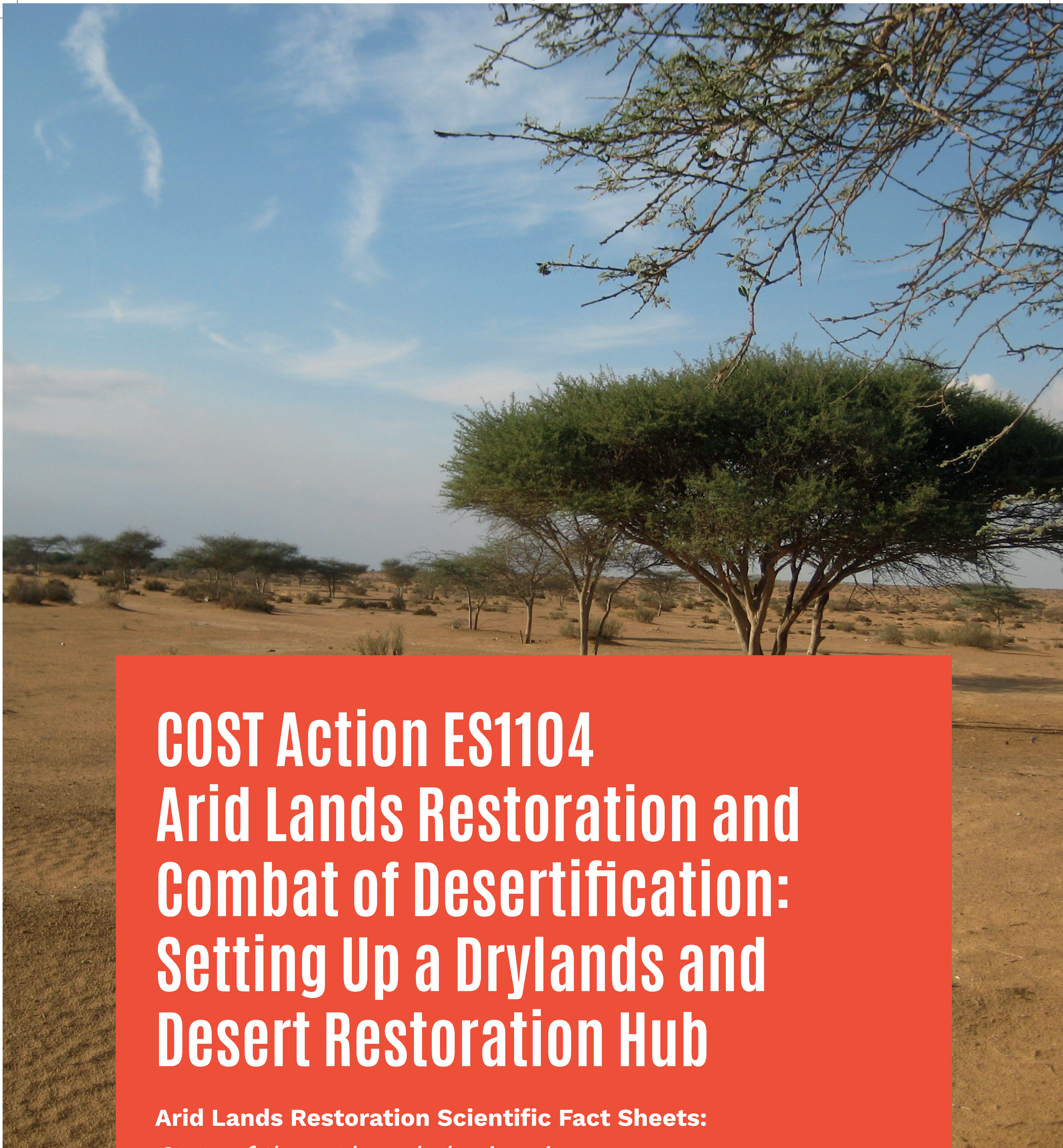

COST Action ES1104 Arid Lands Restoration and Combat of Desertification: Setting Up a Drylands and Desert Restoration Hub

Arid Lands Restoration Scientific Fact Sheets:

State of the art knowledge in science, successes and case studies in restoration

ISBN: 978-0-900822-01-8

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

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Insert Paraecologists in South Africa implementing restoration trials, copyright Ute Schmiedel, University of Hamburg.

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You can find out more about the members of COST Action ES1104 on the Desert Restoration Hub website: **www.desertrestorationhub.com** or the COST Action website: **www.cost.eu/COST_Actions/essem/ES1104**

Cost Action ES1104 was chaired by Dr. Benz Kotzen and managed by Dr. Sarah Milliken at the Department of Architecture and Landscape at the University of Greenwich.

University of Greenwich
Old Royal Naval College,
Park Row
London SE10 9LS

gre.ac.uk

UNIVERSITY of GREENWICH

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INTRODUCTION

The arid lands and desert restoration hub focuses on knowledge and dissemination of dryland restoration techniques, methods, principles, key people and key organisations as well as successful projects and facilitating new projects.

There is a great need to restore existing despoiled drylands and to combat increasing desertification. Restoring habitats improves biodiversity and increases carbon sequestration, and enhances the quality of life for people. An essential measure is the planting of, and reestablishment of vegetation. The successful establishment of vegetation in arid areas is complex requiring the multi-disciplinary skills of arid land experts with various capabilities: in soils, hydrology, ecology, agronomy, land management, etc. However, vegetation restoration techniques in arid areas require review and development. Information on restoration is highly dispersed and often difficult to obtain.

The creation of the 'Drylands and Desert Restoration Hub' is thus aimed to bring together the expertise, knowledge and information on vegetation establishment and management that exists in the EU and around the world.

This publication of fact sheets is one of the final outputs of COST Action ES1104. The fact sheets have been written by participants of the Action in order to contribute useful information in a number of topic areas, which form the expertise of the individual writers. The fact sheets share the broad topic area of restoration, but they are wide ranging as well, dealing with sites within Europe and Africa. They focus on soils, Sustainable Land Management, revegetation and many other areas. An additional final contribution of the Action is the drafting of a white paper. This white paper sets out 5 key recommendations to policy makers and those involved in combatting desertification and in drylands restoration. As a key contribution to the Action, the white paper is located immediately after this introduction.

Chair of the Action: Benz Kotzen	b.kotzen@gre.ac.uk
Vice Chair: Maria Jose Marques	mariajose.marques@uam.es
STSM Coordinator: Simon Berkowicz	simonb@mail.huji.ac.il
Action Project Manager: Sarah Milliken	s.milliken@gre.ac.uk
COST Scientific Officer: Deniz Karaca	Deniz.Karaca@cost.eu
COST Administrative Officer: Tania Gonzalez Ovin	Tania.GonzalezOvin@cost.eu

Factsheets coordinated by Janet Hooke, University of Liverpool
and by Rob Rankine, University of Greenwich.

All of COST Action ES1104 Factsheets are available to download individually
from our website: **www.desertrestorationhub.com**

COST Action ES1104
White Paper on the Restoration of Drylands

June 2016

EUROPEAN COOPERATION
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Drylands are home to some of the earth's most vulnerable ecosystems and are inhabited by more than 40% of the world's population. The 195 Parties (countries) to the UNCCD Convention adopted in 1994 specified that one of their goals is *'to forge a global partnership to reverse and prevent desertification/land degradation and to mitigate the effects of drought in affected areas in order to support poverty reduction and environmental sustainability'.*

There are many causes of degradation of drylands. These include climate change and prolonged periods of drought as well as poor land management practices, such as overgrazing, bad cropping, irrigation practices, and deforestation, all of which reduce soil quality and soil fertility, as well as disastrous floods and fires resulting in impoverishment of the land and a reduction in ecosystems services. The effects are irrefutable: conflicts, hardship, food and water insecurity arise in these affected lands, resulting directly as well as indirectly in the migration of people. The consequences of inaction are therefore a decline in land quality as well as a decline in regional socio-economic conditions. Land abandonment itself may also exacerbate land degradation.

Dryland restoration is a very broad subject encompassing many disciplines. COST Action ES1104 brought together a multidisciplinary and multinational hub of scientists to better understand European and international knowledge regarding the restoration of arid lands and drylands and the combat of desertification. Extensive expertise is available, particularly in Mediterranean basin countries, as desertification is a common problem for many southern European areas. Moreover, additional wide-ranging expertise is found across the breadth of the EU and neighbouring countries due to historical connections between Europe and North African and Middle Eastern states where research and collaboration occur in numerous scientific fields. Credit should be given to the EU and individual EU countries for realising that the EU is not an isolated entity, that it must act in a convergent way in order to reduce disparities between the West and the East and North and South in terms of land restoration, and that the problems of countries affected by land degradation and desertification should be approached collaboratively. Indeed, the problems are world-wide, and there is a need for global collaborations and partnerships and thus the requirement for the proactive involvement of international bodies such as UNCCD, FAO, UNESCO and UNEP in dryland restoration.

Whilst it should be obvious that knowledge on desertification, SLM (Sustainable Land Management), FLM (functional land management) and restoration techniques should be common knowledge across the EU, and indeed across the world, this is unfortunately not the case. For example, there are cases where scientists working on restoration projects are unaware of other scientists from the EU or elsewhere working on similar projects in the same country. Thus there was, and still is, a need for a 'hub of information' to provide a repository about who is doing what, why, where, and when, and to provide information about suitable methods and recommended best local or regional practice. There is also a need for a forum for pan-European collaboration.

One of the greatest tools of the COST Programme is the emphasis on the transfer of knowledge and education in science across the EU, Near Neighbour institutions and other International Partner Countries, and in particular the training and transfer of research skills, knowledge and experience to Early Career Researchers (ECRs). This Action has facilitated capacity building through its six Training Schools and 49 Short Term Scientific Missions (STSMs) for ECRs, providing them with opportunities to increase their knowledge and experience and to work collaboratively with other experts and institutions beyond their home countries.

COST Action ES1104 has run for four years and it has many outputs including a Drylands and Desert Restoration Hub website which provides a repository of information, an ongoing forum for discussion, collaborative papers, hosting of conferences, Training Schools and STSMs. The Action has been particularly successful in building cross-border links across EU scientific institutions and countries, including Israel, the Palestinian State, Jordan, Tunisia and Morocco. We have also included partner institutions and countries from Australia, South Africa, Namibia and

Argentina, and we hosted experts from around the world who helped to spread knowledge and to facilitate collaboration. Additional countries include the USA and China.

Science is always looking towards the future, and future developments are in the hands of today's PhD students and postdoctoral researchers. Thus the Action has provided numerous opportunities for expanding the knowledge and training of ECRs and our conferences have provided occasions for significant numbers of ECRs to present their research to their peers, to the COST membership and to the wider world.

This White Paper is one component of the final outputs of the Action with the aim for the project to continue with a legacy. Whilst the Action has been a success in its activities and outputs, there is an on-going need to highlight land degradation in arid lands and drylands and to note the consequences on the environment and people. We need to ensure that the science is being done but also that the knowledge and experience in restoration practice which is often complex, varied and multidisciplinary, is disseminated beyond scientific research institutions and into the world of policy makers both at the international and local levels. The Action with its five Working Groups have determined five key recommendations based on the experience of its individual members and working groups, the trends within current research, and the directions being investigated by ECRs.

The recommendations of the Management Committee of COST Action ES1104 are:

1. The promotion of applied multidisciplinary research in the restoration of arid land

The Action members have included a cohort of botanists, ecologists, hydrologists, geomorphologists, land management experts, landscape planners, soil scientists and social scientists. A multidisciplinary approach is essential in tackling the complex issues of degradation. Creating local solutions very often needs the combined expertise of a number of disciplines. Restoration action in its many forms, including planting, water harvesting, combating soil erosion, integrating SLM practices, implementing FLM (functional land management) measures etc., is but the first part of restoration practice. Additionally, there is a need for long-term monitoring of restoration projects and integrated assessment, taking into account ecosystem services and trade-offs, and other social and environmental benefits. There is also a need for cost/benefit evaluations of arid land restoration compared with the cost/benefit of inaction and life-cycle analysis assessment of the resilience and sustainability of restoration schemes over time and under changing conditions.

The Action's review paper *'Soil indicators to assess the effectiveness of restoration strategies in dryland ecosystems'* [i] illustrates the point in that it combines the skill sets and experience as a means to assess *'both land suitability for restoration and the effectiveness of restoration strategies in restoring ecosystem functioning and services.'* The selected indicators represent the different viewpoints of pedology, ecology, hydrology, and land management represented by a broad range of authors. The results reinforce the view that a restoration project's success relies on an appropriate understanding of ecology, that is, the relationships between soil, plants, hydrology, climate, and land management at different scales, which are particularly complex due to the heterogeneous pattern of ecosystems functioning in drylands.

On a broader level, there is a pressing need for establishing long-term dryland field stations to allow for controlled experimentation of disturbance and recovery. Interventions that may appear to be successful in the short-term may fail in the long-term or generate unexpected outcomes.

i Edoardo A.C. Costantini, Cristina Branquinho, Alice Nunes, Gudrun Schwilch, Ilan Stavi, Alejandro Valdecantos, Claudio Zucca. Soil indicators to assess the effectiveness of restoration strategies in dryland ecosystems. *Solid Earth* 2016, 7, 397-414; doi:10.5194/se-7-397-2016

2. Engagement with stakeholders

Dryland restoration and mitigating desertification requires multi-stakeholder dialogues and collaboration. Land management is a typical multi-stakeholder issue, concerning individual and community land users, agricultural advisors, enterprises, natural resource managers, government authorities, civil society, land improvement engineers and researchers alike. Today, there are very few restoration projects that would not engage with local stakeholders. But this engagement can still be improved at a number of key levels; farmer/landowner, land agents and local authorities, NGOs, government and national departments. In this sense, there is a need to discover new ways for improving land planning and administration. In fact, local authorities can be made aware of past, present and future situations by incorporating into their daily routine methods and tools able to monitor the state-of-the-art on restoration.

The main way in which participatory processes can support restoration is by enabling learning and meaningful interaction between specialists and local communities. Stakeholders thus need to be involved in research, planning and long-term monitoring of their lands. True, effective collaboration and partnership between stakeholders is the only way to bring land users' many generations of local experience and innovation together with scientists' up-to-date ecological and technical expertise. Moreover there is a need to educate and raise awareness about the causes of land degradation and the benefits of restoration at all levels. There are opportunities for citizen science where data can be collected and information disseminated effectively.

The Action's review paper *'Multifaceted Impacts of Sustainable Land Management in Drylands: A Review'* [ii] stresses that for successful upscaling of land management, attention must be paid to the society/social system from the first involvement stage to the long-term maintenance stage. Long-term ecological success of restoration and/or effective upscaling will always depend on a joint strategy for all proposed management activities, accepted by the majority of concerned stakeholders. The adoption of SLM practices is usually led by imitation. In order to facilitate upscaling of SLM, policies must facilitate the spread of information, support capacity building, and encourage local communities' participation. Studies show that conservation agriculture or other SLMs will not be adopted for the long-term without the solid conviction of land users. Local stakeholders should become involved as early as possible in the planning, implementation and management process, fostering a sense of ownership of the project goals.

There is a linkage between political will and restoration success. This linkage is not only direct, that is, driven by policy measures and funding, but also indirect. It has been demonstrated that policies can be one of the main causes of land restoration or degradation. Land policy determined by regulations and their practical application by local authorities and farmers, can either enhance or impair land use sustainability and soil conditions.

3. Improvement of accessibility to data and publications

Data is everywhere, but if it cannot be readily accessed then it is nowhere. COST Action ES1104 was partly conceived to provide a hub for data on drylands restoration. The idea was to collect information that would be available to all stakeholders around the world, providing information on successful and, where appropriate, failed projects, techniques and methods in drylands restoration. The Action finds that in order to consolidate data that has already been gathered and to prevent unnecessary duplication of research, there is a need to have and provide an overview of both research and restoration projects across the globe. The UNCCD National Focal Points need to keep a database of restoration projects in their own countries that have already been completed or are in progress, preferably with an indication

ii Maria Jose Marques, Gudrun Schwilch, Nina Lauterburg, Stephen Crittenden, Mehreteab Tesfai, Jannes Stolte, Pandi Zdruli, Claudio Zucca, Thorunn Petursdottir, Niki Evelpidou, Anna Karkani, Yasemen Asli Yilmazgil, Thomas Panagopoulos, Eshetu Yirdaw, Markku Kanninen, Jose Luis Rubio, Ute Schmiedel, Adrian Doko. Multifaceted impacts of Sustainable Land Management: a review. *Sustainability* 2016, 8(2), 177; doi:10.3390/su8020177 of their success or failure. This database should be both accessible and continuously updated. The UNCCD has identified the World Overview of Conservation Approaches and Technologies (WOCAT) database **www.wocat.net** as the primary recommended database for best practices on SLM technologies. This allows recording and using SLM knowledge worldwide – from land users to decision makers – to improve local land management.

Another issue is that research either remains unpublished or is synthesised in academic journals. Primary research data is rarely available on-line as open access, thus preventing others from carrying out additional analyses or metadata analyses in the future, long after the research has been completed. Hence, valuable data becomes buried or lost over time. Along the lines of the EC Horizon 2020 program that requires projects to have a data management statement, projects or research funded by international bodies such as UNCCD, FAO, UNEP, UNESCO, etc., should require that primary data be archived and made open access after a given number of years.

Searching for literature on dryland restoration in search engines or in the on-line libraries of international organizations is hindered by the lack of a standardized terminology. For example, titles and/or key words do not necessarily include dryland restoration or land degradation control, but more generic terms such as 'restoration', 'recovery', 'reestablishment', 'amelioration', 'rehabilitation', 'reclamation', 'conservation', etc. This leads to long lists of results that must then be sieved.

On a more practical level, data on drylands restoration may readily be available to researchers but not necessarily to practitioners and local stakeholders. Accordingly, the Action has initiated a range of Fact Sheets consisting of two-page articles summarizing restoration case studies, techniques, and practitioner/stakeholder experience. The concept behind this collection was to establish a prototype information source written by ES1104 Early Stage Researchers, recipients of Short Term Scientific Missions, Management Committee members, and other interested parties.

This would be one of the legacies that were envisioned in the establishment of ES1104. Individuals entering the repository could search the content database and quickly learn about the state of the art in a given area or develop insights into gaps. It would facilitate a dialogue between science and policy-makers and also encourage contacts between interested parties.

The Fact Sheets are intended for distribution to libraries of research institutions as well as local stakeholders, such as NGOs, local land agents, cooperatives etc. (See also Recommendation 5).

4. The adoption of a strategic approach to restoration in land use planning

Restoration activities are usually focused on a specific site or on a plot scale. Environmental factors and conditions which include soils, climate, topography, hydrology, land management, water management and ecological systems can operate at much larger scales and are interconnected. Thus, restoration needs to be conceived at a landscape or watershed scale, and not only at a plot scale. This needs to be disseminated to local stakeholders and supported by the UNCCD Focal Points. This will also facilitate a better understanding of land degradation and restoration at a strategic scale. Additionally, this strategic approach requires long-term research and monitoring of projects.

The Action's review paper *'Landscape approach to dryland restoration: a review of relevant concepts and tools for implementation'* [iii] notes in particular the issue of soil erosion which needs to be approached at the larger landscape catchment scale. Despite much valuable research and activity being focused on soil and land conservation techniques, *'many schemes take a site approach and do not consider the*

iii Janet Hooke, Alejandro Valdecantos, Claudio Zucca, Thomas Panagopoulos, Thorunn Petursdottir, Luca Salvati, Mehreteab Tesfai, Susana Bautista, Niki Evelpidou. Landscape approach to dryland restoration: a review of relevant concepts and tools for implementation. Submitted to *Journal of Environmental Management*.

spatial relations to other parts of the area.' A landscape approach is thus advocated to integrate restoration and conservation actions on a catchment basis. A challenge here is to match restoration planning with administrative boundaries, since policies are usually tailored according to specific private or public limits, namely, properties, municipalities, counties, regions, etc.

5. From Science to Practice and vice versa

In order to provide stakeholders with guidance on effective and sustainable ways to manage land restoration in drylands, a series of Fact Sheets should be produced. These Fact Sheets will set out best practice guidelines across a variety of key issues as well as inform about successful but also failed restoration projects in order to learn from mistakes. The Fact Sheets will thus allow stakeholders to better understand available and effective restoration techniques and to choose those that best apply to their local conditions. Successful projects need to be included as exemplars but also unsuccessful projects as learning tools. Fact Sheets should include aspects such as bioengineering, soft engineering with the aim of increasing vegetative cover as well as innovative methods, techniques and strategies. COST Action ES1104 has commenced this process. It should be continued through the UNCCD National Focal Points and be available through DesertNet International (DNI) and/or the UNCCD websites. Fact Sheets could also need to be based on feedback from practitioners.

Periodic surveys of practitioners and projects should be commissioned. Thus for example, the Action's paper *'Ecological restoration across the Mediterranean Basin as viewed by practitioners'* [iv] has revealed interesting facts regarding motives for restoration, plant choice, plant and seed origin and on restoration results. It is surprising that only one third of projects have been evaluated long-term and that high plant mortality and inadequate biodiversity were reported for 50% of the projects. The conclusions of the paper identify the need for *'improved scientific assistance and information sharing, greater use of native species of local provenance, and more long-term monitoring and evaluation, including functional and ecosystem services' indicators, to improve and spread the practice of ecological restoration in this hotspot of biodiversity'.*

iv Alice Nunes, Graça Oliveira, Teresa Mexia, Alejandro Valdecantos, Claudio Zucca, Edoardo A.C. Costantini, Eleni Abraham, Apostolos Kyriazopoulos, Ayman Salah, Ruediger Prasse, Otília Correia, Sarah Milliken, Benz Kotzen, Cristina Branquinho. Ecological restoration across the Mediterranean Basin as viewed by practitioners. *Science of the Total Environment, Volumes 566-567, 1 October 2016, pp. 722-732*

Benz Kotzen University of Greenwich, United Kingdom

Maria Jose Marques Autonomous University of Madrid, Spain

Rares Halbac-Cotoara-Zamfir Polytechnic University of Timisoara, Romania

Edoardo A.C. Costantini Council for Agricultural Research and Economics, Italy

Cristina Branquinho University of Lisbon, Portugal

Gudrun Schwilch University of Bern, Switzerland

Janet Hooke University of Liverpool, United Kingdom

Simon Berkowicz Hebrew University of Jerusalem, Israel

LIST OF FACT SHEETS

Bio Crusts

Water

Ecology And Plants

Desertification and lichens: physiological response of lichens to climatic and nitrogen stress in dry environments

https://desertrestorationhub.com

INTRODUCTION

Land degradation, together with dust diffusion and nitrogen (N) pollution, contributes to desertification processes in several ecosystems, with a consequent reduction of ecosystem services. In a Mediterranean environment, physical, chemical and biological processes related to soil degradation have been investigated to devise diagnostic techniques and criteria for appraising the status and trends of desertification through a system of indicators. In the framework of a desertification scenario, attention should be addressed also to the biological effects on sensitive atmospheric-depending organisms, which might be profitably used to identify areas exposed to higher risk or monitoring the effectiveness of restoration actions. Lichens depend on the atmosphere for their mineral and water supply and are among the most sensitive organisms to N pollution (Munzi et al., 2014a) and aridity (Matos et al., 2015). Moreover, the accurate knowledge existing of the ecological requirements of different species, allows to group lichens based on their functional traits and distinguish between the responses induced by climatic stress and those induced by N pollution (Munzi et al., 2014b). Lichens' physiological parameters and communities' composition reflect the ecological functioning of ecosystems in the short and the long term respectively. In particular, previous studies suggested that the rapid response of lichens' physiological parameters, for example the photosynthetic performance, can provide early warnings of bioclimatic stresses that specifically reference the atmospheric conditions, integrating and complementing the information provided by other indicators (Pirintsos et al., 2011). In this way, we should be able to use lichens to monitor environmental changes due to the drying up of the habitats and the induced dust diffusion and eutrophication by N pollution. This is relevant for monitoring i) the current trend of desertification occurring in European Mediterranean countries; ii) the impact of nitrogen pollution on sensitive ecosystems; and iii) the effectiveness of restoration practises. In fact, about the latter point, decreasing the intensity of climatic and nitrogen stress, lichen communities will shift from nitrophilous and xerophytic to more acidophytic and hygrophytic ones. Similarly, in case of reduced environmental stress, physiological parameters will change accordingly.

AIMS

Contributing to the development of assessment indicators, using lichens is a tool to witness changes in habitats under desertification risk. Since physiological and metabolic responses are much faster than changes in communities' composition, they can provide a useful tool to detect early stress symptoms of N pollution and climatic stress in forest habitats. For this purpose we tested the physiological responses of transplanted and native lichens in rural/forested sites of Southern Portugal characterized by different aridity and N availability (Figure 1).

Fact Sheet Topic Area:
Different sites in Southern Portugal were selected belonging to "montado", i.e. a semi-natural eco-system composed by extensive pastured cork-oak woodlands in a Mediterranean environment. Three classes of precipitation (climatic stress) were chosen in combination with the presence or absence of pastures (nitrogen stress).

Keywords:
Bioindicators, Environmental stress, Lichens, Mediterranean ecosystems, Physiological parameters.

Authors:
Luca Paoli
Department of Life Sciences,
University of Siena
Italy
paoli4@unisi.it

Silvana Munzi
Center for Ecology, Evolution and Environmental Changes,
Universidade de Lisboa
Portugal
ssmunzi@fc.ul.pt

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COST ES1104
QUICK REFERENCE SHEET 1
April 2017

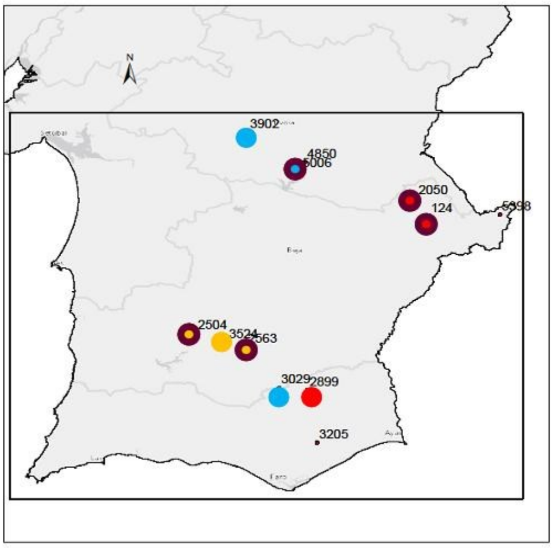

Figure (1): Southern Portugal, localization and codes of the sampling sites.

Class of precipitation: < 500 mm (arid), 500 - 700 mm (medium), > 700 mm (humid); pastures.

Data provided by Cristina Branquinho, Pedro Pinho, Alzira Ramos and Maria João Pereira (Universidade de Lisboa).

Experimental design. In order to assess early effects of N availability associated to climatic stress, lichen thalli (*Parmotrema perlatum* and *Ramalina canariensis*) taken from control areas were transplanted in selected sites (Figure 2) along a combination of climatic (water availability) and N (agricultural practices) gradients in Southern Portugal (Figure 1).

The transplant experiment lasted from January to July 2014. Samples were exposed simulating their natural conditions (Figure 2). Several physiological parameters have been investigated. Here we focus on the photosynthetic efficiency (F_V/F_M ratio) based on chlorophyll *a* fluorescence emission (Munzi et al., 2014a). In parallel, native lichens (epigeic and/or epiphytic), available at each site, were retrieved and analysed. Values of healthy samples generally range 0.60–0.75 (according to the species). Decreases from this range reflect a condition of stress.

Figure (2): Typical study site of Southern Portugal, mostly "montado" (cork forest ecosystems), and a particular of lichen transplants (branches carrying lichen thalli).

Results. Both transplanted and native lichens showed lower performances in those sites classified as drier and higher performances in humid forested sites characterized by a stratified and developed vegetation (Figure 3).

In fact, lichens, as poikilohydric organisms, are strictly dependent on external water availability and therefore their photosynthetic activity and occurrence in desert areas reflect the presence of a regular water supply. Pasture in drier sites of "montado" (in our case rural/forested sites characterized by low N concentrations), had a stimulating effect on the photosynthetic performance of the transplants. Nitrogen may have negative effects on the physiology and biodiversity of N-sensitive lichens at atmospheric levels of NH_3 above 3 µg m^{-3}. By contrast, N-tolerant lichens increase their frequency with NH_3, showing decreased photosynthetic capacity above 50 µg m^{-3} NH_3 (Munzi et al., 2014a). Our results confirmed that monitoring changes in photosynthetic parameters of sensitive species along climatic and N gradients can provide a rapid tool to investigate productivity and ecological functioning of arid ecosystems.

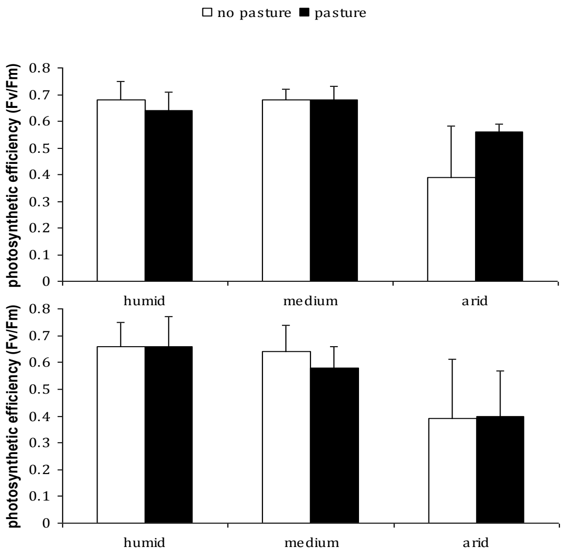

Figure (3): Effect of aridity and pasture on the photosynthetic performance of transplanted (A) and native lichens (B) in rural/forested sites of Southern Portugal (data aggregated).

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Combatting desertification in Iran

https://desertrestorationhub.com

Iran is a semi-arid country with lands vulnerable to desertification mostly due to a rising population and severe pressure on water and land resources (Amirarsalani and Dragovich, 2011). More than 85% of Iran is known as a drylands eco climate (Le Houérou (1992) and 20 % of that are desertified (Pakparvar, 1998). Iran has approximately 5 million ha of mobile sand dunes and 12 million ha of stable sands (Pakparvar, 1998). Most of the sand dunes are located in the central and eastern parts of Iran. Sand dune encroachment may be natural or a result of desertification and represents one of the greatest challenges in arid and semi-arid areas. Sand mobility can lead to various socio-economic problems such as disturbing or hindering agriculture, burying roads and even covering railway lines. Therefore fixation of sand dunes is a desired goal.

Dune stabilization by the use of oil mulch, vegetation and windbreaks are some activities for combatting desertification. However, planting is one of the well-known methods used in the arid and semi-arid areas of Iran to stabilize the dunes. The use of *Haloxylon* has proved successful in this respect. Haloxylon (Saxaul) is a genus of small trees, belonging to the Amaranthaceae plant family and is an indigenous plant of central Asia. In 1965 seeds of Haloxylon were imported from the Turcoman region and planted in the northeast of Iran, Sabzevar.

Figure (1): (Left) *Haloxyolon* planting in Ardestan, Iran

Figure (2): (Right) *Haloxylon Spp.* used in Iranian sand dune fixation.
(Desert of Iran : http://www.irandeserts.com/)

Fact Sheet Topic Area:
Land management in arid and semi-arid areas.

Keywords:
Sand dunes, Planting, *Haloxylon Spp*.

Authors:
Ammar Rafiei Emam
University of Goettingen, Germany.
rafiei99@gmail.com

Geographic location:
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COST ES1104
QUICK REFERENCE SHEET 2
April 2017

The Saxaul is a psammophyte and easily grows in sandy habitats. It is also resistant to arid conditions and well adapted to water scarcity. This tree is now widely used in sand fixation projects in Iran. *Haloxylon persicum* and *H. aphyllum* are two species usually used for afforestation of arid and semi-arid areas and fixation of sand dunes against desertification.

The first attempt to stabilize sand dunes/sheets In Iran was in 1965 in Sabzevar (northeast Iran). About 100 hectares were planted successfully. This approach was then applied to other projects in at-risk areas. Since 1965 more than one million hectares of sand dunes have been stabilized.

For the rural drylands of Iran, successful sand dune fixation projects have improved the environment, enhanced biodiversity, increased carbon sequestration, and provided wood and non-wood production. The biological production of *Haloxylon* in reclaimed lands of Iran is approximately 200 kg per hectare.

Figure 3: (Above) Haloxylon planting in sand sheets of Bafgh, Iran (http://tnews.ir)

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RESTORATION STRATEGIES

a. Mapping spatial distribution of sand dunes, and recognising the hot spot areas,

b. Primary stabilization of sand dunes by mulching, in which the sands are covered uniformly with an artificial or natural protective screen,

Planting steps are as follows:

1. Selecting the seedling with well developed root and aerial systems from the nursery,
2. Planting in the rainy season from January to March,
3. Planting in a very short period of time,
4. Planting one seedling per ha per millimetre of effective rain (Amani and Parvizi, 1996). Generally, a spacing range of 3m×6m is recommended.

Land Degradation Neutrality: Turkey's strategy

https://desertrestorationhub.com

Land degradation is a complex and dynamic process and it is difficult to monitor and assess. With raising awareness on the importance of land degradation, the Sustainable Development Goal 15.3. aims "by 2030 to combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world". With the purpose of achieving a land degradation neutral world, the UNCCD secretariat initiated "Land Degradation Neutrality (LDN) Project" in 2015. Including Turkey, 14 countries were the partners of the project.

Turkey carried out its studies in two microbasins in Gediz Basin-western Turkey. The population of the Basin is 2 million, with mainly agricultural activities and the area has high aesthetic values. Rapid demographic changes, urbanization, industrialization, tourism and inefficient agricultural implementations are the main causes of land degradation in the Basin.

3 parameters of LDN (changing of land use and land cover, trends in land productivity and situation of soil organic carbon stocks) were tested during this pilot project. Classified images of 2001 and 2015 years were generated. Results showed that the areas where intensive traditionally agriculture has been a major land use, have relatively been more under stress or with

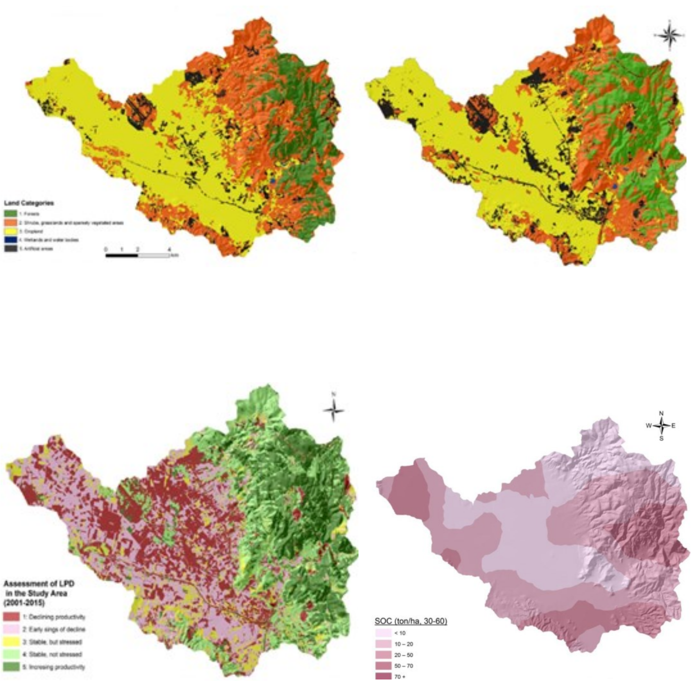

Figure (1) LDN Parameters Analysis for The Gediz Basin

a. Land Cover Change: critical transitions were analysed. From semi-natural land cover classes (forest, shrubs, grasslands and sparsely vegetated areas) to cropland and to artificial surfaces, from cropland to artificial surfaces as well as from cropland to semi-natural land cover types can be seen on Figure 1.

b. Land Productivity Dynamics: Dynamics for the Gediz Basin calculated from satellite images based on LUC and NDVI analysis.

c. Organic Carbon Stock: Surface and sub-surface soil samples were gathered from the Basin in order to see the organic carbon stock.

Fact Sheet Topic Area:
Land degradation neutrality

Keywords:
Action plan, LDN Pilot Project, Land Degradation Trends, Turkey

Authors:

Yasemen Asli Yilmazgil
Expert Ministry of Forestry and Water Affairs
y.karatas@ormansu.gov.tr

Pinar Canli
Expert Ministry of Forestry and Water Affairs
pberberoglu@ormansu.gov.tr

Sevilay Ozcelik Sonmez
Expert Ministry of Forestry and Water Affairs
sozcelik@ormansu.gov.tr

Prof. Dr. Orhan Dengiz
On Dokuz Mayis University
dengizorhan@gmail.com

Geographic location:
Turkey

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The LDN pilot project was a good start for the party countries which are mainly located in arid lands and suffering from desertification.

