locations of Gondwana and Laurasia 150 million years ago illustrating the location of the Negev Desert and noting that Africa and Asia were disjointed. (From The Times Concise Atlas of the World, page 32.)

Figure 5. Photograph of a desert wadi with part of the Eilat Mountains in the distance.

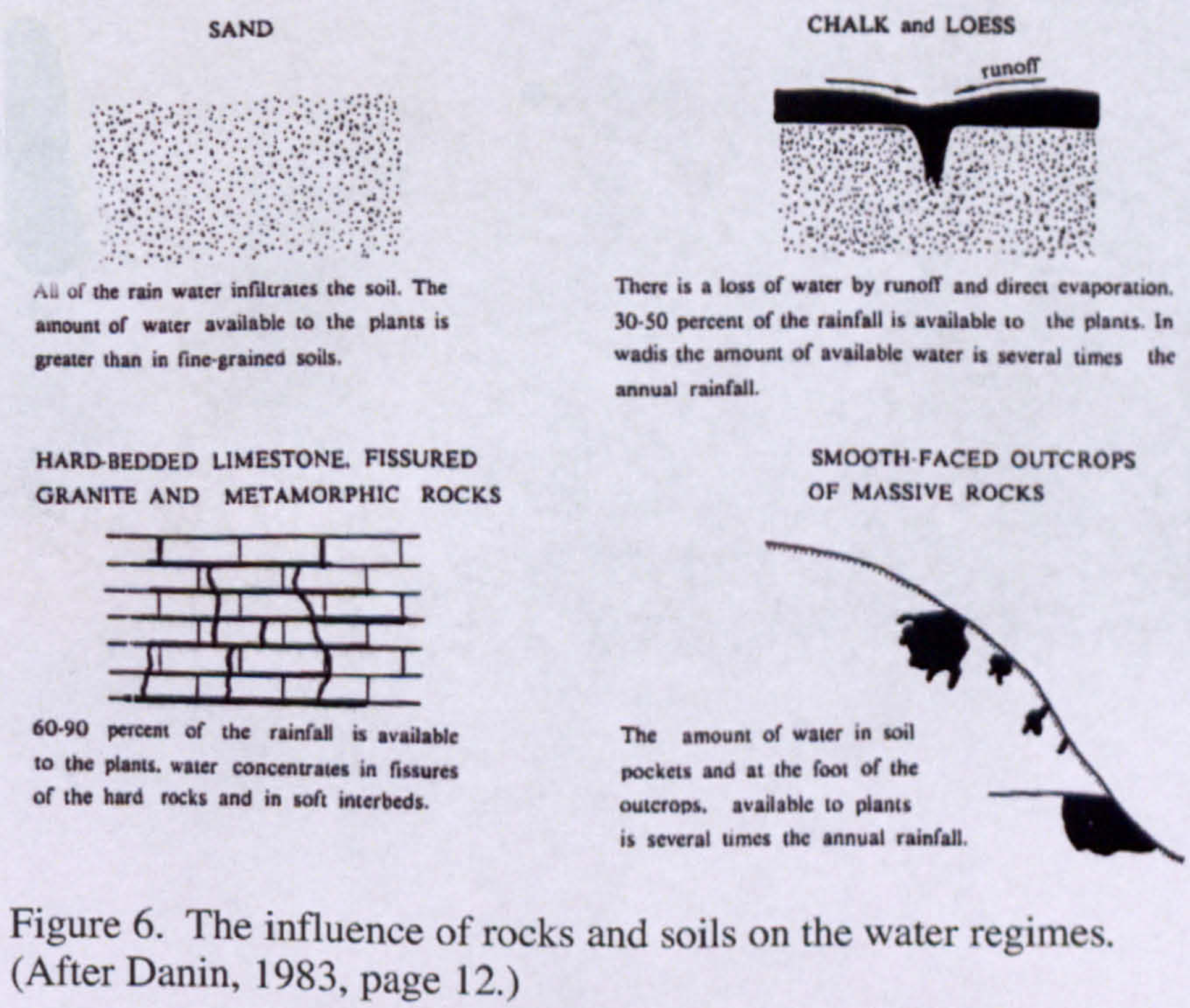


Figure 6. The influence of rocks and soils on the water regimes. (After Danin, 1983, page 12.)

Figure 7. Photograph of a parts of a Neolithic temple with images of a leopard, (foreground) and ibex, (background) constructed out of stones set into the ground located at 'Beqat Ovda', near Ovda airport in the southern Negev.

Figure 8 Photograph of the stables at the Nabatean archaeological site of Mamshit located near Dimona in the northern Negev.

Figure 9. Contemporary Israeli mapping indicating the boundary areas of ancient desert agriculture. Refer to http://www.mnemotrix.com/adasr/map.html and link to detail high resolution mapping illustrating time period layers. (From ADASR, www.)

Figure 10. A contemporary experiment of Nabatean water harvesting techniques illustrating slopes with stones and those with stones collected to increase water flow. In the distance, (hill in shadow), Nabatean walls to direct run-off can be seen.

Figure 11. A typical well established landscape setting as photographed at Kibbutz Revivim, with exotic plant species including *Plumbago sp., Nerium oleander, Eucalyptus sp., Delonix regia* and large expanses of grass.

Figure 12. Israel Nature Authority, 'Shmurat Hatevah' sign at the entrance to a protected nature reserve

Figure 13. View of the 'Druyan' nursery in Beer Sheva illustrating some of the exotic plant species available including *Bougainvillea sp.*, *Canna sp.*, *Asparagus sp.*, *Hibiscus sp.*, and numerous exotic palm species.

Figure 14. View of the 'Druyan' nursery illustrating some of the exotic plant species available including *Hibiscus sp.*, *Fuchsia sp.*, and numerous *Ficus* species.

Figure 15. View of the 'Druyan' nursery illustrating bedding plants including roses, pinks, petunias, geraniums, cockscomb and impatiens to name a few.

Figure 16. *Prosopis* species used as an ornamental tree at 'Midreshet Sde Boqer' on the edge of a protected nature reserve in the Negev Highlands.

Figure 17. *Pennisetum* species used as an ornamental on the protected 'Mamshit' Nabatean archaeological site in the Negev Highlands.

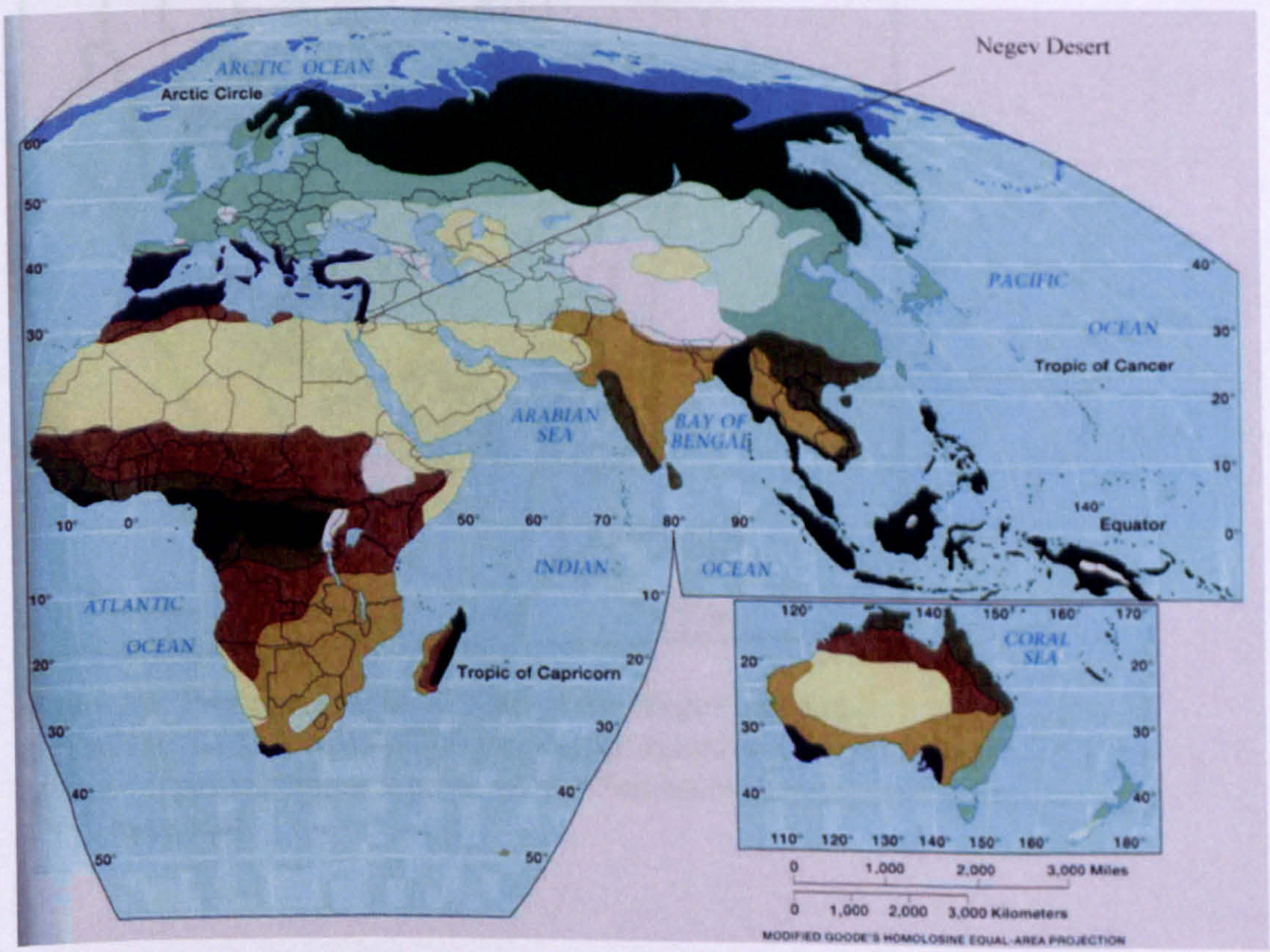


Figure 18. Map illustrating biomes in the earth's eastern hemisphere. The Negev Desert is noted as falling within the desert biome. (University of North Alabama, www.)

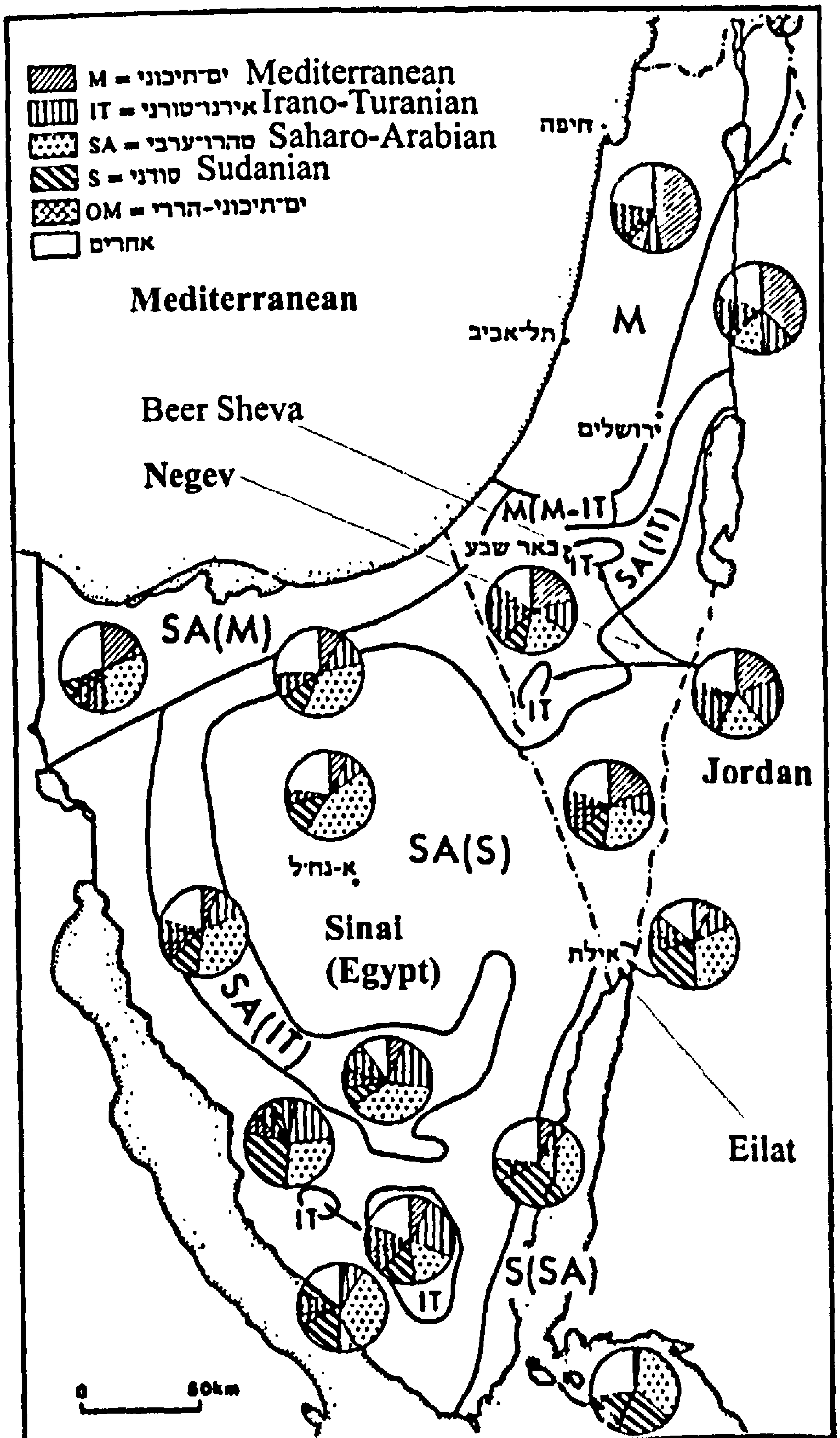


Figure 19. Phytogeographical Map of the Negev and Sinai illustrating the four main phytogeographic zones and distribution ratios of types within each area. (After Feinbrun-Dothan and Danin, 1998, page 10.)