LDN parameters seem sufficient and not very complex for countries to test on the land. However, advanced knowledge on GIS technologies, mapping skills, capacity and finance are very much needed for calibrations on the land and for further studies. Knowledge sharing within the countries shall help to overcome this issue.

Turkey has been implementing “Action Program on Afforestation and Erosion Control Mobilization" and "Action Plan for Combating Desertification". 354 235 ha of afforestation, 2 414 925 ha of rehabilitation, 467 142 ha of erosion control, and 51 617 ha of pasture reclamation was achieved between 2005 and 2012 with an aim to increase public awareness on desertification.

Day by day Turkey gives more importance to understanding the existing situation and factors that accelerate desertification. With the experiences gained in the past, Turkey aims to disseminate its capacity to less developed countries via bilateral agreements, international training and global initiatives. The Ankara Initiative was launched at UNCCD COP12 Ankara/TURKEY in 2015. Turkey will provide 5.000.000 USD dollars for a period of 4 years as an operational budget for the implementation of mainly the LDN activities. The Ankara Initiative will support the global sustainable development agenda and leverage the lessons learned from Turkey’s past experience and approaches to land management.

RESTORATION STRATEGIES

195 party countries of the UNCCD have decided to set voluntary targets for LDN.

The Secretariat has been preparing needed documents and methodologies for countries. Although from the point of Turkish experience on testing LDN, it is a good starting point for understanding land degradation trends, on the other hand the methodology is at a very early stage and needs further work. Land degradation dynamics differs from one country to another. In order to set targets, country capacities and capabilities are needed to be taken into consideration by UNCCD.

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- www.cem.gov.tr
- National Strategy and Action Plan To Combat Desertification (2015-2023)

Dryland restoration based on sustainable land management principles

Drought, loss of organic material, wind and water erosion, soil crusting, salinization, and other processes gradually render soils in drylands infertile. Communities living in dryland areas are capable of stopping degradation and reviving healthy soils. Sustainable land management gives them the means. It turns the threat of desertification into opportunities: they can improve their productivity with minimal use of artificial inputs, increase biodiversity, create carbon sinks, maintain picturesque landscapes that attract visitors, and more. Many of the land use practices have been refined over generations by everyday land users who are experts at efficiently harnessing nature's productive power, even under austere natural conditions. Growing drought and fire resistant fruit trees within rotational grazing systems is one example. The researchers of the WOCAT (World Overview of Conservation Approaches and Technologies) network (www.wocat.net) have recorded this vital knowledge in a standardized way, assessed its impacts on ecosystems and human well-being, and made it available for use by anyone anywhere.

Sustainable land management varies from place to place, but generally focuses on water, plants, structures and stewardship and involves joint assessment of local challenges and resources. Various projects (e.g. WOCAT, DESIRE and others, see references) have developed tools to help assess and select practices which enable the informed, responsive, locally anchored stewardship that is needed to combat desertification. **Joint assessment of local challenges, resources, and way forward**: Each area faces a unique set of challenges. This approach begins by bringing together key stakeholders – land users, local authorities, and others – to set their sustainable land management goals and decide how to achieve them. The goals might include reducing soil erosion and improving farm income. In two workshops, separated by a documentation phase using the WOCAT format, participants identify their problems (e.g. low productivity due to soil fertility loss), assess the potential solutions, and decide which technologies to implement. To maximize the likelihood of acceptance and to minimize the costs, priority goes to adapting and scaling up promising local practices.

Figure (1): The carrob trees provide shade and restore degraded grazing lands in Crete, Greece. Carrob trees are drought- and fire-resistant and provide fodder for sheep and sirup for the market. (Photos G. Schwilch)

https://desertrestorationhub.com

Fact Sheet Topic Area:
Land management.

Keywords:
SLM, water, plant and soil management, stewardship.

Authors:
Gudrun Schwilch
Centre for Development and Environment CDE,
University of Bern,
Switzerland.
gudrun.schwilch@cde.unibe.ch

Geographic location:
Global drylands

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Principles of sustainable land management (SLM) practices

Water: Instead of relying on irrigation water brought in from elsewhere, they capture, store, and channel what little rain does fall and make sure it is not immediately lost through evaporation and surface runoff. Rainfall can be captured on roofs, in catchments, in recharge wells, etc. and directed into fields or into ponds for use later.

Plants: Roots hold soils together; litter on the surface allows water to infiltrate. Trees provide shade and shelter, and ground cover breaks the impact of raindrops. Nitrogen-fixing crops in rotation with other crops require little water and can be eaten or used for livestock fodder. Ploughed under they enhance soil fertility and structure. Elsewhere, it might be better to plant or preserve drought-resistant shrubs or trees, which produce fuelwood or fruits. Large-scale afforestation can stabilize hillsides.

Structures: Plants can form a living, durable barrier to strong winds, rain, or floodwater. Earth or stone terraces control erosion. Fences woven from branches, stone check dams, and rock walls trap soils, reinforce terraces, or buttress plant barriers.

SELECTED KEY REFERENCES

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- CASCADE website: http://www.cascadis-project.eu/

Figure (2): Researchers identifying and recording vital SLM knowledge, and assessing its impacts on ecosystems and human well-being making it available for use by other land users anywhere. (Photos: G. Schwilch, WOCAT database)

RESTORATION STRATEGIES

The multipurpose use of landscapes is vital for sustainable land management. Tying everything together is the **stewardship** or management of drylands. Crops must be harvested and rotated. Barriers and terraces need upkeep. Pests and plant diseases must be kept in check. Forests need thinning to cut fire risks. Soil fertility and moisture levels require monitoring. Livestock keepers graze their animals only in certain areas, allowing other areas to recover.

This highlights the need for national governments, regional bodies (e.g. the EU), and the private sector to provide adequate **financial and social support** (e.g. education) to dryland communities. Public awareness campaigns are needed to champion their work. By saving soils from desertification, they are doing nothing less than preserving life-support systems on behalf of everyone.

Involvement of land users in restoration activities: the role of paraecologists in ecological restoration

ESSEM COST ACTION 1104
Arid Lands Restoration and Combat of Desertification: Setting Up a Drylands and Desert Restoration Hub

https://desertrestorationhub.com

Degradation of dryland systems is a major challenge worldwide. The reasons for degradation are complex and differ among areas depending on the past or present land tenure, governance and socio-economic and natural conditions of the respective area. If the current drivers of the degradation are not attended to they will continue to take effect and counteract the restoration effort. Sustainable and ecological restoration of farmland thus needs the involvement and ownership of the custodians of the land: the land users. Close interaction with land users requires skills that typically do not form part of the training of natural scientists and are thus experienced as challenging.

Involving paraecologists can bridge the gap between scientists / practitioners and land users. A paraecologist is a local resident and a professional (i.e. employed member of a professional team). Paraecologists do not need to have formal schooling in ecology or other sciences, but they bring their local knowledge, an expertise by itself, to the work. They are then trained on the job in one or more fields of ecological science. They contribute to scientific research, outreach and implementation of research results as well as local capacity development, thus enhancing communication between local and scientific communities. Paraecologists support restoration activities through site selection, allocation of local resources for restoration material, help with the implementation of trials, monitoring and evaluation of the restoration effects. As a member of both the local community and the professional scientist/practitioner team, paraecologists facilitate the implementation of innovations and sustainable land management practices by translating languages and sharing local, traditional and scientific knowledge norms and perceptions, as well as religious beliefs between scientists /practitioners and local land users.

Figure (1): Left: Paraecologist in Central India talking with land users about traditional natural resource management.

Figure (2): Right: Paraecologists in South Africa implementing and inspecting restoration trials.

Fact Sheet Topic Area:
Stakeholder involvement

Keywords:
Knowledge sharing, participation, transdisciplinarity.

Authors:
Ute Schmiedel
University of Hamburg,
Ute.schmiedel@uni-hamburg.de

Shekhar S. Kolipaka
Leiden University,
Kolipaka.s.s@gmail.com

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Example (1): Northern Madhya Pradesh, India: Uncontrolled and increasing direct dependence of rural people on semi-arid ecosystems is responsible for habitat degradation, transforming large stretches of government forests into unsuitable areas for human and wildlife use. Further, prevailing traditional local practices of natural resource extraction and livestock management embedded in old practices and strong traditional beliefs and norms pose severe challenges for external agents who aim to address change towards more sustainable natural resource management. To study and address these complex and sensitive topics three paraecologists were trained by the Caracal Conservation and Research Project to engage with local villagers. Between 2012 and 2015 the paraecologists systematically collected information on local people's land use practices, their traditional ecological knowledge and interactions with environment and local wildlife (Kolipaka et al. 2015). The paraecologists also identified innovative and sustainable local strategies of livestock husbandry, corralling and other measures that were developed by one group of land users, and shared these innovations with land users in other parts of the region who were not aware of such innovation.

Example (2): Southern Africa: The BIOTA Southern Africa project (BIOTA-Africa.org) employed and trained eight paraecologists as fulltime project members for over six years. The paraecologists supported the environmental monitoring but also facilitated the ecological restoration activities within the communal farmland. Based on their local knowledge the paraecologists helped to select appropriate sites for the restoration trials, identified areas where material for brush packs can be harvested, arranged with the livestock owners for the local transport of manure as mulch and fertiliser. The paraecologists implemented the restoration trials supported by other community members. Subsequently, they conducted regular monitoring of the sites and communicated the restoration results with the entire farming community during field days and farmer meetings.

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The manifold benefits of the involvement of paraecologists:

Benefits to the external agents from engaging paraecologists

- Increased awareness about the values, needs and visions of the rural land users.
- Access to critical local information on the drivers of degradation and local ecology.
- They receive local assistance to select sites suitable for restoration trials from the land-management perspectives.
- They benefit from local technologies and restoration measures that use locally available material and follow culturally and economically adapted processes.

Benefits for the community

- Paraecologists enhance the understanding within land-user communities for the advantage of restoration measures and sustainable management.
- They work alongside local people (paraecologists) who have the advantage of knowing local languages, understand local culture, and are thus better able to connect with local communities.
- They create awareness among local school children of the value of nature resources.
- They can help to facilitate the communication with researchers / practitioners and thus enhance mutual understanding.

Benefits for paraecologist

- Increased social standing within their community as result of their new role (bridge between community and external agents).
- Continuous personal development through formal and informal learning opportunities and increased earning capacity.

Promotion of integrated land and water management (ISFM)

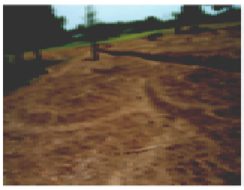
An integrated soil fertility management (ISFM) paradigm is a necessity and a viable set of principles to foster forest-farm intensification as well as to improve the livelihoods specially of rural households of sub-Saharan Africa and certainly so in the upper west region of Ghana. Although challenging ISFM may simply mean optimizing crop productivity through maximizing the efficiency and interactions with which fertilizer, organic inputs and improved germplasm as well as the required associated knowledge are used since these are together scarce resources in the areas where crops intensification are needed. Various studies on the deteriorated environmental situation within this region (e.g. EPA 2004, Amankwah 2012, Nkegbe 2013) point to biophysical and socio-economic factors such as bush burning, slash and burn, tree felling for fuel, open grazing, sand/gravel winning, small scale mining, farming along the banks of streams and, improper infrastructural development as the causes. The impact of these activities on the natural environment has been the loss of vegetation cover, soil erosion, reduction in soil fertility, desertification and loss of wildlife.

Efforts (techniques) to promote integrated land and water management

(a)

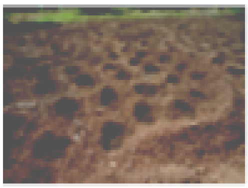
(b)

Compost use is contributing to improved soil fertility (Photographs by courtesy Nkegbe)



(C)

(d)



(e)

(f)

Half-moon (c & d) and zai (d & e) reinforced with stone lining used to control soil erosion on cropped fields at Kanpuo (Photographs by courtesy Nkegbe)

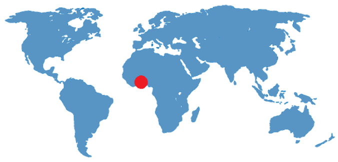
(g)

(h)

Ploughing made across a slope to control soil erosion (g) minimum tillage with Bullocks to reduces soil compaction and increases soil water retention (h) (Photographs by courtesy Nkegbe)

ESSEM COST ACTION 1104 Arid Lands Restoration and Combat of Desertification: Setting Up a Drylands and Desert Restoration Hub

https://desertrestorationhub.com



Fact Sheet Topic Area:
Efforts to promote integrated land and water management (ISFM)

Keywords:
Forest-Farm Systems, On-site and Off-site Benefits

Authors:
Edmund Asare
edmund.asare@helsinki.fi

Michael Poku-Marboah

Olavi Luukkanen

Geographic location:
Ghana (lat. 4° 44′ N & 11° 11′N and lon. 3° 11′ W & 1° 11′ E.

Climate classification (Koppen):
Tropical Moist Climates and Savanna- Wet-Dry Tropical Climates

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However, improved soil fertility management practices (ISFM) provide multiple onsite and offsite benefits, which can be economically significant, including regulation of the flow of water and sediment, controlled soil erosion, storage of carbon in soil, higher and more resilient farm productivity, improved household food security and income levels.


A typical Guinea savannah vegetation showing (left) no conservation activities and (right) with ISFM Western Region, Ghana. (Photograph by courtesy Nkegbe)

Sole *Mucuna spp.* cultivated for soil fertility improvement and fodder


Stunted and scaly-leafed corn growing on a degraded soil (left), healthy maize growing on compost-enriched soil (right)

RESTORATION STRATEGIES

A study by SARI, 2011 reveals embracing a number of site-specific conservation schemes and practices has the ability to deliver the twin goals of conservation and livelihood security as seen in Table 1.

Table (1): Soil analysis at Kanpuo community - Upper West Region of Ghana

Property/Crop Yield	Before application of ISFM technologies	After application of ISFM technologies
pH	5.86	6.83
Organic Matter (%)	0.53	3.04
Organic carbon (%)	0.31	1.76
Total Nitrogen (%)	0.03	0.25
Carbon Nitrogen ratio (C: N) %	9.93	7.14
Bray–Available P (mg/kg)	5.71	38
Available K (mg/kg)	49.37	107.99
Sorghum harvest in 3 years (kg/acre)	150	550
Maize harvest in 3 years (kg/acre)	250	800

Source: Adapted from Nkegbe (2013)

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The potential of remote sensing as a useful tool in post-fire forest management throughout monitoring post-fire resilience

WILDFIRES

Fire is one of the most important disturbances in the Mediterranean region as it shapes and structures many plant communities, forest ecosystems and landscapes. After a fire event, forest functions, nutrient cycling, and soil properties are significantly affected (Figure 1). Moreover, global change is affecting fire regime, increasing fire frequency and area burned, as well as its destructiveness to Mediterranean ecosystems.

Figure (1): Burned Aleppo pine forest in Hellín (Spain), seven days after fire event (Photo: Javier Hedo, 2010)

POST-FIRE RESILIENCE

Resilience is a concept used in social, engineering and environmental fields. Resilience has been defined as the capacity of an ecosystem to respond to a disturbance by resisting damage and recovering in a relatively short period of time in plant communities (Figure 2). The resilience is a function of the composite "resiliences" of the assemblage of species populations (Keeley 1986).

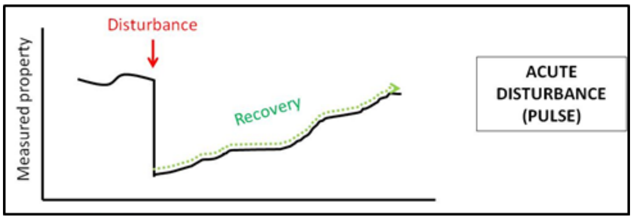

Figure (2) Left: Ecological resilience understood as recovery after disturbance. (Prepared by Javier Hedo, 2015)

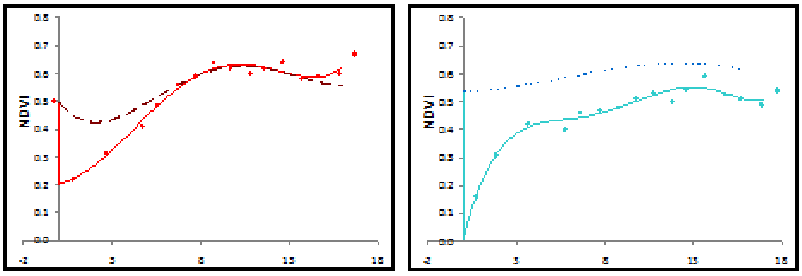

Figure (3) Right: NDVI curves after a fire event, monitored for 18 years.

https://desertrestorationhub.com

Fact Sheet Topic Area:
Aleppo pine forest in South-eastern Iberian Peninsula.

Keywords:
NDVI, resilience

Authors:
Javier Hedo
Department of Genetics and Agroforestry Science and Technology
School of Advanced Agricultural Engineering
Albacete
Spain.
Javier.Hedo@gmail.com

Eva Rubio
Department of Applied Physics
School of Industrial Engineering
Albacete,
Spain.

Geographic location:
Spain

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NDVI MONITORING

From NDVI time series, different patterns or curve types of the dynamics of regeneration of the vegetation must be defined. These patterns are regarded as 'recovery curves' (Figures 3, 5, 7). Each NDVI curve corresponds to an unique pixel. For each pixel different characteristics must be recorded for subsequent crossing with the curves of NDVI. Variables include aspect, altitude, certain pre-fire types of vegetation, fire severity, climatic variables, etc. In this way it can be predicted which areas, after a fire event, will regenerate better or worse depending on their characteristics.

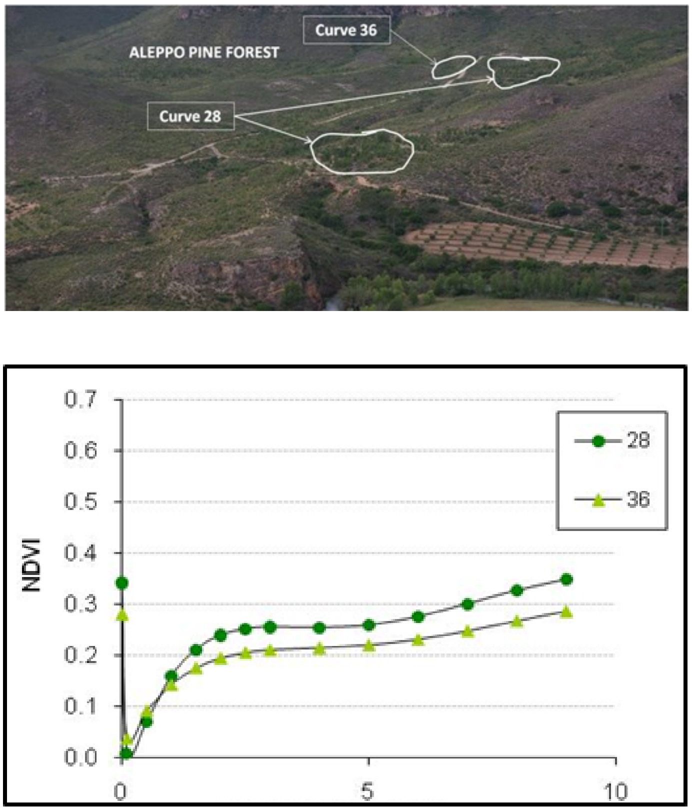

Figure (4): Aleppo pine forest. Two patches with different regeneration curve (Photo: Javier Hedo 2012)

In figures 4 and 5, it can be seen how very close vegetation patches naturally recover differently. As an example, patches that showed curve 36 need more attention on prevention than patches showing better regeneration curves, as curve 44.

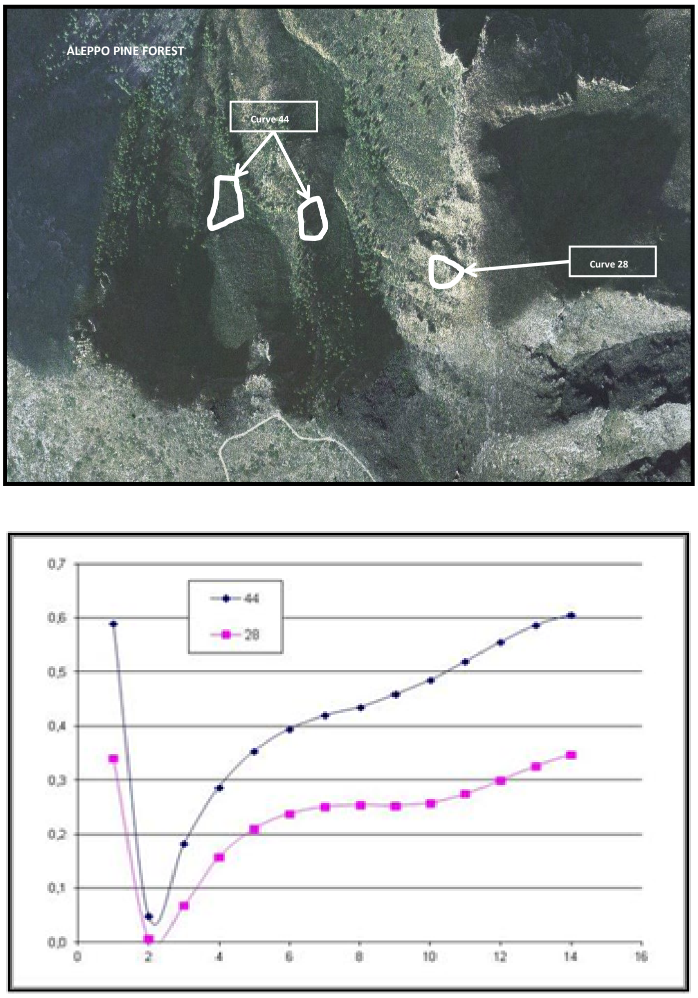

Figure (5): Aleppo pine forest. Two patches with different regeneration curve (Ortophoto)

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RESTORATION STRATEGIES

The issue described in the fact-sheet can be used to improve management in prevention and subsequent restoration processes in post-fire environments. After this tool monitoring, the less resilient pixels need acute restoration or prevention strategies. Tools helping decision makers should include analysis of resilience and adaptive resource management based in scientific knowledge.

Risk assessment of the desertification in the karst ecosystems

https://desertrestorationhub.com

Environmentally Sensitive Areas (ESA) are evaluated with soil, climate, vegetation and management quality indices (MEDALUS) (Kosmas et al. 1999). Ecologically sensitive areas in Karst ecosystems show the most negative effects of desertification. Karst ecosystems have many vulnerable and unique natural resources. People have the power to prevent or slow down the desertification processes. Especially in terms of ecology sensitivity such as "Potential" ESA $_{(P)}$ "Fragile" ESA $_{(F)}$ and "Critical" ESA $_{(C)}$ classes constitute desertification; therefore, practitioners should be more careful in planning rehabilitation processes in the level of fragile or critical ecosystems. Due to the negative effect of soil and air balance, organic matter is mineralized quickly in the karst ecosystems.

Low lying areas have a good ecological condition in the karst ecosystem. They have rich soil, organic carbon content, soil depth and unique flora and fauna. These areas create crucial places for plant survivability in the karst ecosystems. For instance, the soil organic carbon content was determined to be approximately double in the low lying areas compared to other areas in the karst areas located in Kahramanmaras-Andırın/TURKEY (Dindaroglu et al. 2015). Higher lying areas are characterised by shallow soil depths and high surface stoniness making it hard for plant survival. Plant species need to be selected according to the site's ecological sensitivity, and the seedlings' success rate will increase (Dindaroglu, 2015). After the plantation, plant survival rates found higher ESA $_{(P)}$ than ESA $_{(F)}$ and ESA $_{(C)}$. The highest success rates were identified in the most critical sensitive area (C2) respecdtively; *Robinia pseudoacacia L.>Fraxinus excelsior L.>Acer negundo>Betula pendula>Pinus sylvestris* (Dindaroglu, 2015).

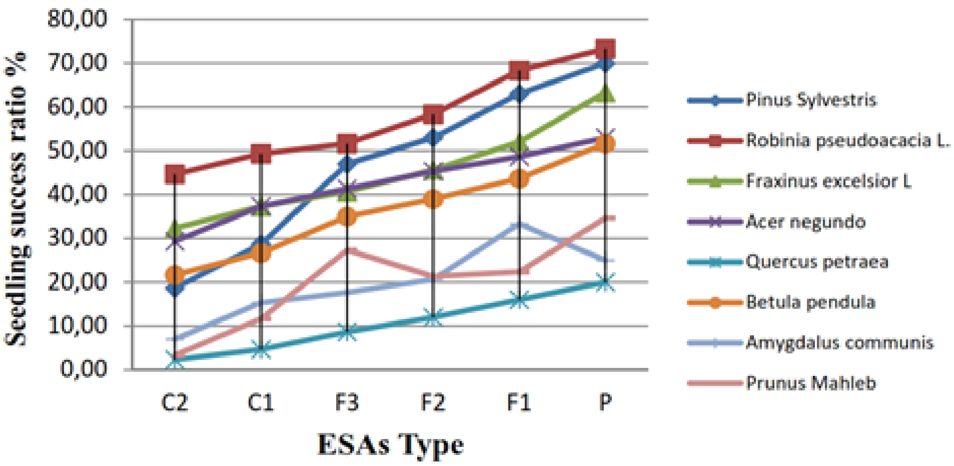

Figure (1): Seedling success ratios of environmentally sensitive types and tree species (Dindaroglu, 2015)

Fact Sheet Topic Area:
Arid Land Restoration and Combat of Desertification

Key Points:

- Identify new index value for karst ecosystem
- Spatial distribution of ecology sensitivity
- Mapping risk of desertification in the karst ecosystem

Keywords:
Desertification, Sensitive areas, MEDALUS, Karst Ecosystems.

Authors:
Turgay Dindaroglu, Ph.D.
Kahramanmaras Sutcuimam University,
Faculty of Forestry.
turgaydindaroglu@ksu.edu.tr

Geographic location:
Turkey, Kahramanmaras.

Climate classification (Koppen):
Semi arid.

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Figure (2): A view from the depressed areas in the karst

Figure (3): A view from the settlement area of the karst ecosystem

Ecological restoration on problematic areas requires long-term planning, cost consideration and patience. Some plant species struggle to adapt to changing ecological conditions. Many species cannot survive in "Fragile" and "Critically" sensitive areas. As the plant's roots will again be faced with problems such as a high calcium and heavy clay content. The aim should be to perform soil remediation without exposure to any adverse conditions during the succession processes in the karst ecosystem. Soil is the only source where we can intervene with effect. If the soil improves, vegetation will have a better chance to survive and this will rehabilitate the ecological character. Soil quality in "Critical" and "Fragile" areas, where there is a heavy clay layer should be improved with deep tillage and added organic matter. After that, a number of different local native species can be tried to revegetate the area.

RESTORATION STRATEGIES

1. A plan with different strategies for different ecological sensitivities should be made.
2. In the first instance an ecological sensitivity map needs to be produced.
3. Low lying areas need to be identified
4. Ecological restoration should commence n "Critical" or "Fragile" areas and where these overlap low lying areas.

Figure (4): A view from the aboveground habitats of the karst ecosystem

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Restoration of degraded Mediterranean rangelands

https://desertrestorationhub.com

Mediterranean rangelands are marginal dry lands mainly used for grazing by domestic animals since thousands of years ago. They are found in the Mediterranean isoclimatic zone of the Mediterranean basin countries. In this zone, in 2008, there were 121 million sheep iamounting to a global stocking rate of 1.8 sheep/ha indicating overgrazing since grazing capacity is around one sheep/ha (Papanastasis, 1998). In addition, inappropriate animal species or grazing system (e.g. communal grazing) and traditional but improper practices such as pastoral wildfires combined with overgrazing have all contributed to the degradation of rangelands in several parts of the Mediterranean region. They are characterized by poor vegetation species composition, largely unpalatable to grazing animals, limited productivity and eroded soils. Degradation, however, does not have the same causes on both sides of the Mediterranean Sea (Puigdefabregas and Mendizabal 1998). In the northern part, it is caused by the expansionof livestock activities in uplands due to migration of the rural people to the urban centres of the lowlands and their consequent undergrazing or even abandonment. Increased grazing pressure is applied only in rangelands around settlements, especially in animal concentration points (Roeder et al. 2007). In the southern part, on the contrary, people remain in the rural areas, where a significant part of rangelands has been converted to arable lands to accommodate the food needs of the increasing human population resulting in increased pressure on the remaining rangelands thus leading to their overgrazing and degradation.

Figure (1): Degraded rangeland (Cyprus)

Figure (2): Degraded rangeland (south Tunisia)

In restoring degraded rangelands, two main types of thresholds should be crossed: the biotic interactions (e.g. poor plant species composition) and the abiotic limitations (e.g. soil erosion) (Papanastasis, 2009). The former type can be accommodated with the grazing process, namely by applying appropriate grazing management. This includes soft measures such as an adjusted stocking rates to the grazing capacity of the restored land, the right kind of animal species, and an appropriate grazing system. The damaged abiotic factors, on the contrary, cannot be repaired by the grazing process alone; hard measures should be also applied such as technical works (e.g. dams to halt soil erosion, trails and watering points to improve animal distribution, etc.), fertilization to increase soil fertility, plantation of fodder shrubs, sowing palatable herbaceous species or a combination of all these measures.

Fact Sheet Topic Area:
Rangeland restoration

Keywords:
Domestic animals, biotic interactions, grazing management, abiotic limitations, technical works, plant species introduction, community participation.

Authors:
Vasilios P. Papanastasis,
Aristotle University of Thessaloniki, Greece
vpapan@for.auth.gr

Geographic location:
Mediterranean region
Mediterranean-type climate

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Overall, grazing management should be part of the restoration plan. This is because there is a long history of grazing by livestock. Excluding domestic animals from such ecosystems may lead to several ecological problems that include loss of biodiversity and devastating wildfires. It should be applied though in an appropriate way, namely the number and kind of animals as well as the grazing system should be accordingly adjusted. If livestock need to be temporarily removed during the restoration period, alternative feed resources should be provided. Farmers should also be involved in the restoration plan, particularly in the communally grazed rangelands. Without community participation it is unlikely that any interventions to halt degradation due to livestock grazing in Mediterranean rangelands will succeed.

RESTORATION STRATEGIES

1. Grazing management should be part of any plan implemented to restore degraded Mediterranean rangelands.
2. If grazing activities have not been irreversibly damaged the physical environment of Mediterranean rangelands can then be restored by applying appropriate grazing management. However, if the damage is irreversible then additional to grazing actions other works are required; earth works, fertilization and introduction of new plant species by sowing or planting.
3. If livestock have to be temporarily removed from the restored rangelands alternative feed resources should be provided for them.
4. Local stakeholders should be part of the restoration plan.

Figure (3): A degraded rangeland in the island of Crete that can be restored by appropriate grazing

Figure (4): A degraded rangeland in south Tunisia restored with earth works and shrub plantation

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Rehabilitating wadi Kharrouba at the Governorate of Marsa Matrouh in the North Western Desert of Egypt

https://desertrestorationhub.com

The Matrouh Rural Development project (MARSADEV) was operational between March 2014-February 2017 and was funded by the Italian Cooperation under a special funding agreement with the Egyptian Government. The aim of the project is to develop and support activities that improve the living conditions of the Bedouin rural communities who live in the North West region of Matrouh Governorate. The project is aimed at recovering degraded lands, preventing erosion, enhance water saving and harvesting, enriching soil fertility, improving crop yields, providing appropriate conditions for livestock management, alleviating poverty, and finally boosting socio-economic conditions and gender issues inside the local communities. The project also aims to enhance local agricultural production by improving the agro-processing capacities and encouraging organic farming.

In 2013 local Bedouin communities in the project area were estimated as 22,000 households with a population of 152,000. The climate is characterized by hot summers and mild winters with a mean annual temperature ranging between a maximum of 25°C and a minimum 15°C. The average annual rainfall varies from 100 to 140 mm/ year registered between November to March often in torrential rainfall events associated with extreme erosion. Wadis are small to medium watersheds surrounded by endless rocky areas with limited vegetation. Wadis represent the only possible place where rainfed farming could occur, that in some specific cases is further supported by supplementary irrigation coming from cistern and reservoir water.

Fact Sheet Topic Area:
Land and water management in arid regions

Keywords:
Land reclamation, water harvesting, cisterns constructions, Bedouin communities.

Authors:
Pandi Zdruli
CIHEAM Mediterranean Agronomic Institute of Bari, Italy
pandi@iamb.it

Geographic location:
North Africa

Climate Classification (Koppen):
Arid

Collaborating institutions

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In 2013 wadi Kharrouba was a barren, heavily eroded and abandoned landscape.

In November 2015 wadi Kharrouba has been totally reclaimed and rehabilitated and is now ready to be given to Bedouin people. In Spring 2016, 13 ha of land was planted with local varieties of figs and olives adapted to arid conditions. The overall cost is about €500.000.

RESTORATION STRATEGIES

In early 2014 land reclamation activities included:

- Land levelling using heavy machinery.
- Dike construction at every 70 metres distance in the lower terraces and up to 30 metres in the upper ones for a total of twenty terraces.
- Establish semicircle terraces to control erosion on wadis sloping lands.
- Plant includes native plants like *Moringa olieifera, Opuntia ficus -indica*, *Medicago arborea, Atriplex spp.* to provide additional income for local people.
- A reservoir was built in the uplands of the wadi to supply irrigation water.

Water harvested inside the wadi during the rainy season 2015 - 2016 after all terraces were built.

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CIHEAM
IAM BARI

https://www.facebook.com/Marsadev-project-Egypt

Rangeland restoration: fodder shrub plantation in central Morocco

https://desertrestorationhub.com

Plantation of fodder shrubs is one the most used methods to combat desertification and improve the productivity of the degraded rangelands. The interventions implemented in Ouled Dlim (North-West of Marrakech, Morocco) are a well-known example. Here Atriplex nummularia, a halophyte native to Australia, was extensively planted to recover productivity of degraded arid rangelands and mitigate land degradation. The climate of the area is arid, with average annual rainfall of 202 mm, and of Mediterranean type, with a warm dry season spanning from April to October, and high inter-annual and intra-annual variability. The objectives of the interventions were: i) increasing the standing green fodder biomass especially as a reserve for the dry season; ii) providing an inter-annual "buffer" feeding reserve of standing fodder to cope with severe and prolonged droughts; iii) establishing vegetation cover to mitigate soil erosion and to provide wood fuel and shelter for the wildlife. The interventions substantially achieved the goals.

An integrated analysis of multi-temporal RS-based and field biomass measurements revealed that on average the plantation sites produced 2.21 to 3.61 Mg ha-1 of dry biomass more than the surrounding untreated rangelands, with the best performing plantations yielding a difference of up to more than 7 Mg ha-1. Field studies demonstrated that the consistent biomass production was followed by the increase in soil carbon stocks, estimated to around 5 t ha−1 during the plant life cycle. The ecological functions of the soil were also positively affected. The SAR (Sodium Adsorption Rate), a measure of soil alkalinity, was especially increased by up to 350% in the topsoil under canopy. Finally, the impact assessment could be made by taking the plant's life cycle into account. When the plants are 10 to 12 years old, they become senescent, and their green to woody biomass ratio very low. The useful production phase lasts from 7 to 9 years. Overall, the well managed and well developed plantations were rewarding. Here the economic value of the fodder biomass produced could compensate the investment needed for the intervention, besides generating a range of ecological benefits in the short term.

Figure (1): Atriplex nummularia plantations in Ouled Dlim.

Fact Sheet Topic Area:
Rangeland restoration

Keywords:
Fodder shrub, halophyte, Atriplex nummularia.

Authors:
Claudio Zucca
ICARDA (International Center for Agricultural Research in the Dry Areas) & Dept. of Agricultural Sciences and NRD, Univ. of Sassari, Italy.
c.zucca@cgiar.org.

Geographic location:
Central Morocco

UNEP aridity class:
Arid

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This was true particularly in the best developed plantations where the nutrient cycling capacity of the soil surface was improved by up to 80% compared to the surrounding rangelands. The performance remained relatively good across different types of degraded soils.

A participatory assessment recently performed in the frame of the EC-funded FP7 PRACTICE project highlighted some further positive impacts. The analysis of socio-economic data and the results of stakeholder interviews and focus groups indicated, on average, a positive cost-benefit balance, and a positive social perception of the enhanced biodiversity and habitat value. The increase of social cohesion generated by the cooperative management of the plantations established in the commonly owned lands was also valued.

On the other hand, some critical aspects were observed. First, the biomass production proved to be strongly depended on the quality of management. Poorly managed sites did not impact ecosystems significantly. In economic terms, they did not pay back. Second, a strong increase in salinity was also observed at the soil surface under the plants' canopy, in connection with the plant's active accumulation of soluble salts in the leaves (as drought tolerance mechanism).

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RESTORATION STRATEGIES

The interventions addressed by this document substantially achieved their goals and can be considered as a success story. Some lessons were learnt thanks to the evaluation conducted in the field with the active participation of the stakeholders, which should be considered to improve future restoration plans. Farmers implementing restoration need support and monitoring by extension officers particularly during early phases (grazing exclosure after planting; managing grazing exploitation during third year) to ensure good plantation development and significant impact. Plants tolerated direct grazing. However more intensive exploitation schemes based on biomass harvesting by farmers would allow for optimal use of green biomass and reduce salt accumulation (by leave litter) in the topsoil. Medium and long-term strategies are needed to maintain the plantation productivity, considering the short plant's life cycle duration. These may vary from re-plantation to substitution with autochthonous forest species, depending on the strategic goals.

Figure (2): Atriplex seedlings produced by the Ouled Dlim breeder cooperative.

Quarry rehabilitation: success evaluation after 30 years

Quarrying activities entail the complete removal of soil and vegetation before extraction, causing a deep change in the local topography and extensive barren surfaces. Rehabilitation of these highly degraded areas requires active restoration efforts, whose outcomes should be evaluated in view of the defined restoration goals. As restored ecosystems are very dynamic over time, it is important to follow their evolution, and evaluate their success in the medium to long-term.

CASE STUDY: We aimed to evaluate the success of restoration actions performed in two quarries (marl and limestone) from a cement company located in SW Portugal. The climate is dry sub-humid Mediterranean, with an average annual temperature of 15.6ºC and average annual precipitation of 735 mm. The extraction process at the quarries is conducted from the top to the bottom of the mountain, allowing the beginning of rehabilitation works in older parts whilst the extraction takes place, giving origin to a chronosequence of rehabilitated sites. Rehabilitation began in 1982 and consists in the addition of a layer of marl on the barren substrate, followed by plantation and/or hydroseeding. Most of the planted species are native and can be found in the undisturbed surrounding vegetation. However, fast-growing species, such as *Pinus halepensis*, were also planted with the aim of minimizing the visual impact of the quarry and allegedly acting as nurse plants. Hydroseeding mixtures are mostly composed of generalist herbaceous species which often tend to become dominant.

METHODOLOGY: To evaluate the success of the restoration actions along the chronosequence of rehabilitated sites, we selected and compared three sites in each quarry, in order to represent areas rehabilitated in the 1980s, 1990s and from 2000 onwards, and two sites in the surrounding natural vegetation, as reference. Vegetation at reference sites ranged from rupestrian to Mediterranean maquis formations, with a maximum height of 5m, dominated by evergreen sclerophyllous shrubs. At the quarry, limestone sites were planted, while marl sites, which had steeper slopes, were first hydroseeded and then planted, in order to try to avoid erosion.

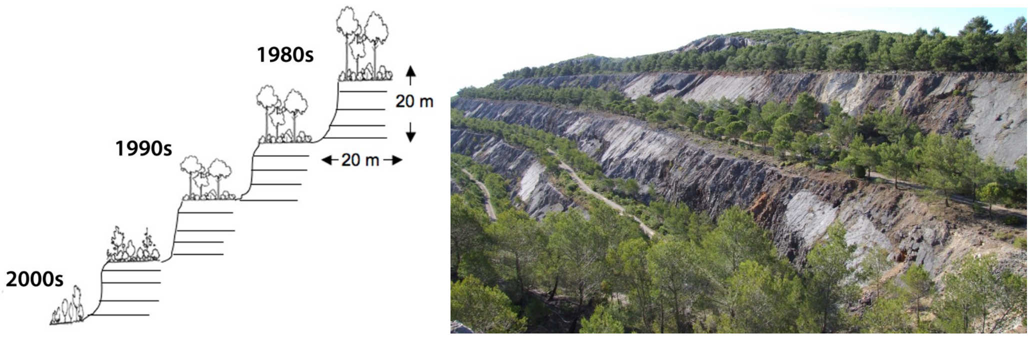

Figure (1): Study area: (**above left**) schematic representation of the quarry platforms illustrating the site recovery as the revegetation takes place from the top downwards (Correia et al. 2001); and (**above right**) picture of the limestone quarry platforms. Copyrights: T. Mexia / SECIL

https://desertrestorationhub.com

Fact Sheet Topic Area:
Reforestation

Keywords:
Reforestation, success evaluation, native species, chronosequence.

Authors:
Teresa Mexia
tmmexia@fc.ul.pt

Alice Nunes
amanunes@fc.ul.pt

Otília Correia
odgato@fc.ul.pt

Centre for Ecology, Evolution and Environmental Changes, Faculdade de Ciências, Universidade de Lisboa.

Geographic location:
Portugal (38°29'47.0"N 8° 56'51.5"W)

Climate classification (Koppen):
Mediterranean climate (Csa)

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The structure and diversity of vegetation were evaluated in 15 plots ($9m^2$) per site.

MAIN RESULTS: Plant diversity (Shannon-Wiener index) in most rehabilitated sites was still lower than in the undisturbed reference sites. The only exception was observed in the younger site of marl quarry, whose higher diversity value was related to a greater presence of hydroseeded species. Nevertheless, there was a slight increase in the Sorensen similarity index with rehabilitation age.

Plant cover was similar for all sites. More recently rehabilitated sites had higher cover of herbaceous species, while shrub cover tended to increase with rehabilitation age, although never achieving the values of the reference site. The main difference in vegetation structure between rehabilitated areas and the reference sites was due to presence of *P. halepensis*, especially at the limestone quarry. Pine cover increased with rehabilitation age, dominating over native shrubs in the older quarry sites (80s and 90s).

Figure (2): Limestone sites rehabilitated in the 1990s: (**top**) area with greater *P. halepensis* cover; and (**bottom**) well developed shrub cover. Copyrights: G. Oliveira / SECIL

RESTORATION STRATEGIES

It is important to use native species in rehabilitation programmes.

- The use of generalist hydroseeding mixtures was responsible for the major differences in herbaceous species richness and cover.
- *P. halepensis* introduction probably had an important role at an earlier phase of the rehabilitation process, but later it was responsible for the main difference between the vegetation of older rehabilitated sites and reference sites.
- Most of the planted species established successfully and achieved a cover similar to reference sites.

After 30 years of rehabilitation, there are still native species that fail to establish. It is thus important to improve plantation methodologies for their success. The use of non-native species (as nurse-species, to mitigate landscape impacts, to control erosion, etc.) may be helpful at first, but adaptive management measures may be necessary to prevent non-native species dominance over time.

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Reforestation of degraded croplands with pine tree: a successful case of restoration with Calabrian pine in Southern Italy

https://desertrestorationhub.com

Important reforestation programmes of the Sila Mountain, with the main purpose of soil conservation and hydrogeological control, started in 1955. Before the area was planted, soils were subjected to very strong erosion, caused by the repeated cultivation of potato and rye, and by excessive grazing. The climate is sub-mountain Mediterranean, characterised by heavy autumn and winter rainstorms and a somewhat summer aridity. Despite elevation, the mean temperature is fairly high, especially in summer, so that the climate induces quite a rapid weathering of saprolitic rock and favours soil development. A concern was raised about the possible consequences of pine plantation on soil fertility. In such environments, reforestation with conifers may actually imply the induction of soil podzolization (soil acidification and clay leaching), which affects soil fertility and may hamper the introduction of broadleaf species.

A monitoring study was conducted to assess soil modifications. Soil conditions at the time of plantation (1958-1960) were extremely poor: neither vegetation cover nor an organic layer was present. Soils belonged to Dystric Xerorthents and Xerochrepts (Soil Taxonomy). The species used in the reforestation project was *Pinus nigra* var. calabrica Schneider. Over the years, as a consequence of the very good performance of the plantations and lack of silvicultural treatments, thinning became urgent. The different thinning strategies were tested. The monitoring of soil conditions showed that the original poorly developed Entisols and Inceptisols transformed in well expressed Umbrisols. Soil erosion was reduced to a negligible extent and soil water holding capacity increased notably, up to five times compared to the original soils. As regards the effect of silvicultural treatment, the different thinning strategies resulted to have no negative influence on soil development and conservation, when the light and even the heavy and very heavy grades had been adopted. Actually, the thinning favoured an increase in the microbiological activity, in terms of biomass of the A1 horizon, probably due to the increased lightening in texture of the soil surface.

Figure (1): Soils reforested with Calabrian Pine developed a thick humus layer (Umbric horizon)

Keywords:
Reforestation, Calabrian Pine, soil organic carbon, soil erosion.

Authors:
Edoardo A.C. Costantini
Council for Agricultural Research and Economics,
Agrobiology and Pedology Research Centre
edoardo.costantini@crea.gov.it

Geographic location:
Latitude: 39.41 N
Longitude: 16.38 E

Municipality:
Spezzano della Sila

Locality:
Varco San Mauro

Elevation:
1247 m asl

Link to closest climate database:
Camigliatello silano

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The organic carbon density in Pachic Umbrisols formed under a Calabrian Pine afforestation in the Sila mountain (southern Apennines) reached 5.83 % in the first 10 cm, and 3.89 % in the first 60–80 cm. Considering that OC before tree plantation was less than 1 %, the OC accumulation in 27 years was more than 30 kg m–2.

Figure (2): Eroded soils cultivated with potatoes in the Sila mountains

Figure (3): Reforestation with Calabrian Pine in the Sila Mountain (Calabria). Foreground and background forest stands have been subjected to different thinning strategies: heavy and light thinning.

RESTORATION STRATEGIES

The reforestation with the autochthone Calabrian Pine was a win-win practice, since it resulted able to provide good timber production but also to improve remarkably soil ecosystem services like:

i. Water regulation
ii. Erosion control
iii. Carbon sequestration

without any loss of soil fertility. No negative effects of pine plantations, in terms of podsolization, were observed. The thinning at different intensities did not affect the positive effects of reforestation, therefore, even the highest degree of exploitation of the forest that was adopted was ecologically sustainable.

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- www.soilmaps.it

Area closure and reforestations with Acacia: protection and restoration of degraded arid lands in pre-Saharan Tunisia.

https://desertrestorationhub.com

This fact sheet discusses the protection and reforestation of degraded arid lands in central and southern Tunisia (Bled Talah region) with the tree species *Acacia tortilis* subsp. *raddiana*. *A. raddiana* is a native trees species which is able to tolerate extreme drought and to persist on the edge of the Sahara desert (Figure 1). Arid Tunisia, i.e. the central and southern part of Tunisia, is characterized by an extremely irregular spatiotemporal rainfall pattern, a limited amount of rain (350mm maximum per year), a limited number of days of rain (15 to 40 days a year) and a high average annual temperature (18 to 21 ° C).

Protection of the plantation area is established by means of a fence. The protection of the Bled Talah region was initiated in 1936 and from then on several actions were undertaken such as the construction of a tree nursery and the creation of Integral Protection Zones (IPZ) through complete fencing. The park consists of three IPZ or core areas which are completely fenced, two agricultural zones (AZ) and three buffer zones (BZ) (Figure 2).

The Bled Talah area was designated as a UNESCO Biosphere Reserve in 1977. Bou Hedma National Park was officially created by the Ministry of Forests in 1980 covering an area of approximately 16,000 ha. Acacia plantations are set up following a 3m x 3m grid using seedlings of *A. raddiana* (Figure 3). Seedlings are planted in the bottom of infiltration pits which are constructed for rainwater harvesting (Figure 4). The purpose of reforestation is the rehabilitation of degraded drylands and restoration of the original forest-steppe ecosystem in the Bled Talah region, which suffered for over a century from over exploitation of natural resources and intensification of agricultural activities.

Since the 1970s, several reforestation campaigns with *A. raddiana* in the Integral Protection Zones were conducted by the Ministry of Forests. Reforested areas are developing well but protection by guardians is needed to prevent local people from tree cutting. In the last decade, the management strategy of the park shifted more and more towards conservation without new reforestation programs as funds and means provided by the government are rather limited.

Figure (1): Bou Hedma National Park with a forest-steppe ecosystem

Fact Sheet Topic Area:
Tunisia

Keywords:
Area closure, reforestation.

Authors:
Maarten De Boever
Ghent University
Maarten.DeBoever@UGent.be

Geographic location:
Bou Hedma National Park

Climate Classification (Koppen):
Dry-summer subtropical climate (Cs)

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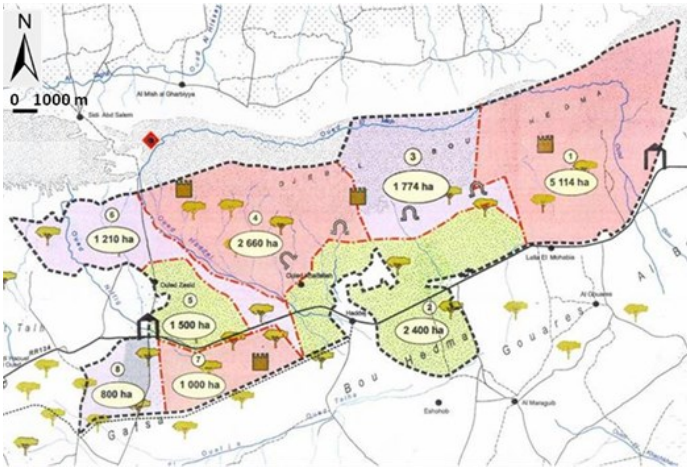

Figure (2): Map of Bou Hedma National Park with different management zones (legend for colours: IPZ: red; AZ: green; BZ: white)

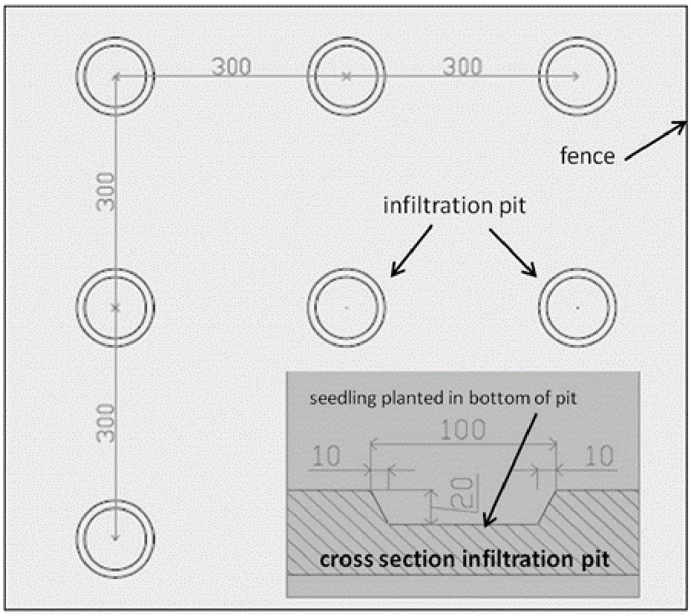

Figure (3): Technical drawing of plantation grid and infiltration pits

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RESTORATION STRATEGIES

- Area protection using a fence to prevent grazing by domestic animals and wild fauna from escaping;
- Rehabilitation and restoration by means of reforestation using seedlings of native species;
- Reforestation improves the livelihoods of local people directly through income generation from employment in the park and indirectly through increased fodder production; and
- Success of reforestation depends on the involvement of both government and local people.

Figure (4): Plantation with Acacia seedlings (Bou Hedma National Park)

Participative forest restoration in a semiarid Moroccan area

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Ecological restoration is a suitable tool to revert land degradation in semiarid areas (SER 2004). Although restoration projects are increasingly employing participative approaches (Egan et al. 2011), stakeholders are barely involved in all restoration phases particularly the implementation of the restoration interventions (Khater et al. 2012). We developed an integrated project for participative forest restoration (RESEP2B). The project has three main objectives: (i) *technical*: by exchange of knowledge and experiences on ecological restoration aims and techniques; (ii) *social*: through collaboration between the administration and local population; and (iii) *educational*: with a purpose of enhancing common awareness on risks of ecosystem degradation and opportunities provided by ecological restoration.

The restoration action was carried out in Béni Boufrah, a semiarid area of Northern Morocco (Figure 1) characterized by a high human pressure on natural resources and serious problems of soil erosion and flooding. The restoration process involved a wide range of stakeholders and included workshops and meetings, environmental education activities and field visits.

Forest restoration consisted of the plantation of Barbary Red Cedar (*Tetraclinis articulata* Vahl Masters) and lentiscus (*Pistacia lentiscus*) in a plot of 1 Ha. Planting was carried out in October 2014 and March 2015 by 90 persons including students, members of local cooperatives and NGOs, forest technicians, authorities' members, farmers, fishers and other stakeholders.

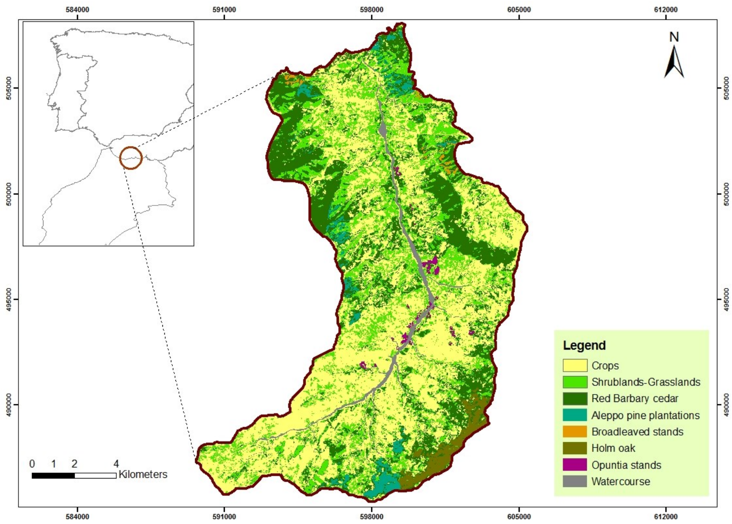

Figure (1): Location and main land uses of the Béni Boufrah catchment

Fact Sheet Topic Area:
Ecological restoration

Keywords:
Environmental management, collaboration, stakeholders.

Authors:
Mchich Derak
Direction Régionale des Eaux et Forêts et de la Lutte Contre la Désertification du Rif.
Avenue Mohamed V, BP 722, 93000,
Tétouan,
Morocco
Mchich78@gmail.com

Geographic location:
Morocco

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Figure (2): The restoration process as imagined by a student from the Béni Boufrah high school.

Most participants expressed their appreciation of the experience and stated that they had learnt new ideas on ecological restoration. They also showed their willingness to participate in future initiatives aimed at recovering local natural forests.

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Although the plot was not enclosed, it has remained free from vandalism or grazing. This allowed considerable rate of seedling survival and significant vegetation recover. Furthermore, some neighbours voluntarily decided to take on the surveillance of the plot and to monitor its evolution.

RESTORATION STRATEGIES

Forest restoration in Moroccan rural areas has a technical and social dimension and requires the consideration of a series of factors: consultative identification of the restoration targets, common identification of the most suitable restoration techniques, enhancement of stakeholder awareness of the restoration role through environmental education programs, active social participation in field operations, encouragement and acknowledgment of participants, economical subsidies for needy populations and a sufficient level of communication and information on the restoration event (Figure 3). By doing so, social acceptability and the success of restoration actions may be improved.

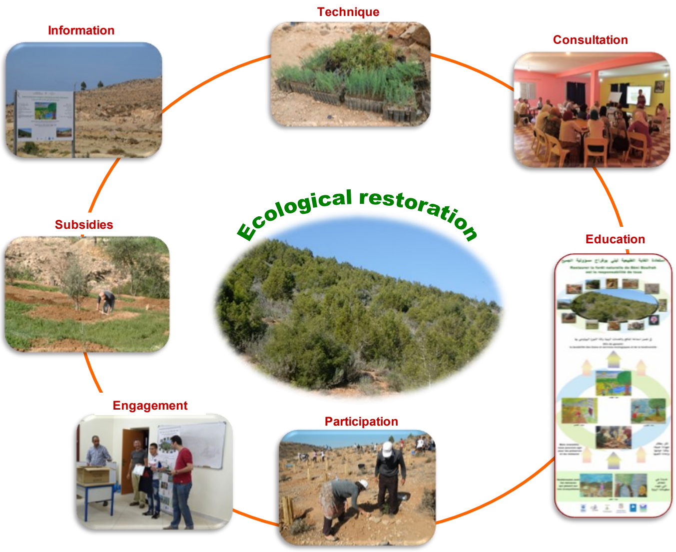

Figure (3): Integrative framework for participative restoration process

Climate change adaptation strategies in dryland forestry

Often, in afforestation and reforestation activities in drylands (or more explicitly in semi-arid regions), the mere reliance on precipitation leads to the desiccation of trees and failure of forestry projects. Therefore, extensive forestry lands in these climatic regions require the provision of planted vegetation with supplementary water. For example, artificial irrigation of new seedlings has been common during the very first (three to five) years in many of such projects. However, in the longer run, such irrigation schemes become rather expensive, considerably increasing the maintenance costs of these forest lands.

Therefore, in several dryland countries, forestry and restoration projects usually rely on runoff harvesting systems that greatly increase the water quantities available to trees. The principle of these systems relies on the concept of source-sink ecosystems, where trees are planted in so-called sink patches, where source areas contribute runoff water, along with associated dissolved and suspended resources. Several schemes of source-sink ecosystems have been developed and utilized for this purpose. Of these schemes, limans, micro-catchments, and contour bench terraces (Figure 1) are of particular importance. While planning each of these schemes, careful consideration should be paid to the rainfall/runoff rate and to the consequent water quantities expected to be accumulated in the sink patches. Rainfall/runoff rate depends on several physical and biotic factors, of which the precipitation regimes are predominant. Additional relevant physical factors are the hillslope's incline and roughness, as well as the soil's texture and rock fragment cover. Of the main relevant biotic factors are the existing vegetation's characteristics (e.g., shape and cover).

In addition to expected modifications in the rainfall/runoff rate, for example due to the establishment of herbaceous vegetation in the source areas which tends to increase surface roughness as well as to intercept some of the raindrops, special care should be paid to possible changes in precipitation regimes in the future. Namely, the foreseen scenarios of climatic changes with a high probability of lower precipitations in semi-arid regions should be taken into account while planning the source-sink ecosystem with the focus on allowing the source areas to contribute enough water to the sink patches.

Figure (1): Contour bench terrace system, comprised of lateral, low ridges formed across the hillslopes' contours to certain intervals. Photographed in the semi-arid northern Negev of Israel.

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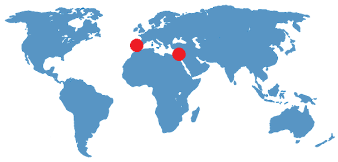

Fact Sheet Topic Area:
Forestry

Keywords:
Soil erosion control; source-sink geo -ecosystem; water runoff harvest

Authors:
Ilan Stavi
Dead Sea and Arava Science Center,
88820 Yotvata
Israel.
istavi@adssc.org

Alejandro Valdecantos
Centro de Estudios Ambientales del Mediterráneo (CEAM),
Parque Tecnológico Paterna,
46980 Valencia,
Spain.
a.valdecantos@ua.es

Geographic location:
Israel, Spain.

Climate classification (Koppen):
Semi-arid (BSh)

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In areas where runoff production is expected to be low, other eco-technologies might be implemented to the water harvesting system. In the LORAIN project in SE Spain it was observed that the efficiency of micro-catchments in capturing runoff was improved by installing a small waterproof fabric upslope of the planting hole (Figure 2). This positive effect was more pronounced in events of low intensity and volume which represent the most common ones during the summer season.

Another relevant case study is the Ambassador's Forest in the semi-arid northern Negev, Israel, where the scheme and intervals of contour bench terraces across the hillsides were planned according to prevailing precipitation regimes of the late 20th century. However, as the forest was eventually established in the early 21st century, with average precipitation rates 10% to 20% lower, the planted trees received significantly less runoff water than anticipated. As a consequence, irrigation of the new seedlings in this forest was necessary for up to seven years after planting to assure their survival. It is therefore suggested that planning future forestry projects should consider climatic forecasts for the next decades.

Figure (2): Small waterproof fabric upslope a planting hole. Photographed at the LORAIN project in SE Spain.

RESTORATION STRATEGIES

- While establishing forestry projects in degraded lands, attention should be paid to minimizing further disturbance of the ground surface.
- Similarly to other land-uses, in forestry, the soil organic carbon concentration and dynamics are among the most important indicators of geo-ecosystem functioning.
- In addition to the planted trees, careful monitoring of the entire ecosystem's net primary productivity should also be conducted.
- Special care should be paid to the herbaceous vegetation characteristics, including cover percentage, aboveground biomass, species richness and diversity.
- Planning of forestry schemes should adequately address anticipated climatic scenarios, with the corresponding ratio of source and sink areas.

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Adaptive management in restoration: benefits of pine thinning in mixed plantations

https://desertrestorationhub.com

CASE STUDY

Our aim was to test pine thinning as a management tool to decrease competition and improve functioning of a ‘restored’ ecosystem dominated by pines. The target site was a restored quarry in the SW Iberian Peninsula (mean annual rainfall 735 mm, mean annual temperature 15.6 °C, dry sub-humid climate). The vegetation consisted of mixed plantations of Aleppo pine and late-successional Mediterranean shrubs. Pine density before thinning varied between 0.21 and 0.87 pines/m^2 and their cover was >80%. A 35% pine thinning was performed, and its effects on the understory plant diversity and functional composition (based on functional traits) and on woody species growth, were evaluated for two years.

BACKGROUND

Aleppo pine (*Pinus halepensis* Mill.) has been extensively planted as a restoration tool in the Mediterranean Basin. Its drought and edaphic tolerance and alleged role as a nurse plant, which would later facilitate the transition into mixed forests, have been the reasons for the widespread use of this pine. However, in many cases, such plantations have resulted in extensive stable areas dominated by pines, with low diversity and resilience. Increasing efforts are being made to overcome these limitations.

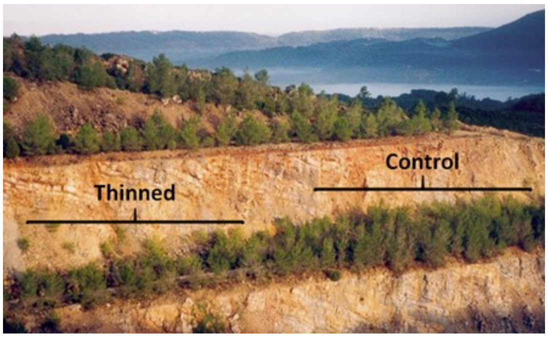

Figure (1): A 10-year old mixed plantation of Aleppo pine and late-successional Mediterranean shrubs at the target quarry site: general view (left); thinned and control plots (above).

Adaptive management allows for redirecting unexpected or undesired restoration trajectories through management practices, and pine thinning could be an interesting tool to foster the transition of pine dominated areas into more diverse, functional and resilient ecosystems. However, the effects of pine thinning in these ecosystems are poorly understood, are evaluated mainly through species diversity, and are frequently contradictory.

Fact Sheet Topic Area:
Adaptive management in restoration

Keywords:
Mediterranean, Aleppo pine

Authors:
Alice Nunes
amanunes@fc.ul.pt

Graça Oliveira
g.oliveira@fc.ul.pt

Teresa Mexia
tmmexia@fc.ul.pt

cE3c
Centre for Ecology, Evolution and Environmental Changes, Faculty of Sciences, University of Lisbon, Portugal

Geographic location:
Portugal

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While conventional diversity measures revealed no effects of pine thinning (unchanged species richness and diversity), the functional approach showed significant changes in functional composition, which may be critical to accelerate ecosystem recovery.

Thinning promoted key functional traits by increasing the density of species with N-fixing ability, semi-deciduous leaves and annual life cycle mostly with dispersal strategies not dependent on animals. In the medium term, these changes are expected to contribute to improve nutrient cycling, ecosystem resilience to drought and fire, and biotic fluxes. These are common early limitations to the ecosystems' recovery in highly degraded areas such as post-exploited quarries.

Thinning also favoured the basal growth of co-planted shrubs, indicating a competitive relief (e.g. for light and water). Consistent results were obtained for two stands with different pine densities and dimensions, thus reinforcing their possible generalization to different initial conditions.

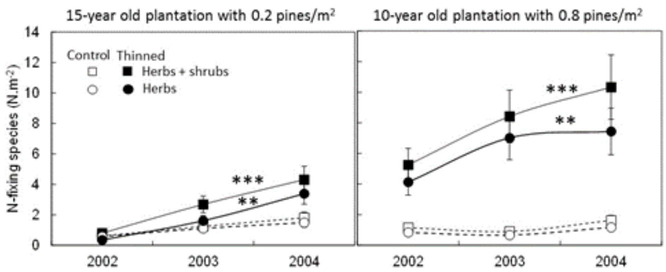

Figure (2): Changes in density of N-fixing plants over two years after pine thinning (performed in 2002) for control and thinned plots (mean ± SE, n=24).

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RESTORATION STRATEGIES

- Pine thinning was useful to alleviate competition and promote changes in functional structure of the plant community in mixed stands.
- In addition to the classical taxonomic approach to diversity, the study of functional traits of organisms may provide a better understanding of the effect of management practices on ecosystems (e.g. through species effects on ecosystems processes). Hence, it should be adopted in restoration monitoring, particularly when the aim is to rebuild functional and resilient ecosystems.
- Our findings may help researchers and managers to convert Aleppo pine dominated areas into more diverse and resilient ecosystems, particularly in Mediterranean areas.

ACKNOWLEDGEMENTS

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Sustainable utilization of saline soils: restoration with best management practices

Salinity is a serious threat to crop production globaly. Saline soils contain sufficient neutral soluble salts to adversely affect the growth of most crops. Salinization is the process by which water-soluble salts accumulate within the root zone of soil. Salts in soil result either through the weathering of parent minerals or from the inappropriate management of land and water resources. The salts have adverse effects on crop growth by increasing the osmotic pressure and thereby decreasing the availability of water for the plants. The moisture stress in saline soils results when plants are unable to uptake water across a high salt concentration gradient. Available water capacity of soils with increasing salt concentration tends to be reduced because more water is retained at the permanent wilting point compared to non-saline soils. The adverse effects of salinity are most pronounced in the arid regions of Turkey. Salt concentration increases as soil water contents decrease, and the adverse effects are further worsened with increasing drought intensity. Accurate data on the extent of saline soils in Turkey is not available despite the fact that the salinity problem is a real threat to soil health in the country. According to the reconnaissance soil survey reports, salinity and sodicity threaten 1.518.722 ha of the land resource. Saline soils mostly constitute a large part of the unproductive lands (74%). The unproductive/degraded lands in Turkey are 5.48% of the total cultivable land and 17% of the 8.5 million ha of economically irrigated land.

Figure (1) Below: Saline and abandoned soils in Central Anatolia of Turkey. Drought, overgrazing and salinity together results in the destruction of native vegetation. Only plants that are unpalatable to animals can survive.

Figure (2) Above: No-till system reduces evaporation and prevent salts rising up by capillary action in the saline soils

Extreme saline soils are mostly abandoned in Turkey. Salinity in such areas results in; decline of native vegetation and loss of habitat, increase soil and wind erosion and reduce native biodiversity. The salinity also cause undesirable changes in the populations dynamics of native plants, and increase weedy species densities and pressure for consolidation of agricultural properties.

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Fact Sheet Topic Area:
Restoration

Keywords:
Salinity, Best Management Practices, Boron Toxicity

Hikmet Gunal,
Gaziosmanpasa Univ.,
Faculty of Agric.,
Soil Science and Plant Nutrition Dept. Tokat, Turkey
hikmet.gunal@gop.edu.tr

Huseyin Onen,
Gaziosmanpasa Univ.,
Faculty of Agric. Plant Protection Dept. Tokat, Turkey
huseyin.onen@gop.edu.tr

Engin Ozgoz,
Gaziosmanpasa Univ.,
Faculty of Agric. Biostystem Eng. Dept. Tokat, Turkey
engin.ozgoz@gop.edu.tr

Geographic location:
Central Anatolia, Turkey

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The restoration of unproductive lands in arid regions is a real challenge for any of the developing countries, especially where populations are rapidly increasing. However, the recovery capability of lands in arid regions is lower than the lands of humid regions because of the harsher negative impacts of land degradation in arid regions.

Since water is a major limitation to agricultural production in arid regions, salt removal from the soil profile by extensive use of water appears to be impractical. Irrigation to maintain salts below the root zone in the soil profile can provide enough non-saline soil to grow crops. Effective irrigation practices in saline soils wash soluble salts beyond the rooting depth and can decrease electrical conductivity (EC). However, the patchy distribution of salts in the salt affected soils should be taken into consideration when reclaiming these types of soils.

The leaching requirement is important and should be calculated for each crop to prevent/avoid the adverse effects of high EC in irrigation water. Irrigation with high EC water requires extra amount of water for the leaching of salts from the root zone to prevent accumulation of salts that would limit the yield potential of crops. Rising water table due to the excessive irrigation and risk of waterlogging should be avoided since a capillary rise of the water table may bring soluble salts into the root zone. Thus, the application of more water is required for salinity control while less water is necessary to avoid a rise in the water table and a decrease in the quality of groundwater due to leaching of salts. Advancements in irrigation technologies such as sprinkler systems provide an opportunity to irrigate with adequate leaching fraction.

In arid climates, plant residues and mulch layers created by reduced tillage or no-till practices help soils to remain wetter thus allowing precipitation and irrigation to be more effective in leaching salts from the surface.

Figure (3): Consequences of conventional versus no till applications in saline soils of Central Anatolia, Turkey.

Adding manure and compost improves the water-holding capacity of soils.

Crop rotation and tillage systems promoting the adequate infiltration and permeability should be preferred. These are necessary to increase organic matter content for soil aggregation and avoiding compaction.

Deep tillage may bring up salts from deeper soil horizons to the surface, thus should be avoided.

Figure (4): Increased organic matter Improves aggregate stability of saline soils of Central Anatolia, Turkey.

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Soil skeleton and chemical properties in a Mediterranean climate: effects of rock fragmentation and/or deep tillage practices

In Puglia, southeastern Italy, before the establishment of vineyards and orchards, farmers often carry out deep tillage, by using hydraulic hammers and grinding machinery, in order to stimulate root penetration and vine establishment, thus leading to major changes in the soil structure (rocks fragmentation). The presence of abundant skeletal material is considered necessary to obtain high-quality table grapes and fruit, since rock fragments are chemically active and release nutrients. Moreover, roots can explore a larger space since the bottom rock has been ground. There are very few reports on the combined effects of deep tillage and rock fragmentation on changes in soil physical and chemical properties when altered by mechanical operations, in particular rock fragmentation. Therefore, the objective of this study was to evaluate the effects of rock fragmentation and/or deep tillage on soil skeletal material and selected soil chemical and physical properties. Soil samples were collected at 0–20 and 20–40 cm of depth from four plots (germplasm repositories of University of Bari) where different species are grown: wine and table grape cultivars; bitter and sweet almond cultivars; sweet cherry cultivars; and different cherry rootstocks grafted with the sweet cherry cultivar Lapins. These plots were subjected to rock fragmentation and/or deep tillage over a period of 20 years with different machinery types. After 20 years, the soils were studied in order to verify physical and chemical changes. In all the analyzed soils, the 0–20 cm layer contained more skeletal material than the 20–40 cm layer. On the basis of total soil skeletal material, the five soils were ranked in the following order: sweet cherry > cherry rootstocks > grape > almond > undisturbed. The results indicated that soils subjected to rock fragmentation and/or deep tillage presented a major change in chemical properties, leading to the progressive reduction in organic matter (OM) and nitrogen and to an increase in total and active calcium carbonate. In particular, rock fragmentation and/or deep tillage caused major modifications in soil physical properties, above all a great increase in the skeletal material content and changes in the skeletal size fractions compared to undisturbed soil (Figure 1).

Plot	Depth (cm)	Skeletal material (%)			
		Coarse	Medium	Fine	Total
U	0-20	41.8 c*	45.8 a	12.4 a	11.4 a
G		9.5 b	69.2 bc	21.3 b	45.2 c
S		4.0 a	73.7 c	22.3 b	76.0 c
A		13.3 b	64.5 b	22.2 b	31.2 b*
C		8.9 b	67.5 bc	23.6 b	64.0 d*
U	20-40	25.4 d	50.9 a	23.7 ab*	7.8 a
G		7.7 bc	70.9 bc	21.4 a	41.4 c
S		2.0 a	73.0 c	25.0 bc	72.7 c
A		9.5 c	68.5 b	22.0 a	18.7 b
C		5.5 b	67.6 b	26.9 c	55.2 d

Figure (1)

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Fact Sheet Topic Area:
Soil restoration

Keywords:
Mediterranean, chemical properties, soil skeleton, fragmentation, tillage.

Authors:
Dott. Giuseppe Ferrara
Department of Soil, Plant and Food Science,
Tree Fruit Unit, 5th floor
Campus, Via Amendola 165/A – 70126
Bari (Italy)
giuseppe.ferrara@uniba.it

Geographic location:
Bari, Puglia (Italy)

Climate classification (Koppen):
Csa

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Figure (1): Values of total skeletal material (%) and skeletal size fractions (%) in the five plots at two different sampling depths. Capital letters in the column "Plot" represents the different samples: "U"= undisturbed; "G"= grape; "S"= sweet cherry; "A"= almond; "C"= cherry rootstocks. Data represent mean values of three replications for each sample. For the same depth, different letters within columns indicate a significant difference among samples ($P \leq 0.05$) according to the Tukey's test. The symbol (*) indicates significant differences ($P \leq 0.05$) between sampling depths at the same plot (Student's test).