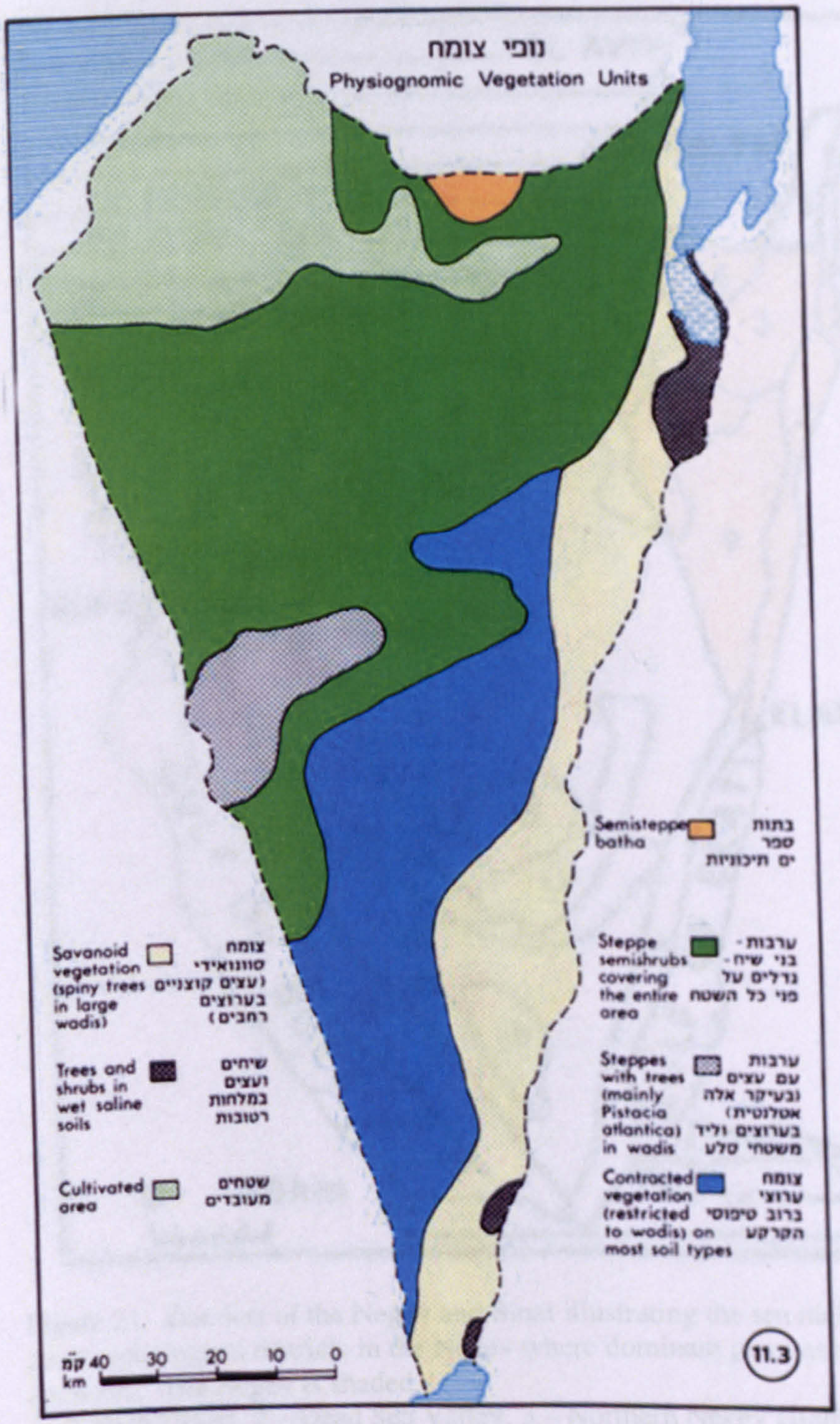


Figure 20. Physiognomic Vegetation Map of the Negev illustrating the seven main physiognomic vegetation zones. (After Stern et al, 1986, page 80.)

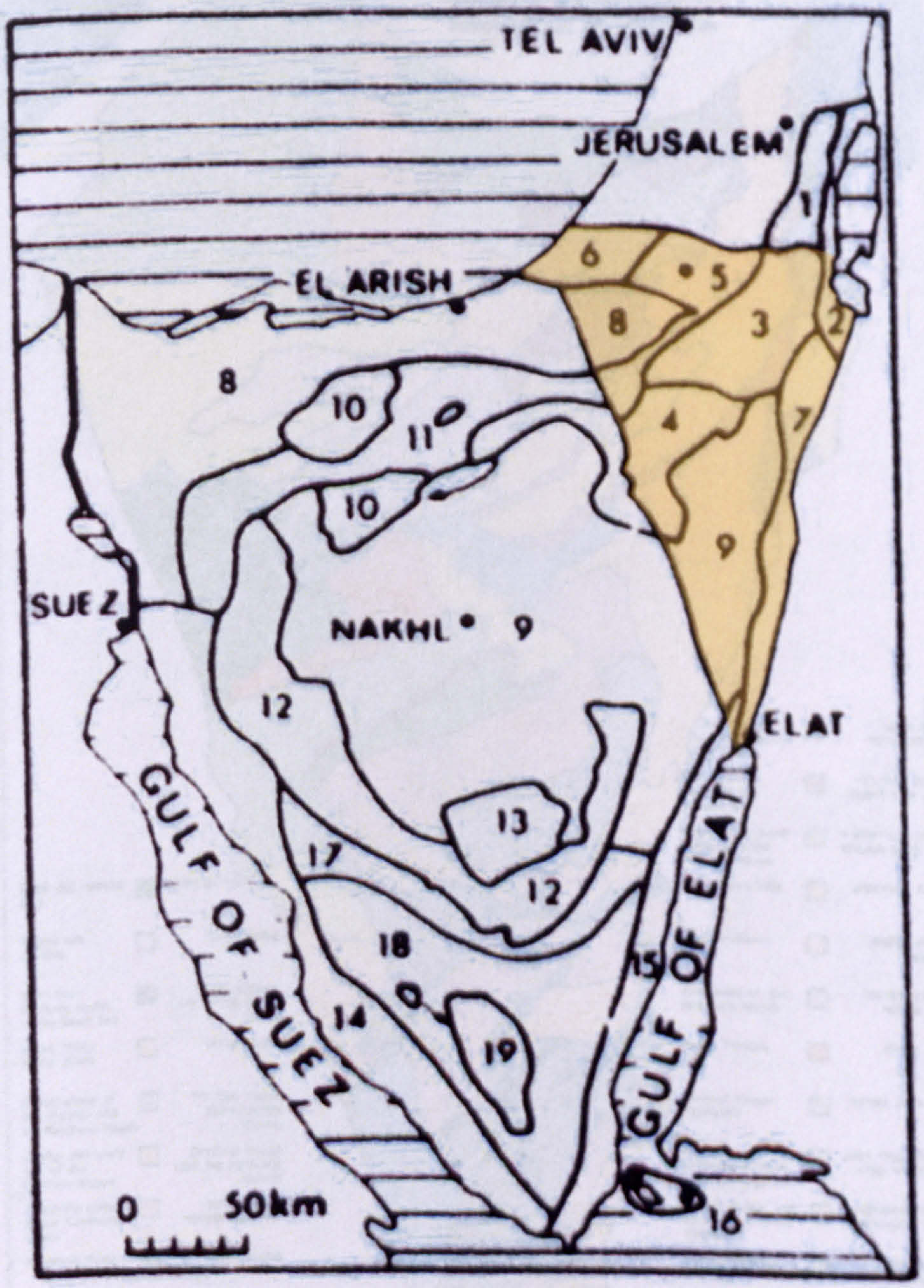


Figure 21. Districts of the Negev and Sinai illustrating the ten main geomorphological districts in the Negev where dominant plant associations are noted. The Negev is shaded.
1 - Judean Desert, 2 – Dead Sea Valley, 3 – Northern Negev Highlands, 4 – Central Negev Highlands, 5 – Negev Lowlands, 6 – The Coastal Plain of the Negev, 7 – Arava Valley, 8 – The Mediterranean Sands and Salt Marshes, 9 – Gravely Plains of Central Sinai and Southern Negev and 15 – Coastal Plain and Foothills of the Gulf of Eilat.
(After Danin, 1983, pages 37 – 53 and 63.)

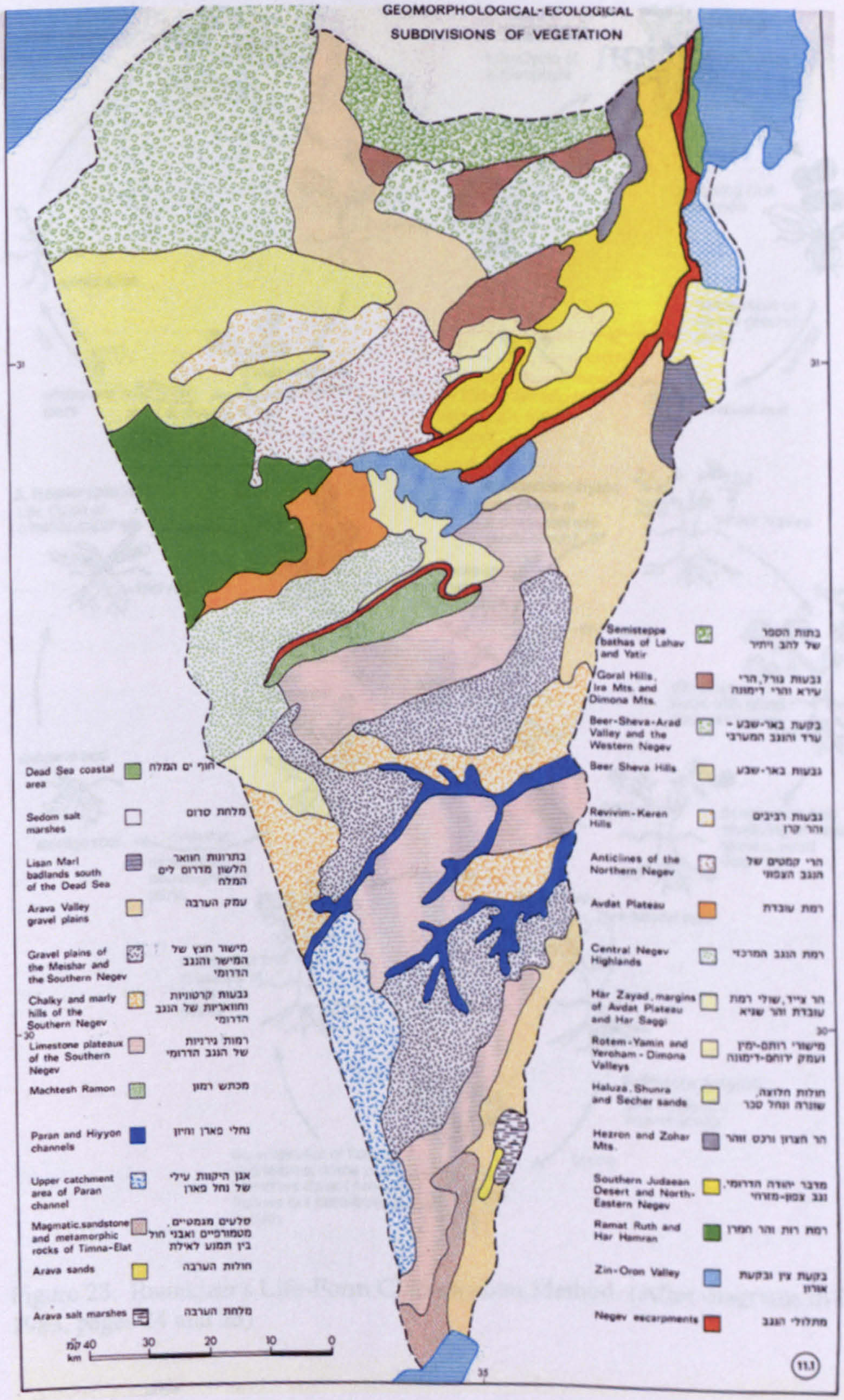


Figure 22. Districts of the Negev illustrating 29 Geomorphological-Ecological subdivisions of Vegetation. (After Stern et al, 1986, page 78)

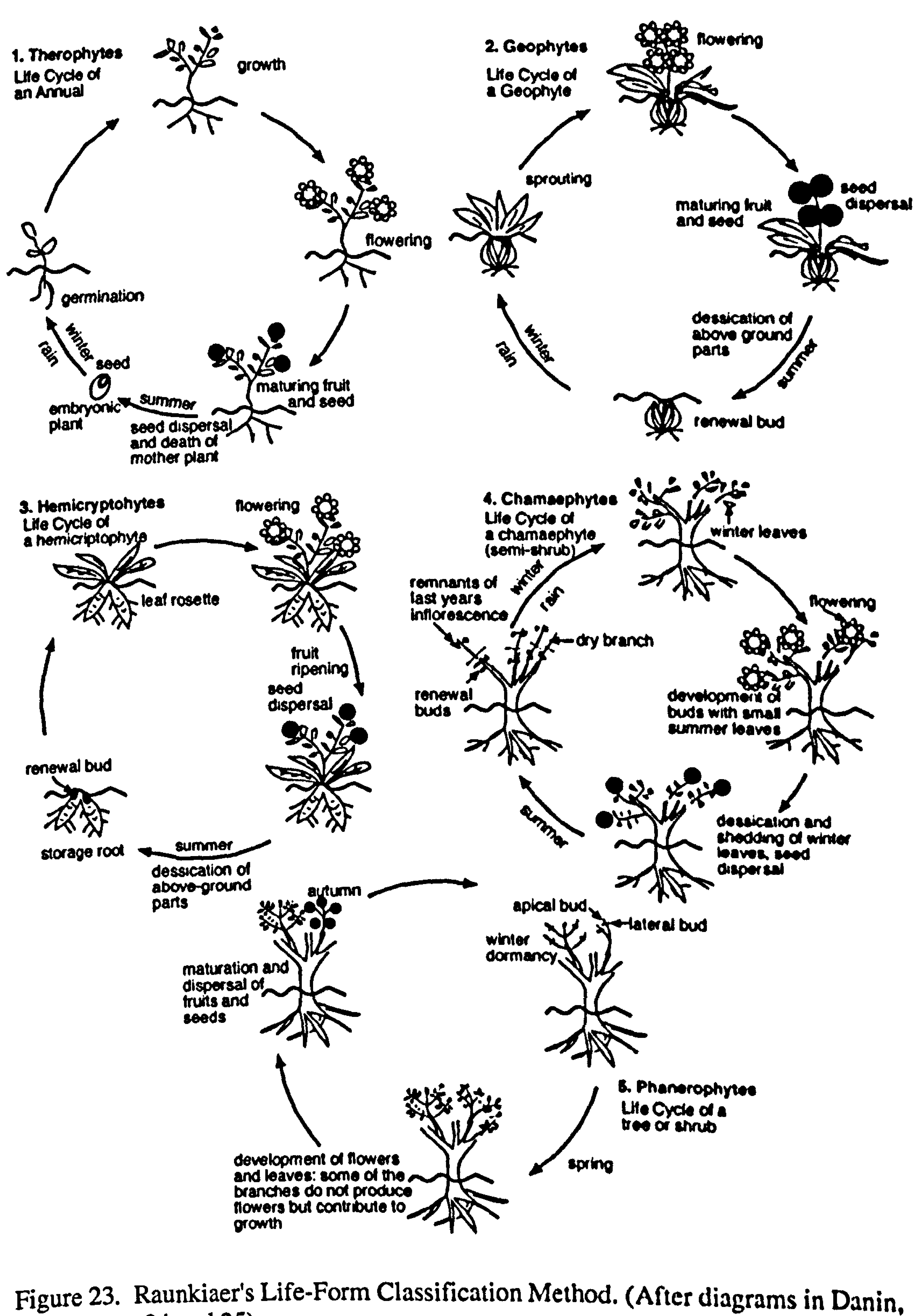


Figure 23. Raunkiaer's Life-Form Classification Method. (After diagrams in Danin, 1983, pages 24 and 25)

Figure 24. Eucalyptus species planted in the northern Negev where the Negev appears to resemble an Australian desert. Note the earth mounds, which have been formed to retain winter rain water, which is directed into the plantation and held there by the mounds.