Most physical and chemical properties of the fine earth fraction are highly dependent on fragmentation and/or deep tillage. There is an obvious need to study the long-term sustainability of these soil management processes based on extensive cultivation. The quality of cultivated soils in the Mediterranean region is affected by various intensive agricultural practices including rock fragmentation and/or deep tillage. Soils in large vineyard and orchard areas of Puglia and Sicily (and in other Mediterranean countries) have been and still are affected by anthropogenic processes. The change of a natural soil into an anthropogenic one affects different aspects such as erodibility, biodiversity, landscape modifications, pollutants and agriculture sustainability. In particular, soil erosion and hydrology are negatively influenced by these cultural practices, with serious problems such as loss of fertility in cultivated soils, flooding and erosion.

Figure (2): Soil erosion after heavy rains.

RESTORATION STRATEGIES

Soil structure is a key property in influencing soil quality, and much environmental damage in intensive arable lands, such as erosion, desertification, pollution and compaction, are a consequence of soil structural degradation. Thus, it is easy to understand that fragmentation of rocks and/or deep tillage before plantation of a vineyard or an orchard can lead to serious changes in soil chemical and physical characteristics with negative consequences. It is dramatically clear that in areas subjected to such practices and sensitive to high soil losses by water erosion, reduction in organic matter OM and nitrogen content, and calcium carbonate enrichment, some strategies should be applied to prevent serious problems to both the environment and agriculture. In order to minimize such negative effects over time, the application of a living mulch (cover crops) will improve soil structure, allowing an increase in OM and other mineral elements not considering the better infiltration rate and the reduced erodibility. The presence of cover crops also has positive effects on the quality of fruit production. Another strategy to restore structure and fertility could be the application of various organic mulches (pruning residues, straw, etc.) and the use of mature compost.

Figure (3): Grinding of the skeletal fraction for the rock fragmentation

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Soil restoration on tailing dumps: evaluation of soil restoration

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FLOTATION TAILING DUMPS

Flotation tailing dumps have resulted from copper ore mining in mining industries. The tailing dumps studied for the fact sheet are located in south-western Romania, on the right bank of the river Danube, 2 km south of Moldova Nouă town (Figure 1). The soil on the tailing dumps is an anthropogenic protosoil with a dusty-sandy texture, which is easily blown away by strong winds in the area (Figure 2). Plantations were set up over 20 years ago along the slopes and plateaus of the two tailing dumps, "Boşneag" and "Danube Valley" to stabilize them against wind erosion.

SOIL STABILIZATION ON TAILING DUMPS USING FOREST SPECIES

The main forest species that were used on the Moldova Nouă flotation tailing dump, and that had the best results, were chosen by testing a large number of woody plants. The 3 main forest species chosen were; *Elaeagnus angustifolia* (oleaster), *Robinia pseudoacacia* (locust) and *Hippophae rhamnoides* (willow thorn). They have quickly created a local environment (with shadows, vegetal debris, slowing down winds, with retention on water, etc.) which is favourable for the installation of numerous vegetal species and soil restoration.

ACTUAL STATE OF LANDS IN TERMS OF SOIL RESTORATION

In all areas of the tailing dumps the soil is completely restored, and under the coverage of trees canopies the litter from trees continuously improves the soil. In future it is necessary to extend the forest areas on all affected surfaces in order to stabilize and restore the soils and establish planting.

Figure (1) Left: Tailing dumps from Moldova Noua (GoogleEarth)

Figure (2) Right: Unstabilized tailing dump (Photo: O. Merce, 2014)

Fact Sheet Topic Area:
Tailing dumps from Moldova Noua area, Romania.

Keywords:
Tailing dumps, soil restoration, Moldova Noua.

Authors:
Ilie-Cosmin Cântar
"Marin Drăcea" National Institute for Research and Development in Forestry

Ion Chisăliță
Banat University of Agricultural Science and Veterinary Medicine "King Michael I of Romania" from Timisoara
cantar.cosmin@yahoo.com

Geographic location:
South-Western Europe

Climate classification (Koppen):
c.f.b.x.

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An evaluation of soil restoration was made by studying the connections between stand characteristics (especially density) and the amount and content of litter (small deadwood, leaves and herbaceous plants, fruits and seeds, and decomposed material and sterile hummus whose origin is difficult to establish), see Figure 3.

The chart below shows that the litter amounts and components are similar across the sites. The forest plantation from the slopes of Bosneag tailing dump however showed double the quantities of small dead wood in the litter composition in comparison with the plateau of the same tailing dump. This is because the oleaster, being mostly shrub species, tends to age rapidly as the branches and bark level are constantly renewed through sprouting. Plantations from the plateau of Lunca Dunarii tailing dump contained the lowest amounts of deadwood among all variants studied, which may be due to the reduced percentage of oleaster. The large amount of decomposed and difficult to determine material with hummus is due to the low percentage of oleaster in the in undergrowth. True mixed forests - plantations from the slope of the Lunca Dunarii tailing dump - developed well horizontally, and especially vertically with high quantities of organic matter (small deadwood, leaves, herbaceous plants, fruits and seeds).

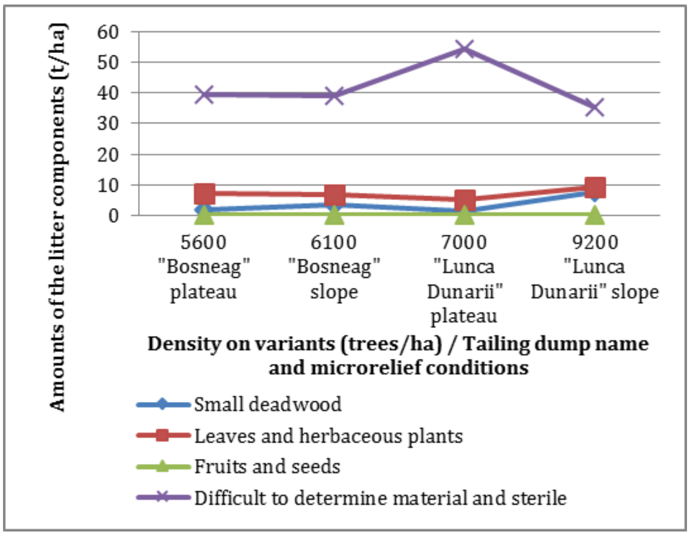

Figure (3): Amounts of the litter components per hectare on the four variants studied.

RESTORATION STRATEGIES

The issue described in the fact sheet can be used to improve restoration on tailing dumps by using the following steps established through experience:

- Tailing dump surfaces that are unstable because of aeolian erosion and not prone to spontaneous vegetation needs to be covered with topsoil collected from the dump site before the establishment of the construction;
- Planting the pioneer species of trees *Robinia pseudoacacia, Elaeagnus angustifolia, Syringa vulgaris, Cotinus coggygria* in our case, for c.f.b.x. climate classification) need to be done in high densities and using a large assortment of species;
- Evaluation of soil restoration can be done by soil analysis, and by analyzing the topsoil content in small deadwood, leaves and herbaceous plants, fruits and seeds and sterile hummus Where the last category has high values, the stand is not closed against wind erosion and density needs to be increased.

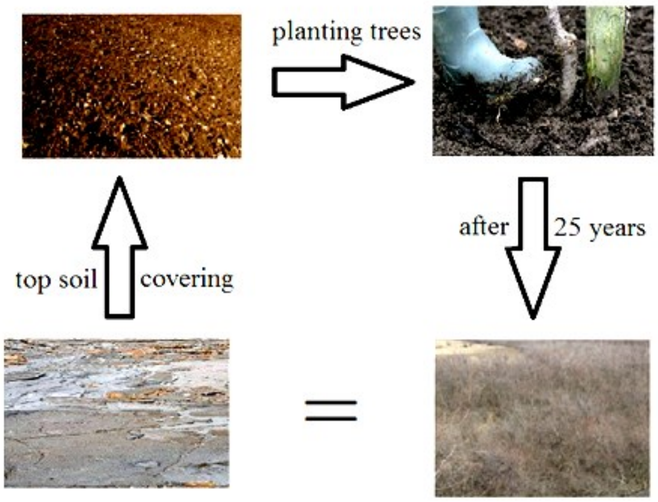

Figure (4): Cycle of ecological reconstruction on tailing dumps.

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Soil restoration and revegetation in semiarid calcareous quarries

Mining and quarrying generate landscapes without soils and vegetation, and their restoration is always mandatory once the mining activity has finished. In arid and semiarid areas, restoration from previously removed topsoils is not always possible and mining spoils are used as revegetation substrates despite their stoniness, chemical and biological deficiencies and very poor soil structure, which drives low infiltration rates, increases runoff and accelerates erosion.

Soil restoration in semiarid areas consists in creating structured substrate or topsoil with suitable physical, chemical and biological properties, as well as planting native species (e.g., *Macrochloa tenacissima*, *Anthyllis cytisoides*, *Anthyllis terniflora*, *Genista umbellata*). Suitable substrates have to be amended with low cost organic residues, composted or not (e.g., organic urban wastes, sewage sludge from used urban water), at doses around 1 kg m^{-2} which enhance soil recovery and hence plant establishment and growth (Luna et al., 2014). After planting and recurrently during first summer, irrigation is required (minimum 2 L/plant). Addition of mulches (5 cm thick), either mineral (e.g., gravel) or organic (e.g., pine wood chips) was also tested. Soil recovery six years after the plantation was assessed by measuring essential soil physical, chemical and biological properties: stability of aggregates, porosity, infiltration, enzyme activities and soil microorganisms. A net improvement with regards non-restored soils was observed (Figures 1-5) (Luna et al., 2014; Luna et al., 2015).

Figure (1)

Figure (2)

Figure (3)

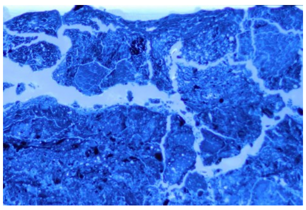

Figure (4)

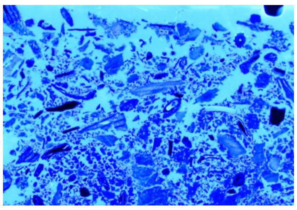

Figure (5)

Figure (1 & 2): Shows an active calcareous quarry with steep slopes quite prone to soil erosion once the topsoil has been removed.

Figure (3): Shows a restored hillslope where organic amendments, mulches and native species had been planted.

Figures (4) and (5): (5 x 3 cm) Show surface aggregation in control (left) and compost amended (right) plots.

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Fact Sheet Topic Area:
Addition of organic amendments and mulches improve mine soil properties and vegetation establishment in arid and semiarid environments.

Key-words:
Compost, sewage sludge, wood chips, gravel mulch, quarry restoration.

Authors:
Lourdes Luna,
Albert Solé-Benet,
EEZA-CSIC,
Almeria,
Spain.
lourdes@eeza.csic.es

Climate (Koppen):
Bsh – Bwh; aridity index = 0.75 (boundary arid – semiarid).

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Plants were evaluated through survival and growth (Table 1 and Figure 6). *Macrochloa tenacissima* shows the highest survival rates with any treatment and *Anthyllis terniflora* the lowest rates. Plant growth responds to organic amendments but not to mulches (wood ships can even have a negative effect).

Table (1): Survival percentage of the planting species. (Mt: *Macrochloa tenacissima*; At: *Anthyllis terniflora*; Ac: *Anthyllis cytisoides*)

	NO AMENDMENT			SEWAGE SLUDGE			COMPOST		
	NM	GM	WC	NM	GM	WC	NM	GM	WC
Mt	100.0	94.3	94.3	77.1	100.0	94.3	97.1	85.7	100.0
At	0.0	6.7	20.0	6.7	6.7	13.3	6.7	6.7	13.3
Ac	32.0	52.0	44.0	36.0	12.0	32.0	24.0	44.0	0.0

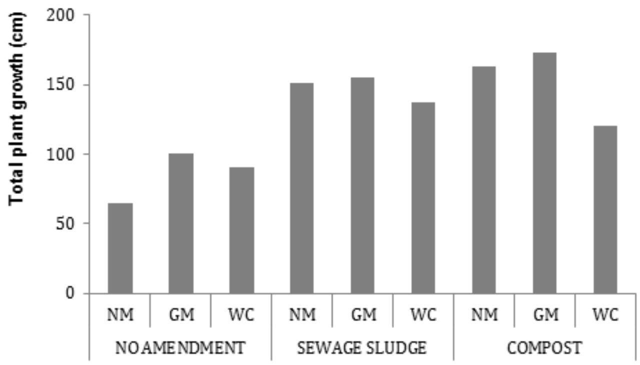

Figure (6): Total plant growth. (NM: No mulch; GM: Gravel mulch; WM: Wood chips mulch)

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RESTORATION STRATEGIES

- Soil properties are improved by sewage sludge at short term and by compost at medium term.
- Organic amendments clearly increase plant growth.
- Alpha grass (*Macrochloa tenacissima*) is the most suitable species for restoring this type of arid/semiarid environment. The green upper part of Figure (1) is a natural alpha grass community covering the surroundings.
- Despite preserving soil moisture, in general mulches have not been positive for both soils/substrates and plants probably due to the interception effect of light rains (Bainbridge, 2001), the most frequent in the area.

Figure (7): Alpha grass 6 years after plantation

Soil phytoremediation: concepts and news

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A common definition of **phytoremediation** is: 'The use of green plants to remove pollutants from the environment or to render them harmless' (Salt, Smith, and Raskin 1998). This is an emerging technology that has been used to ameliorate degraded environments rich in heavy metals or organic pollutants. The concept encompasses several techniques used to different objectives or conditions:

- **Phytoextraction**: the use of plants that accumulate pollutants in their harvestable parts to remove pollutants from the soil.
- **Phytoestabilization**: the use of plants that accumulate or adsorb pollutants to roots, or alter soil physico-chemical conditions leading to decreased pollutant bioavailability.
- **Phytodegradation**: degradation of organic pollutants by using plants and their associated microorganisms.

Phytoremediation for ameliorating heavy metal-contaminated sites arose from the interest in using **metallophytes** - plant species that colonize sites enriched in heavy metals. This ability ranges from mere metal-tolerant to hyperaccumulator. Metallophytes can be used as indicators of soil anomalies while hyperaccumulators can potentially be used to remove excess of heavy metals from a contaminated soil.

Hyperaccumulators: plants with the ability to uptake extraordinarily high amounts of a certain metal to their leaves or shoots. The concentrations of accumulation required for such denomination are variable among metals but identify extreme physiological behaviour: 100 µg/g for Cd, Se and Ti; 300 µg/g for Co, Cr and Cu; 1000 µg/g for Al, As, Ni and Pb; 3000 µg/g for Zn; and 10 000 µg/g for Mn.

Pros and cons:

Phytoremediation may be a sustainable solution for contaminated soils for ameliorating degraded soils, in comparison with the traditional solution of landfill. The main difficulty is the challenge of growing plants in a low quality substrate partially due to excess metals or saline conditions (Manousaki et al., 2011; Parraga-Aguado et al., 2014). In the case of drylands, there's the additional challenge of dry climatic conditions and low nutrient availability in the soil. Using soil amendments and native species are some hot points of current research to improve the applicability of phytoremediation.

Recent advances:

There's a body of research about using hyperacumulator species not only to soil remediation but also to metal exploitation in soils where traditional mining is not profitable - **phytomining** (van der Ent et al. 2015). Using halophyte species to restore metal contaminated and saline soils is another option being explored recently. **Halophyte species** are adapted to high salinity and may be more resistant to harsh conditions of drylands. (Manousaki and Kalogerakis 2011).

Fact Sheet Topic Area:
Soil remediation.

Keywords:
Phytoremediation, mine sites, degraded soil.

Authors:
Melanie Köbel,
Helena C Serrano
&
Cristina Branquinho

Centre for Ecology, Evolution and Environmental Changes,
Faculdade de Ciências,
Universidade de Lisboa.

mkobatista@fc.ul.pt
hcserrano@fc.ul.pt
cmbranquinho@fc.ul.pt

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RESTORATION STRATEGIES

By identifying the native species and their tolerance/ phytoaccumulation properties, better suited species can be chosen to improve the success of restoration programmes.

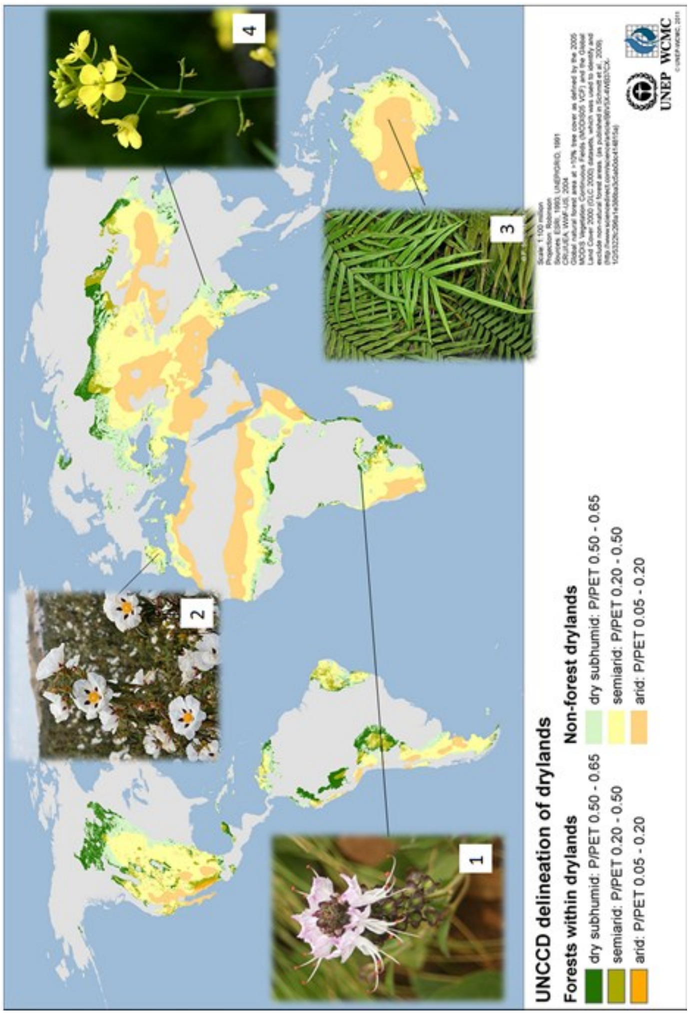

Figure (1): World map showing drylands and four examples of hyperaccumulator species. Arrows are only indicative of native area.

1. *Ocimum centraliafricanum*;
2. *Cistus ladanifer*;
3. *Pteris vittata*;
4. *Brassica juncea*.

Sources of the pictures:

Map - www.unccd.int;

1. www.ispotnature.org;
2. flora-on.pt;
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4. www.zimbabweflora.co.zw

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Soil organic carbon dynamics and soil physical quality: secondary effects of land-use and management

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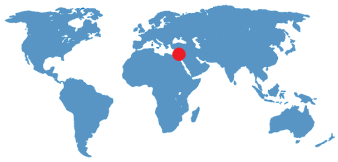
Soil organic carbon (SOC) is an important component of the global carbon cycle (Figure 1), and therefore has a crucial impact on the environment. The SOC concentration and composition is highly prone to land-use change. From an ecological point of view, the change of land-use from natural land into cropland, grazing land, or woodland decreases (or changes) the natural plant cover and composition. The resulting fewer (or modified) input sources of organic material decreases the SOC pool and modifies its composition. In drylands, where physical conditions are relatively harsh and vegetation cover is comparatively scarce, the input of SOC is rather small.

The SOC pool is crucial as it impacts the physical quality of soil. This is because the SOC determines the soil aggregation processes and the soil structure formation. Specifically, the SOC affects the formation and stability of macro-aggregates (aggregates larger than 250 µm) that considerably affect the physical quality of soil. Generally, the greater the content and the more stabilized the macro- aggregates, the lower the soil bulk density. Also, the greater the content and the more stabilized the macro aggregates, the larger the: (1) soil resistance to shear; (2) the soil aeration; (3) the infiltration capacity of water; (4) the hydraulic conductivity of soil; and (5) the water retention capacity of soil.

In croplands, in addition to the effects of land-use conversion (the clearing of natural plants), the elimination of crops and crop residues together with the tillage action considerably modifies the soil structure, and therefore, also affects SOC stocks. First, the elimination of crop residues, either during or after the crop is harvested for hay-feeding or for stubble-grazing for example, exposes the ground surface, and therefore increases the risk of raindrop splash impact and the formation of sealed mechanical crusts. Secondly, tillage action causes the breakdown of macro-aggregates, resulting in lower hydraulic conductivity of soil, and the diminished stability of soil against erosional processes. At the same time, the deformation of the soil structure and the breakdown of macro-aggregates increase the oxidation rates of SOC, which is emitted as carbon-dioxide into the atmosphere.

Figure (1): No-till corn agro-ecosystem. Notice the thick layer of corn residue covering the ground surface. Photographed in Ohio, the United States.



Fact Sheet Topic Area:
Soil quality and functioning

Keywords:
Agro-ecosystem; land degradation and desertification; soil management

Authors:
Ilan Stavi
Dead Sea and Arava Science Center, 88820 Yotvata,
Israel.
istavi@adssc.org

Geographic location:
Israel

Climate classification (Koppen):
Semi-arid (BSh)

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Overall, the modifications in soil characteristics in rangelands and woodlands are smaller than those of croplands. Nevertheless, unmanaged stocking rates or unsustainable forestry practices could lead to considerable modifications in the soil structure and SOC pools, resulting in land degradation and accelerated soil erosion.

The key issue is thus the need for judicious practices in each of these land-uses, aimed at sustaining the function of these agro-ecosystems whilst supporting a range of related ecosystem services such as carbon sequestration, soil erosion control, and others (Figure 2). When considering the restoration of degraded drylands, special focus should be paid to replenish the SOC pool, which is expected to facilitate the recovery of soil and vegetation. Considering potentially self-restoring capacity, SOC replenishment could be conducted passively, i.e., by halting any use of the degraded agro-ecosystem for a certain period of time, until soil functions become accomplished to a similar state as before degradation processes took place. At the same time, in an event of heavily degraded agro-ecosystems or when physical conditions are extremely harsh, active restoration measures should be taken. Specific measures should be determined in accordance with land-use and prevailing physical conditions, and can include, among other: (i) reduced tillage or no-till; (ii) retaining of crop residue on the ground surface (Figure 1); (iii) soil amending with organic materials such as livestock manure; (iv) cover cropping (Figure 2); (v) increasing surface roughness through modifying the landform's micro- or meso-topography; (vi) planting perennials and deep-rooted vegetation, etc.

RESTORATION STRATEGIES

- In addition to concentration of total organic carbon, also its contents of functional fractions is important, as these fractions determine the sequestration capacity on the one hand, and the soil food web activity on the other hand.
- Among the functional fractions, the readily decomposable (labile or soluble) fraction is of particular importance in terms of soil microbial biomass and activity.
- Assessing the sequestration capacity vs. biological availability of soil organic carbon pool can be determined by several indices which focus on the total organic carbon and the labile fraction
- The soil stratification ratio – the layering of soil organic carbon across the soil profile – also uses as an indicator of soil quality

Corn planting on Hairy vetch cover crop.
(Photographed in Ohio, the United States.)

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Soil erosion and conservation in Romania: limiting factors of productive capacity of agricultural soils

Romania's land area is 23,839,100 ha; 0.16% of the world's surface. Worldwide, Romania is ranked #83 for areal extent, and it consitutes 4.81% of the Europe's surface (ranked #12). Romania has 14,856,800 ha of agricultural land which represents 62.3% of the total surface; 0.65 ha per capita. At the national level, 72.5% and 27.5% of soils in Romania can be broadly classed as very poor and good/very good, respectively, based on intrinsic soil characteristics, climate, topography, and ground water.

Romania has a specific geographical situation, namely (Teaci, 1995):

i. Romanian territory is located in the southeast portion of Central Europe at the cross roads of several high and low pressure centers that form regularly at the borders. The influence of these air masses is altered by the presence in the central regions of the Carpathian mountain chain resulting in a diverse climate with average annual rain fall amounts between 350 to 1,400 mm and average annual temperatures between 2 and 11.5°C.

ii. At the national level, almost all soils in the international classification system are present in Romania; each soil type having specific properties and characteristics.

iii. On approximately 12.5 million ha (7.5 million ha arable), soil fertility is adversely affected by erosion, acidity, low humus content, extreme texture (clay, sand), excessive moisture, chemical pollution, etc. (Figure 1)

Restrictive factors of agricultural soils productive capacity in Romania are:

Steppe zone: The limiting climatic factors, that require differentiation towards soil management use, include: long periods of drought, high temperatures, high frequency winds (wind erosion in areas of sand), low relative air humidity, and harsh frosts during winter. Negative phenomena most commonly encountered in this area are salinization, excess water, temporary deficit of rainfall, and poor to very poor supply of humus, phosphorus, and potassium.

Forest-steppe zone: Limiting factors of the area include: drought, erosion, temporary excessive moisture, soil compaction, slope, exposition, groundwater depth, occurrence of white frost period, and early/late frosts; climate is also highly variable from one sub-area to another. Irrigation and water conservation measures in the soil have a very important role in the forest steppe.

Forest area: Limiting factors of the area include mixed relief, reduced field surface, excess surface moisture, lower soil fertility compared to previously studied areas, soil erosion, landslides, primary and secondary soil compaction, soil acidity, pronounced diverse spectrum of weeds and vegetative development opportunities compared to previous areas.

In hilly and mountainous regions, the main limiting factor of crop production is the very diverse topography with slopes in all shapes and sizes.

https://desertrestorationhub.com

Fact Sheet Topic Area:
Land management and soil restoration.

Keywords:
Land Use, Limiting Factors, Differentiated Soil Management.

Authors:
Rusu Teodor
University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca.
trusu@usamvcluj.ro

Geographic location:
Romania

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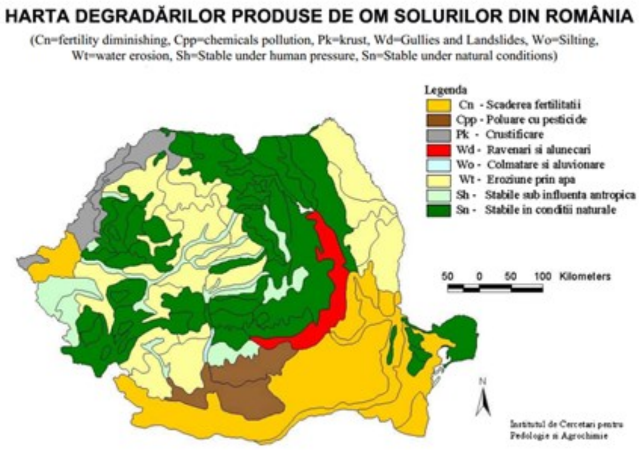

Figure (1): Map of soil degradation produced by humans in Romania (Research Institute for Soil Science and Agricultural Chemistry, 2013)

On the ***sloping lands*** of Romania, it is estimated that each year about 125 million tons of soil is eroding (Neamtu, 1996), of which, around 35% is transported into the river system. Due to this, about 33% of the agricultural area is affected by slope erosion processes and landslides. The land uses which are most affected are orchards (65.6%), grass lands (58.3%) and arable lands (20%).

Soils on slopes present specific features: edaphic useful volume is reduced (regosoils, lithosoils, rendzinas) on the southern slopes, reduced structural stability (podzolic and podzolite soils for north and west slopes), and an excess of moisture on the northern slopes (black soils clinohidromorfe). The diversity of soils and their characteristics is complemented by the super position of several processes of degradation such as surface and deep erosion, landslides, excessive moisture, compaction, etc.

In recent years the national legislation made significant steps on monitoring and conservation of soil, including the Government Emergency Ordinance 38/2002 and the Order of the Ministry of Agriculture and Rural Development regarding the Program 278/2011 of achieving the *National System for Monitoring Soil - Land for Agriculture and Soil - Forestry and Forest Vegetation*. Given the serious problems with sloping lands, an essential change is expected from the effects of the Government Emergency Ordinance 34/2013 on the organization, administration and operation of permanent grasslands. Also here one may include the cross compliance rules, including the 13 GAEC (Good Agriculture and Environment Conditions), the 15 Minimum requirements for fertilizer and plant protection products and the 15 SMR (Statutory Management Requirements).

RESTORATION STRATEGIES

Harnessing the sustainable arable lands on slopes and their conservation implies that the organization of the territory and differentiated soil management will achieve the following:

i. Cultivation of an assortment of plants suitable for the purposes and conditions offered by the slopes and design of crop rotations with an anti-erosion role;
ii. Use of anti-erosion culture systems on slopes, level curve direction in strips, grassed strips and arable terraces;
iii. Application of differentiated soil management elements, respecting regional planning projects;
iv. Execution of soil tillage on the general direction of level curves;
v. Adaptation of agro-components such as: fertilization, integrated control of weeds (especially herbicide application), and the maintenance, mechanization, and harvesting of the specific land.

Steppe, Forest-Steppe and Forest Area in Romania

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Soil conservation and land planning: restoration of terraced landscapes in Sicily

https://desertrestorationhub.com

Fact Sheet Topic Area:
Soil conservation and land planning

Keywords:
Soil Erosion Risk, Rural Development Programme, Risk Area Identification, Sustainable Land Management, Policy-makers, Stakeholders.

Authors:
Edoardo Costantini CREA-ABP
edoardo.costantini@entecra.it

Maria Fantappiè

Geographic location:
eastern Sicily

In Europe not all local regional authorities (LRAs) have the capacity and tools in order to understand the magnitude of the problem of soil degradation. The EU directives are adopted by the legislation of every Member State, and translated into national and regional laws and regulations which define the scope of the Directive's application. Usually policies are defined in accordance with the administrative boundaries, mainly at the municipality level. A delimitation of the area of application based on the geographical and environmental characteristics of the territory is generally absent. Consequently, financial resources are distributed to a wide territory, not only to the targeted area. This fact causes a waste of resources and energy, and the risk of failing to achieve the environmental protection objectives of the measures. Sometimes the available subsidies are so limited, since they are distributed among many potential users, or the farm costs involved in the adoption of the measure are so underestimated, that stakeholders do not even apply for them. In the framework of the LIFE08ENVIT000428 Project 'Monitoring for soil protection' SOILPRO (http://www.soilpro.eu; accessed 05/04/15), a new perspective in confronting environmental issues with local and regional administrations (LRAs) has been introduced, which involves the support of research institutions. Instead of preparing studies, the research institutions provided support office services, while LRAs discover new ways for land planning and administration. In fact, LRAs can be made aware of past, present and future situations by incorporating into their daily routine, methods and tools able to monitor the state-of-the-art findings on soil degradation. These tools and methods are mainly accessible to scientific organizations. Today, web technology allows these tools to be widely used at low cost by other institutions. Web applications may be easily replicated, minimizing budget and cost limitations. Modules can be easily added for extending functionality.

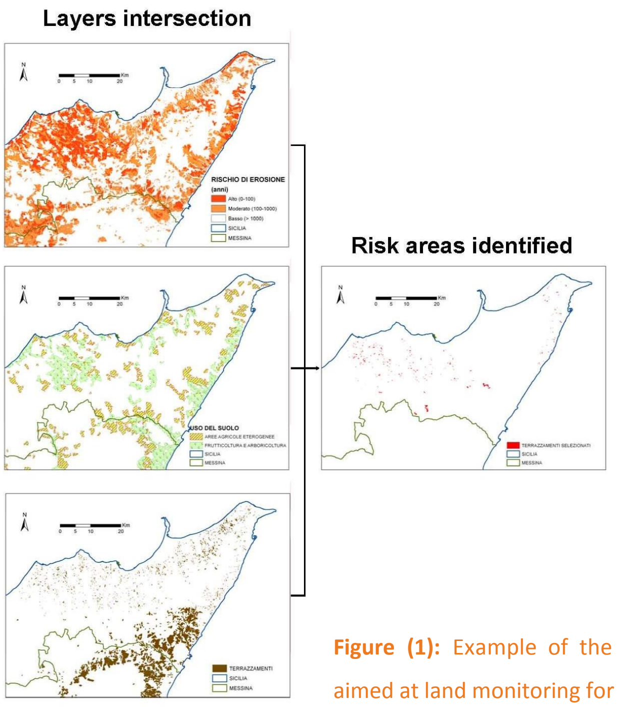

Figure (1): Example of the results obtained with a GIS software aimed at land monitoring for soil protection (http://www.soilpro.eu).

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Two new actions were proposed and approved in Plan 2 (environmental and countryside improvement) of the Rural Development Plan of Sicily, the Action 214/1G (contrasting hydro-geological instability and recovery of traditional agricultural landscapes), combined with 216A2 (unproductive investments in agricultural farms). In these measures in order to obtain subsidies, farmers must comply over a period of five years with the following obligations:

1. Maintenance and recovery of terraces and ditches to enhance water infiltration and reduce runoff and soil erosion.
2. Plantation and pruning of local tree species and Mediterranean maquis, not only of agricultural interest, but to reduce fire risk.
3. Maintenance of cover crops in orchards, without the use of herbicides.
4. Prohibition of burning crop residues, to encourage chopping and the burial of crop residues.

The second obligation was particularly focused on hazelnut cultivation, with the purpose to strongly reduce the propagation of fires and consequently decrease the phenomena of erosion and desertification. This involved improvement of the coppices, and the elimination of brambles and dead plants. The activity also foresaw new plantations in abandoned terraces due to fires, with eradication of dead plants and mixed use of non-productive, local autochthonous plants, especially endangered species and varieties.

The measure was welcomed by farmers, as testified by the large number of applications. Eventually, 1,650 of the 1,800 presented applications were accepted by the regional authorities, for about 10,000 ha of beneficiary.

RESTORATION STRATEGIES

A database with all necessary data to assess the soil degradation processes, in particular, soil organic matter decline, soil erosion, soil compaction, salinization, landslides, and acidification was developed. The methodology introduced new innovative spatial tools for risk area identification (RAI). The response and auxiliary data were inserted in a GIS Project to apply the spatial statistical models and obtain the maps of intensity of the degradation processes. These maps were intersected with administrative and land use maps in order to identify the administrative and land use boundaries of the areas most affected by the soil threats. Thanks to the RAI methodology, participating staff of Regional Authorities were able to identify soil degradation risk areas. Finally, with the assistance of scientific institutions, they developed management and action plans for the identified high risk areas. The delimitation of eligible areas where to apply interventions was specifically calibrated and finalized for the risk areas derived from the specific carto-graphy.

Figure (2): Example of restored terraces.

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Recycle an invasive species: utilization of the invasive *Acacia longifolia* as a soil amendment

https://desertrestorationhub.com

Invasive plant species are a threat to many ecosystems worldwide and thus a major driver of global change. Among the invasive plants, Australian Acacia spp. are especially aggressive and change ecosystems fundamentally by altering nutrient cycles due to their capacity to fix nitrogen and quickly create large amounts of biomass. In some parts of the world (eg. South Africa) this has already lead to a decrease in freshwater streams and the degradation of local ecosystems. In southern Europe, the shrub -like tree *Acacia longifolia* is invasive in coastal and Mediterranean ecosystems (Figure1, left) leading to complete ecosystem degradation by outcompeting native plant species and ultimately creating a mono-specific plant cover. In this process, large amounts of above and belowground biomass are produced, which alter edaphic conditions and lead to long-term establishment of the population. However, even though eradication measures for these species are of fundamental importance to drive back invasive species spread, local stakeholders often see little incentive to decrease invasive species cover as plant eradication is time and energy consuming with no financial benefits for the stakeholders involved. At the same time, there is a serious problem of decreasing soil fertility levels due to the loss of soil organic matter (SOM) worldwide. In Europe, especially the Mediterranean basin is very poor in SOM and thus soil organic carbon (Figure 1, right) levels. Agricultural soils with low SOM levels exhibit low nutrient and water retention capacity, which can lead to eutrophication of nearby limnic and coastal ecosystems. Nutrient leaching also affects native vegetation, altering ecosystem structure. Additionally, leached nutrients might be taken up more rapidly by invasive species, thus exacerbating the problem.

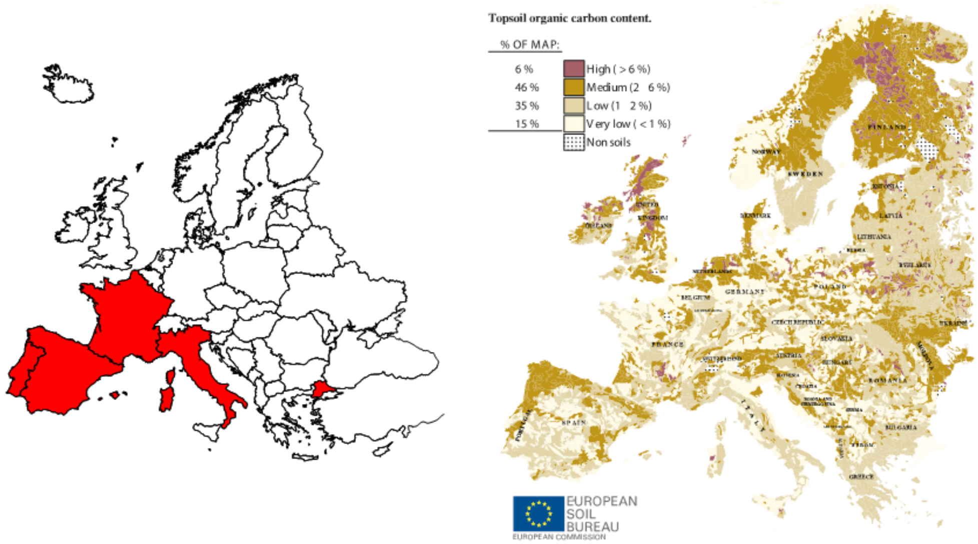

Figure (1): Left: *A. longifolia* distribution in Europe, source: DAISIE (see below). **Right:** Topsoil organic carbon content in Europe, source: ESDAC (see below)

Fact Sheet Topic Area:
Portugal

Keywords:
Acacia, Invasion, Soil Amendment

Authors:
Florian Ulm
Mariana Ramos
Cristina Cruz
Cristina Máguas

University of Lisbon
ulm.florian@gmail.com

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Here we would like to propose a framework to create a win-win situation that could help to resolve the described problems simultaneously (Figure 2, top). It was recently shown that it is possible to create green waste compost (GWC) of good quality from *A. longifolia* biomass (Brito et al. 2013). The local production and utilization of this GWC as a soil amendment could be a useful tool to alleviate the pressure on adjacent native vegetation while increasing soil quality in arable land. In terms of restoration efforts, constant removal of invasive aboveground biomass will give a competitive advantage to native species, which in turn might help in their medium-term reestablishment. Additionally, if it can be shown that this GWC is helping to decrease nutrient and water leaching of the agricultural soil, its production might be a crucial incentive for local stakeholders to eradicate Acacia spp. to obtain their biomass. While this can be of economical benefit as less fertilizer is leached and thus input can be decreased, this also has beneficial effects on the surrounding native ecosystems by decreasing eutrophication.

Plant invasion and soil degradation are both multifaceted problems that need integrative approaches, which connect scientific research and stakeholder demands. The local production of Acacia GWC and its direct use in agriculture might have big potential as a novel way to cope with several environmental pressures and recover degraded soil at the same time.

RESTORATION STRATEGIES

The implementation of the framework described here could potentially help restoration by:

- Increasing soil organic matter levels;
- Increased soil water and nutrient holding capacity;
- Decreasing invasive species cover; and
- Decreasing pressure on adjacent native species

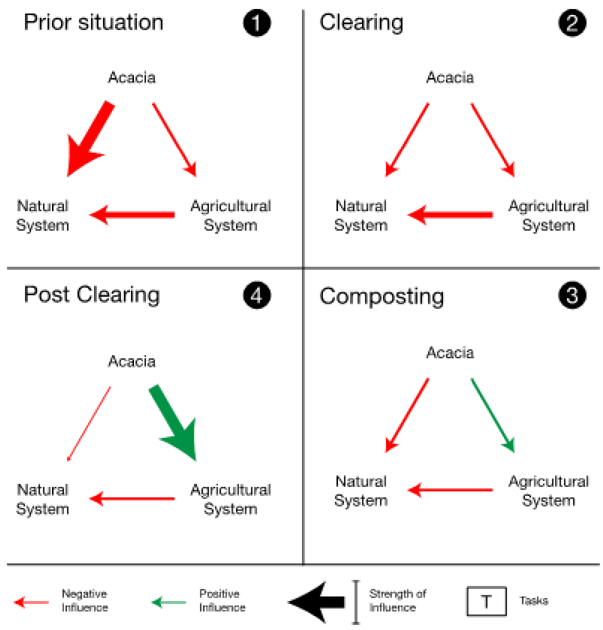

Figure (2): Top: Schematic of possible benefits of using invasive Acacia spp. as soil amendment in agricultural systems. This could lead to a decrease in Acacia spp. abundance and lower eutrophication by fertilizer leaching.

Bottom: *A. longifolia* in flower, photo taken in February 2016 at an invaded site in Odemira, south Portugal.

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Monitoring the evolution of soil moisture in the root zone system of *Argania spinosa* in a semi arid climate

https://desertrestorationhub.com

Argania spinosa is an endemic Moroccan tree designated as an UNESCO biosphere reserve since 1998. This species plays essential local ecological and economical roles. The woodlands, though open, protect the soil against erosion and desertification, they shade different types of crops, and they help maintain soil fertility in an arid climate, while a valuable oil, much appreciated in cosmetics, is obtained from the seeds (Charrouf & Guillaume 2002). Adult trees can survive in fairly dry climates where annual rainfall ranges from 100 mm to 300 mm. Further south, rainfall decreases to less than 100 mm, but in these regions of the Saharan climate, the tree can still grow following temporary water courses (M'Hirit *et al.* 1998). As a consequence of human pressures, the argan woodlands are steadily decreasing in terms of density and wooded area extension. This trend has been enhanced by several consecutive unusually dry years (Charrouf and Guillaume, 1999).

The argan woodlands in Southwestern Morocco underwent a dramatic 40% density decline between 1970 and 2007 (De Waroux & Lambin, 2012). Increased drought has been demonstrated to enhance tree mortality in forests. The Argania ecosystem is particularly suitable to study the effect of water scarcity and the coupling between hydrological and biological processes of different subsurface layers.

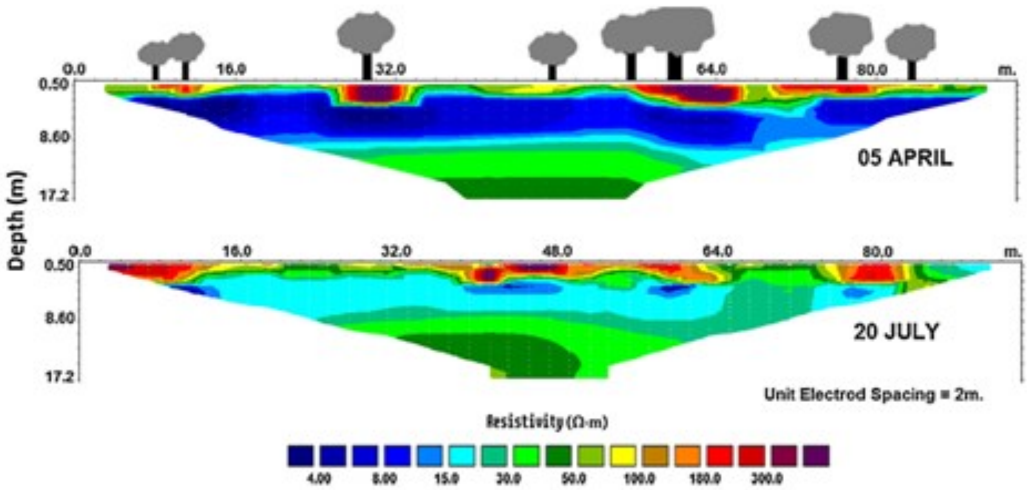

Figure (1): 2D electrical resistivity imaging profiles derived from the RES2DINV inversions from early spring (April) till midsummer (July). Soil moisture is determined by resistivity values from 2 to 18 Ωm. (Ainlhout *et al.* 2015)

Fact Sheet Topic Area:
Admine forest in Southwestern Morocco, Morocco

Keywords:
Argania spinosa, soil moisture, electrical resistivity imaging.

Authors:
Fatima Zohra Ainlhout
Department of Technical Sciences,
Polydisciplinary Faculty of Taroudant,
Ibn Zohr University,
Morocco.

Said Boutaleb
Department of Geology,
Faculty of Science,
Ibn Zohr University,
Morocco.

Mari Cruz Diaz Barradas,
Juan Jauregui & Maria Zunzunegui
Department of Plant Biology and Ecology,
Sevilla University,
Spain.
fzainlhout@gmail.com

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We investigated the temporal variation in root-zone moisture after a rain event, using a geophysical technique called Electrical Resistivity Imaging. The study was conducted in an intensively utilized forest traditionally managed for agriculture and livestock. The Admine forest, is located in the suburbs of Agadir city. The climate is semiarid and temperate due to marine influences. The results reveal that the rain water remained mainly below the root structures (Figure 1). The trees extract water from below the soil zone, probably from the weathered ground layers to depths of 3-6 m. During the first month of the experiment, the surface of the soil moisture, decreased by more than 70%. This descent was more marked outside Argan roots where, except for early April, soil resistivity values were out of the range of moist soil at the same depths. In the Admine forest, which is almost depleted of vegetation, the top soil is strongly affected by evaporation because of climatic conditions. This suggests the role of roots in regulating the redistribution of soil moisture. Argan trees occur in a wide array of soils, except in aeolien sand. Our results suggest that this absence can be explained by the difficulty to maintain moisture in such soil types after a rain episode.

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RESTORATION STRATEGIES

- The Electrical resistivity imaging is a useful tool providing decisive information in the study of soil moisture content, redistribution processes and water availability to the plant. This information improves our knowledge of soil–vegetation interactions, and may be used to improve vegetation development, management of water sources and productivity modeling.
- Reforestation efforts in the Argan forest are confronted with difficulties in the field. The reintroduction of the species in regions having suffered a regression. New areas should include an irrigation program, which is necessary for the seedlings' survival in summer during the first five years after reforestation.

Figure (2): Admine Forest (Morocco).

Learning from failures: land restoration without accurate soil knowledge

Land evaluation results from an integrated set of environmental surveys that allows the classifyication of different soilscapes according to their degree of aptitude for defined agricultural or non-agricultural uses. The most well-known system that meets such requirements is the Land Suitability Classification System (FAO, 1981). Land suitability evaluation is the process of assessing the suitability of land for specific kinds of use. These include major kinds of uses, such as rainfed agriculture, forestry, land utilization or types described in more detail, for example rainfed arable farming based on sorghum, irrigated rice production or the plantation of Douglas fir. Suitability is assessed, classified and presented separately for each kind of use. It is important that to be effective, such system must be applied before any land restoration project, and not afterwards. In fact, in this latter case the only possible objective is to highlight significant inconsistencies of the environmental choices! This is what occured in Mustigarufi, a study area located in the central part of Sicily (Italy). This area is mainly characterized by gypsiferous outcrops, largely irregular morphology, climate that alternates hot and dry summers with relatively mild and rainy winters. In the Mustigarufi area, during the 1960's an afforestation land restoration project of more than 3,200 hectares with *Eucalyptus camaldulensis* was established. The main aim was to initiate an economic enterprise: i. e. to obtain timber to produce cellulose for a paper factory, thus developing new job opportunities. Unfortunately the enterprise was a complete failure: 30 years after planting, timber production was completely unsatisfactory. Therefore: no timber, no cellulose, no paper factory, no job opportunities! The Soil Science Unit of the University of Palermo (IT), was consulted to explore the reason for the failure and planned a detailed soil survey for the application of the land suitability system for the *Eucaliptus camaldulensis*, the species chosen for the afforestation.

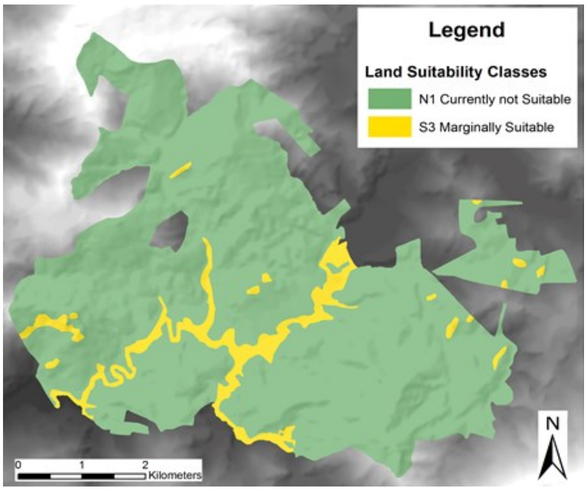

Figure (1): Land Suitability map of the Mustigarufi area (land use: Eucaliptus camaldulensis)

https://desertrestorationhub.com

Fact Sheet Topic Area:

Land restoration without accurate soil knowledge

Keywords:
Soil survey; land management; land evaluation systems.

Authors:
Carmelo Dazzi
Carmelo.dazzi@unipa.it

Giuseppe Lo Papa
Department of Agricultural and Forest Sciences
University of Palermo,
Italy

Geographic location:
Sicily, Italy

Climate classification (Koppen):
Csa

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The detailed soil survey, carried out after 5 years on the site at a scale of 1:10.000, highlighted some significant elements of great importance for the application of the land suitability system. Soils, in particular, were strongly influenced by the features of parent material, climate and morphology. A common feature of these soils is the presence, in more or less high quantities, of clay, carbonates and soluble salts. The salts are mainly calcium and magnesium sulfates and chloride.

Data of soil properties and environmental features characterizing the Mustigarufi area have been used for the Land Suitability Classification System for *Eucalyptus camaldulensis.*

Results demonstrated that 88% of the 3,200 hectares are not suitable (N1) for *Eucalyptus camaldulesis* growth. The main soil limitations for this species in Mustigarufi are: soil texture (too clayey), soil depth (shallow) and the excess of active carbonates and soluble salts (high salinity). Furthermore, almost 7% of the soilscape has been evaluated as being marginally suitable (S3), due to soil texture that shows poor suitablability for growing *Eucalyptus camaldulensis*. The remaining 5% of the landscape is occupied by infrastructure.

Figure (2): Benchmark soil profiles of the study area. These soils are not suitable for the *Eucalyptus camaldulensis* due to the presence of clayey and saline horizons; moreover climate features and land morphology are also not suitable.

RESTORATION STRATEGIES

- The fundamental principle of land restoration states that any project of land planning and management needs accurate and complete knowledge of the soilscape features.
- Soil knowledge provides basic information for planning new land development strategies and land use changes.
- The information achieved in soil surveys may be used to predict or estimate the potentials and limitations of soils for many specific uses. In most projects, soil studies should form an indispensable part of the basic planning process, otherwise very costly mistakes can be made. Soil survey and land evaluation expenses are perceived costly, and consequently land planners frequently skimp or even omit such works in preliminary and final plans.
- The use of information achieved by soil surveys avoids failure in land management. Ignoring the importance of soil limitations when planning land use changes can lead to project failure

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Evaluation of soil conservation measures in the Rural Development Programmes of the Region of Murcia (Spain)

In Spain, water erosion has been worsened due to the intense agricultural mechanization in the last decades. This situation is made worse by the use of soils of very low agronomic quality, hillsides with steep slopes and ignoring practices and traditional structures for soil conservation. Furthermore, the progressive abandonment of marginal crops (non-profitable) has accelerated more intensively this process. It leads to very important losses of fertile soil which is not admissible in these territories. Besides this there are other important collateral problems that occur downstream on infrastructure, people, crops and even ecosystems. This is the case in south and southeast regions of Spain like the region of Murcia. To minimize this problem one of the most relevant tools available for European states and regional governments are the named Rural Development Programmes. They provide a range of measures some in the form of grants to combat erosion. Wide ranging research has been carried out with the general aim to provide improved knowledge about these frameworks from the seventeen Spanish regions. Below are the results and analysis of the region of Murcia dating from the 2000-2006 and 2007-2013 periods

The region of Murcia is characterized by its extensive areas with a high risk of desertification, especially concerning erosion. We have identified and assessed the main measures with the potential effects on soil conservation as well as the particular practices and technical requirements taken into account. By means of a field study on a representative sample of plots where these measures had been applied we could validate some of them with regard to the impacts on soil conservation. As a result of this, two key groups of measures in soil conservation have been identified: Forestation and agri-environmental measures. In the first case, there are three grants: Forestation in agricultural lands, in non-agricultural lands and agri-forest systems. Secondly, the agri-environmental measures are a big and a heterogeneous group of measures: There were 117 types of which we estimated that about 30% of them could be useful. They were thus designed to fight against erosion in different types of productive orientations. Regarding the specific techniques included in each measure, we have identified about 300 interesting ones that cover soil conservation and tillage techniques, livestock management, living conservation structures, production systems, conservation infrastructure and other cultural operations. In the region of Murcia, four measures were assessed in field (Figure 1): (i) forestation in agricultural lands, (ii) extensification of rainfed herbaceous crops, (iii) soil conservation and (iv) environmental integration of vineyards.

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Fact Sheet Topic Area:
Soil conservation.

Keywords:
Erosion, rural development, soil conservation, forestation.

Authors:
Fernández Carrillo, M.A.
Romero Díaz, A. and Belmonte Serrato,F.
University of Murcia.
miguela.fernandez4@carm.es

Geographic location:
Region of Murcia, Spain

Climate classification (Koppen):
Semi arid-hot Mediterranean

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RESTORATION STRATEGIES

Many of these measures applied in the Rural Development Programmes had a very positive effect to improve soil conservation. In general, respect to forestation, it supposed an improvement of the vegetal cover soil, favouring the recolonization with natural species over the years (Figure 2). Meantime some agri-environmental grants increased: i) conservation and maintenance of soil conservation elements (e.g. retention terraces, benches, walls, drainages, etcetera), ii) maintenance and implantation of alive structures such as the prohibition of removing vegetal cover, steep banks or boundaries with natural vegetation, wooded in different ways, iv) reduction or elimination of tillage, v) increasing of organic matter, vi) decreasing of the effective livestock load, vii) maintenance of crop wastes, among many others. All this involves other positive impacts with respect to the biodiversity, rural landscape, reduction of water pollution and improvement of in situ water harvesting.

Figure (1): (Top) (Soil conservation measure): Planting strip perpendicular to the slope composed of *aromatic plants*, in almond tree rainfed orchard.

Figure (3): (Right) (Ex): Photo of the ecological corridor connecting natural areas. Source: M. Sánchez Martín (2009).

Figure (2): Forestation example using *Pinus halepensis* as the main species. Comparative after 16 years. Source: **(Top)** (M. Sánchez Martín, 1999); **(Bottom)** (M.A. Fernández Carrillo, 2014).

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Bioengineering techniques for soil and water restoration after forest fires

https://desertrestorationhub.com

Traditional soil and water conservation schemes should be expanded to include bioengineering approaches which offer interesting and more integrated possibilities in restoring burned areas. Soil restoration after fires should include functional and landscape criteria. In the initial restoration stages interventions should focus on soil protection aspects. This should lead to medium and long term end points to recover its natural dynamics in the biophysical and climatic context of the affected area. Bioengineering approaches include methodological aspects coming from traditional soil and water conservation schemes together with civil engineering techniques that incorporate new concepts. These concepts give priority to the use of living plants and biological materials to perform engineering functions under a principal to reinforce the ecological succession of the affected area. Specific actions for soil conservation can be preventive or involve cultural measures and measures of defence. The first, using simple soil management techniques, seeks to improve soil properties (structure, organic matter content, infiltration) adequate management of vegetation cover, hydrological monitoring and management (runoff, permeability, drainage, erosion). Some of these preventive measures include grazing control, stubble treatments, organic fertilizers, phytosanitary control, surface mechanized work, mulching and maintenance of plant cover. Preventive defence measures include: contour levelling, strip cropping, terracing, bench terracing and drainage ways.

The function of vegetation and plant material in bioengineering can be divided into four groups:

A. Soil protection techniques (covering action);
B. Land stabilizing techniques (mechanical, root penetration);
C. Combined construction techniques (inert materials); and
D. Supplementing stabilizing techniques (seeding, planting)

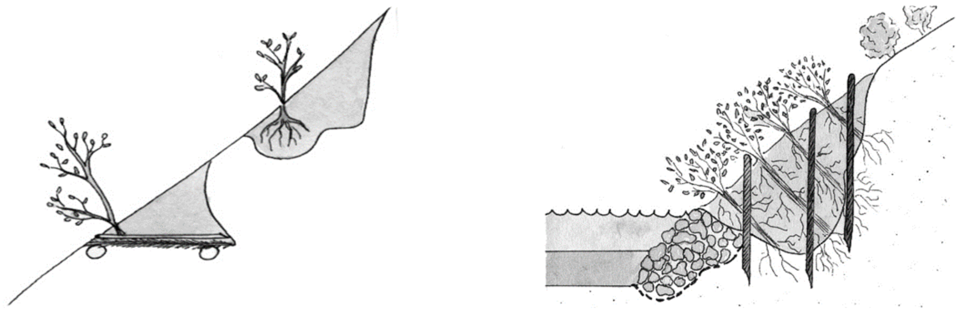

Figure (1): Diagrams of Brush mattress construction, Branch packing, Cordon construction and Live slope gratings as examples of bioengineering techniques for soil restoration after forest fires (Andreu,V. Rubio,J.L.et al.,2008)

Fact Sheet Topic Area:
Bioengineering techniques for soil and water restoration after forest fires

Keywords:
Forest/Wild fires, restoration, bioengineering soil conservation, sediments traps

Authors:
José Luis Rubio,
CIDE-CSIC,
Valencia,
Spain.
jose.l.rubio@uv.es

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The aspects of bioengineering are:

A. Effective on post fire emergency interventions
B. More ecological adapted approach providing long term efficiency and multifunctional benefits
C. Low cost and landscape integrative
D. Emerging, promising and fast growing approach
E. On the negative: Labour needs, lack of knowledge and availability of plant materials.

Bioengineering applied to the restoration and soil conservation includes methodological aspects and principles of action from traditional and conventional soil conservation techniques. It also incorporates various civil engineering techniques such as the use of gabions, geotextile or tights. All this however under an inclusive approach that seeks to develop effective, economic and environmentally acceptable soil protection techniques. Its novelty lies in the priority given to the use of plant materials drastically reducing the use of hard construction elements, more typical of civil engineering elements. These are not discarded depending on the circumstances and are used in the initial stages of intervention, but the purpose is their progressive incorporation and coverage by biotic elements. The goal is the ecological coherence with the possibilities and limitations of the biophysical and climatic zone and depending on the type of action pursued. In its final stages it comes to the incorporation of special living plant material to perform engineering functions but all under an adapted design ecological succession merging, promising and fast growing approach.

RESTORATION STRATEGIES

How can the issue described in the fact sheet be used to improve restoration? By including bioengineering techniques in any of the three main domain of intervention in restoring burned areas:

A. In emergency treatments;
B. In medium-long term restoration intervention: by increasing resilient communities; improving diversity and structure and by enhancing ecological succession
C. In prevention strategies: by reinforcing the resilience capacity of forest to wildfires impacts

Figure (2): Application of bioengineering techniques for soil and water conservation after forest fires in Cordoba, Spain (Ruiz et al., 2008)

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Agricultural soil restoration: soil organic matter and more

https://desertrestorationhub.com

Soil Organic Matter (SOM) is a pool of heterogeneous organic substances and organisms that are or were living in and on the soil. It is present in all soils at different rates (from traces to up to 20%). SOM is rich in N, P, K, S and micronutrients. Carbon makes up around 54% of SOM.

SOM influences the chemical, physical and biological conditions of soil. SOM is an indicator of soil fertility and soil quality. The implications for agricultural productivity, air and water quality, and food security are evident. Decreasing SOM is thus a major threat for many soil processes related to water and nutrient cycling. We blame the weather when there is no water and plants wilt. However the capacity of soil to capture and retain water is also important. The capacity of soil to hold water depends on its grain size, depth, structure and organic matter content. Inadequate cropland management practices (i.e. excessive tillage, reduction of fallows, burning of crop residues, drainage of wetlands, eliminating windrows, overuse of chemicals, etc.) reduce soil depth, destroy soil structure, compact the soil and decrease SOM content. Continuous extraction of biomass (e.g. through harvest) without replenishment (e.g. fertilizer, compost, manure) inevitably leads to a reduction in SOM. Additionally, eliminating soil fauna hampers water infiltration and facilitates erosion processes.

Fact Sheet Topic Area:
Agricultural Soil Restoration

Keywords:
Soil Quality, Carbon Sequestration, Soil Water Holding Capacity, Land restoration.

Authors:
Maria Jose Marques
Autonomous University of Madrid
mariajose.marques@uam.es

Gudrun Schwilch
University of Bern.
Gudrun.Schwilch@cde.unibe.ch

Thomas Panagopoulos
University of Algarve
tpanago@ualg.pt

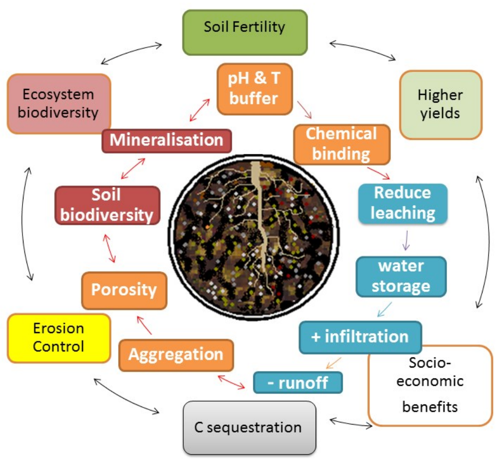

Figure (1): Left: Influence of Organic Matter in chemical, physical and biological condition of soil and global outputs

There is a need to restore SOM contents of agricultural land, particularly in drylands. Although native levels of SOM may not be possible under agriculture, there are sustainable land management practices that may produce both economic and environmental benefits.

<u>On-site benefits (plot level)</u>

- Helps to build soil;
- Increases water holding capacity;
- Increases infiltration;
- Increases drought resistance;
- Increases biological diversity;
- Increases soil fertility and thus improves yields; and
- Moderates soil temperature.

<u>Off-site benefits (landscape level)</u>

- Creates a drought-resistant land;
- Surface water is cleaner;
- Improves groundwater recharge and prevents floods;
- Prevents excessive diffusion of fertilizers and pesticides; and
- Increases resilience and adaptability to climate change.

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SOM may be increased in agricultural land by:

- adding manure, compost and/or organic residues;
- leaving residues on the soil surface;
- using cover crops;
- rotating crops with pasture or perennials;
- using cover crops into the cropping rotation; and
- reducing the intensity/frequency of tillage.

Only 10-20% of added manure or residues becomes part of SOM. The biological activity and its diversity are important for maintaining SOM and nutrient levels, in a stable soil ecological system.

Leaving residues (mulching) on the soil surface prevents erosion, reduces evaporation from the soil surface, facilitates infiltration and buffers soil temperatures.

Cover crops (perennial grasses and legumes) are any crop that is grown to provide soil cover, regardless of whether it is later incorporated into the soil or not. They may be grown to prevent soil erosion, to reduce nutrient leaching and results in an increase in SOM.

Well-managed **crop rotations** not only improve soil C inputs and yields, they also maintain long term soil fertility, reduce need for fertilisers, break plant pest cycles and control erosion. **Reduced tillage** and No-tillage also improve biodiversity and soil structure, saving time and fuel.

Figure (2): Demonstration day to publicise conservation agriculture in Guadalajara, Spain.

RESTORATION STRATEGIES

Soil restoration is in the hands of land users. Dissemination and training of different strategies to increase SOM are needed at national and local levels. All farmers want to obtain economic profits from their lands, most of them want to conserve soil properties in the long term, and some of them are committed to the environmental protection. All these goals can be obtained by the restoration of SOM because this initiates multiple changes contributing to increase soil resilience, i.e., its ability to recover after disturbance, breaking the vicious circle of progressive degradation caused by intensive agriculture. Land use and farming practices are major factors influencing soil resilience. Importantly, all the practices mentioned in this fact sheet must be adapted to any cropping system at different soil types and climatic conditions to be effective.

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WEB RESOURCES

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- http://www.fao.org/docrep/009/a0100e/a0100e00.HTM
- http://esdac.jrc.ec.europa.eu/content/soil-carbon-sequestration-climate-food-security-and-ecosystem-services
- http://www.soilquality.org.au/factsheets/how-much-carbon-can-soil-store
- http://www.extension.umn.edu/agriculture/tillage/importance-of-soil-organic-matter/
- http://esdac.jrc.ec.europa.eu/themes/soil-organic-carbon-content

Optimal array of sand fences for soil protection and restoration

https://desertrestorationhub.com

Stabilization of wind-blown soil particles is a fundamental aspect of **conservation and anti-desertification activities** and the first step for **restoration of land** affected by wind erosion. Sand fences of different types and materials have been constructed since ancient times to reduce wind velocity and induce dune formation. We have found that there is an optimal height of the sand fences, for which the amount of material needed to protect a given area of soil is reduced to a minimum, as we show in the present contribution. As a matter of fact, sand fences are commonly erected in sequential array (Figure 1a), the efficiency of which depends mainly on the fences' porosity and height, as well as on the spacing between the fences. We have investigated the influence of these different parameters on the efficiency of an array of fences by means of numerical simulations using Computational Fluid Dynamics, or CFD (Herrmann et al., 2005; Araújo et al. 2009; Araújo et al., 2013). While details of our calculations can be found in Lima et al. (2017), here we discuss the implications of our results for soil restoration practices. Figure 1b shows a snapshot of our numerical simulations (parameters specified in the caption). In this simulation, the wind velocity far upwind of the fences at a height of 1 m above the soil is 9,2 m/s, which is representative for sand-moving winds (Pye and Tsoar, 1990). The colour code in Figure 1b denotes the magnitude of the horizontal wind speed in presence of the fences (see legend).

We find that, for given fence height h_f and porosity φ, there is a threshold spacing between the fences, L_t, under which the wind speed u is reduced down to values smaller than the minimal threshold for sand transport, u_t, over the entire soil area on which the fences have been erected. This minimal threshold wind speed is of the order of 5 m/s (at 1 m height) for loose sand, but can be larger if the soil contains moisture, crusts or vegetation (Pye and Tsoar 1990; Kok et al. 2012). The main plot in Figure 2 shows L_t as a function of h_f for different values of φ and u_t (see caption). We see from this plot that L_t increases with h_f for all values of φ and u_t, as expected. In other words, the higher the fences, the more distant they can be placed apart while still obtaining $u < u_t$ over the entire terrain.

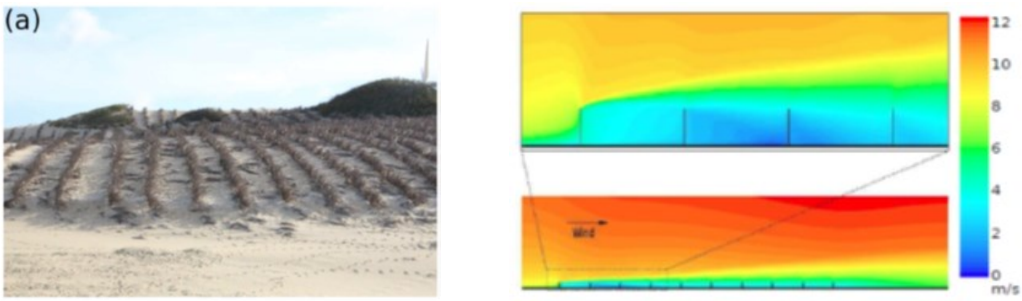

Figure (1): (a) fences of coconut leaves in Paracuru, near Fortaleza, main city of the State of Ceará in Northeastern Brazil (photo by first authors, I.A.L. and A.D.A.); **(b)** time-averaged wind velocity magnitude obtained for an array of fences of height 20 cm, porosity 40% and spacing 2 m.

Fact Sheet Topic Area:
Aeolian soil stabilization

Keywords:
Soil erosion, sand fences

Authors:
Izael Lima
Ascânio Araújo
José Andrade Jr
Departamento de Física,
Universidade Federal do Ceará,
Fortaleza, Brazil

Hans Herrmann
Departamento de Física,
Universidade Federal do Ceará,
Fortaleza, Brazil
&
Institut für Baustoffe, ETH Zürich,
Switzerland

Eric Parteli
Department of Geosciences,
University of Cologne, Germany

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To address the question of the optimal array of fences, that is, the one for which the amount of fence material required to completely shield the soil from wind erosion is minimum, we introduce the cost function C, defined as

$$C = h_\mathrm{f} \times \frac{S}{L_\mathrm{t}}, \qquad (1)$$

where S is the total downwind distance of the area to be protected. Thus, the fraction S/L_t gives the length of the field over which the fences have been erected, in units of numbers of fences.

The dependence on C/S on h_f is shown in the inset of Figure 2, for different values of u_t and φ (see caption of Figure 2). We see that, for all studied values of φ and u_t, C/S displays a minimum at h_f ≈50cm. This fence height is thus the optimal fence height to obtain total protection of a given soil area while ensuring minimal fence material.

Moreover, we see from the inset of Figure 2 that C/S has a maximum at around 1.25 m. This result is surprising, considering that the height of fences is often chosen to be 1 m (Pye and Tsoar, 1990). Our result suggests the need for revisiting this choice. We also see from Figure 2 (inset) that C/S decreases with h_f as the fence height exceeds 1.5 m. However, using such large fences is not recommendable as they are more difficult to fixate in the soil, compared to their counterparts of height 50 cm.

RESTORATION STRATEGIES

We propose that restoration strategies employing arrays of sand fences for large-scale soil protection can be optimized by employing fences of height about 50 cm. Total soil protection is achieved with minimal amount of fence material if this value of fence height is employed, without regard of fence porosity φ and threshold wind speed for aeolian sand transport u_t (Figure 2).

We note that although the soil properties affect u_t and thus the maximal spacing L_t that guarantees total protection against soil erosion, our simulation results suggest that the optimal fence height is valid both for mobile dune sand and for a terrain containing stabilizing elements or moisture. We thus conclude that the efficiency of restoration strategies based on crusts or crop cultivation (Pye and Tsoar 2009) might be improved by applying the optimal fence height obtained from our simulations. Our predictions should be now confirmed experimentally.

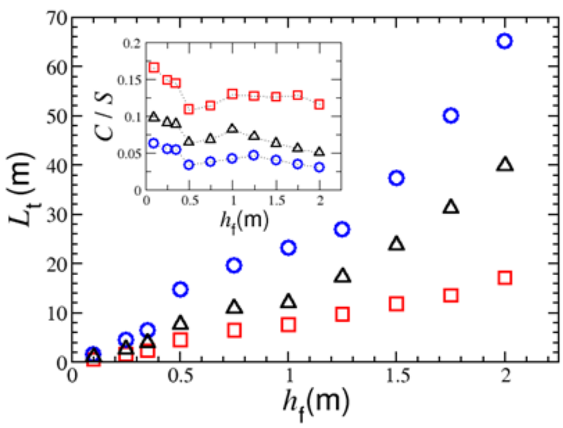

Figure (2): Maximal spacing L_t for total soil protection against wind erosion (main plot) and cost function C rescaled by the terrain distance S (inset), as a function fence height h_f, for different values of porosity (φ) and threshold wind velocity u_t: φ =50%, u_t = 5m/s (squares); φ =20%, u_t = 5m/s (triangles); φ =40%, u_t = , 7.4m/s (circles).

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Recovery of biological soil crusts after grazing exclusion: implications for soil ecosystem services

Biological Soil Crusts or biocrusts are a complex association of lichens, mosses, cyanobacteria and other microorganisms living in the soil surface, predominantly in drylands (Belnap et al. 2003). In drylands, where vascular vegetation is commonly sparse, biocrusts cover vast areas of soil surface; up to 100% of plant interspaces in most arid ecosystems, and contribute greatly to ecosystem functioning and services. Biocrusts fix carbon and nitrogen, stabilize and protect soil surfaces from erosional forces (e.g., wind and rain), provide habitat for soil micro and mesofauna, and influence soil-water and soil-atmosphere relationships (Belnap et al. 2003). They have been identified as useful indicators of soil and ecosystem status; e.g. the proportion of cyanobacteria, lichens and mosses in biocrusts relates tosoil organic matter content or soil compaction. Also, biocrusts act as ecosystem engineers: they can modify topsoil conditions such as texture, porosity and nutrient availability. Furthermore, because of their potential effects on soil dynamics, since they are quite manageable, and in the first phases they grow relatively fast, biocrusts have been proposed as useful restoration tools in drylands to recover soil structure and function (Bowker 2007); for example in highly degraded areas or unstable soils (e.g. dune systems).

Although biocrusts are common in natural and managed ecosystems, their abundance and composition is greatly influenced by land-use management and operating disturbance regimes. In particular, livestock grazing affects biocrust development and functioning (Concostrina-Zubiri et al. 2015) due to mechanical disturbance and via changes in vascular plants and soil physico-chemical properties. At the agro-silvo-pastoral system "Companhia das Lezírias" in Southern Portugal (Figure 1a) livestock grazing has been identified as a potential threat to cork-oak woodland regeneration.

However, other key components of the ecosystem, such as biocrusts, are also threatened. Thus, passive restoration strategies such as livestock exclusion have been implemented in selected stands.