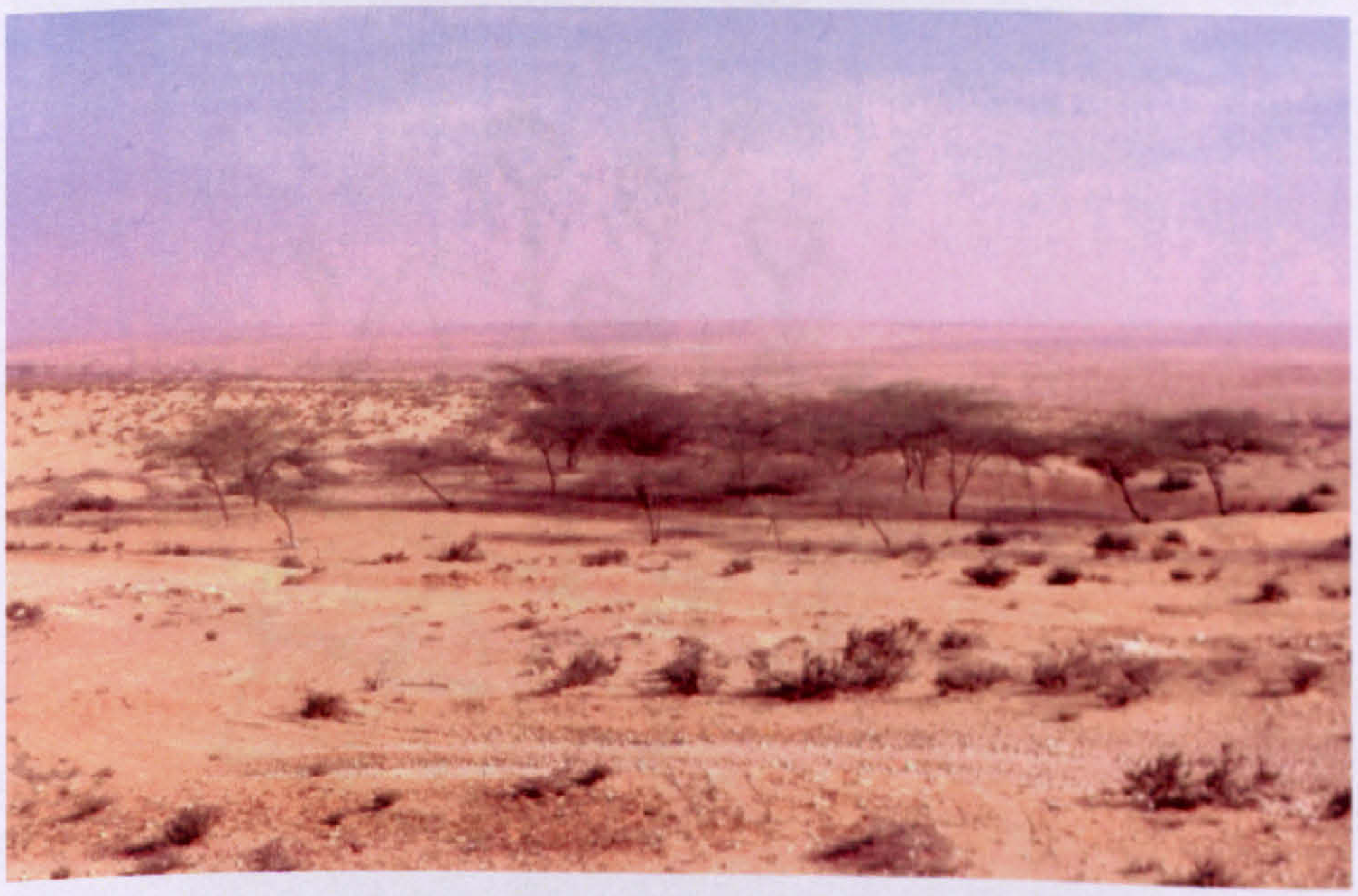


Figure 25. Photograph of *Acacia raddiana* species planted in the Negev by the Jewish National Fund, (JNF).

Figure 26. Photograph of the Australian *Atriplex halocarpa* formerly known also as *A. spongiosa* located in the northern Negev.

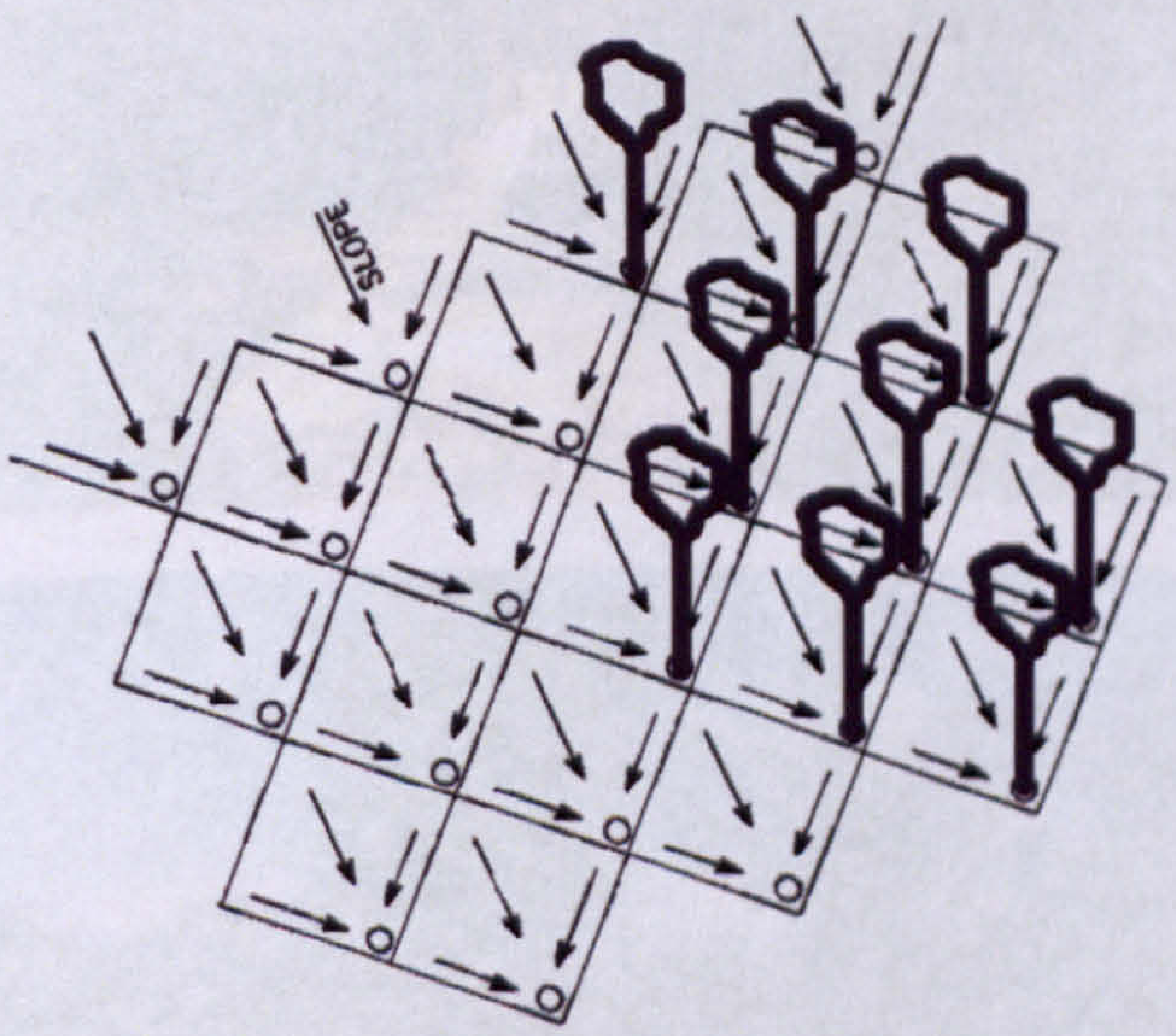


Figure 27. Diagram of' Negarim', which are micro-catchments using earth or stonewalls that collect, hold and direct water on slopes.

Figure 28. Photograph of landscaped park leading towards Ben Gurion's Grave at 'Sde Boqer'. Planting is characterised by the use of xerophytic species from around the world.

Figure 29. Photograph of a pathway and planting in a housing district at 'Midreshet Sde Boqer' with the use of South African aloes and other exotic plants.

Figure 30. Photograph of aloe and other succulent species grown at 'Midreshet Sde Boqer' by Prof. Gutterman.

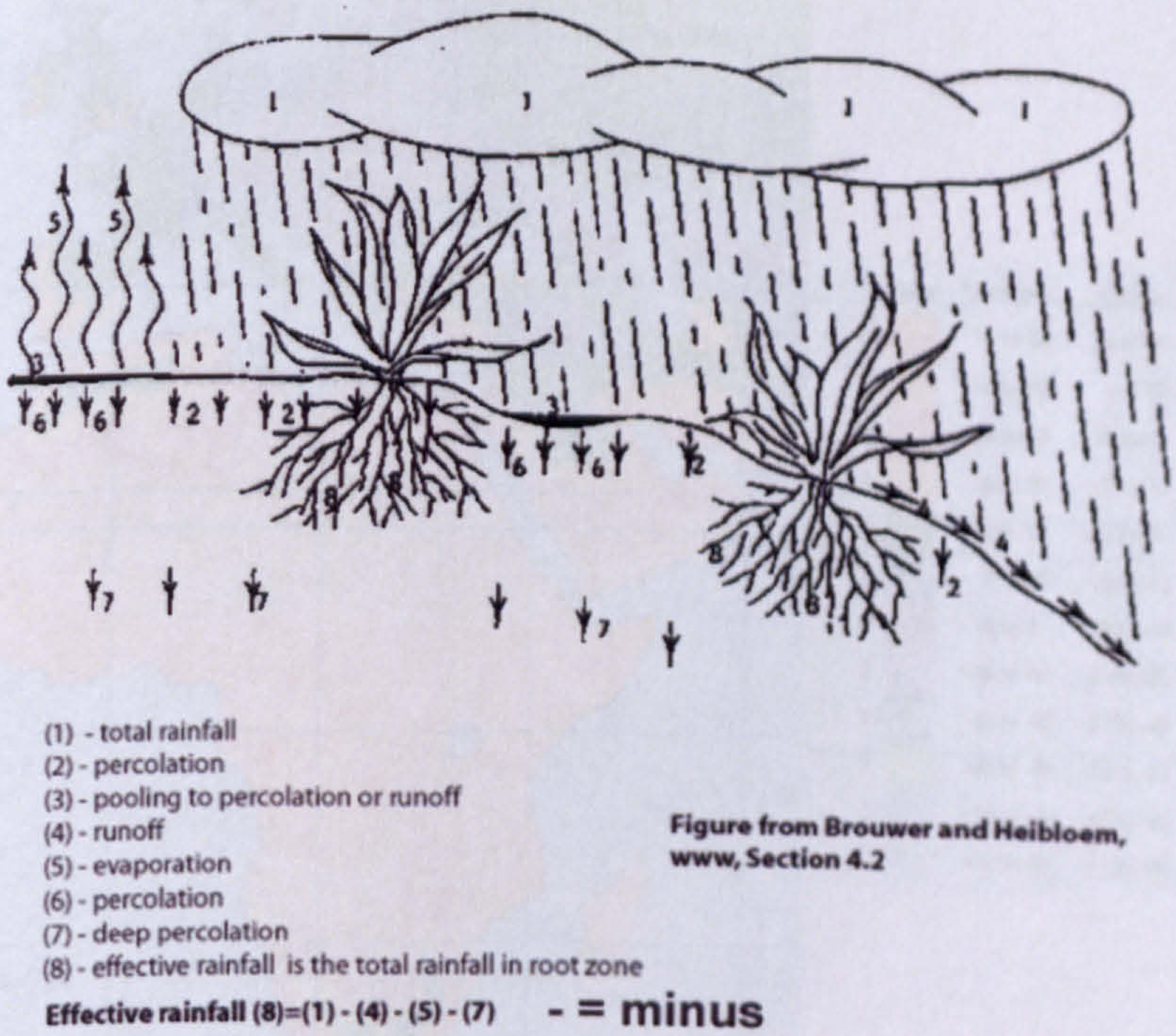


Figure 31. Effective rainfall: Only water that reaches and that is available within the root zone is valuable to the plant. (After Brouwer and Heibloem, www., Section 4.2)

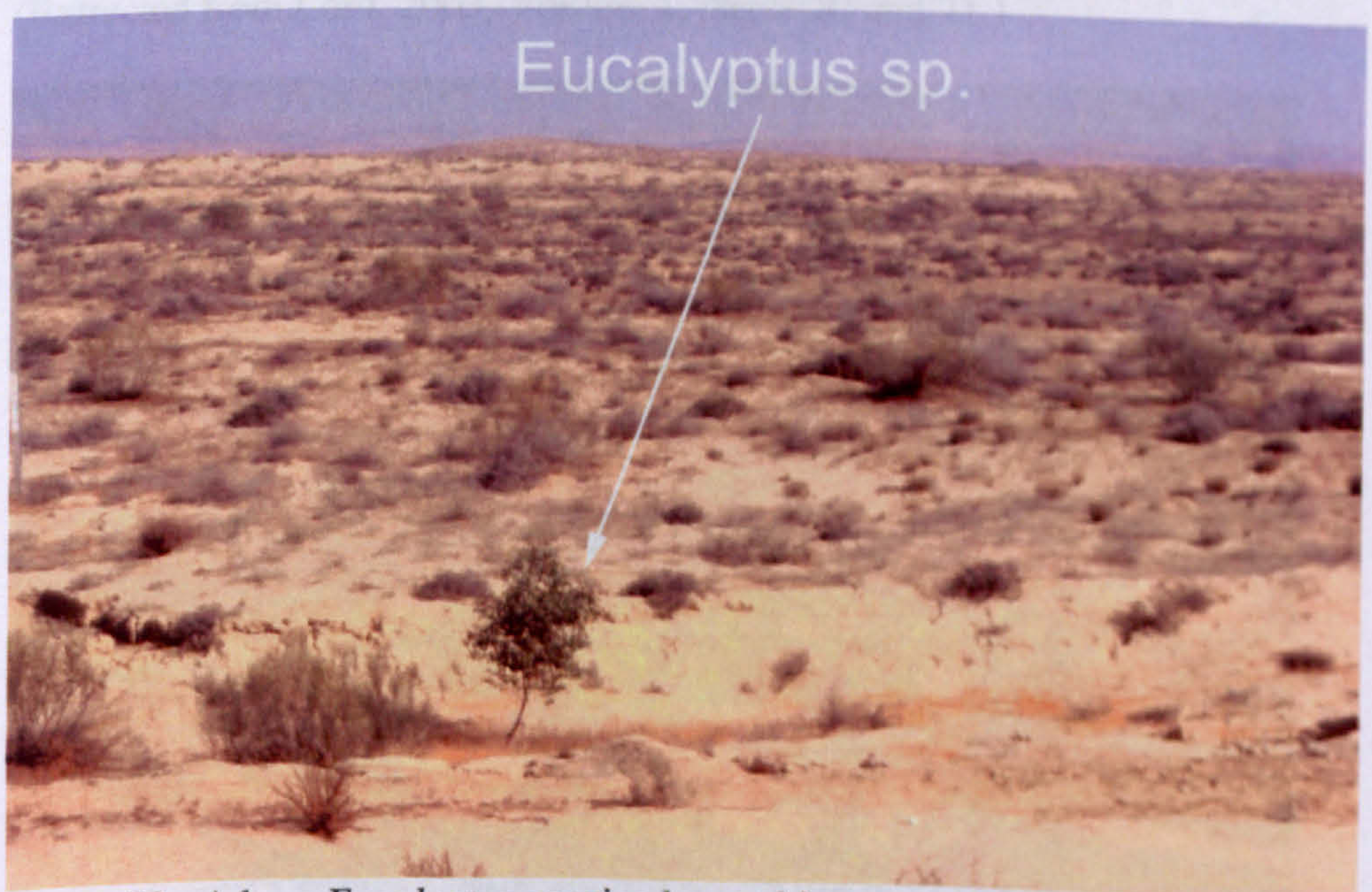


Figure 32. A lone *Eucalyptus* species located in a protected area in the sands of the northern Negev. It is suggested that this tree is self-seeded from groups located some kilometres away.

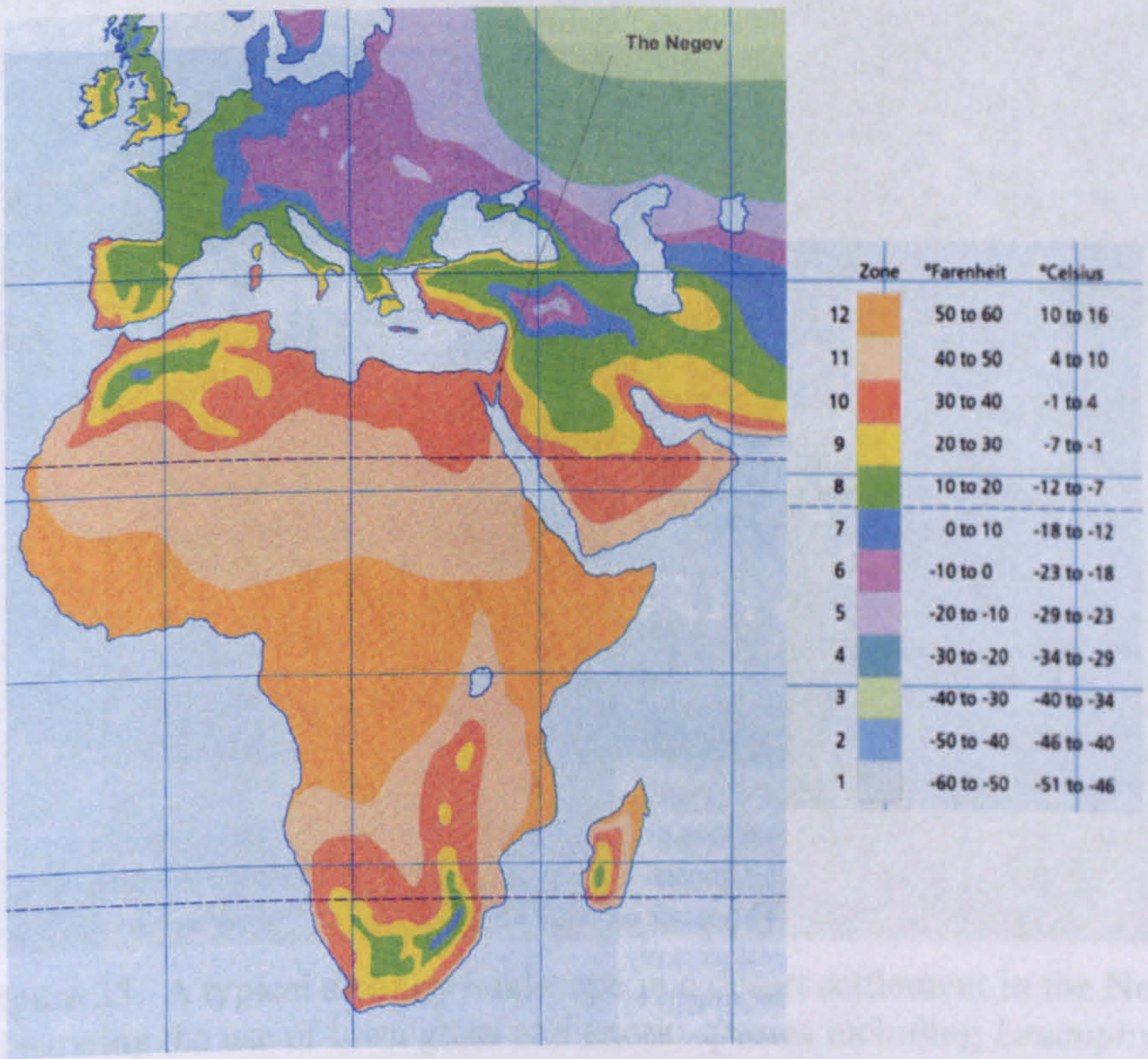


Figure 33. Plant hardiness zones for Africa the Middle East and Europe. (Extracted from Lord, 2003, Volume 1, pages 20 and 21.)

Figure 34. A typical amenity landscape in a desert settlement in the Negev – Species include shrub roses, juniper and eucalyptus species.

Figure 35. A typical amenity landscape in a desert settlement in the Negev illustrating the use of lawn grass and exotic species including *Leucophyllum* species from the U.S.A. in the foreground

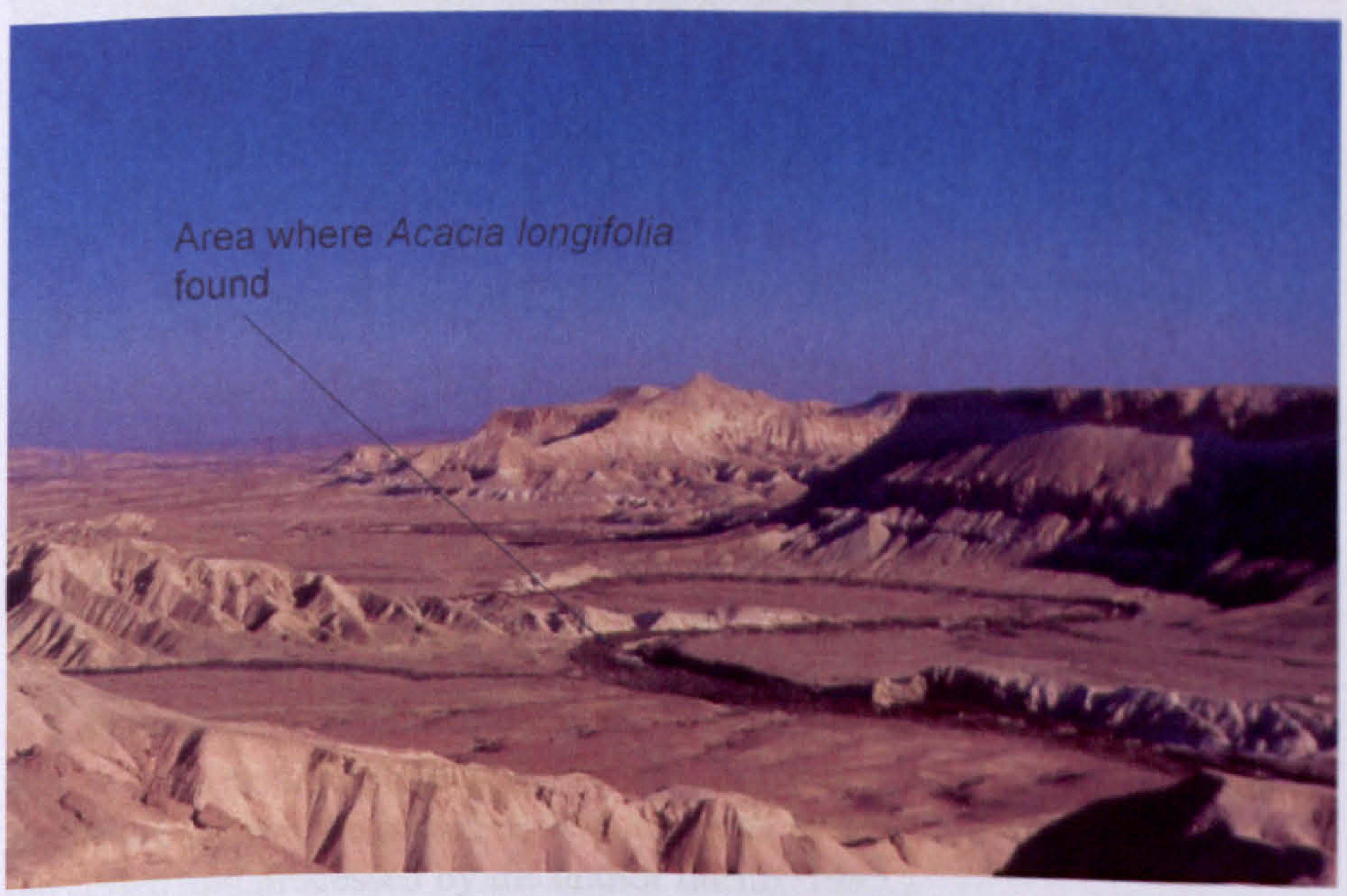


Figure 36. Photograph of Wadi Zin, a protected nature reserve, wherein the author located *Acacia longifolia.* It is suggested that the specimen was deposited as a waterborne seed into the remote protected area from specimens located in the higher areas some kilometres away from where the photograph was taken. (See Appendix I, Figure 3 for photograph of the specimen located.)

Figure 37. Photograph of the author noting the exotic species being grown in the JNF nursery for use in public areas.

Figure 38. Photograph of gladioli fields at Kibbutz Revivim. The loessal desert areas form the backdrop. (Photograph of fields planted, managed harvested and processed by the author during 1995.)