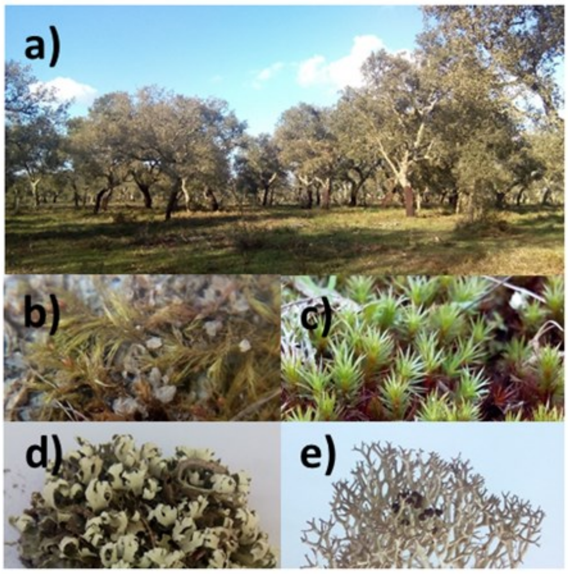

Figure (1): a) Cork-oak woodlands at Companhia das Lezírias, and examples of biocrust functional groups in the region: **b)** short mosses, **c)** tall mosses, **d)** foliose lichens and **e)** fruticose lichens **.**

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Fact Sheet Topic Area:
Biological Soil Crust Ecology

Keywords:
Managed cork-oak woodlands, Grazing exclusion, Topsoil properties.

Authors:
Fundação da Faculdade de Ciências de Lisboa, Portugal

Laura Concostrina-Zubiri
lczubiri@fc.ul.pt

Cristina Branquinho
cmbranquinho@fc.ul.pt

Forest Research Institute
Bulgarian Academy of Sciences
Bulgaria

Ibrahim Molla
mollata@abv.bg

Emiliya Velizarova
velizars@abv.bg

Geographic location:
Portugal

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Grazing exclusion led to an increase in total biocrust cover from 3% in grazed sites to 17% in sites excluded from grazing. Among the different functional groups of biocrusts i.e. groups of species with similar attributes present in the region (Figure 1b, c, d, e), fruticose lichens increased 6 and 7 times after 7 and 17 years of grazing exclusion, respectively (Figure 2a). (Díaz & Cabido 2001)

On the one hand, this increase can be seen as a clear, simple indicator of ecosystem recovery after grazing exclusion. On the other hand, the increase of fruticose lichens had several implications for ecosystem functioning, since this functional group presents a higher capacity to retain water in their tissue through time (~19h) and reduces significantly topsoil temperature (15cm depth) up to 0.6º C, compared to bare soil, in the exclusion sites (Figure 2b).

Grazing exclusion allowed the recovery of biocrust cover and function i.e. maintenance of aboveground humid microsites and buffering of topsoil temperature, improving soil services (i.e. microclimate regulation) which in turn can promote the regeneration process of cork-oak woodlands, one of the main concerns in the agro-silvo-pastoral system Companhia das Lezírias.

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RESTORATION STRATEGIES

Strategic exclusion of livestock in selected stands, when affordable, is a relatively fast and effective strategy to accelerate the recovery of ecosystem structure and function, and then, services. Biological soil crusts play a major role in succession after grazing exclusion by regulating topsoil conditions, such as soil surface humidity and temperature.

There is a need to conduct field/laboratory experiments to determine the effects of biocrusts in cork-oak regeneration; e.g. seed germination in open microsites vs. biocrusts microsites.

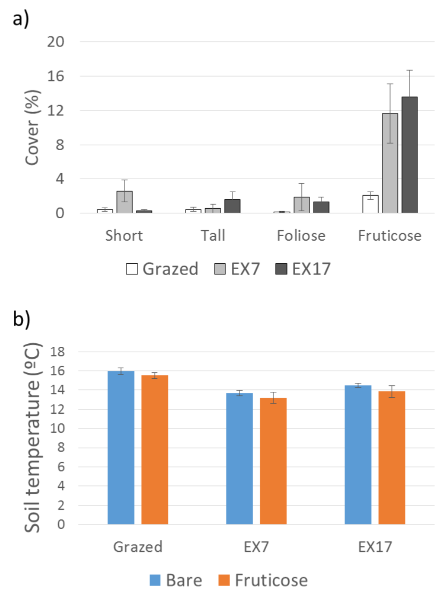

Figure (2): a) Mean cover ± SE of biocrust functional groups under grazing pressure ("Grazed") and after 7 and 17 years of grazing exclusion ("EX7" and "EX17"); **b)** Mean soil temperature ± SE in bare soil and under fruticose lichens **.**

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- I.M. acknowledges COST ACTION 1104 for funding the short-term scientific mission at Faculdade de Ciências de Lisboa, Portugal.

Induced biological soil crusts: a large scale rehabilitation approach in China

China is a developing country with vast areas affected by desertification. From the end of the 1950s to the middle of the 1970s desertification spread at a rate of 1560 km^2/year. Soil degradation represents a threat to 40 million people and a further threat is the number of days (30 to 100) of sandstorms; characterized by winds greater than force eight. National plans to combat desertification include: tree/ shrub planting and grass growing, enclosing land for natural revegetation, aero-seeding of tree and grass seeds, improving low-yield farmland and pasture, cultivating cash crops and maximizing utilization of run-off water[1]. Actual research programs aim at finding eco-friendly and economically sustainable approaches. Among soil microorganisms, cyanobacteria are beneficial to soil health and deserve special attention. They are ubiquitous prokaryotes which have a high biotechnological versatility. While representing valid tools to attain carbon (C) mitigation[2], they are also widely known to improve land productivity due to the release of vitamins, growth factors and amino-acids. In addition, they accumulate high amounts of C (as high as 1000-folds of that of the environment[3]) and release some in the form of extracellular polysaccharides (EPSs). In addition, many species can fix nitrogen (N) under a wide range of conditions[4] so that they can provide available N in the soil. The use of cyanobacteria as soil fertilizers has been tested in different studies[5].

They are able to withstand desiccation, high temperatures, unsuitable pH and lack of nutrients[5]. *Microcoleus vaginatus* is a non-heterocystous desert pioneer and a first colonizer of desert soils, whose exudates create a first stable organo-mineral layer for the subsequent recruitment of other phototrophic and heterotrophic organisms[6]. By inoculating soil with *M.vaginatus* it is possible to elicit the formation of induced biological soil crusts (IBSCs) which can reach different levels of development in short time spans. Given the effects of BSCs on habitat dynamics, and their potential capability to shift the state of high a-biotic stress environments[7] their introduction through inoculation-based approaches could represent feasible alternatives to common land rehabilitation methods.

Figure (1): (left) IBSCs with different morphologies displayed in the experimental area in Qubqi desert, Inner Mongolia, China. **(right)** A site inoculated 8 years before the picture was taken, showing IBSCs with shrub and herb coverage. (Photo by Federico Rossi.)

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Fact Sheet Topic Area:
Soil reclamation, biotechnological rehabilitation approaches

Keywords:
Cyanobacteria, biological soil crusts (BSCs), induced biological soil crusts (IBSCs), desertification.

Authors:
Federico Rossi, PhD
Roberto De Philippis, PhD.
Department of Agrifood Production Sciences and the Environment,
University of Florence,
Florence,
Italy.
f.rossi@unifi.It

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Although some attempts at fostering BSC recovery through crust slurries or crumbled BSC inoculation have been tried[8,9] only one example of large scale cyanobacterial inoculation is documented. Following the Chinese government project titled: "Engineering Application of Integrative Artificial Algal Crust Technology in Shifting Sand Stabilization procedure for a large area", an experimental area of 30 km^2 in Dalate banner of Inner Mongolia at the eastern edge of Qubqi desert, was massively inoculated with cyanobacteria, after validations at laboratory level and optimization of the mass-cultivation system and dispersal strategy. For massive cyanobacterial cultivation, an open 100 hl raceway pond was used, while cyanobacterial culture was dispersed using a sprayer mounted on a tank truck[10]. For the next 15 days, inoculated soil was micro-irrigated to sustain cyanobacterial adaptation and lower soil surface temperature[11]. The approach led to the quick development of IBSCs (Figure 1), with the first cyanobacterial crusts forming within 7 to 20 days from the inoculation, and the succession to moss crusts taking place within a three year time span[11,12]. Surveys on the inoculated sites reported an increase in diversity of bacterial, fungal and vascular plant community due to the improvement of nutrient conditions[11,12,13] with an increase in soil fines, bulk density, organic matter and exopolysaccharide contents[10,12,13].

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RESTORATION STRATEGIES

The results obtained with this large scale inoculation study point out that this technology could be used to address rehabilitation of high a-biotic stress systems and even applied to hyper-arid environments. The results of this study underline how the technique demonstrates effective results in improving soil stability and nutrient conditions, allowing the onset of vegetation.

While different members of the order Nostocales resulted in effective natural fertilizers in the agricultural field, *M.vaginatus* demonstrated especially effective for large-scale inoculation under highly stressing conditions. Based on this, and following the general workflow (Figure 2), the technology could be adapted to fit different purposes ranging from conservation to remediation. In each specific case, the methodology (including the choice of a proper inoculant) should be modified according to the type and the levels of the stresses of the considered system. Further research should focus on the implementation of mass-cultivation and mass-inoculation techniques.

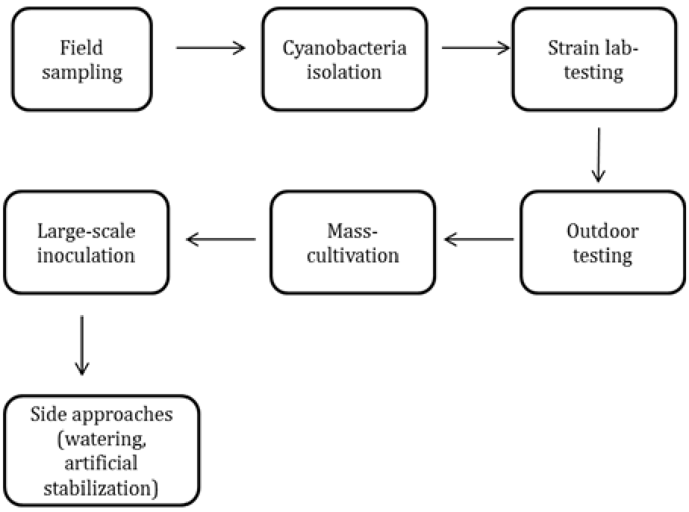

Figure (2): General workflow of a large-scale inoculation approach from the isolation of cyanobacterial strains to mass dispersal on inoculation site and side-approaches (e.g., water provision or introduction of straw checkerboard to increase the percentage of inoculation success).

Green roofs with biocrusts: sustainable solutions for urban drylands

Green roofs are plant-based spaces placed on a waterproof layer on top of homes, factories, offices and other buildings. They are widely used in northern Europe because they increase the services provided by green spaces in urban areas (Oberndorfer et al. 2007). These green infrastructures improve not only urban aesthetics, but also improve the building's thermal regulation, decreasing the use of air conditioning and the attenuation of flash floods due to intensive rain events, since they increase the retention time of rainwater. They contribute to the reduction of the urban heat island effect, which results from an increase in temperature in urban environments due to reduced vegetation cover, also mitigating heat loss during the winter (Berardi et al. 2014). Furthermore, they contribute to biodiversity conservation, an increase in carbon sequestration improving air quality, improve the buildings' soundproofing, increasing roof durability, and lag spread of potential fires.

Green roofs began in northern regions, with cold and humid climates (e.g. Germany, The Netherlands, Canada), enabling low cost maintenance, having no requirement to install irrigation. However, in Mediterranean areas or regions in similar latitudes characterized by a hot climate with dry summers the use of classical green roofs require irrigation because most vascular plants cannot withstand the summer period without watering both due to survival reasons and/or aesthetic ones. Green roofs will only provide an advantage if the system can be cheap and sustainable. For that we need to find ways of eliminating irrigation or watering except only in periods of extreme drought. The possibility of creating green roofs with limited or reduced water needs can overcome the setting up and maintenance costs. In extreme cases, where there is no water available for irrigation, the choice of the group of organisms is crucial.

Figure (1): Moss-dominated biocrusts can remain dry for long periods and resume growth after watering **[see Figure (2)]** making them ideal candidates for green roofs in Mediterranean urban drylands.

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Fact Sheet Topic Area:
Adaptation to climate change in Mediterranean drylands

Keywords:
Adaptation, biocrusts, green roofs

Authors:
Ricardo da Cruz de Carvalho, PhD
rfcruz@fc.ul.pt

cE3c
Centre for Ecology, Evolution and Environmental Changes, Faculty of Sciences, University of Lisbon, Portugal

Geographic location:
Lisbon, Portugal

Climate classification (Koppen):
Csa

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In deserts, soils are covered with biological soil crusts (biocrusts), a complex mosaic of cyanobacteria, green algae, lichens, mosses, microfungi and bacteria. Biocrusts occur in all hot, cold, arid and semiarid regions and can represent up to 70% of the coverage in some plant communities. These biocrusts are able to grow when water is available, but in extreme drought conditions, their entire metabolism cease, and they can remain under these conditions for long periods (from months to years) and return to normal function when water becomes available. Due to these characteristics, they are termed desiccation tolerant, i.e. they survive the loss of practically all water in their cells. Moss-dominated biocrusts are able to retain water up to 500% their weight which can be used for growth and, therefore, being self-sustained. Furthermore, mosses do not have roots and are able to grow in a very thin substrate layer, decreasing the weight load on buildings and can even be used in walls.

The selection of suitable species can change this technology and may contribute to the conception of a solution that can be used in urban spaces, combining reduced water requirements and moss-dominated biocrusts to restore green spaces in cities.

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RESTORATION STRATEGIES

- Organize workshops with stakeholders, researchers and decision-makers for the benefits of green roofs in urban spaces (in particular using biocrusts.)
- Evaluate potential urban areas in the municipalities both for roof tops but also in disturbed green-potential fields, for increased ecosystem services.
- Make a list of suitable moss-dominated biocrusts for Mediterranean areas.
- Organize local events for citizen awareness and action measurements.

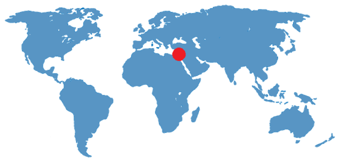
Figure (2): Hydrated Mediterranean moss-dominated biocrust that can be used in green roofs. Photo: Teresa Afonso Paço.

Biological soil crust structure and water redistribution in an arid sand dune ecosystem

https://desertrestorationhub.com

Biological soil crusts (BSCs) are communities of cyanobacteria, green algae, bacteria, lichen, fungi and mosses that live in and on the uppermost millimetre of many dryland soils. By providing vital ecosystem services, such as the input of carbon and nitrogen into the soil, as well as an increased surface stability or the input of nutrients via dust capture, they enhance the fertility and productivity of dryland ecosystems around the world. The fact that BSCs cause or enhance surface runoff in the Negev (Figure 1) has been well established for almost three decades[1]. It is also well known that BSCs of different successional stages have different effects on water redistribution in drylands around the globe[2,3,4,5], but the exact reason for this has long been subject to critical discussion. Among the factors that influence the generation of surface runoff are surface micro-topography, hydrophobicity, pore clogging and rainfall characteristics, but the change of the structure of the pore system with crust succession is understudied so far. Microscopic observations, as well as structure elucidation with computed micro-tomography (µCT) revealed the presence of vesicular pores that showed a high abundance in the subcrust region of cyanobacterial crusts and whose abundance decreased with succession. These pores are a phenomenon of abiotic origin and are known to drastically reduce infiltration by limiting the connectivity of the pores due to their isolated spherical nature. Their abundance decreases with crust succession from cyanobacterial to lichen and moss dominated BSCs, recreating the pore connectivity and thereby infiltration capacity of the BSCs. Further, 2D thin sections revealed the existence of capillary barriers at the interface of coarse and fine grained layers of the early stage crusts (Figure 2), also known to reduce infiltration. These layers are destroyed by bioturbation during crust succession, which is another mechanism that explains the existing runoff patterns in the Negev.

Figure (1): (top) Traces of sediment transport caused by surface runoff in the NW Negev in January 2011 **(bottom)**. The three different successional stages of BSCs in the Negev[6]. Photos: Vincent Felde



Fact Sheet Topic Area:
Runoff in an arid ecosystem

Keywords:
Biological soil crusts (BSCs), desertification, soil microstructure, surface runoff.

Authors:
Vincent Felde, MSc,
Institute of Soil Science and Soil Conservation (IFZ),
University of Giessen,
Germany.
Vincent.Felde@umwelt.uni-giessen.de
&
Felde@uni-kassel.de

Geographic location:
NW Negev desert, Israel

Climate classification (Koppen):
BWh

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Since hydrophobicity seems to play only a minor role in runoff generation in the Negev[8], it seems likely that water movement in this ecosystem depends largely on the rainfall characteristics, as well as the structural properties of the crusts. BSCs of later successional stages have pore systems that are more favorable for water movement so that water on the run-on sites can infiltrate into deeper layers and is no longer prone to evaporation, which enhances overall ecosystem productivity.

RESTORATION STRATEGIES

- Primarily because of their role in dune stabilization, BSC disturbance must be avoided to keep the ecosystem stable.
- Protecting the BSCs from disturbances (grazing, trampling, vehicle traffic) also maintains their role in water redistribution in this dry ecosystem and by reducing the evaporative losses secures the existence of local hotspots (i.e. fertile islands) at the run-on (micro-) sites, which helps combat desertification.

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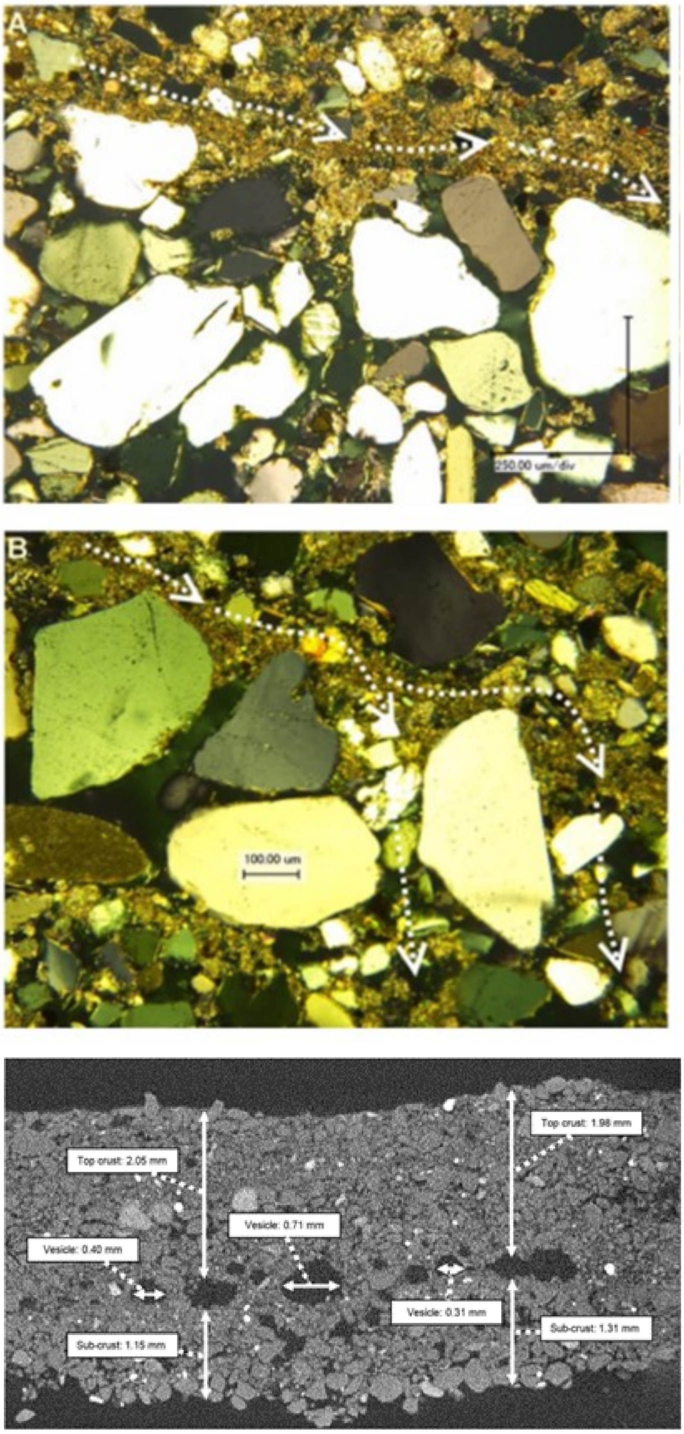

Figure (2): (top) A sudden change in pore size due to a change in texture causes a capillary barrier effect at the interface between topcrust and subcrust, reducing the connectivity of the pore system[6]. **(middle)** Where fines are washed into large pores, the connectivity of the pores is recreated. **(bottom)** CT-cross section of a cyanobacterial BSC with vesicular pores in about 2 mm depth. These structures are also likely to influence cyanobacterial activity within the crust[7].

ACKNOWLEDGEMENTS:

The scientific work presented in this fact sheet was funded by the DFG ("Biotic and abiotic factor affecting biological soil crust formation and recovery in a semiarid dune ecosystem, Gaza and NW Negev" (Project FE 218/14-2), and was supported by the Arid Ecosystems Research Center of the Hebrew University of Jerusalem.

Biological soil crusts in drylands: microscopic water reservoirs with macroscopic effects

https://desertrestorationhub.com

Biological Soil Crusts (BSCs) are aggregations of soil particles and organisms (mainly cyanobacteria, microalgae, microfungi, bacteria, lichens, and bryophytes), ubiquitous throughout the world. BSCs are widely recognized as beneficial to soil fertility due to their contribution to soil stabilization and to the increase in their carbon, nitrogen and moisture content, mitigating desertification effects. They also influence soil hydrology at small and large scales. The water related issues, namely water savings, have fundamental importance in arid and semi-arid areas. It is widely acknowledged that sheath-forming and polysaccharide-excreting species of cyanobacteria are the dominant inhabitants of dryland-BSCs (see Figure 1), and are able to rapidly swell up to 13 times their dry volume. Indeed, they are the primary successional producers of the organic matrix that aggregates soil particles. Other organisms contributing to the matrix formation, but in later successional stages, are heterotrophic bacteria and microfungi. The excreted material is usually described as extracellular polymeric substance (EPS), which is composed of varying proportions of polysaccharides, proteins, nucleic acids, lipids and humic substances. Polysaccharide sheaths, surrounding the cyanobacterial filaments, form a three-dimensional net (visible in Figure 1), entrapping soil particles and microbial cells, and thus stabilizing the soil. Moreover, these sticky polymers work as micronutrient traps, hitching dust and mineral particles (Figure 2).

Figure (1) Left-top: BSC collection site, coastal area of central Portugal. **Left-bottom:** a BSC sample. **Right:** Cyanobacteria and their EPS. The EPS is organized in sheath surrounding the filamentous cyanobacterium, possibly *Microcoleus* sp. The autofluorescence photomicrograph shows: under blue light excitation the polymeric matrix (appearing green here); under red light excitation autofluorescing cyanobacterial cells (appearing red here).

Fact Sheet Topic Area:
Drylands biological soil crusts.

Keywords:
Cyanobacteria, EPS, BSC.

Authors:
Alessandra Adessi
University of Florence
Alessandra.adessi@unifi.it

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Thus, the crust can be indeed considered held together by the presence of these sugar-based polymers, primarily produced by cyanobacteria. Due to the presence of EPSs, water can be captured and retained more easily in BSCs as compared to bare soil. Figure 3 shows the rapidity with which bare soil (in brown) loses its relative water content, when compared to a BSC (in green), that contains EPS. It is indeed the presence of EPS that allows the water to evaporate more slowly. This data is crucially important for understanding the use of BSCs in ecological restoration programs, especially in drylands. In drylands the limited success of restoration projects is typically due to water constraints for plant survival. The preservation or the inoculation of cyanobacterial BSCs, as a stand-alone strategy or together with other strategies, in restoration projects must be considered to increase the success rate in a cost-effective way. Increasing vegetation and/or BSCs cover can arrest desertification, or be an important climate change adaptation measure.

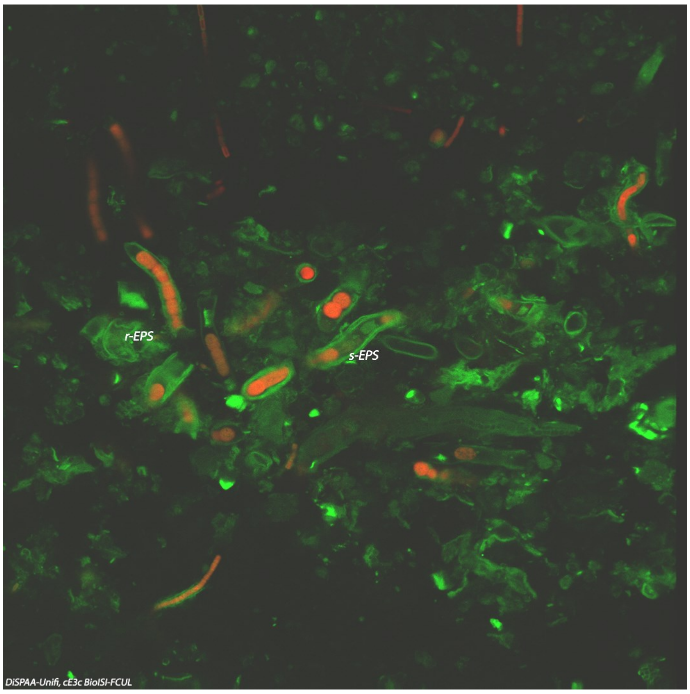

Figure (2). A cyanobacterium, possibly *Nostoc* sp., and its EPS. The EPS is either organized in sheath (s-EPS), surrounding the filaments; or it is released (r-EPS) in a colloidal form.

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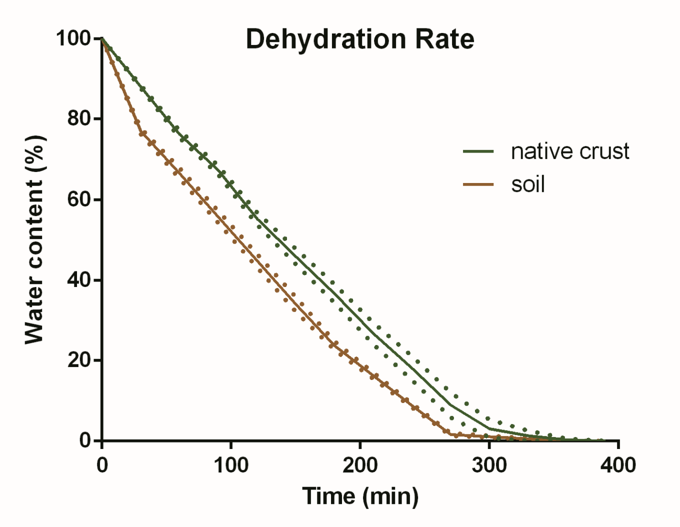

Figure (3): Dehydration rate of a BSC compared to bare soil. The brown line indicates bare soil, the green line indicates BSC. The dots indicate the standard error of the mean.

RESTORATION STRATEGIES

- Preserving BSC colonization in drylands by limiting grazing and other sources of disturbance
- Enhancing BSC colonization through cyanobacterial inoculation (either sequentially or simultaneously with plants)

Acknowledgements: *Data presented in this factsheet was collected during two STSMs financed by the COST Action 1104 to AA (UniFI), in collaboration with cE3C and BioISI at FC-UL.*

Monitoring and information system: a helpful approach for minimizing ecological impacts of invasive plants

The introduction and spread of exotic plants to new geographical locations are increasing globally with each passing day. The exotic plants become invasive in new habitats and pose severe threats to the biodiversity, economy, agriculture, human health, infrastructure and cultivation system's integrity (Vila et al., 2011). However, limited available resources are barriers for acquiring knowledge of each introduced exotic plant. Therefore, these plants are ignored as a casual occurrence at their first record and ignorance leads to successful establishment and invasion of new habitats. Eradication of each exotic plant at the first record is also virtually impossible as all exotic plants are not invasive. There are some approaches through which invasive plants can be monitored and prioritized for management according to available resources. Monitoring and information system (MIS) is a reliable tool for perceiving the presence of alien plants at a given area (world, continent, country, province, city etc.) (Keefra et al., 2010). MIS integrates several approaches including early detection, diagnosis, collection and analysis of data, risk analysis, prioritization and rapid response (Figure 1). Early detection and rapid response (EDRR) is the key theme of successful MIS. This system integrates a number of working groups which are assigned different tasks according to the layout of the system (Keefra et al., 2010). Early detection groups work on recording the occurrence of new invasive plants.

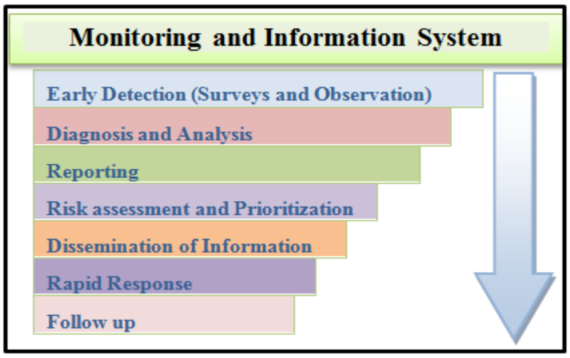

Figure (1): A typical flow chart of Monitoring and Information System (Onen, 2015)

The data relating to new occurrences (pictures, location etc) are provided to other working groups which diagnose and analyse the possible risks associated with the plants. The exact and accurate diagnosis of the plant is the key of success of an effective MIS system. After the species has been diagnosed, it is reported to the higher office formulating the quarantine and biodiversity regulations. The working groups in these institutes process the data by searching the suitable literature available on the plant for further processing. If huge number of plants are reported, these are prioritized by risk assessment techniques. Rapid response action is taken against the plants having highest risks associated with them. The data are made available publically through website or smart apps to create awareness (Wittenberg and Cock, 2001).

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Fact Sheet Topic Area:
Restoration

Keywords:
Invasive plants, Early detection, Mapping

Authors:
Huseyin Onen,
Gaziosmanpasa Univ.,
Faculty of Agric. Plant Protection
Dept. Tokat,
Turkey
huseyin.onen@gop.edu.tr

Shahid Farooq,
Gaziosmanpasa Univ.,
Faculty of Agric. Plant Protection
Dept. Tokat,
Turkey
csfa2006@gmail.com

Hikmet Gunal,
Gaziosmanpasa Univ.,
Faculty of Agric.,
Soil Science and Plant Nutrition
Dept. Tokat,
Turkey hikmet.gunal@gop.edu.tr

Geographic location:
Turkey

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Figure (2): Web based and Smart phone apps based MIS In different countries

The ideal geographic location of Turkey and increasing tourism, trade and development in the country make it an ideal location for biological invasions. A number of alien plants have been reported in the country severely interferring with different ecosystems (Onen, 2015). Therefore, MIS can be efficiently utilized to cope with the increased invasion of alien plants. The MIS is being created through a project funded by the Scientific and Technological Council of Turkey (TUBITAK) as a part of Cost Action (TD-1209 Alien Challenge).

The surveys for recording the occurrence of alien plants In Turkey have been completed over a considerable portion of the country (Figure 3). Different species recorded as worst invasive plants in the country have been prioritized for developing the current and potential distribution maps. The maps are being created (Figure 4) and soon will be available publically on the website of the system.

The website of MIS is (www.i-bil.org) is in the local language. The English version will also be available at the end of 2016. The rapid response action against the plants will be recommended after data analysis and potential distribution modeling under current and changing climat scenarios.

At the end, recommendations will be made for the necessary actions needed to be taken against these plants. Additionally, the system will be open to report new occurrence in any area of the country and experts in the field will diagnose and update the maps of the newly recorded plant. Moreover, early warnings will be issued in the areas at the risk of invasion by a specific plant. The awareness will be created among the people for eradication of the invaders at their first occurrence. The whole system will help to minimize the ecological impacts of invasive plants.

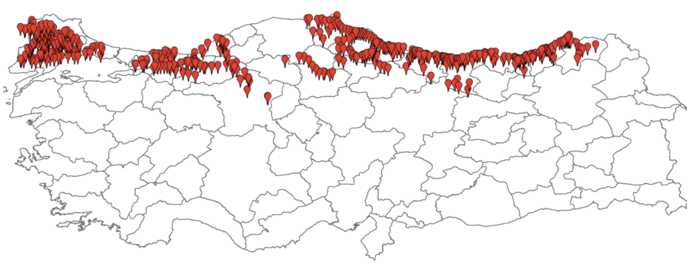

Figure (3): Surveyed region for creation of MIS in Turkey

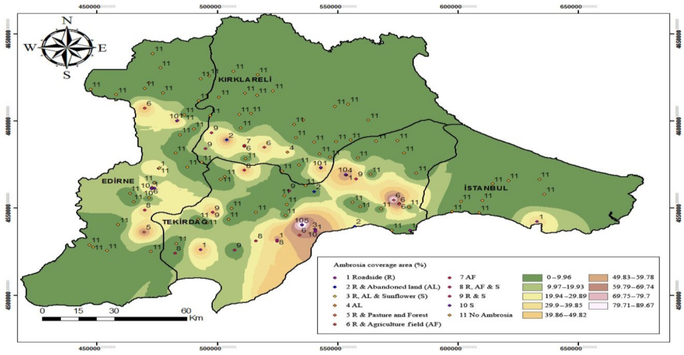

Figure (4): Spatial mapping of common ragweed in Thrace region of Turkey (Ozalsan et al., 2016)

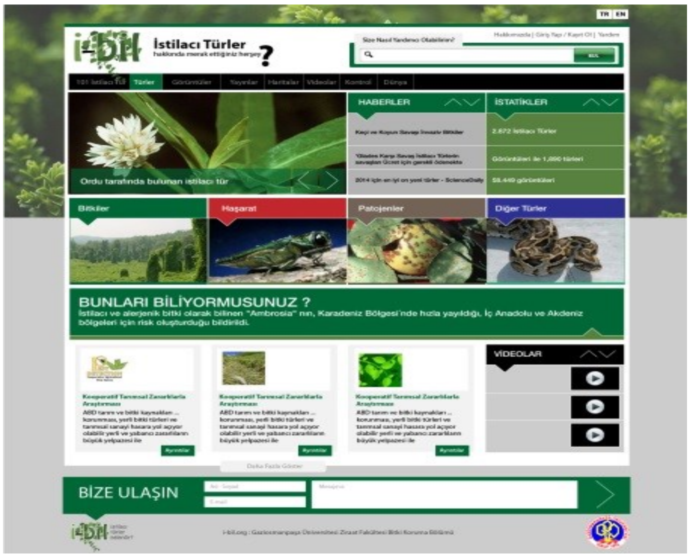

Figure (5): Website of the MIS in Turkey

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The role of small hydraulic units (Jessour) in the mount of Matmata-Tunisia & land protection and restoration in mountainous regions.

Tunisia is located on the southern shore of the Mediterranean, within an arid to semi-arid climate covering three quarter of its territory (Boufaroua, 2002). It is characterized by limited and fragile natural resources, which are the subject of intense exploitation (Ounalli & sghaier, 2009), associated with a marked water deficit, especially in the arid and semi-arid regions. The south-east of Tunisia is characterized by an arid Mediterranean climate, the mean annual rainfall is between 100-200 mm. Rainfalls despite its scarcity, can be torrential and a threat to agricultural soils due to the high erosive activity.

The jessour (small hydraulic units) are the most important system for water harvesting used for agricultural production in this area, which is based on rain fed farming. In fact, serious attempts to exploit the runoff water for rainfed agriculture and reduce water erosion in mountainous regions have led to a great increase in the popularity of this technique. However, despite their significant morphological role, the "jessour" has been reported to have a fragile structure, which can be easily destroyed in case of excess runoff retained behind dykes, representing therefore a real danger to the small villages in the downstream. The risk of destruction was carefully assessed regarding overflow to all the works of a micro-watershed (El-Jouabit-Tounine-Mareth) in the mountains of Matmata.

Thereby, to harvest and store this water, small hydraulic units called "jessour", have been developed since ancient times in the "talwegs" as a common practice of retaining runoff and erosion arisings, which are used, then, as sediment for agricultural purpose. Nevertheless, during the exceptional flood, the jessour can be damaged in various ways and this can create a real danger for the villages located in downstream areas and can cause the demise of some species through land loss and the destruction of natural habitats (Chehbani, 1990). The assessment of these jessour is important (Moussa et al, 2011) and there is a major challenge to determine its optimal use as an efficient strategy of water storage and erosion prevention.

Figure 1: (Above) Degraded land caused by jessour destruction caused by flood water.

Figure 2: (Below) Small hydraulic unit (Jesr) filled with water and sediments.

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Fact Sheet Topic Area:

Prevention of land loss in lands with slope

Key Points

1. Land protection from water erosion.
2. Restoration of terraces behind small hydraulic units.
3. Restoration of natural plantation in catchment area of jessour.

Keywords:
South-eastern Tunisia, land protection, restoration, water conservation.