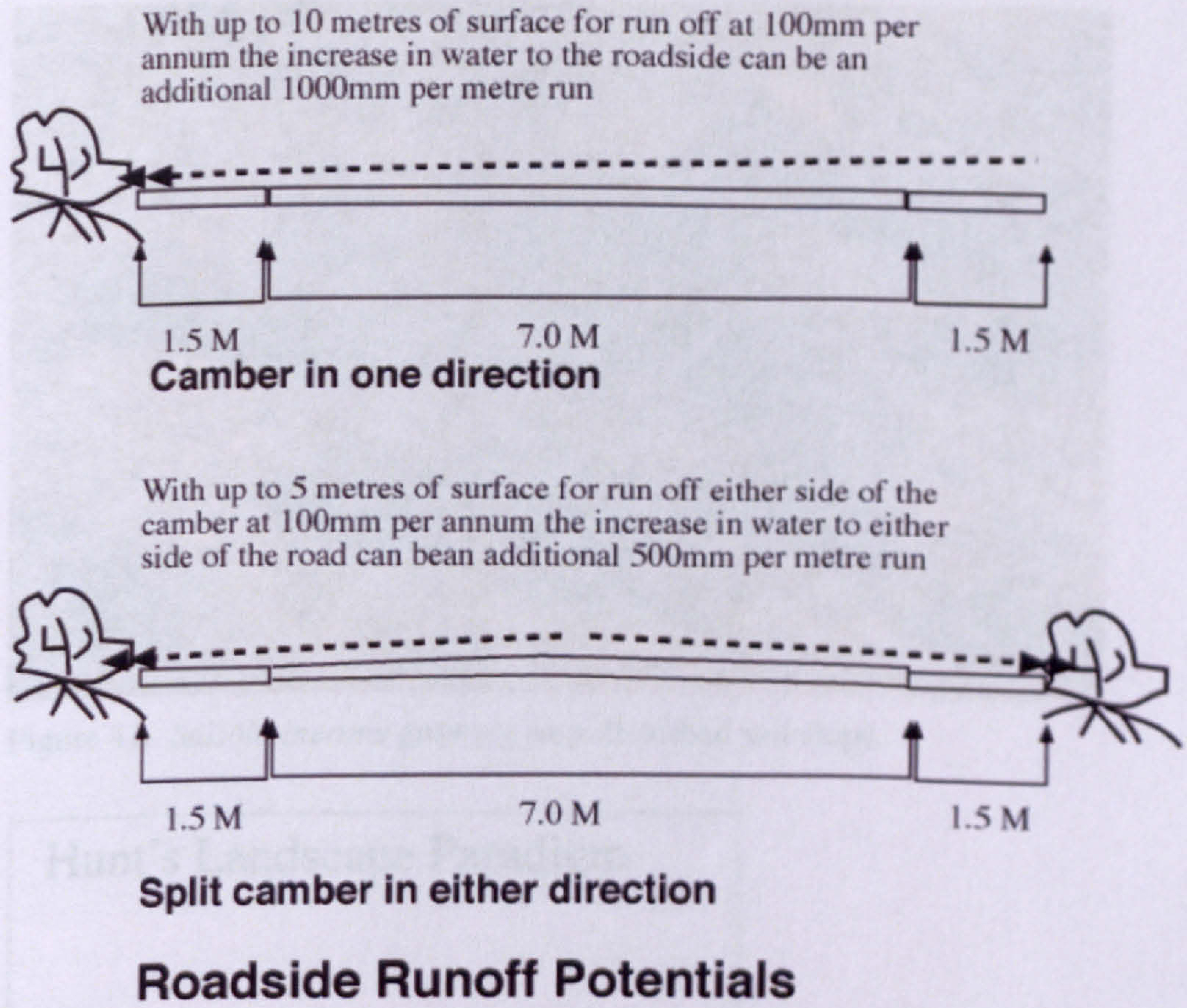


Figure 39. Runoff potentials for road in the Negev receiving 100mm of rainfall per annum.

Figure 40. A large specimen *Zygophyllum dumosum* growing on chalk that was disturbed as part of road building.

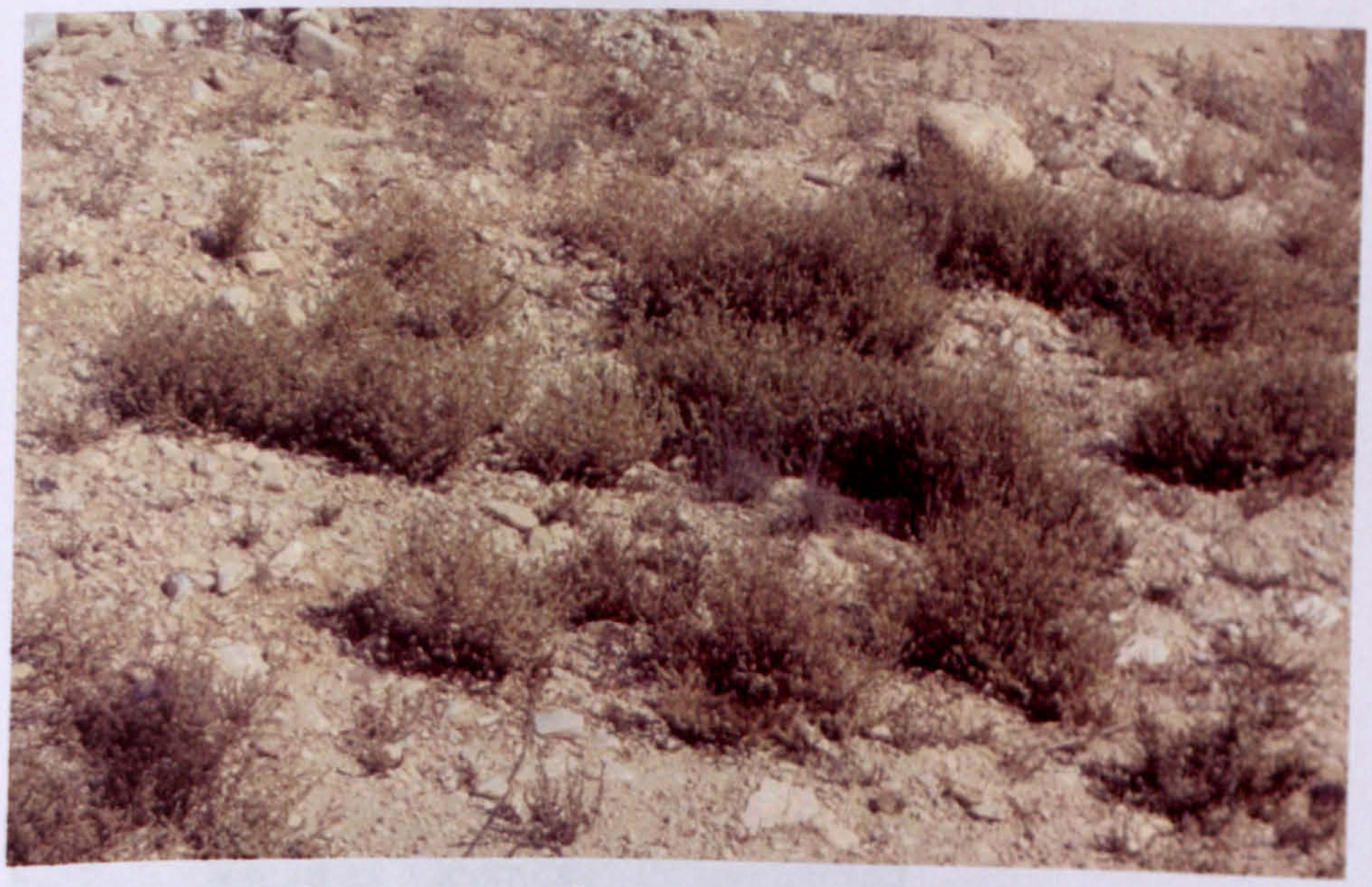


Figure 41. *Salsola inermis* growing on a disturbed soil slope.

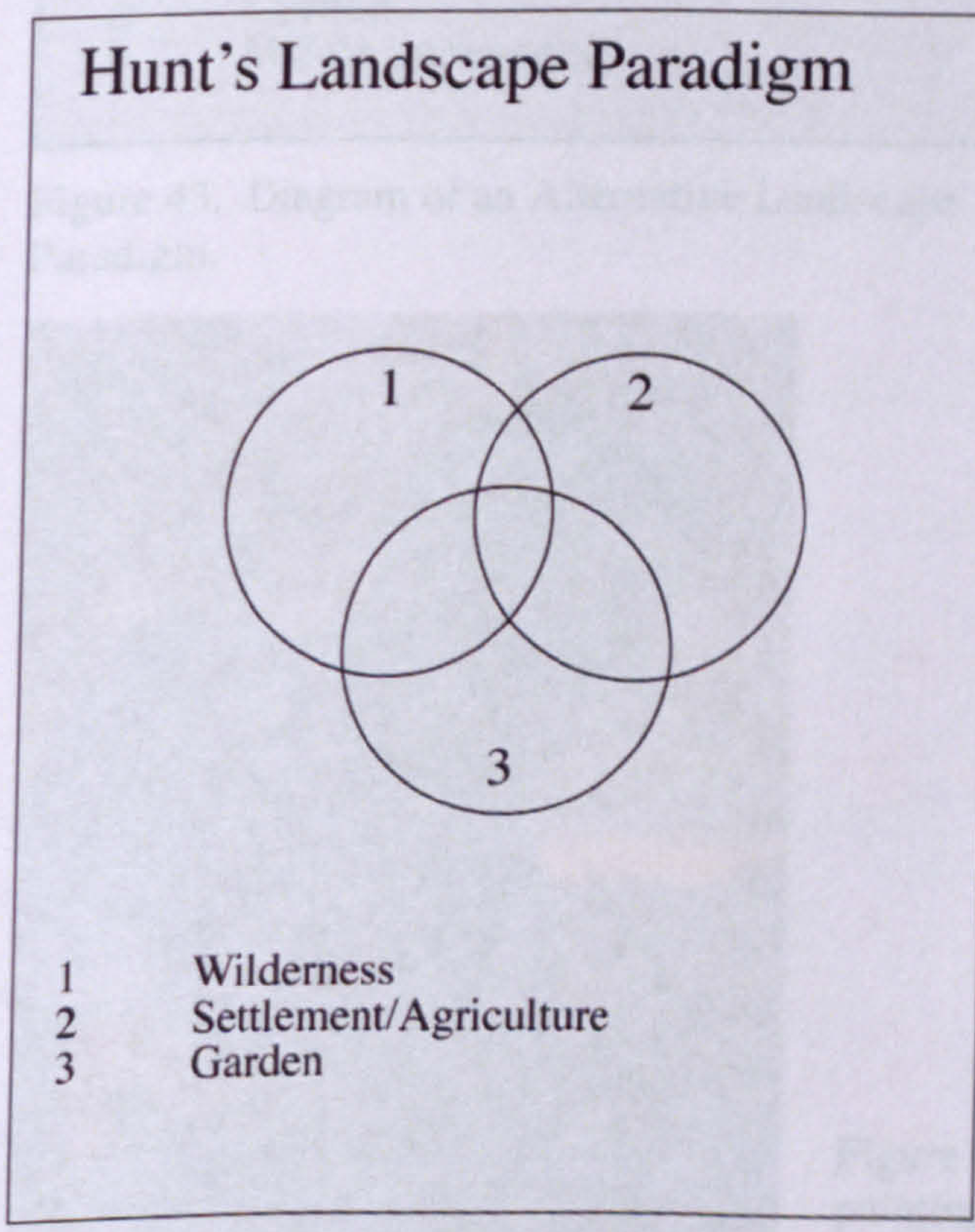


Figure 42. Diagram of Hunt's Landscape Paradigm as visualised by the author.

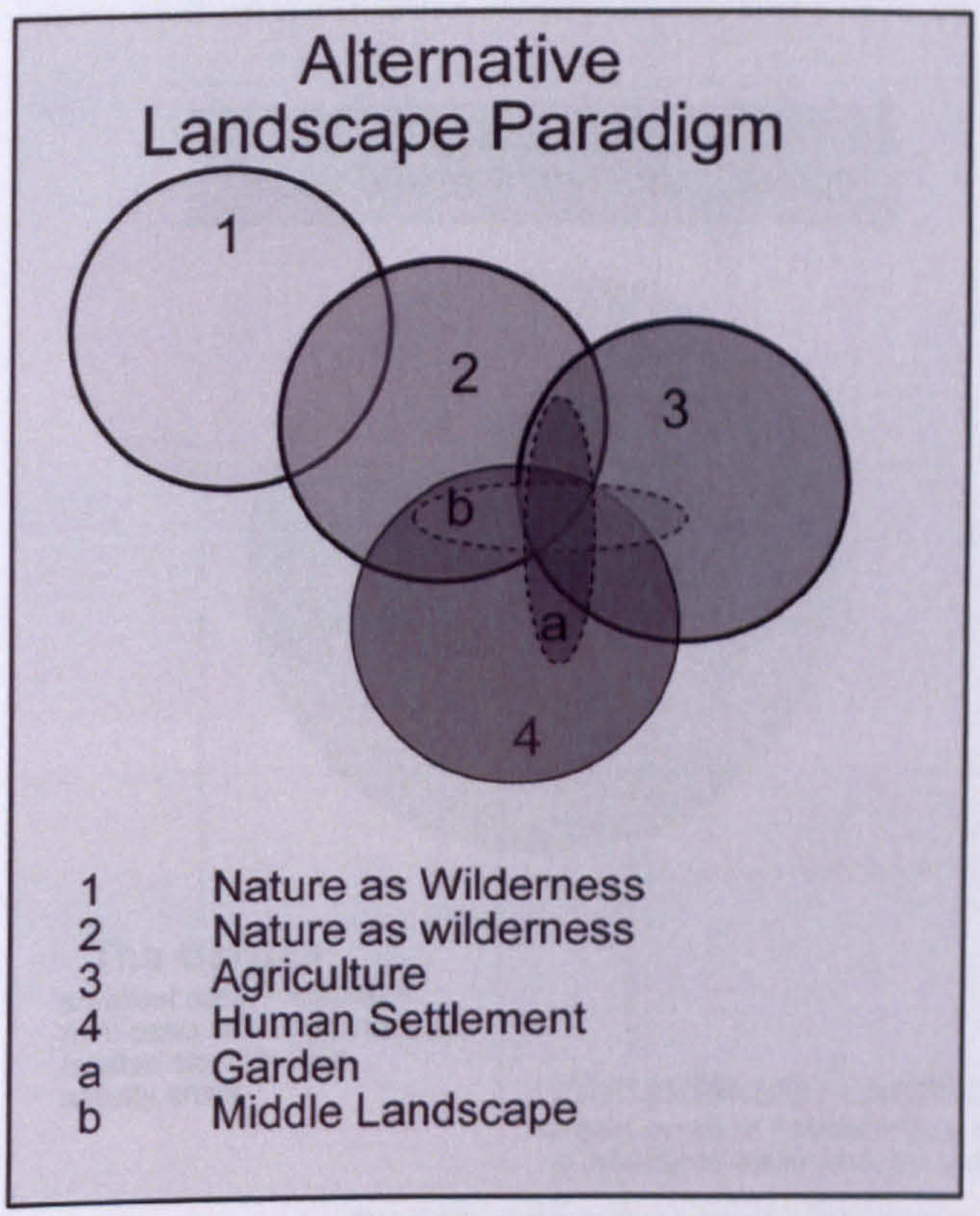


Figure 43. Diagram of an Alternative Landscape Paradigm.