Authors:
Ines Gasmi, PhD
Institute of Arid Regions
gasmi-ines@hotmail.fr

Geographic location:
Tunisia

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The research area of our micro watershed is 304,7719 ha containing almost 619 jesr, with a density of 2 jesr per ha, with very varied areas between 3 m² and 13 375 m².

The majority of jessour located on the studied watershed successfully retain water; there are only 50 non-functional jesr (8%), which have destroyed tabia (earth dykes) because of the heavy flooding. The functional jessour has preserved its hydro morphological role thanks to the permanent effort of farmers who always try to maintain these small units.

Topography does not prevent tillage, and farmers are effectively occupy their plots. The jessour, in this area, are characterized by the correct size and the correct positioning of drainage systems such as "Masraf" and "Manfes", which are the central and lateral spillways of the system. These spillways are used to remove excess water to the next units downstream.

According to the study, ongoing maintenance of the system is required to improve land restoration in this area as well as to protect the native species growing in catchment area of the jessour.

RESTORATION STRATEGIES

1. To achieve better conservation of soil and water and fight against water erosion, these works must be studied and properly sized to retain runoff water during exceptional events and prevent disasters related to overflow.
2. Local stabilisation is important for the protection of lands located on slopes against water erosion and to maintain the natural planting in the region.

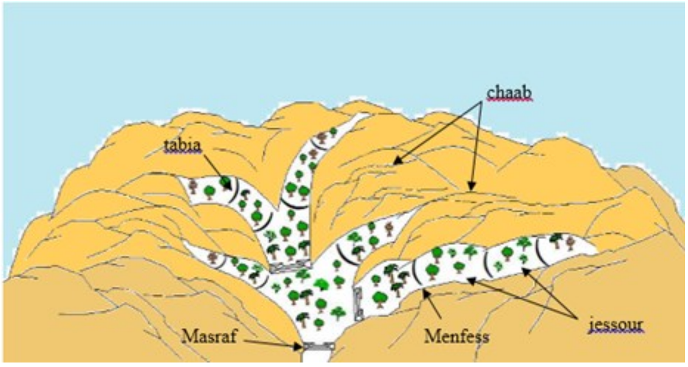

Figure (3): Components of jessour

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Unlocking the potential of rainwater harvesting

https://desertrestorationhub.com

Water scarcity is one of the major challenges dry and people are facing today. There is extensive knowledge on water management practices, in particular on rainwater harvesting (RWH). RWH has a great potential to improve water supply, food security, climate resilience, and human well-being by providing affordable and renewable sources of water (Barron et al. 2009). However, the progress in adoption and upscaling the different types of RWH technologies (e.g. Figures 1-4) is slow due to several factors (Table 1).

Table (1): SWOT analysis of RWH technologies

Strengths (+)	**Opportunities (+)**
• Build on local knowledge • Increase water availability • Improve soil quality • Cost-effective in general • Access to drinking water • Reduce women loads to fetch water	• Enormous local knowledge & practices • Growing demands for food, water & energy • Resilient to climate change • Dry land restoration
Weaknesses (-)	**Threats (-)**
• Disputes over water rights • Socio-economic benefits are realized in long term • Loss of agricultural land • High initial investment cost • Slow adoption & upscaling	• Climate change & extremes (e.g. big floods) • Inappropriate policies • Outmigration to cities • Disappearance of local knowledge

Figure (1): Rooftop WH

Figure (2): Macrocatchment WH

Figure (3): Microcatchment WH

Figure (4): Floodwater harvesting (spate irrigation)

The followings are alternative approaches to enhance adoption and upscaling RWH technologies:

Training and Extension: This includes awareness raising, farmer visits by researchers and extension worker, training workshops and seminars on RWH, field educational visits to water harvesting sites, hands-on training and demonstration plots.

Farmer innovations: Stimulating technical innovations by farmers on local knowledge and experiences that have been developed over the years in RWH practices and upgrading the innovative techniques into scientific knowledge through participatory research for wide spread implementation and dissemination.

Farmer field schools (FFS): FFS build up knowledge and capacity of land users to diagnose their problems, identify solutions, develop and implement plans with or without support from the outside. Moreover, FFS provides opportunities for diversified learning processes, e.g. learning by doing (Liniger et al. 2011).

Fact Sheet Topic Area:
Rainwater harvesting

Keywords:
Dry lands, restoration, water harvesting, water management, livelihood security.

Authors:
Mehreteab Tesfai
Norwegian Institute of Bioeconomy Research
Pb 115, NO-1431 Ås
Norway
mehreteab.tesfai@nibio.no

Jannes Stolte
Norwegian Institute of Bioeconomy Research
Pb 115, NO-1431 Ås
Norway
jannes.stolte@nibio.no

Sources for Images
Figures (1), (2) & (3): Mekdaschi-Studer and Liniger (2013)
Figure (4): Khan, R.S. et al (2014)

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Water users association*:* aiming at mobilizing and pooling financial, technical, material, and human resources of land users to operate and maintain the RWH structures. ***Participatory land use planning:*** used for planning communal or common property (for e.g. between upstream and downstream water users) to develop communally binding rules such as water use rights, conflict mitigation at village or catchment scale (Liniger et al. 2011). ***Integrated catchment management (ICM):*** is the co-ordinated planning & management of land, water and other environmental resources for their equitable, efficient and sustainable use at catchment scale (Batchelor, 1999). ICM ensures that upstream developments are not made at the expense of downstream & vice versa. Under ICM, the RWH technologies are linked to the entire value chain i.e. from resource conservation to consumption in which the producers and the consumers mutually benefit from the catchment. ***Multiple use of water services:*** is an approach that recognizes the harvested rainwater will be used for multiple purposes (agriculture, domestic) taken into account the water quality and quantity plus people's water needs and priorities. ***Payment for ecosystem services:*** is the mechanism of offering rewards to land users in exchange for managing their land to provide ecological services (Liniger et al. 2011). Those who benefit pay for the services they get and those who provide, get

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LINKS TO WEB RESOURCES

- *https://www.wocat.net/*
- *http://spate-irrigation.org/spate-irrigation-network/*
- *http://www.harvestingrainwater.com*

RESTORATION STRATEGIES

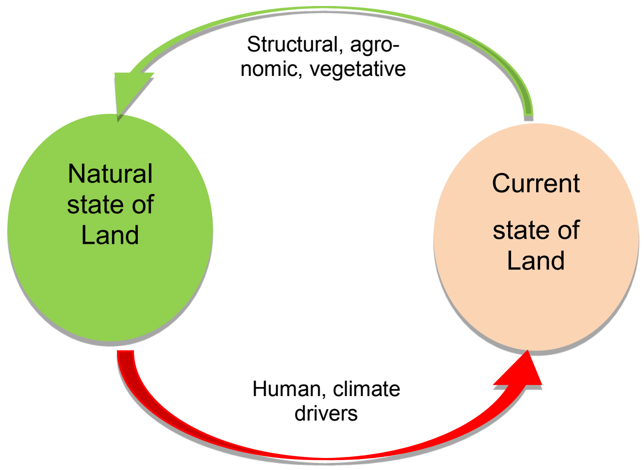

Figure (5): Causes, effects & possible measures to land restoration.

- Establish enabling policies and legislation for (e.g. long- term land lease) that secures land users to invest in permanent RWH structures in combination with other sustainable land management (SLM) practices including agronomic, vegetative and management measures (for e.g. area closure).
- Provide technical knowhow and capacity building on land restoration measures including RWH techniques to the land users and other stakeholders through training and extension.
- Implement the right type of RWH technology i.e. technically applicable, economically viable, socially acceptable and environmental friendly at landscape, catchment & household levels.
- Regular maintenance of the RWH structures and monitor and evaluate their impacts on land restoration and livelihood security.
- Develop cost-sharing strategies (including subsidies), incentives and payment for ecosystem services.

KEY MESSAGES

- RWH practices are not a panacea for all dry land problems but when combined with other land restoration measures (e.g. agronomic, vegetative and management such as area closure) they are more effective in increasing water supply and food security, resilience to climate change and variability and improving livelihood security.
- Selecting the appropriate water harvesting sites and technology under the prevailing biophysical and socio-economic conditions are among the most important prerequisites for successful RWH systems besides reliable rainfall and enabling policies.

Tracking restoration success: using ecological indicators to evaluate the improvement in local conditions

https://desertrestorationhub.com

A critical step in the process of restoration of degraded ecosystems is the evaluation of its success. This is necessary to assess ecosystems composition, structure and functioning, and to evaluate if ecosystem services provision has been restored.

ECOLOGICAL INDICATORS

It is extremely challengin, costly and complex to measure all components of ecosystems, so ecological indicators are used. These are measurable characteristics of the structure, composition, or function of ecosystems (Niemeijer & de Groot, 2008), and are used to evaluate and communicate ecosystems states in a relatively simple way.

FUNCTIONAL DIVERSITY AND SPECIES TRAITS

Several works have shown that functional diversity is better than species richness to understand an ecosystem's response to environmental change (Lavorel et al. 2011). It takes into account species redundancy and includes information of its functions, having also the potential to be universal and applicable at broad spatial scales, as it is not linked to species *per se*. A functional trait is a characteristic of an organism considered relevant to its response to the environment and/or its effects on ecosystem functioning; and its value and range in a given ecosystem are measures of functional diversity (Díaz & Cabido 2001) .

Figure (1): Examples of lichen traits. Main types of photobiont: (a) *Trentepohlia*; (b) other green algae; (c) cyanolichens; (d) jelly cyanolichens.

LICHENS

Lichens are amongst the most sensitive organisms to environmental change, providing signs before other less sensitive components of the ecosystems (Pinho et al. 2009). They respond to micro (Pinho et al., 2010) and macroclimate (Concostrina-Zubiri et al. 2014; Matos et al. 2015), caused for example by loss of vegetation. They also respond to change in air quality and land-use, e.g. changes caused by dust. Lichens respond to environmental change by altering its functional diversity, e.g. the relative proportions of species with different traits, such as a photobiont type (Figure 1).

Fact Sheet Topic Area:
Tracking restoration success

Keywords:
lichens, functional diversity, restoration

Authors:
Paula Matos, FCUL
psmatos@fc.ul.pt

Pedro Pinho, FCUL
paplopes@fc.ul.pt

Laura Concostrina-Zubiri, FCUL
lczubiri@fc.ul.pt

Cristina Branquinho, FCUL
cmbranquinho@fc.ul.pt.

Geographic location:
Portugal

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Changes in lichen functional diversity can be used to track the success of restoration, even in its early stages. Standard methods are available to measure these changes.

USING LICHENS AS ECOLOGICAL INDICATORS

Excessive grazing leads to degradation of soil protection and quality, but adequate management can be used to restore these services. Lichens growing in soil will change along the degradation and recovery process (Concostrina-Zubiri et al. 2015) by altering the proportion of fruticose and foliose growth forms (Figure 2a).

Macroclimatic change, caused for example by the ongoing climate change, will impact local conditions. Lichens living on tree trunks respond to these changes by shifting the proportions of species with different photobiont types (Matos et al., 2015), from the cold humid -loving cyanolichens species, to the water-stress tolerant species with green-algae (Figure 2b).

Dust from soil resuspension, caused for example by processes of desertification and land-degradation will decrease air quality. Lichens living on trees will respond to that (Pinho et al., 2008) with a replacement of pollution-sensitive species by pollution-tolerant ones, such as the nitrophytic replacing the oligotrophic species (Figure 2c).

RESTORATION STRATEGIES

Lichen function diversity measured in optimal conditions can be used to set the goal of restoration of degraded ecosystems (reference state). Lichen functional diversity characterization in degraded sites can be used to understand which ecosystem functions have been decreased and how far it is from the reference state.

Monitoring these changes during the restoration process can be used to track its success in reestablishing ecosystem biodiversity and functions.

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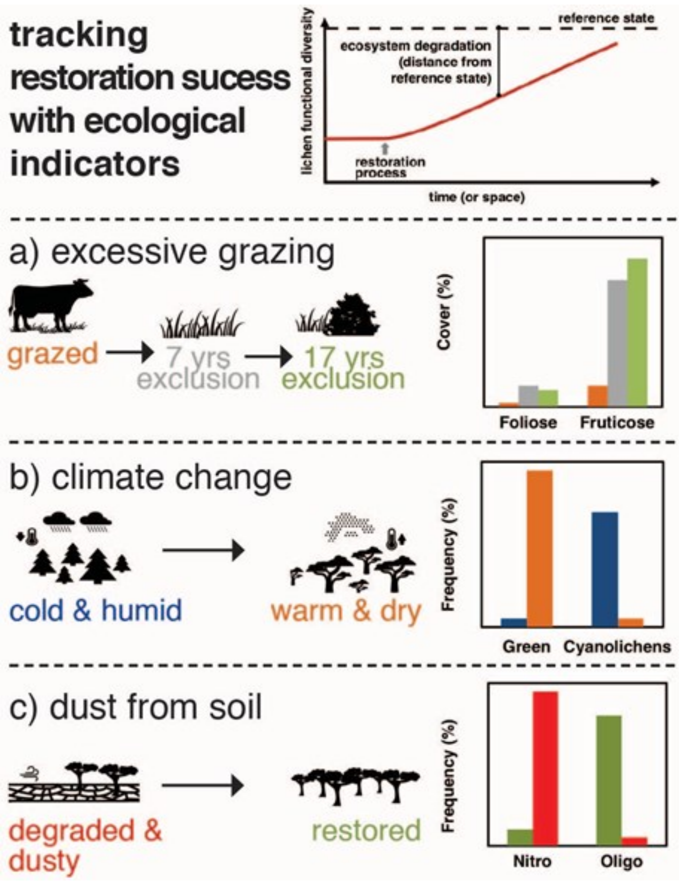

Figure (2): Conceptual framework to track restoration success using lichen functional diversity.

Adaptation to climate change by planting drought tolerant native plant species

https://desertrestorationhub.com

According to the IPCC's (Intergovernmental Panel on Climate Change) first report in 1990 global average temperature increases were between 0.15°C and 0.3°C per decade. This can now be compared with observed values of about 0.2°C per decade—an unavoidable global problem leading to an increasing drought risk. Figure 1 projects the earth's surface warming to 2100 with a decrease in winter and spring precipitations (Demir et al., 2013). The projected change affects the years between 2013-2099 The problem is inevitable and "adaption" is seen as one of the solutions to combat climate change. One of the solutions for achieving adaptation to climate change lies in plantaing with native species.

In order to chose native plants for dryland restoration, various considerations have to be taken into account: Even native species have different provenance. Being native to a region is not sufficient, it also need to be matched to the purpose and be local for successful restoration and long term survival. Conventional planting schemes can make strong first impression but may fail to survive hard (drought) environmental conditions.

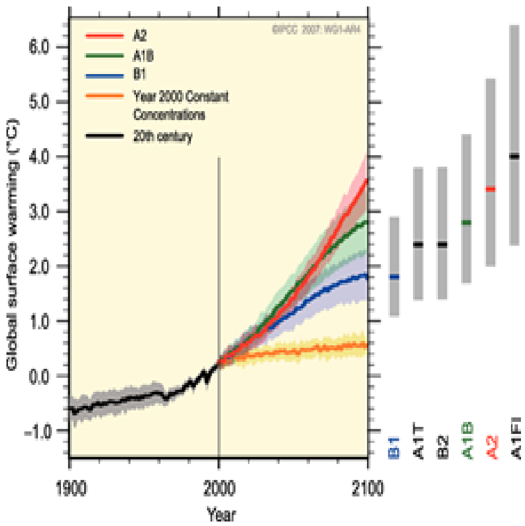

Figure (1): Multi Model Averages and Assessed Ranges for Surface Warming (Best estimates for global average surface air warming for six SRES emissions marker scenarios, each colour represents different scenarios)

Rather then local cultivated plant species, cultivated for properties of reduced dormancy and enhanced speed of germination, it has proven advantageous to chose species with well developed dormancy and/ or slowed down germination processes as this aids long-term survival. Another related research study on the subject of the adaptation potential of Mediterranean native species to climate change demonstrated that native species had limited dispersal and migration capabilities beside their resistance to hard drought conditions. Regarding planting techniques; seeds should be stratified in restoration areas. Especially groundcovers hold the fine soil with hairy root system.

Fact Sheet Topic Area:
Adaptation to climate change and aridness; Adaptation to extreme conditions; restoration with native drought tolerance plant species.

Keywords:
Adaptation, restoration, climate change, native plant species.

Authors:
Beyza Sat Gungor Ph.D
Ozyegin University,
Faculty of Architecture and Design,
beyza.gungor@ozyegin.edu.tr

Geographic location:
Turkey, Istanbul

Climate Classification (Koppen):
Csa

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A stratified structure helps combat erosion and should be planned from ground level up: firstly, ground cover is used for the stabilization of soil. Then this level of planting can be added to and supported with shrub and tree species in appropriate areas. A stratified approach and structure is important due to ensure plant survival and sustainability (Maiti, 2013).

According to Turkey's current restoration research studies for drylands some edible native groundcover species are remarkable. Currentl research focuses on both alternatives for agri-food production and restoration together. These species are *Capparis spp., Acantholimon spp., Astragalus spp., Euphorbia spp., Thymus L., Rosmarinus officinalis L., Calendula officinalis L.* and *Cartamus tinctorius L.* The species are tested and are shown to survive in rocky, shallow soil conditions as well as in drought and extreme temperatures.

These and other native, local species that are drought tolerant should be used for restoration studies.

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- http://guncelbilgiyazar.blogspot.com.tr/2015/01/kurak-ve-yarkurak-bolgelerin.html
- http://dergipark.ulakbim.gov.tr/sdumuhtas/article/view/5000147638/5000145721
- http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0006392

RESTORATION STRATEGIES

Planting is one tool in the restoration of drylands. To achieve this goal, some techniques and approaches need to be considered: These are

1. Determining the local native plant species and its provenance for a restoration area,
2. Production / cultivation of chosen plant species (nursery establishment, etc)
3. Repikaj process to produce healthy seedlings.
4. Preparing the restoration area for planting, for instance creating ditches to hold water.
5. Planting using appropriate techniques and considering a stratified structure as well as plant species that are similar the to natural compositions

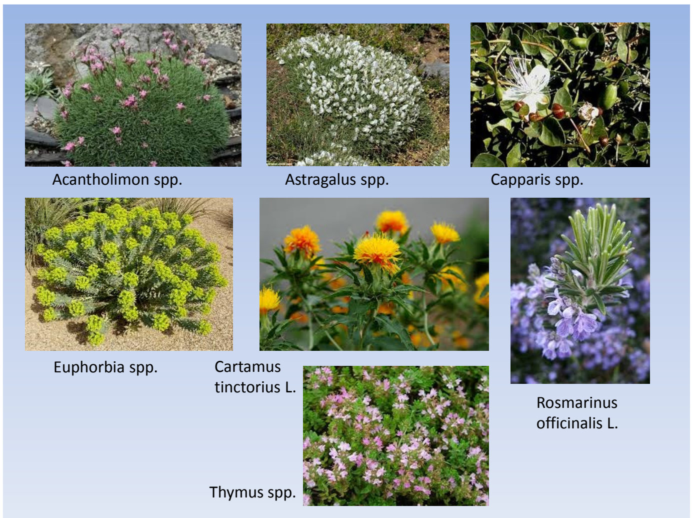

Figure (2): Some of the drought tolerance native plant species that have been focused on recent researches.

Revegetation techniques: use of biosolids in dryland restoration

https://desertrestorationhub.com

Mediterranean forest soils usually are shallow, with high stoniness and poor structure and low content of organic matter and nutrients. The proportion of humic substances is also relatively low revealing a predominance of mineralization over humification processes. In addition, vegetation in degraded drylands is scarce and patchy and soil microbial populations are highly altered and with a low proportion of simbionts. Water availability is the main key factor determining seedling establishment in restoration actions of drylands, but soil fertility (organic matter and nutrients) is especially important in shallow poor-structured soils although subordinated to water stress. Biosolids or sewage sludges are the refuse produced during the depuration process in the waste water treatment plants (WWTP). The origin of the waste water and the specific treatment determine the physicochemical characteristics of the sludge. In general, they contain high amounts of organic matter and nutrients (nitrogen, specially, and phosphorus, but low potassium as this nutrient is lost throughout the depuration process). They can also contain heavy metals, in case of WWTP close to industrial areas, and pathogens, if no thermal treatment/composting is conducted. Specific analytics of sludges are required before their application on the land.

The largest proportion of both N and P in the biosolids corresponds to organic forms reducing the risk of leaching as these forms are less mobile than the inorganic ones. Losses of N by volatilization are minimized by incorporating the biosolid into the soil. Nutrients in organic forms are mineralized gradually and the effects on planted seedlings last longer than in case of inorganic fertilizers. On the other hand, the application of organic amendments to soils promotes microbial activity and improves soil physical properties such as infiltration, water holding capacity and aggregate stability. These have

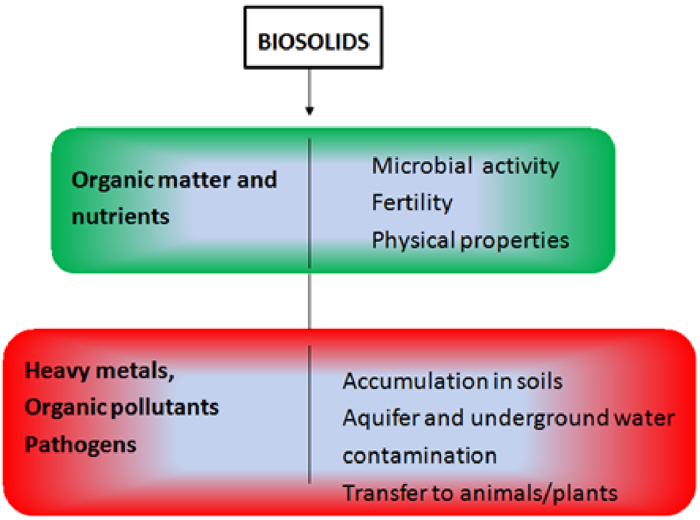

Figure (1): Positive (green box) and potential negative (red box) impacts of the application of biosolids in drylands restoration.

Fact Sheet Topic Area:
Revegetation Techniques

Keywords:
Compost, planting seedlings, salinity, sewage sludge.

Authors:
Alejandro Valdecantos
Fundación CEAM
Valencia
Spain.
a.valdecantos@ua.es

David Fuentes
Ecodrone Works
Alicante
Spain.
ecodroneworks@gmail.com

Geographic location:
Mediterranean Basin

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The application of biosolids in drylands usually does not improve the survival of planted seedlings or even can increase seedling mortality. This negative effect is related to:

- The increase of soil electrical conductivity as a consequence of, at the short term, the high salinity of some sludges and, at the medium term, the mineralization of the organic matter
- The proliferation of competitive native vegetation, mainly grasses
- Using high doses of fresh sludge with a high water content can result in physical problems (as cracks and holes) in the soil as sludge dries out

The main positive effect of biosolids on the introduced seedlings is in a significant increase of plant growth. Vegetation, both natural and artificially planted, in many drylands is limited by nutrients (especially by P in carbonated soils) and the application of these biosolids which are rich in organic matter and nutrients reduces these limitations, releasing deficiencies and promoting ecophysiology and, finally, growth. However, seedling growth is enhanced only once a minimum threshold of water availability is guaranteed and seedling survival is not compromised.

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- http://www.epa.gov/biosolids

RESTORATION STRATEGIES

In general, the application of biosolids in Mediterranean degraded drylands:

- Does not change seedling survival;
- Low to moderate application doses (10-30 Mg dry weight ha-1) promote seedling growth and restoration success; and
- The increase of soil electrical conductivity is the main negative effect, especially when combined with severe drought episodes.

The use of biosolids can be a useful technique in actions devoted to the restoration of the vegetal cover of degraded drylands.

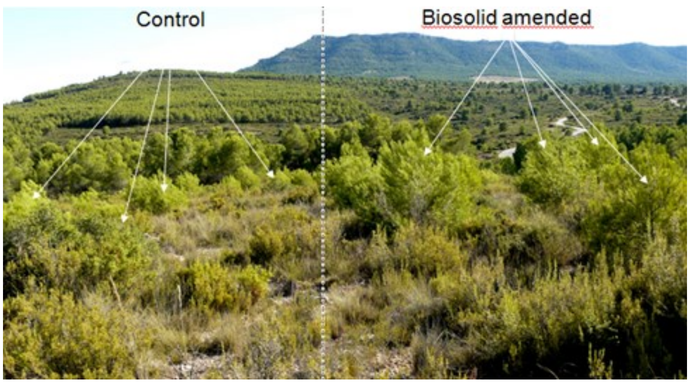

Figure (2): At the forefront, reforestation with *Pinus halepensis* seedlings in Zarra (Valencia, E Spain) with and without the application of biosolids. The picture was taken 10 years after planting.

Restoring plant communities: the importance of research on seed ecology

https://desertrestorationhub.com

For many reasons seeds play a pivotal role in plant community restoration. First of all, seeds are usually easy-to-collect from the wild and can be stored in relatively small spaces, making possible the *ex situ* conservation of entire plant communities in structures devoted to seed conservation, such as the germplasm banks. This invaluable opportunity is the result of the huge progress of the last years in the seed science (Li and Pritchard 2009). The just collected and/or stored seeds are then available for both laboratory, glasshouse and field investigations, into seed dormancy, germination requirements and soil seed bank, or storage aimed towards ecological restoration. In fact, since many activities of plant community restoration are carried out starting from seeds, it is of vital importance to know the environmental conditions required to break seed dormancy and those required for seed germination after dormancy is broken, in order to know precisely how to treat the seeds before their introduction and when and how to sow them to ensure successful restoration. Understanding how to stimulate the germination of specific plants is also useful if we want to propagate them *ex situ* and then to perform the community restoration through transplants rather than through direct sowings.

Laboratory/glasshouse research. The prediction of successful recruitment in the field and regeneration after disturbance rely on laboratory (Cochrane et al. 2002) and glasshouse research into germination requirements (i.e. light, temperature, water potential, plant-plant interaction, etc.). Comparative germination experiments among different seed provenances of the same species are helpful for deciding which one is more suitable for the specific restoration project. Several studies demonstrated that seed provenance matters in species reintroductions and habitat restoration (Bischoff et al. 2006; De Vitis et al. 2014). Large between-provenance differences in the germination traits can affect the early development of the target community and thus the success of short- and medium-term ecological compensation areas. Selection is expected to favour appropriate responses to local environmental cues and may result in site-specific adaptation of germination traits (Bischoff et al. 2006).

Figure (1): Germination test of *Malcolmia littorea* seeds. This species occurs in the sandy coastal habitats of the SW Europe and the NW Africa. The germination requirements of this endangered species were investigated in order to contribute to its conservation strategy (De Vitis et al. 2014).

Fact Sheet Topic Area:
Seed ecology

Keywords:
Seed, dormancy, ex situ conservation, germination requirements, restoration.

Authors:
Marcello De Vitis
Scotia Seeds Ltd.
Mavisbank
Angus DD9 6TR
Scotland
UK
marcellodevitis@scotiaseeds.co.uk

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Field research. *In situ* sowing experiments offer a direct way to identify the suitable conditions for seed germination and seedling establishment of the plant species of a target community. Common treatments of the sowing plots include vegetation mowing and mulching and/or soil plowing. Sowing trials are also useful to understand whether suitable, unoccupied habitat patches exist at a regional scale and to study dispersal limitation from nearby patches (Turnbull et al. 2000). Finally, investigation and knowledge acquisition on soil seed bank densities and composition play a significant role in many aspects of practical land management and restoration because it may provide useful information about the former plant composition of a degraded habitat. When a soil seed bank occurs it might act as a natural source of seeds for a community recovery only if other common measures of restoration, such as the topsoil removal, useful to remove nutrients from a eutrophic grassland with a mineral soil, are avoided (Bakker et al. 2005).

RESTORATION STRATEGIES

Prior to community restoration, acquiring knowledge about the species reproductive biology and ecology is highly recommended. In the last years, the attention of research towards the investigation on native seeds aimed towards restoration activities has notably increased as the number of small and medium enterprises devoted to the native seed production (e.g. Scotia Seeds Ltd., UK; Semillas Silvestres, Spain). The NASSTEC (Native Seed Science, Technology and Conservation Initial Training Network) project, funded by the EU seventh framework programme and started in 2014, is currently one of the widest European initiatives that links academia, the private sector and stakeholders for native seed research, production and use for restoration purposes (www.nasstec.eu). For examples of outstanding conservation projects, including projects on drylands restoration, please visit http://www.kew.org/science-conservation/research-data/science-directory/projects.

Figure (2): Emergence of *Malcolmia littorea* (San Felice Circeo, Italy) following an experimental seed sowing as part of a reintroduction plan.

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Plant assisted bioremediation as a green technology for recovering a historically contaminated soil from PCB contamination

Phytotechnologies not only promote degradation of pollutants, but also give additional benefits such as soil quality improvement, soil carbon sequestration and provide biomass for energy production. The remediation of multiple contaminated sites (e.g. from organic and inorganic toxic compounds) is a very complex issue and plant-assisted bioremediation can be an effective green strategy for soil recovery (Abhilash *et al.,* 2012).

A poplar-assisted bioremediation strategy has been applied to a contaminated site located close to Taranto city (Puglia Region) in Southern Italy. The site has been used for several decades as an unsupervised waste disposal tip. It was contaminated by trace concentrations of both PCBs and heavy metals (Be, Sn, Pb, V, Cd, Cu, Zn) and in some areas the legislation limits were also exceeded. Soil texture analysis conducted initially showed the presence of inhomogeneous textural classes; soil was characterized by a pH ranging from 7 to 7.5, a scarce amount of the main nutrients (N, P, K) and of organic carbon. Haphazard vegetation covered the area before the planting scheme began.

A clone of poplar (*Populus generosa x Populus Nigra*), already applied successfully in a previous work (Bianconi *et al.*, 2012), was used for plant-assisted bioremediation of a PCB and heavy metals (Be, Sn, Pb, V, Cd, Cu, Zn) contaminated soil. In the experimental area (750 m^2) about 650 poplar cuttings were planted in 8 rows and mulching was carried out for each planting row to control the developing of weeds. An accurate drip irrigation system was then set up.

Owing to the low amount of minerals (N, P, K), organic carbon (C) and low bacterial activity municipal waste compost was added (26 tons ha^{-1}) for improving soil quality and promoting synergistic plant–microbe interactions (Grenni *et al.,* 2009; Barra Caracciolo *et al.,* 2015).

Figure (1): Poplar cutting plantation on the contaminated soil.

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Fact Sheet Topic Area: Soil Remediation and Plants

Keywords:
Plant assisted bioremediation, PCB contaminated soil

Authors:
Valeria Ancona[1*], Anna Barra Caracciolo[2], Paola Grenni[2], Martina Di Lenola[2], Claudia Campanale[1], Vito Felice Uricchio[1], Angelo Massacci[3]

[1]Consiglio Nazionale delle Ricerche, Istituto di Ricerca Sulle Acque (CNR-IRSA), Bari, Italy

[2]ConsiglioNazionaledelleRicerche, Istituto di Ricerca Sulle Acque (CNR-IRSA), Roma, Italy

[3] Consiglio Nazionale delle Ricerche, Istituto di Biologia Agroambientale e Forestale (CNR-IBAF), Roma, Italy

*valeria.ancona@ba.irsa.cnr.it

Geographic location:
Taranto, Apulia Region (Italy)

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One year after the poplar planting, chemical analysis showed a general decrease in both PCB_S and heavy metals. The synergic action of plants and naturally occurring microorganisms promoted biodegradation of the organic contaminants and the phyto-containment of the inorganic ones. A general improvement of the soil quality was also observed in terms of bacterial activity. However, microbiological analysis for identifying the microbiological populations directly involved in the biodegradation process are in progress.

Figure (2): Development of first shoots from poplar cuttings

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RESTORATION STRATEGIES

How can the issue described in the fact sheet be used to improve restoration?

- to promote a rapid cover of the contaminated soil by using tree species to improve soil quality and landscape;
- to check tree growth adopting opportune cultural practices to control the spreading of weeds and to favour a rapid poplar rooting;
- to use organic fertilizers such as compost to biostimulate both microbial activity and plant development

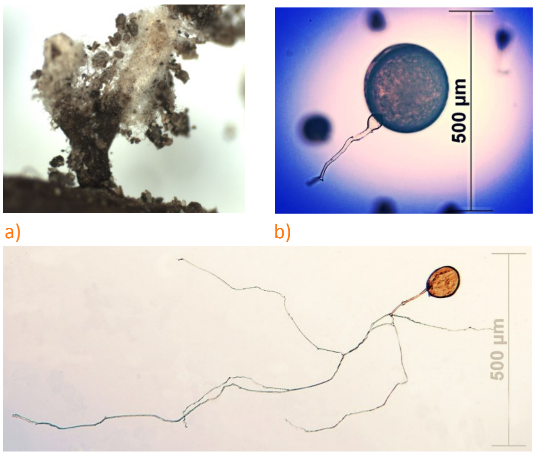
Figure (3): Growth of poplars 1 month (above) and 5 months (below) after the planting.

Afforestation to combating desertification: does mycorrhiza inoculated seedling increase arid and semi-arid land afforestation success in Turkey?

https://desertrestorationhub.com

Mycorrhizae are the symbiotic associations between soil fungi and plant roots (Frank 1885). Mycorrhizae play an important role in afforestation. Because of its latitudinal position and the rain-shadow that arises from the Taurus Mountains on the south and Black Sea Mountain series on the north, about 2/3's of Turkey's land cover is considered as arid and semiarid. Interactions of climate and anthropogenic disturbances on vegetation cover have for a long time made these steep hilly terrains prone to both water and wind erosion. Thus the biggest challenge for Turkish foresters is afforestation of these erosion prone arid and semiarid lands.

Approximately 5.25 million ha of land area is socially, economically and ecologically feasible for afforestation practices in Turkey. A considerable amount of these potential afforestation areas suffer from water deficiency during the growing season. Data from different parts of the world suggest that mycorrhiza inoculation can significantly promote plant growth in such stressful environment. Thus using mycorrhiza inoculated seedling may increase plantating success in these water deficient landscapes of Turkey.



a) b) c)

Figure (1): (above)

(a) Mycelium (b-c) Mycorrhizal spores

(Photos by Bulent Toprak)

Figure (2): ***(right)*** Growth differences of Cedar (*Cedrus libani*) seedlings without (left) and with-mycorrhizae (right) inoculation grown in inland part of Turkey. (Photo taken 3 years after inoculation)

Fact Sheet Topic Area:
Myorrhiza

Keywords:
Mycorrhiza, afforestation, arid/semi-arid land, pine, cedar, oak.

Authors:
Bulent Toprak
Duzce University
Forestry Faculty
Turkey,
bulenttoprak@duzce.edu.tr

Geographic location:
Turkey

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Figure (3): Turkish Oak (*Qercus cerris*) seedlings with-mycorrhizae inoculation grown in inland part of Turkey. (Photo taken 3 years after inoculation)

The project is entitled "Differences in Survival, Growth and Nutritional Status of Ectomycorrhiza and Arbuscular Mycorrhiza Inoculated Black Pine (*Pinus nigra*), Cedar (*Cedrus libani*) and Turkish Oak (*Quercus cerris*) Seedlings in Semi-Arid Ecosystems in Turkey".

Preliminary results of the nursery study indicate that seedling height, root collar diameter, root length, leaf area index, shoot dry weight, root dry weight, shoot fresh weight, root fresh weight and shoot to root dry weight ratio and Dickson quality index were significantly different (P-value <0.05) among treatments (mycorrhizal and non-mycorrhizal) for Black Pine, Cedar and Turkish Oak. Results of field trial data revealed that seedling height, root collar diameter, leaf area index, survival rate, soil nutrient loss, soil and leaf nutrient content, soil moisture were significantly different (P-value <0.05) among treatments (mycorrhizal and non-

SELECTED KEY REFERENCES

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RESTORATION STRATEGIES

Mycorrhizal fungi occur naturally in all soil where plants grow. But events such as site preparation, erosion, drought, overgrazing etc. reduce mycorrhizal fungi in soil. Beneficial mycorrhizal fungi are often eliminated in disturbed soils and thus artificial mycorrhiza inoculation is necessary.

Mycorrhizae inoculation can significantly increase the survival rate and growth of seedling and enhance ability of seedling to cope with stress situations such as high lime, water and nutrient deficiency. Thus using mycorrhiza inoculated seedling may increase success of restoration in semi-arid areas.

Figure (4): Black Pine (*Pinus nigra*) seedlings without mycorrhizae and low survival rate on the left and inoculated seedlings with high survival rate on the right. (Photo taken 3 years after inoculation)

Agricultural intensification: agroecosystems degradation and restoration

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Agroecosystems (ecosystems used for agricultural production) cover almost half of the Earth's surface. Their expansion and exploitation are considered among the main causes of terrestrial habitat destruction. However, agriculture has a complex relationship with agroecosystems conservation. On the one hand, agricultural productivity is negatively affected by the effects of ecological degradation, but, on the other hand, many agricultural practices seriously damage the production systems themselves.