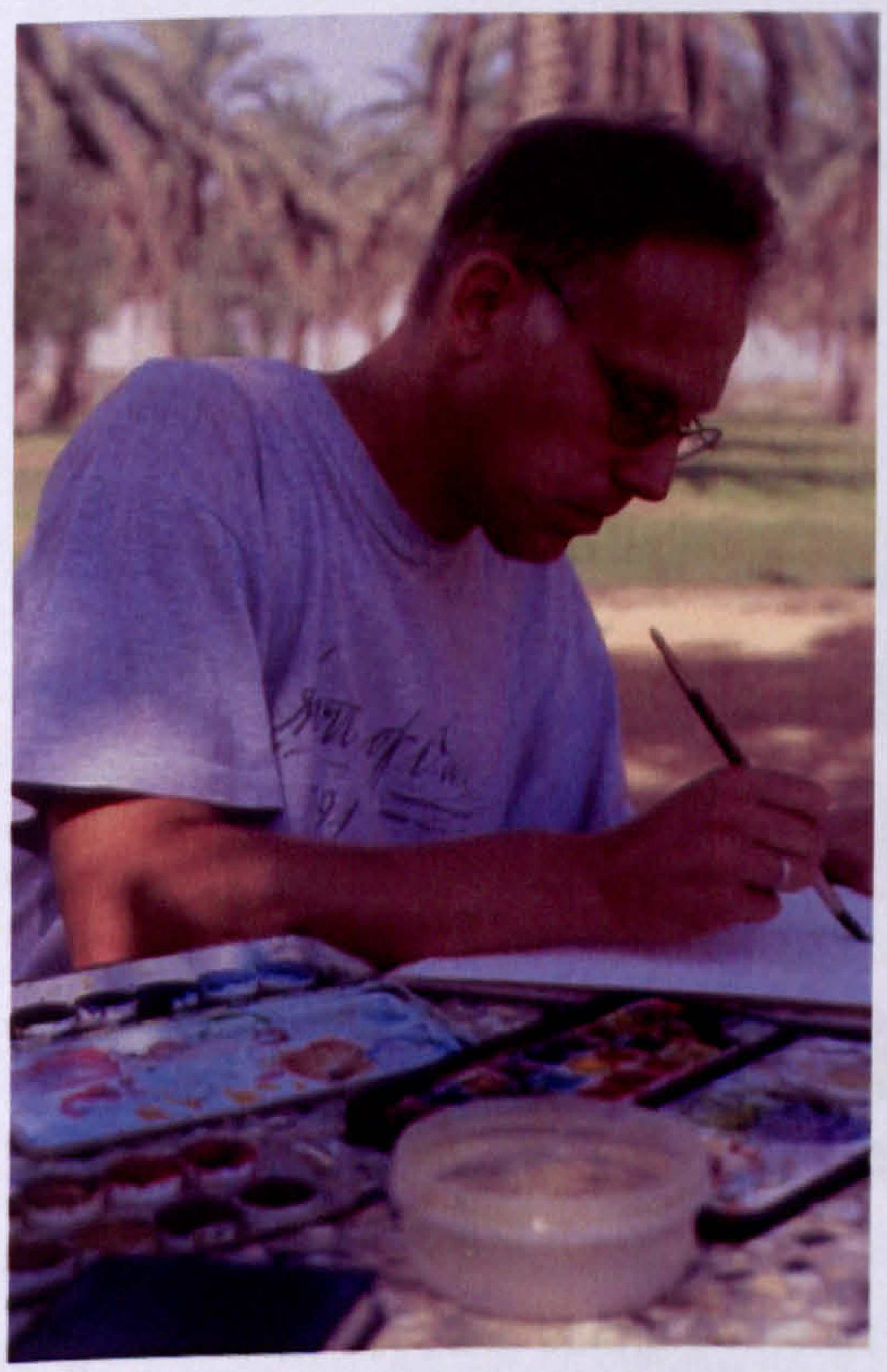


Figure 44. The author painting at a picnic spot within a date plantation.

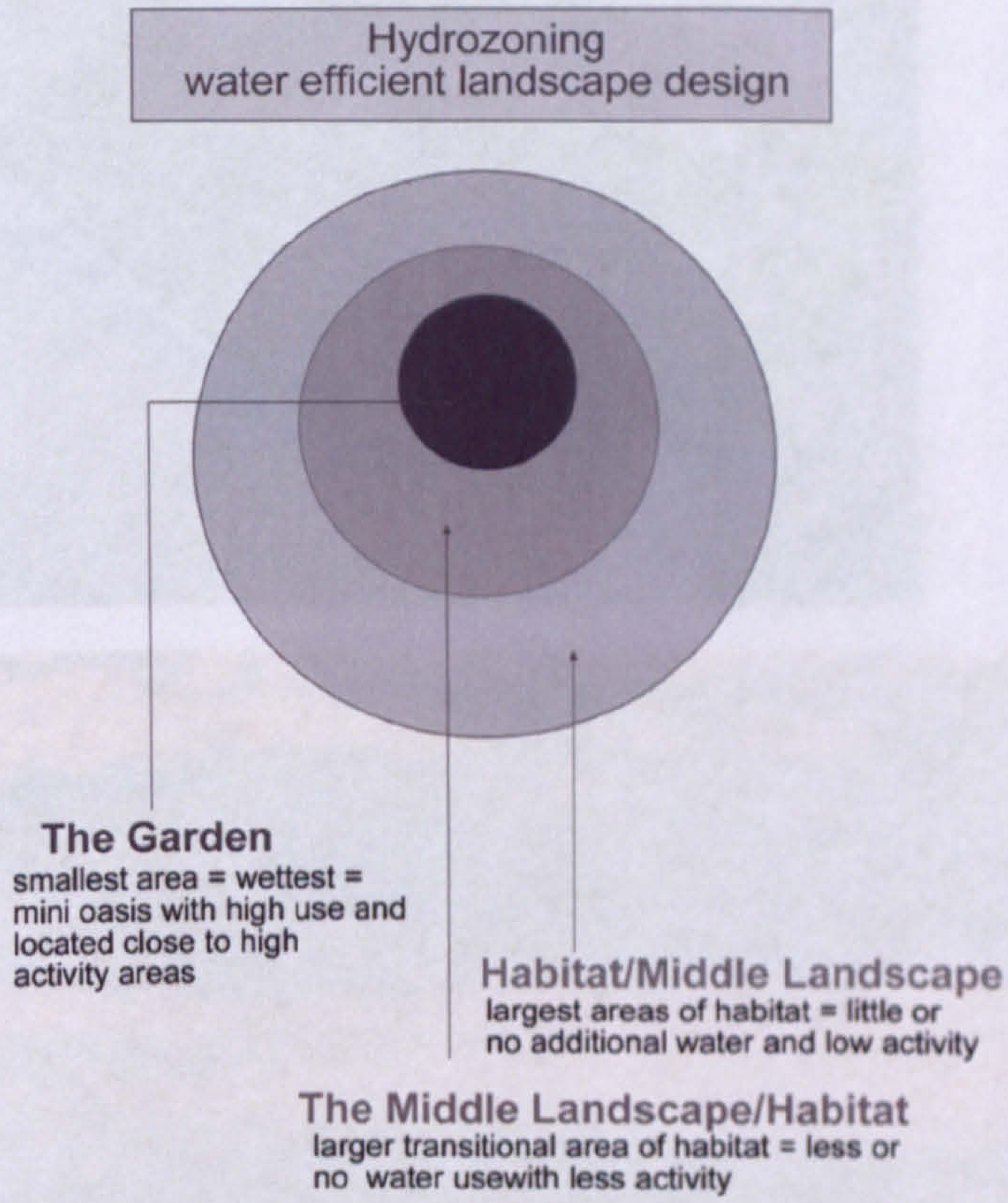


Figure 45. Diagram illustrating hydrozoning and the concept of the middle landscape combined together.

Figure 46. Watercolour colour swatches made by the author early in the research to record flower and leaf colours.

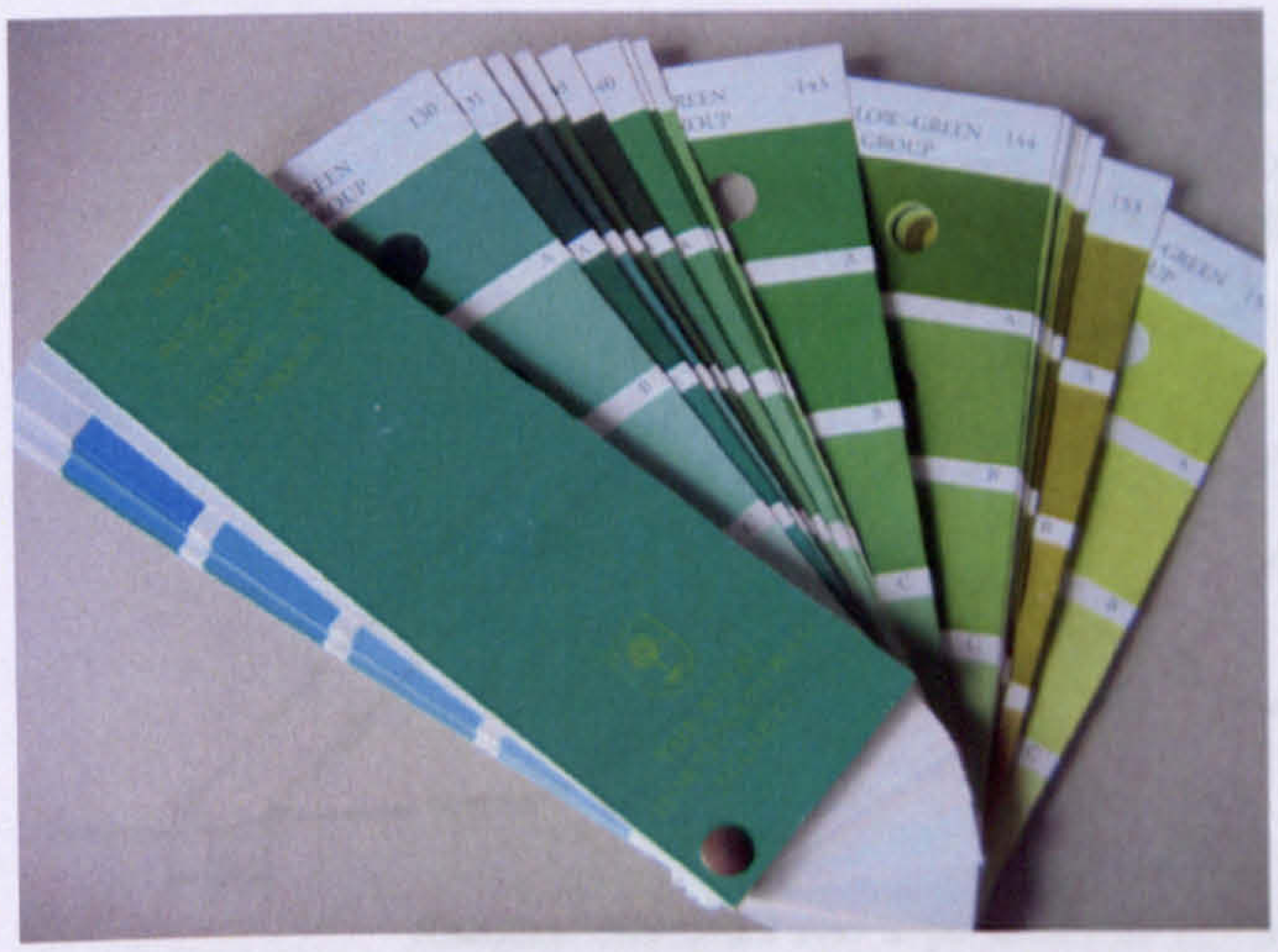


Figure 47. Royal Horticultural Society, green range colour chart fan. One of the four colour chart fans used by the author to determine leaf, flower, fruit and bark colour of the native Negev species.

Figure 48. Springtime flower display in the 'Habsor' badlands of the Northern Negev.

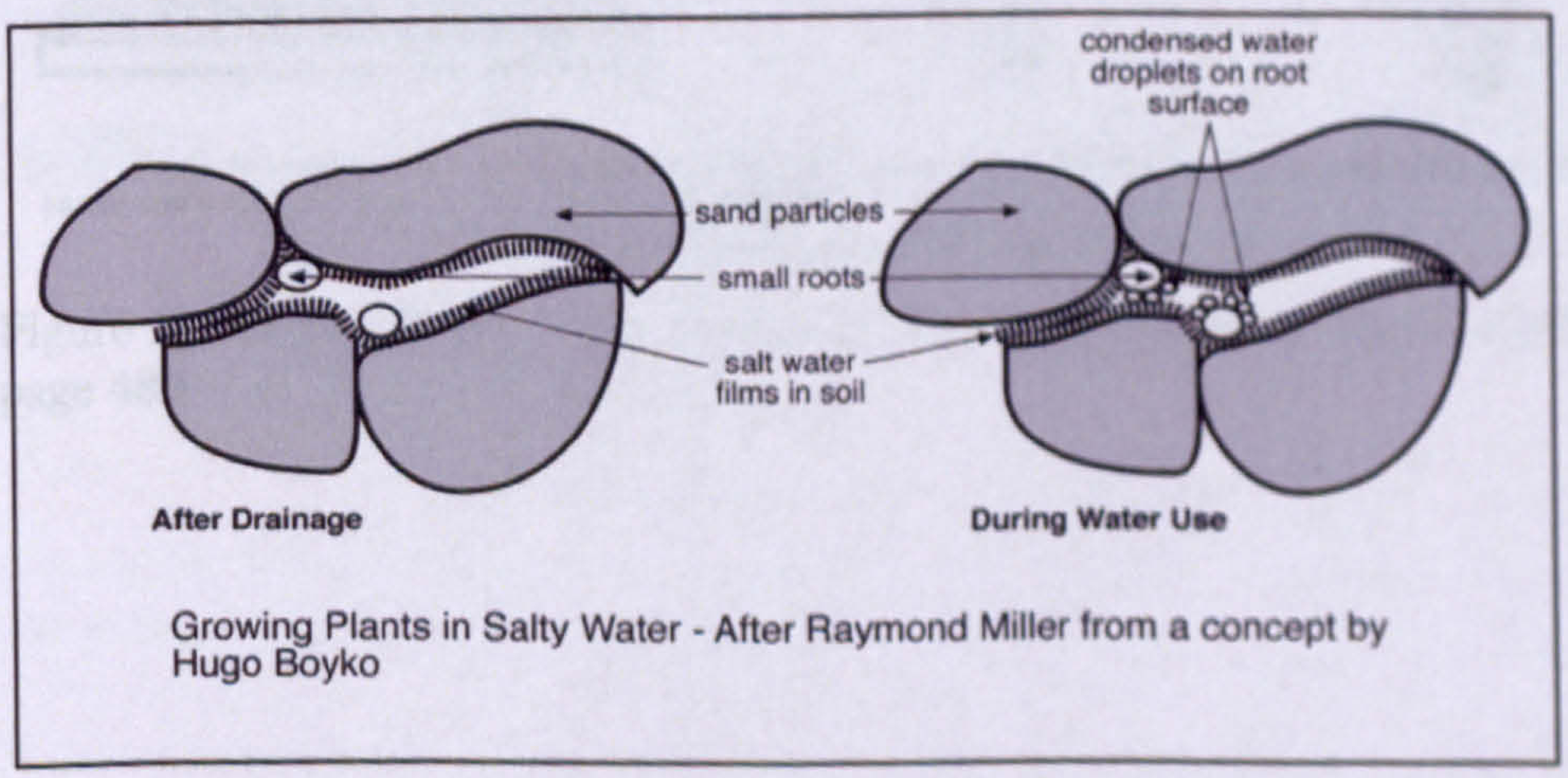


Figure 49. Rocks and sands are important in soils as they allow saline water to evaporate and condense as distilled water, which then becomes available to the plant's roots. (After Miller and Donahue, 1990, page 140.)

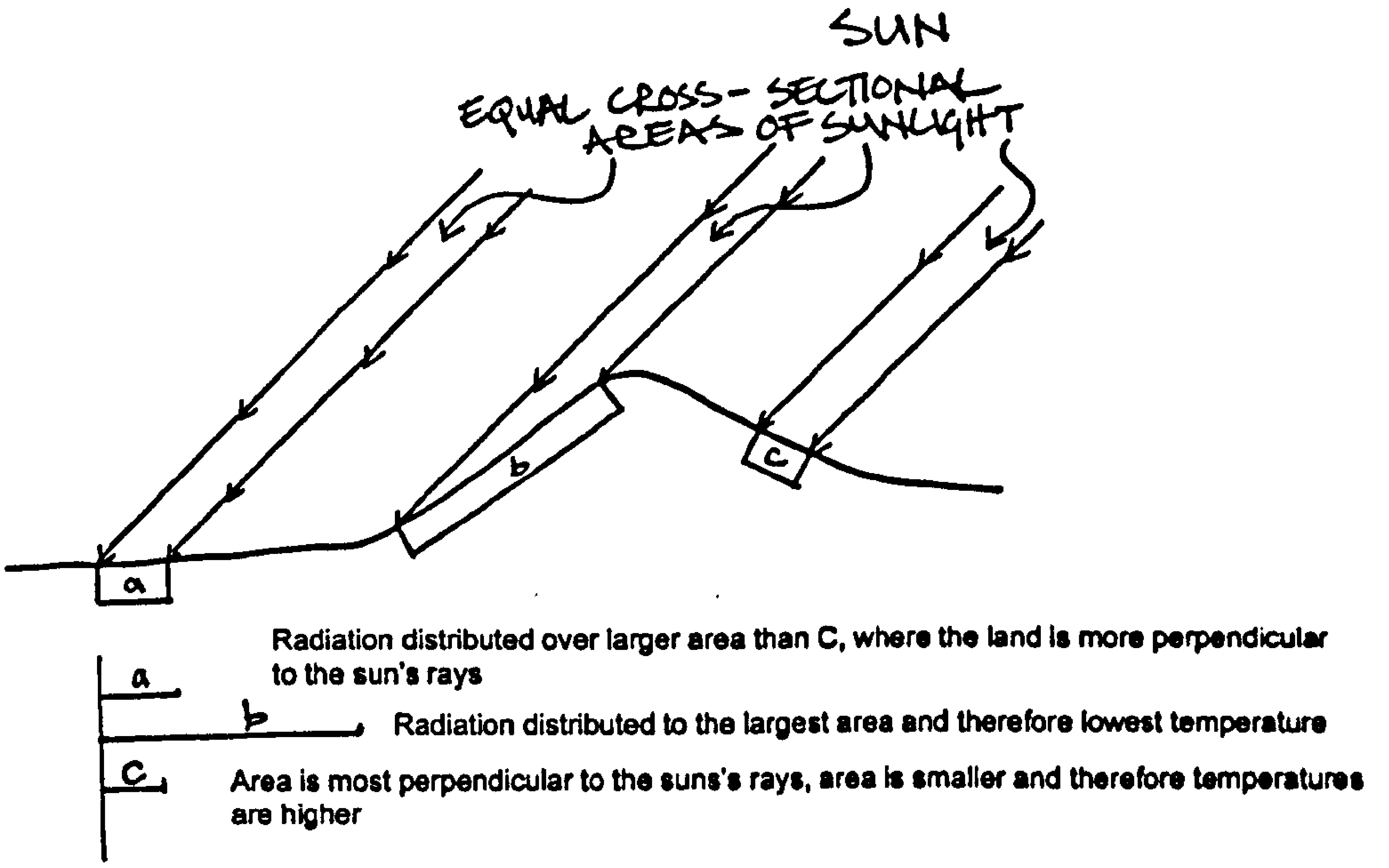


Figure 50. Radiation and heat distribution on slopes. (After Miller and Donahue, 1990, page 70.)

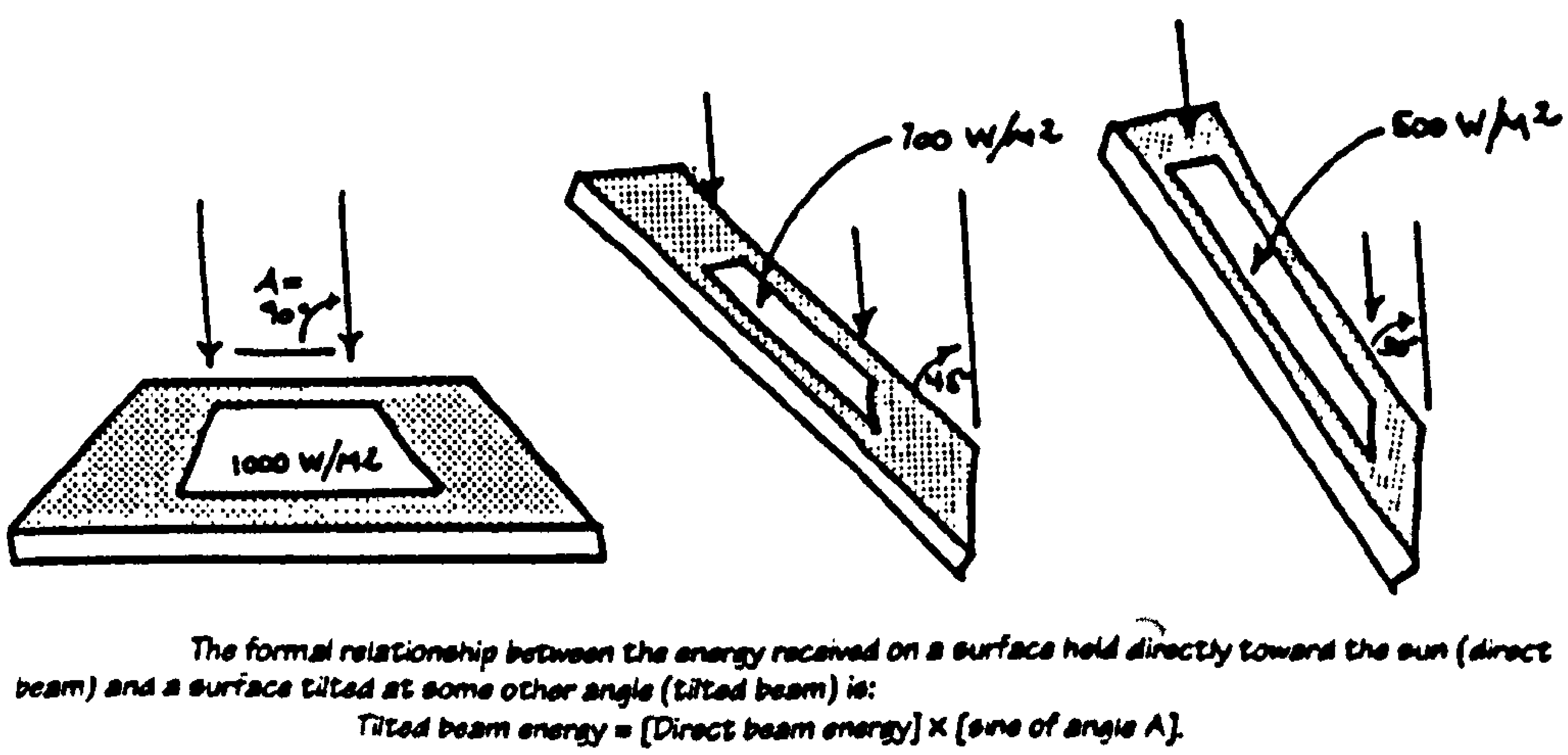


Figure 51. Slope affects energy received. (From Brown and Gillespie, 1995, page 48.)

Figure 52. Photograph of 'Avdat Farm' where Nabatean runoff water harvesting techniques are used to grow a range of crops.

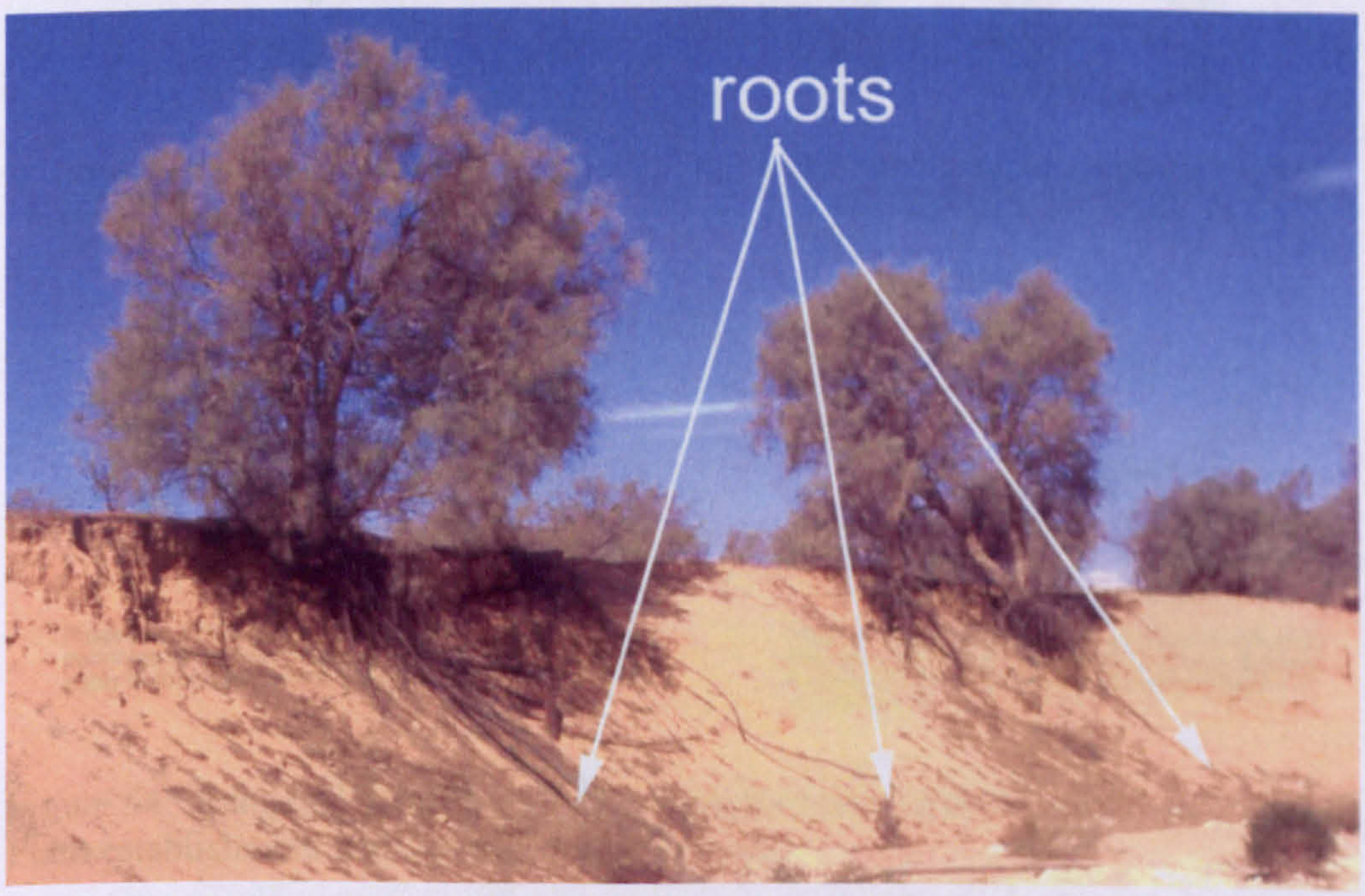
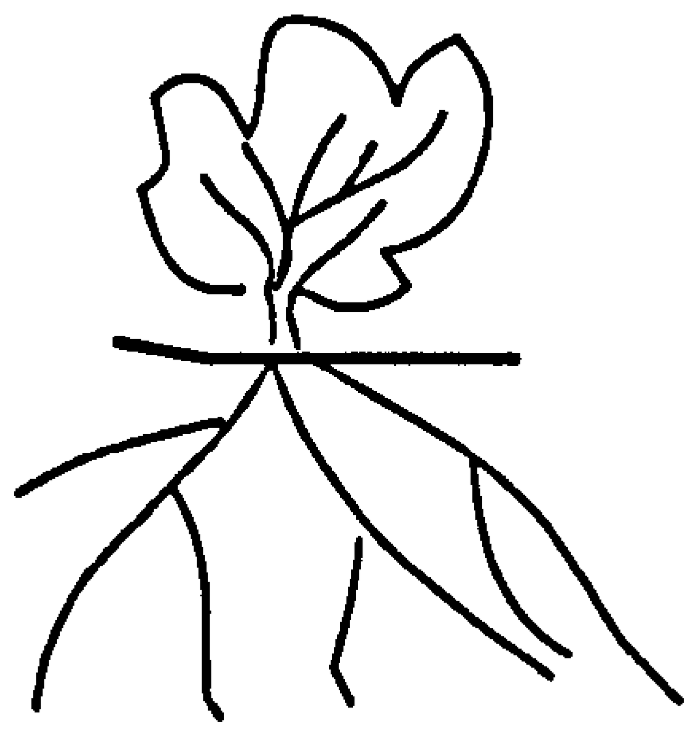