From the 1950s-60s, the incorporation of technological advances in farming led to important increases in crop production (yields doubled without equivalent increases in arable land surface) through profound changes in agricultural practices. The introduction of high-yield crop varieties (the green revolution) was accompanied by heavy use of chemical inputs and farm mechanization.

This agricultural intensification has had very negative effects in agroecosystems, causing soil damage (erosion, compaction) and biodiversity loss at every scale, from soil communities to landscape elements. Thus, intensive agriculture represents a major threat to ecosystems function, since maximization of provisioning services has been achieved at the expense of important supporting and regulating (even cultural) services.

Figure (1): Photo of the study area, cereal crop agroecosystem, in Central Iberian Peninsula. Buildings at the end of the image are the city of Madrid.

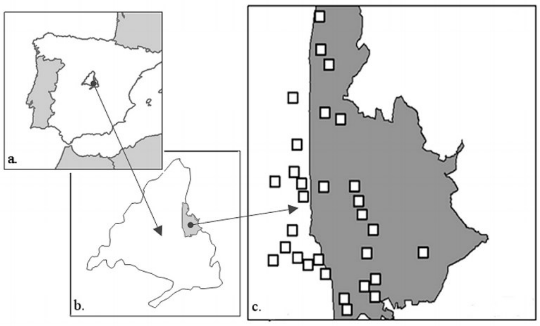

Figure (2): Map showing the study area location in central Iberian Peninsula and the 30 sampled groups of cereal fields. Shadowed region in images b and c represents the extension of a regional protected area.

Fact Sheet Topic Area:
Agroecosystems

Keywords:
Agriculture, biodiversity, ecosystem services

Authors:
Irene Guerrero
INEA-Universidad de Valladolid, Spain.
Irene.guerrero@inea.uva.es

Geographic location:
Madrid, Central Iberian Peninsula
40°40’N, 3°25’W

Climate Classifcation (Koppen):
Bsk

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CASE STUDY

In an agricultural area in central Spain, we studied the effect of agricultural management on farmland biodiversity measured as species richness of birds, carabids and vascular plants.

We collected data in 30 groups of cereal fields where the selection was based on grain yield along a gradient of management intensification. This agricultural land use intensity was measured at two distinct spatial scales: plot and landscape.

We observed that, for the three biological groups, species richness showed a negative response to agricultural land use intensity. Nevertheless, each group response was related to different management factors and spatial scales probably due to their different ecological requirements and dispersal capabilities. Thus, giving an idea of the complexity of the relations between agricultural intensification and the components of agroecosystems.

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RESTORATION STRATEGIES

Ecological restoration in agricultural systems requires significant changes in industrial agricultural practices. Farming systems need to be sustainable and their management must facilitate restoring of ecosystem function, allowing ecosystem services delivery.

Agricultural policies around the world tend to halt this ecological degradation by encouraging farmers to apply practices that benefit agroecosystem functioning.

Some of these measures include:

- Agricultural landscape restoration by including trees, hedges, fallow lands, non-crop field margins and other landscape features.
- The diversification of crops both across space and over time.
- Reducing fertilizer and pesticide use and improving soil protection.

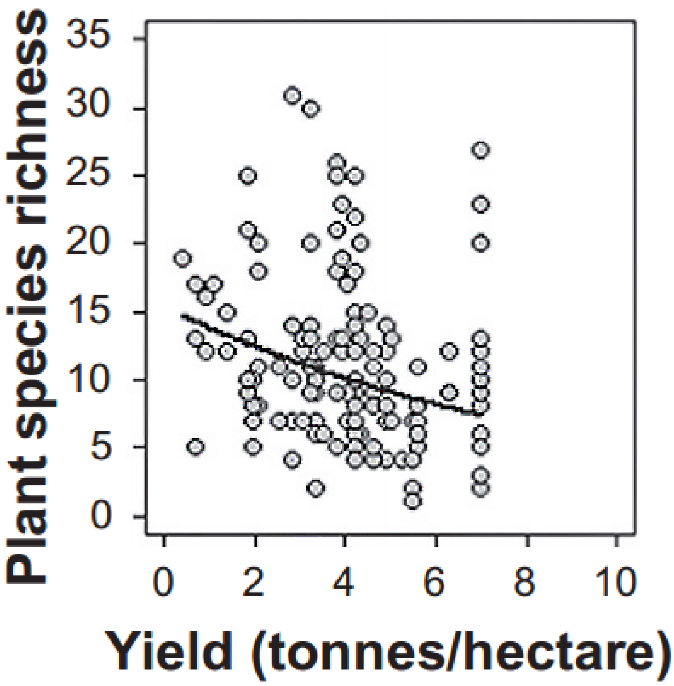

Figure (3): Response of plant species richness to agricultural management intensity measured as grain yield at the case study area. From Emmerson, M., et al., 2016.

Invasive plants in agricultural ecosystems: an emerging issue in sustainable yields

https://desertrestorationhub.com

Agricultural ecosystems are the most dynamic habitats facing frequent distructive disturbances. The movement of goods, land preparation, irrigation practices, plant protection measures and harvesting of crops are the forms of disturbances faced by agricultural habitats (Farooq et al., 2015). The increasing occuurence of invasive plants in agricultural habitats is being reported in different parts of the world since the last decade. The most prominently reported invasive plants include Ambrosia artemisiifolia L., Cyperus esculentus L. and Eleusine indica (L.) Gaertn., Sorghum halepense (L.) Pers. etc, particularly in Europe (Essl et al., 2009).

The invasive plants not only compete for moisture and nutrients and decrease the yield, but also make cultivation difficult with increased costs. The enormous reproductive capacities of invasive plants result in dense monoculture stands soon after their first occurrence in new localities. The rapid invasion is the result of their tolerance to adverse environments, resistance to applied herbicides and tillage practices. Majority of the recorded invasive plants exhibit tolerance for warm climates, therefore these are indications that increasing aridity with changing climate will further worsen the situation (Folak and Essl, 2012).

Agricultural crops such as sunflower, rice, maize, wheat, soybean, horticultural crops etc. are being invaded by several exotic plants. For exmple, ragweed has been pointed out as an emerging threat for sunflower production and human health in Turkey (Ozaslan et al., 2016). The plant exhibit higher tolerance to abiotic stresses (drought and salinity) and soil types indicating that ragweed will have competition advantage over sunflower with changing climate.

Figure (1): Monoculture of common ragweed resulting in increased cultivation cost.

Figure (2): Common ragweed in sunflower field, complete failure of crop.

Fact Sheet Topic Area:
Restoration

Keywords:
Invasive plants, Agricultural ecosystem.

Authors:
Shahid Farooq
Gaziosmanpasa Univ.
Faculty of Agric.
Plant Protection Dept.
Tokat, Turkey
csfa2006@gmail.com

Huseyin Onen
Gaziosmanpasa Univ.
Faculty of Agric.
Plant Protection Dept.
Tokat, Turkey
huseyin.onen@gop.edu.tr

Hikmet Gunal
Gaziosmanpasa Univ.
Faculty of Agric.
Soil Science & Plant Nutrition Dept.
Tokat, Turkey
hikmet.gunal@gop.edu.tr

Geographic location:
Turkey

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The cultivation, irrigation and fertilization practices in irrigated agricultural areas benefit weeds including the exotic plants for growth and dispersal. Therefore, appropriate management with these plants in irrigated arid and semi-arid regions will improve the production.

Besides, Improper irrigation practises and use of low quality water (saline) raise the soil salinity thet negatively impacts the cash crops while favours the little or no harm to invasive plants. Therefore, invasive plants pose severe risks for sustainable yields in different habitats.

The presence of invasive plants not only threatens the sustainable yields of crops but also presents severe risk for soil health and land value. Invasive plants change the nutrient cycle and extract available nutrients leaving soils less fertile. Invasive plants may cause substantial change in the soil microbial communities which are involved in improving the soil fertility. With the change in below ground communities, the above ground communities are also changed thus converting the habitat into a different environment. The presence of invasive plants in arid ecosystems can also virtually make productive lands barren. As moisture is the most vital element in these habitats, invasive plants extract the available moisture and nutrients thus making the soil resource poor. Moreover, production of enormous amounts of vegetative structures (seeds, rhizomes etc) and the subsequent spread, decrease the land value (price). The world population is increasing rapidly and more food will be needed in the coming decades. The increasing food demands can be met either through cultivation of more area or/and sustaining and improving yields. Increasing aridity has already been accepted as a barrier for sustainable agriculture. Plant invasions can halt both of the options if left unaddressed. Therefore, concrete efforts are needed to reduce the negative impacts of invasive plants in agricultural ecosystems.

The lack of unawareness of farmers about the adversities of invasive plants is worsening the severity of social and economical impacts. It has widely been accepted that success of management and prevention of invasive plants lies in public awareness and acceptance of the issue. The public must be informed through media and other available means. Prevention, is always better than cure, therefore the introduction of invasive plants should be avoided through using clean seeds and equipment. A tough stance should be taken on any new occurrences of invasive plants in agricultural habitats. The risks associated plants introduced for soil reclamation should be kept in mind. Expert advice should be taken for the effective management of invasive plants.

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Figure (3): Occurrence of invasive vines in kiwi plantations from Black Sea region of Turkey

Figure (4): Various invasive plant in a maize filed from Thrace Region of Turkey

Figure (5): Heavy infestation of different invasive weeds in tea plantation from Black Sea Region of Turkey

Impacts of invasive plants on ecosystem functioning and biodiversity in terrestrial ecosystems

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Biological invasions are a major threats to ecosystem functioning and native biodiversity. A conservativeestimate indicated that invasive species are responsible for the decline of 42% of U.S. endangered species. Furthermore, in the rest of the world 80% of extinctions of endangered species are due to the invasion of non-native species (Pimentel et al., 2005).

Exotic plant invasion poses serious global and regional ecological and conservation threats to native biodiversity. Invasive species is the 2nd largest reason for biodiversity loss after habitat defragmentation (Gaertner et al., 2009). Besides replacing the native species, invasive plants also change the ecology of a given habitat by changing the nutrient cycle and soil pH (Drenovsky et al., 2007). Decreased pH can lower nutrient availability resulting in decreased native plant growth, particularly on nutrient poor sites. Native plants are also important mediators of interactions between associated insects, pathogens and other plants. Therefore, invasive plants can significantly alter native biodiversity including plants, insect and microbial communities. Due to the absence of natural enemies and greater tolerance, invasive plants rapidly expand their range in different habitats including roadsides, abandoned lands, agricultural habitats, waste lands, forests etc. Invasive plants form dense monocultures (Figure 1) which replace many native species changing the ecology of habitats. The monocultures replace the range of native plants, insects and microbial communities thus disrupting ecosystem services.

Figure (1): Dense monoculture of *Sicyos angulatus* L. (Bur cucumber) in Black Sea region of Turkey.

Figure (2): Dense monoculture of common ragweed in pasture of Thrace region of Turkey.

Ecosystem services are the benefits provided by ecosystems which make human life possible and worth living. The services can be divided into four categories i) supporting (nutrient cycling), ii) provisioning (food, fibre), iii) regulating (carbon sequestration) and iv) cultural services (recreation, tourism). Due to the replacement of native communities with invasives, these services are severely affected impairing the functioning and productivity of ecosystems.

Fact Sheet Topic Area:
Restoration

Keywords:
Invasive plants, Ecosystem functioning, Biodiversity.

Authors:
Huseyin Onen
Gaziosmanpasa Univ.
Faculty of Agric.
Plant Protection Dept.
Tokat, Turkey
huseyin.onen@gop.edu.tr

Shahid Farooq
Gaziosmanpasa Univ.
Faculty of Agric.
Plant Protection Dept.
Tokat, Turkey
csfa2006@gmail.com

Hikmet Gunal
Gaziosmanpasa Univ.
Faculty of Agric.
Soil Science and Plant Nutrition Dept.
Tokat, Turkey
hikmet.gunal@gop.edu.tr

Geographic location:
Turkey

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The change in ecosystem services depends on the type of habitat invaded. Invasive plants invading agricultural lands severely decreases the productivity as well as land values (Figure 3). The invasion of pastures leads to loss of forages and forage value. Incidence of fire in forests, loss of asthetic beauty in parks and gardens are the other ecosystem services severely impacted by invasive plants. The increased incidence of fire due to exotic plant invasions completely change the ecology of habitats. Large-scale invasion of *Bromus tectorum* in North America has permanently, altered the native plant community (Chambers et al., 2007). A similar transformation has occurred in Hawaii following the invasion of exotic grasses.

Centaurea solstitialis has decreased the recreation value of large areas in the western United States as well as costing millions of dollers per year with losing the livestock forage values (Eagle et al., 2007). Moreover, different invasive plants influence the nutrient cycling function of soils. Severe changes in the nutrient cycling causes vital disturbance in the nutrient regimes which results in the replacement of species. *Heracleum mantegazzianum* is reported to increase soil conductivity, pH and extractable phosphorus, and decrease the fungal/bacterial ratios.

The increasing incidence of common ragweed in sunflower fields has been recently reported in Turkey. The plant has resulted in complete failure of sunflower crop in different parts of the Thrace region of Turkey. Moreover, the occurrence of ragweed along roadsides causes allergy problems to ragweed allergenic populations. Invasive plants can also increase the risk of floods by narrowing stream channels and decreasing holding capacity (Figure 4).

The adverse impacts of invasive plants need to be addressed. The impacts can be minimized through following steps:

- Prevention and quarantine laws
- Early detection
- Spatial mapping
- Awareness and eradication camapaigns
- Effective monitoring
- Regulating seed imports
- Management practices

Figure (3): Mile-a-minute weed and tree of heaven in natural habitat causing reduction in land value and replacing native species.

Figure (4): Different invasive plants along stream side.

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Ecological study of vegetal cover and soil under cement dust pollution: case of Gabès cement plant southeastern Tunisia

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The increase in industrialization, extensive urbanization, mining and industrial activities have been stated among the main causes of soil contamination which have a negative impact on the quality of the environment (Abanuz, 2011). In recent years soil pollution has been marked as an important environmental issue in both developed and developing countries which face a serious pollution problem (Abanuz, 2011, Esmaeli et al, 2014). The establishment of a cement plant in urban area generates damage in the deterioration of air quality. It affects not only the soil-plant interface but also human health and the latter is the result of heavy metal transfer through the food chain (crop uptake and soil ingestion by grazing livestock (Nicholson, 2003, Bermudez et al, 2010). One of the current research soil decontamination methods for heavy metal polluted matter is phytoremediation which is the use of plants to accumulate contaminants and to restrict their contamination from the polluted source through phyto-rehabilitation, phyto –extraction and phyto-stabilization. This study fits into the framework of the study of industrial pollution impact on the natural vegetal cover and the selection of pollution-resistant plants in order to revegetate contaminated soils. In this factsheet an ecological study of vegetal cover in a highly contaminated site situated near Gabès cement plant in southeastern Tunisia is discussed. Four sites were chosen according to their distance to the cement plant (Site 1 at 1 Km, site 2 at 3Km, site 3 at 6Km and site 4 at 12 Km).

Figure (1): Gabes Cement Plant

Fact Sheet Topic Area:
Ecology and phytoremediation

Keywords:
Industrial pollution, vegetal cover

Authors:
Ines Bayouli
Arid Regions Institute
IRA Médenine
Tunisia
Bayouli_ines@yahoo.fr

Geographic location:
Gabes, Tunisia.

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Surveys of vegetal cover were carried out assessing biodiversity, variations between sites according to species abundance and variations in floristic composition. The most abundant perennial species found in the first site were *Helianthemum intricatum, Gymnocarpos decander* and *Atractylis serratuloides.* The second site is characterized by the presence of *Gymnocarpos decander, Annarhinum brevifolium* and , *lygeum spartum* . These species are distributed along the four sites and selected for phytoremediation and in order to prove their nurse potential within degraded soils.

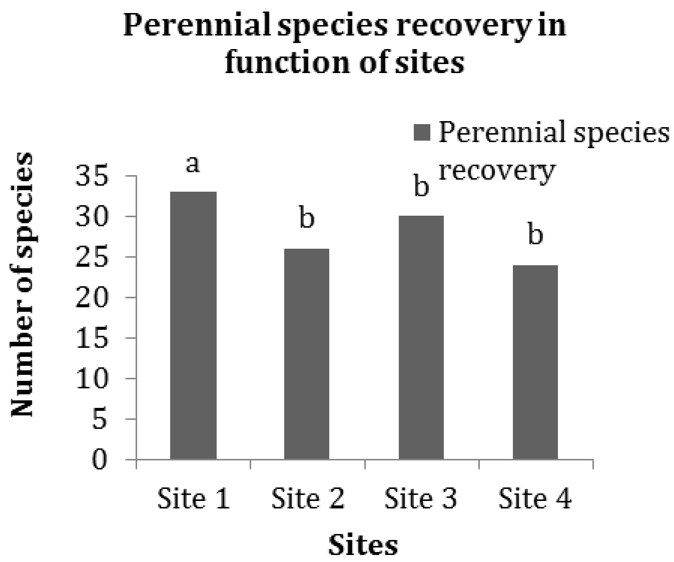

Figure (2): Variation of perennial species in function of distance

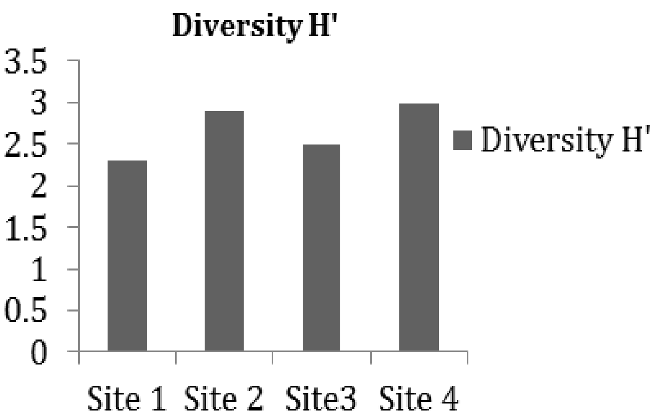

Figure (3): Variation of diversity H' (Shannon and Wiener Index)

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Exotic species: target or tools for restoration?

As human activities become more global and international trade and transport expands, exotic species are growing in number, extent, and impact. Invasive Alien Species that reaches sufficiently high abundances can alter ecosystems and reduce biodiversity, and at the same time affect human, animal and plant health, agriculture, forestry, fisheries, land stability and infrastructures. Ecological restoration aims to fix anthropogenic changes to diversity and ecosystem dynamics by reconstructing habitats and return them to a previous healthy condition. This usually includes the re-establishment of species, assemblages, structure, and ecological functions that prevail in the system before the changes took place. At the landscape level, absolute ecological restoration is generally unfeasible due to land-use and other resources conflicts and costs. In restoration programs, exotic species are playing a dual role; they may be the condition leading to the restoration decision, or they may be the valuable catalysts for their succession.

In protected areas, exotic species cause significant management problems, and therefore their removal is essential for the management of parks and reserves. Naturally and human-mediated disturbed areas, i.e. the priority areas for restoration, are highly suitable places for exotics colonization since they can preferably exploit pathways created by human activities. Indeed, exotics may be the first species to colonise a disturbed area, even if they were not part of the local pre-disturbance community. Eradicating a small population of an exotic species is not always ideal, as they can limit the range of feasible restoration options and make the response of the system to restoration unpredictable. For a newly arrived exotic, managers may just not have enough knowledge to deal with. Aside, the exotic may have left behind it a legacy in the form of a seed bank or of a chemical or physical habitat modification that could alter succession processes. In this case, a long-term restoration management goal that would for example lead to a native species assemblage is debatable. In addition, an abundant exotics presence could make the initial conditions of an ecosystem difficult to

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Fact Sheet Topic Areas:
Native versus non-native species in restoration

Keywords:
Exotic species, Invasive species, Management, Restoration

Authors:
Alexandros Galanidis
Biodiversity Conservation Laboratory,
Department of Environment,
University of the Aegean,
Greece
agal@env.aegean.gr

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When the benefits of using non-native species in restoration are exceeding the potential risks of their introduction, exotics can be used as ecological substitutes. Native species are often locally unavailable, absent or extinct, or cannot establish and be competitive in a badly degraded area. Sometimes, there is a lack of planting stock from local material or a need for more ecological and horticultural information regarding native species. At the same time, functionally or structurally analogous exotic species might speed up restoration and fulfil native species role. Or else, they could better control an exotic invader and replace its population through secondary succession. In these cases, where exotic species donot threaten surrounding ecosystems, and exotic may do the job more quickly or effectively and provide economic and ecological payoffs, and their presence can be tolerated or even being preferred.

RESTORATION STRATEGIES

Along with severely degraded areas, restoration practitioners often have to cope with the practical reality of limited recourses and short funding cycles. Apparently, non-native species are part of their efforts either as a target or as a tool. Exotics are not "good" or "bad" by default, so their prohibition or use should be a case-specific decision. Good knowledge of ecological theory, a fair estimation of potential landscape-scale impacts and a socioeconomic justification of any action could stand as fundamental guidelines. Risk is always an issue when exotics are involved, but risks, when unavoidable, are to be taken.

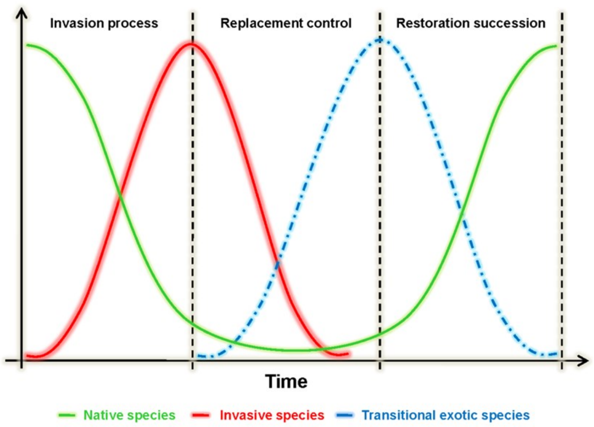

Figure (2): Exotics as tools for restoration: the Replacement and Restoration model. During Invasion process, native dominance declines as invasive exotic colonise the area. During Replacement control, a transitional exotic that outcompete the invasive exotic is planted. At the last stage (Restoration succession), the transitional exotic can no longer regenerate due to its specific growth characteristics, but the favourable conditions it provides allows the re-establishment of native communities. Adapted from Zhou et al. Scientific Reports 5, (2015).

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Grass reseeding as a means of combating land degradation in the African drylands

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Land degradation remains a central problem to the sustainable development of dryland ecosystems in Africa (Mganga et al. 2015a). Studies have estimated that approximately 30-40% of Kenya's arid and semi-arid lands (ASALs), which constitute 80% of the country's landmass, are quickly being degraded and that another 2% have completely been lost (Nyangito et al. 2008). Much of the soil loss occurs when vegetation cover is removed. This leaves soil unprotected from water and wind. Evidence of degradation in these dryland ecosystems in Africa is evidenced by a decline in soil productivity, loss of biodiversity, increasing rate of erosion and change in vegetation cover. Shifts in the state from grass dominated lands to bushy and woody dominated vegetation types is indicative of severe degradation (Mganga et al. 2015b). Grass reseeding technologies using indigenous perennial grasses can be used to combat the degradation in the drylands (Mganga et al. 2010).

Pure stands of *Cenchrus ciliaris, Enteropogon macrostachyus* and *Eragrostis superba* were established in a semi-arid environment in Kenya to determine and compare their potential to combat degradation. Quadrat method (Cox, 1990) of destructive vegetation sampling was done at 2.5 cm stubble height to estimate biomass production (kg/ha DM) and plant densities (plants m^2). Percentage basal cover (%) was estimated using the step-point method (Evans and Love, 1957). Simulated rainfall using a Kamphorst rainfall simulator was used to estimate runoff (cm^3) and sediment production (kg/ha)

Figure (1): Seedbed preparation using ox -driven plough: creating micro-catchments to harvest rainwater for grass reseeding.

Fact Sheet Topic Area:
Sustainable land management

Keywords:
Reseeding, rainwater harvesting, semi-arid, Africa.

Authors:
Kevin Z. Mganga
Dept. Range and Wildlife Sciences
South Eastern Kenya University
P.O. Box 170-90200
Kitui, Kenya

Geographic location:
Kenya, Africa

Climate Classification:
Semi-arid

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Grass species	Biomass yields	Plant density	Basal cover	Runoff	Sediment productio n
CC	1026a	7a	30a	117a	41a
EM	744b	36b	54b	240b	123b
ES	896c	5a	23a	487c	321c

where: CC -*Cenchrus ciliaris,* EM - *Enteropogon macrostachyus,* ES - *Eragrostis superba*. Column means with different letters are significantly different.

Figure (2): Experiment with 3 perennial grass species

Pastoral communities inhabiting the dryland ecosystem in Kenya use indigenous perennial species; *C. ciliaris, E. superba* and *E. macrostachyus* to reseed denuded patched. This is attributed to their indigenous knowledge of the grasses and their multiple benefits. *E. superba* has been identified by pastoral communities e.g. Il Chamus, for fattening livestock (Wasonga et al. 2003). Similarly, C. ciliaris is highly palatable and nutritious to livestock. Moreover, it prolongs grazing periods, increases carrying capacity and recovers well from grazing. Furthermore, the sale of grass seeds also fetches a good price in the market. The current market price is $10US/kilo.

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Sustainable land management strategies like grass reseeding and rainwater harvesting have a great potential to improve ecosystem functionality and resilience, alleviate pasture scarcity, provide ecosystem services e.g. C sequestration, reduce soil and biodiversity loss and create alternative income generating activities. This shows that in addition to combating land degradation, these simple technological strategies are improving the livelihoods on the pastoral communities in the drylands by cushioning them against the vagaries of nature.

Figure (3): Trenches to harvest rainwater, increase infiltration, reduce surface runoff and conserve the soil.

Vegetation response and recovery to water flow in Mediterranean ephemeral channels

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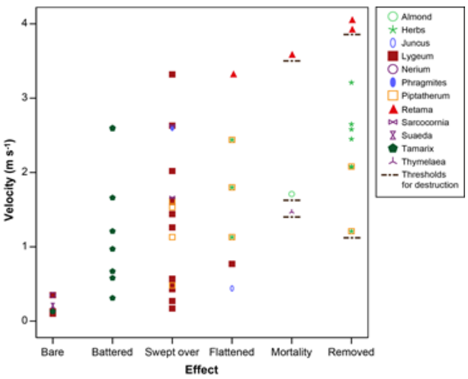
Much of the removal of soil and transfer of off-site effects in catchments takes place via the stream channels. In channels in the drier parts of the Mediterranean-type region, where water only flows occasionally, vegetation growth within the channel can be quite abundant. Field measurements and theoretical analyses have been applied to assess the effects of different types of vegetation on erosion and deposition processes within channels and to provide guidance for restoration and prevention of degradation. Quadrats have been monitored over a period of years to measure the interaction of flow processes and vegetation. Reaches have been mapped and cross-sections measured in detail to detect effects of flow events. Lengths of channel with contrasts in vegetation characteristics have been examined in relation to processes and connectivity of sediment transfer down systems. Thresholds for removal of different types of plants are calculated from measured impacts of flood events. Effects of a range flows, including an extreme flood, have been measured and threshold velocities for removal of plants calculated, indicating the forces that different plant species can withstand. The increased knowledge of process–vegetation interactions is used to make recommendations on channel management. Research investigated the types of vegetation which grow in the channels, the conditions for their growth and the effects of vegetation on processes, such that locations and types of vegetation that could be used for reducing erosion and degradation were identified. Most of the field measurements were undertaken in the Cárcavo catchment in the northeast of Murcia province in SE Spain, the driest part of Europe, having an average 300mm annual rainfall. Types of vegetation occurring in these Mediterranean ephemeral channels range from herbs growing opportunistically with available moisture and substrate, through grasses, to typical Mediterranean shrubs, and to phreatoyphytes, large shrubs with long roots tapping groundwater in gravels deep below the river beds. Vegetation has the potential to decrease channel erosion and sediment transfers in dryland environments by increasing channel bed resistance and roughness. The decreased velocities of flow also increase sedimentation, by trapping within and downstream of individual plants. Research has shown that the aerial parts and the flexibility of stems affects the roughness and resistance offered by plants and their response to flows. Root type, density and strength influences the resistance to erosion.



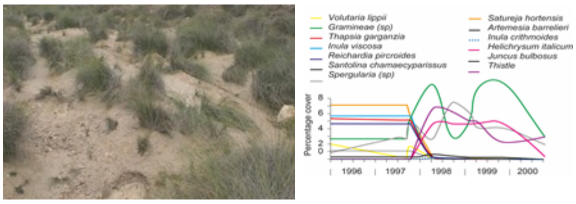


Figure (1): (Top) Sedimentation in Lygeum in a channel; variations in response of species to a flood in September 1997 on measured quadrats.

Figure (2): (Left): Response of plants to of calculated velocities of flows in channels in SE Spain (Sandercock and Hooke, 2010)

Fact Sheet Topic Area:
Vegetation resilience

Key points:
Plant types and species that grow Mediterranean channels have differing resilience to floods. Conditions for damage have been identified, with implications for use of vegetation in restoration.

Keywords:
Plants, floods, damage, thresholds, hydraulics, river channels.

Authors:
Janet Hooke
Department of Geography and Planning
University of Liverpool, UK.
Janet.hooke@liv.ac.uk

Geographic location:
Murcia, SE Spain.

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Measurements in a range of flow events in channels in SE Spain show the following results:

- Many herbs are easily removed even by low flow.
- Many grasses offer high resistance and encourage sedimentation, e.g. *Lygeum spartum* . They may exhibit increased growth after floods because of increased moisture.
- Many of the low-growing Mediterranean shrubs are highly adapted to the environment and show stasis in growth during droughts, so are highly persistent; they can offer high roughness but some are susceptible to excavation or mortality due to inundation.
- Deep-rooted plants such as *Tamarisk canariensis* and *Retama sphaerocarpa* are highly resilient and not easily destroyed. They can still survive even with a length of the main tap root exposed. They can be flattened in floods but survive. Burial by sediments and impacts from coarse sediments can cause destruction. If any stems or trunks remain after a severe flow then these rapidly resprout (as illustrated).
- Single stemmed trees such as Poplar and crop trees such as almond and olive, growing on banks and floodplains, are very vulnerable to high flows and can be broken off by force of flow.

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RESTORATION STRATEGIES

This type of information and the approach demonstrated by the research can be used to design strategies and select species that would be suited to different positions in a channel or differing zones of vulnerability to water flow. It helps to identify which types of plants would be likely to survive flows that occur in such locations. In general, the native Mediterranean plants found growing in the channels are highly adapted to the environment, with its infrequency of moisture supply, the often loose, low nutrient substrates, and having the strength and flexibility to withstand high forces.

Once vegetation is established this can have positive feedback effects by increasing infiltration and organic matter content, so encouraging further growth and sedimentation and preventing erosion. Vegetation is suggested as an alternative to engineering solutions such as check dams, particularly in situations where flow forces are low, i.e. in shallow gradient and wide channels.

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Figure (3): (Top) Photographs of Nogalte channel in SE Spain before and after a major flood. (Below) Retama spp. resprouting after flood, and root exposure of Retama.

Landscape methods for solving the dilemma of planting native versus non-native plant species in drylands

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INTRODUCTION

The European Landscape Convention (ELC) 2000, notes that *'landscape is the concern of all and lends itself to democratic treatment, particularly at local and regional level'* (Council of Europe). When it comes to land restoration and planting in drylands and arid areas, there is a pressing need to resolve methods that can determine native versus non-native plant use. This is because whilst plant introductions may have positive objectives they can have negative landscape and ecological impacts. Whilst the negative impacts on ecology and ecosystem services is often well understood by scientists the landscape impacts and the landscape methods for determining native versus exotic plant use are not so well established and discussed. This fact sheet advances a number of simple and more complex methods for determining native versus exotic plant use, but it should be noted that the impacts on all ecosystems should be considered when determining use in these often fragile areas and invasive species should definitely not be used. (Figures 1 and 2)

DETERMINING NATIVE VERSUS EXTOTIC PLANT USE USING THREE LANDSCAPE METHODS

Landscape Test 1

The simplest form or test is to determine whether exotic plant use would be detrimental to the 'genius loci'. The term genius loci, is used to describe the spirit of a place or sense of place, which is created from the elements which determine landscape character combined with landscape quality/value. In most cases the spirit of place is intimately linked to ecological character and value and If the spirit of the place is worth retaining, then it must be the case that introducing foreign species may destroy this genius of place and thus in simple terms only native species should be used.

Figure (1): *Prosopis juliflora* in northern Kenya. The ecosystem and landscape character has changed helping to cause loss of groundcover species and thus erosion

Figure (2): Restoration of functional habitat with grasses on left with contrasting bush encroachment on right in northern Kenya

Fact Sheet Topic Area:
Determining native versus exotic plant use using landscape methods

Keywords:
Native plants, non-native plants, exotic plants, determining plant use, landscape sensitivity, landscape character, landscape quality, genius loci, European Landscape Convention.

Author:
Benz Kotzen
Dept. of Architecture and Landscape
University of Greenwich,
London, UK.
b.kotzen@gre.ac.uk
benzkotzen@blueyonder.co.uk

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Landscape Test 2

This simple test is based on the sensitivity of an area to change Where areas are sensitive to change then only native species should be used. It should be noted that dryland and arid areas are generally much more sensitive to change than more temperate areas. The balance in the landscape that is provided by the makeup of soils, water, fauna and flora, people and land management, climate and microclimate can readily be tipped into decline by changes in any one of the criteria (Figure 3).

Sensitivity Rating (Potential acceptance to change if non-native species are used)	**Aim** – to maintain / repair / enhance the landscape quality and landscape character of the area
Highly sensitive to change	Where the use of non-native species would greatly negatively affect landscape character and genius loci. Only native species to be used.
Moderately sensitive to change	Where the use of non-native species would negatively affect landscape character and genius loci. On balance native species to be used
Low sensitivity to change	Where the use of non-native species would not detrimentally affect landscape character and genius loci. Both native and non-native can be used

Figure (3): Determining planting type relative to Sensitivity Criteria (Benz Kotzen)

Landscape Test 3

This more complex test uses a landscape paradigm which illustrates a number of landcape zones which make up the world's landscapes. Nature with a capital "N" denotes areas that are largely unspoiled, where man rarely treads and in these areas only native plants should be used. In areas which could be described as being nature with a small "n", for example where habitat and ecology are part of providing a dominant landscape character then the default should be towards using native plants. Agricultural areas function with the use exotic species and thus exotic species can be used but taking account of the surrounding areas. In built up areas and in gardens both kinds of planting can be used, but it is suggested that native planting should be used in the large "middle landscape" . These are 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 (Figure 4).

Landscape Test 4—(Figures 5 and 6)

Environmental Impact Assessment (EIA) was devised to determine the potential impacts of proposed development on the environment and people. The Landscape and Visual Impact Assessment (LVIA) process as part of EIA determines the potential significance of the effect of development, by first determining the sensitivity or vulnerability of the land to change to the type of development proposed and tying this into the magnitude of change that would occur. The process of determining sensitivity to change takes into account landscape character and landscape quality and landscape value.

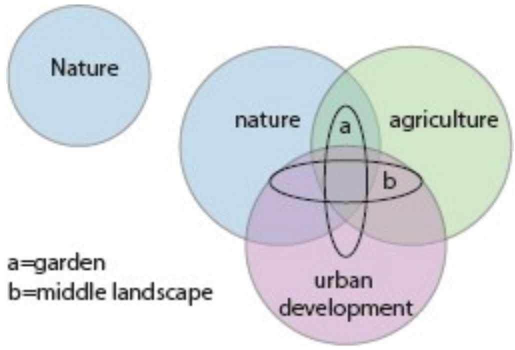

Figure (4): Typical Landscape paradigm for determining native versus non-native use (Benz Kotzen)

Major adverse impact—where the presence of non-native species causes a substantial significant detrimental impact in te landscape area

Moderate Adverse Impact - where the presence of non-native species causes a noticeable detrimental impact to the existing landscape area.

Minor Adverse Impact - where the presence of non-native species causes a minor detrimental impact to the existing landscape

No Change / Negligible - no discernible detrimental impact to the existing landscape / inconsequential changes to landscape

Figure (5): Hierarchy in impact from Adverse to Beneficial

		Significance Thresholds (Impact)		
Magnitude of change caused by using non-native species	**Large**	Moderate		Major
	Interme-diate	Minor/ Moderate	Moderate	Moderate/ Major
	Small	Minor	Minor/ Moderate	Moderate
	Negligible	No Change/ Negligible	No Change/ Negligible	No Change/ Negligible
		Low	**Moderate**	**High**
		Sensitivity of Landscape to Change if using non-native species		

Figure (6): Impact ,matrix which can be used to predict change in the landscape as adverse as well as beneficial

REFERENCES

- Council of Europe, 'European Landscape Convention', http://conventions.coe.int/Treaty/EN/Reports/Html/176.htm

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