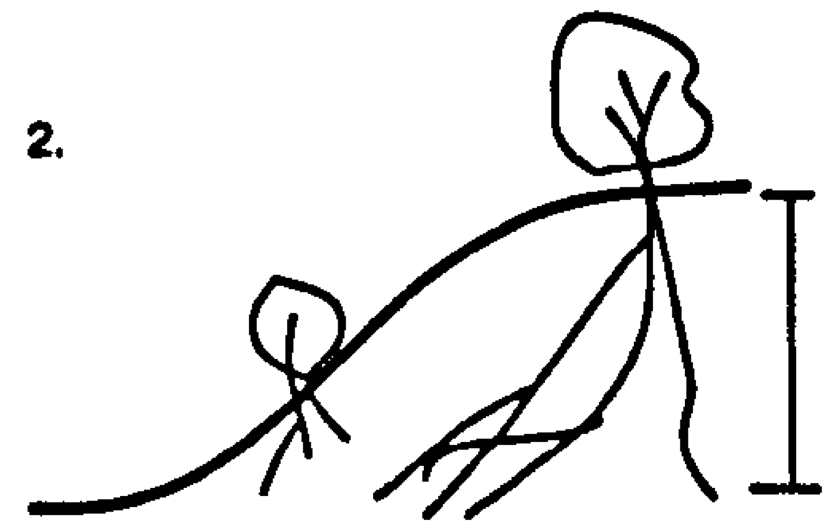
Figure 53. Photograph of *Tamarix aphylla* on the 'Mashabim sands' illustrating the extensive water seeking root system.

1.



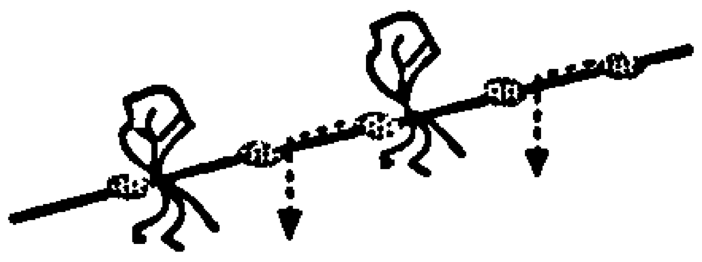
. Use plants with known extensive root systems such as*Tamarixaphylla* and *Zygophyllum dumosum* in areas where water is available deep below ground

2.



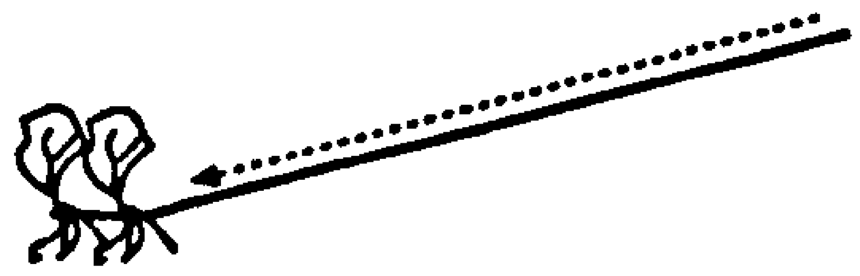
Plants with extensive root systems can be located on elevated areas

3.



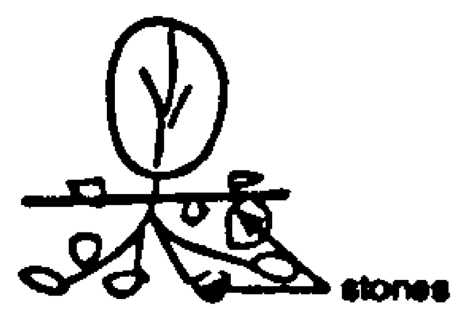
Stones and course material slows down run-off and increases percolation into the ground alloing for planting on slope

4.



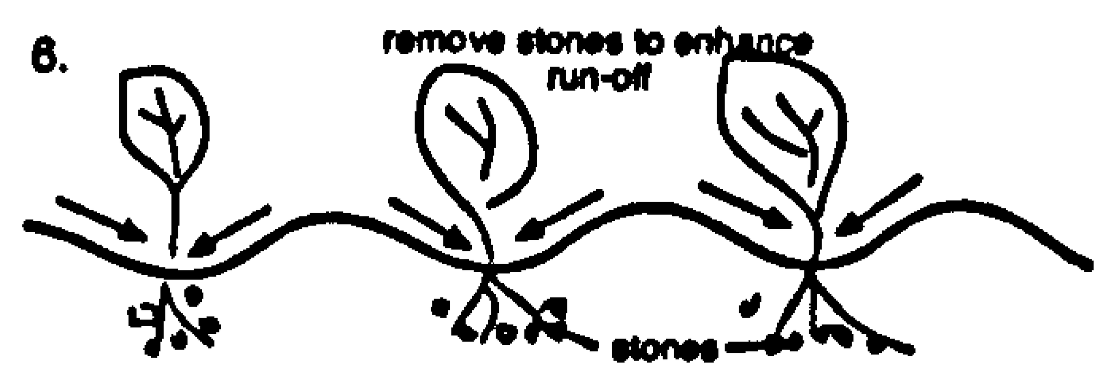
Removal of stones and course material aids run-off and water can be collected below slope to provide for planting

5.



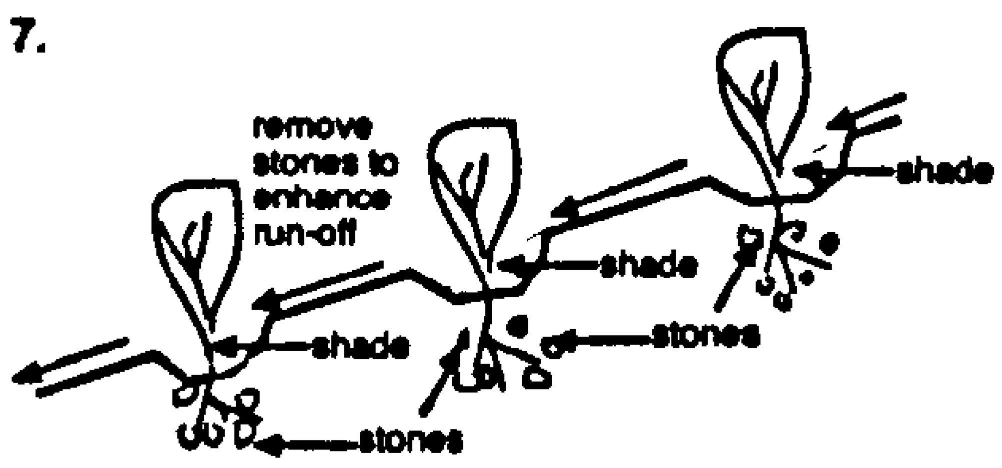
Stones and course material facilitates the condensation of pure distilled water in saline areas. Distilled water is then taken up by roots. (See Figure)

6.



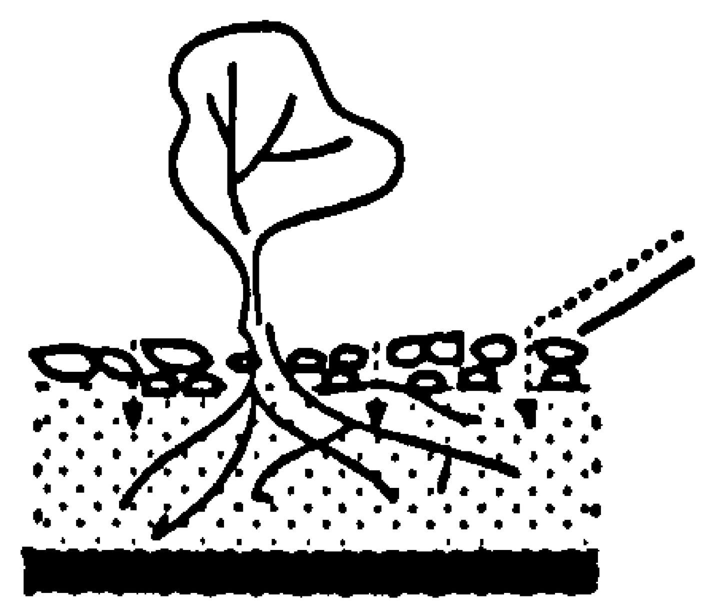
Ridge and furrow created allowing water to collect in furrows and become available to plants. Furrows can be centred apart to allow for more run-off to collect

7.



Ridge and furrow on slope, existing or man-made promotes water collection and plant uptake. Or direct water to microcatchments (negarin)

8.



Ideal planting profile with coarse material above to promote percolation, silts below to retain moisture and clay below root systems to reduce further percolation.

Figure 54. Range of micro-landscape measures that would improve Plant establishment and survival in desert areas.

Figure 55. Photograph of a small wadi in the Negev highlands illustrating a complex mix of plant species that integrate aesthetically. and that are associated ecologically.

Figure 56. Detail of wadi plants described in Figure 55 above illustrating a broad mix of annual and perennial species growing in association with one another.

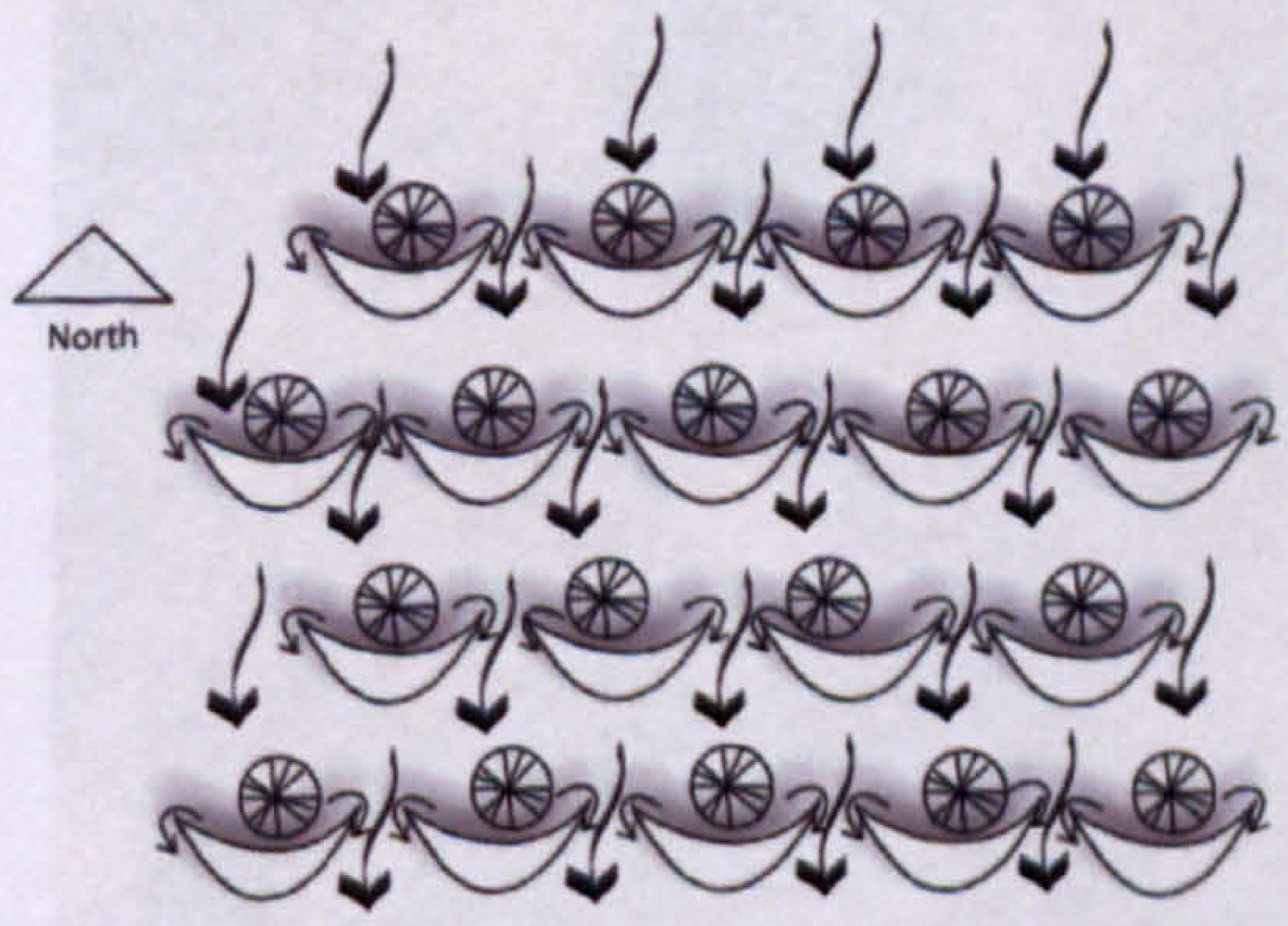


Diagram illustrating rainwater harvesting on a north facing slope with 'barkhan' type shade enhancers and rain water collectors. Large arrows indicate downward flow of water along slope. Small arrows indicate water overflow from 'barkhan' collectors

Figure 57. Diagram of providing barkhan type micro-catchments similar to the 'negarim' illustrated in Figure 17.

Figure 58. Fresh and older porcupine digging in the Negev illustrating accumulation of detritus (mulch) in the older diggings with *Asphodelus aestivus* growing within the holes.

Figure 59. Porcupine digging in the Negev illustrating accumulation of detritus (mulch) with *Tulipa systola* growing within the hole.

Sustainable Landscape Planting in the Negev Desert

Appendices – CD Rom

(Note: The CD Rom includes all the appendices including Appendix A, which has also been printed and is located immediately prior to this sheet.)