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RESEARCH ARTICLE

Does the exotic equal pollution? Landscape methods for solving the dilemma of using native versus non-native plant species in drylands

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Abstract

There is a need to resolve methods to determine the merits of native versus non-native plant use in drylands and indeed in more temperate areas around the world. This is because whilst plant introductions may have positive objectives, they can have significant negative landscape and environmental impacts. A key discussion on this issue focuses on whether the use of non-native plant species can be considered to be pollution and pollutive based on the concept that pollution can be regarded as 'matter out of place'. The consequences of putting the wrong plant species in the wrong place can be extremely detrimental to the landscape character, quality and value of the land, let alone the effects on ecosystem structure and functioning as well as on biodiversity. These effects can also affect human communities who may rely on the landscape, for example, for tourism. It is thus necessary that the discussion on how decisions are made in determining plant choice evolves so that the right decisions are made when planting is necessary, for the land, for nature and for the people. This discussion has been initiated through COST Action ES1104, which focused on the restoration of degraded dry and arid lands. This article discusses a number of landscape methods based on sustainability principles to determine when and where native and non-native plants could and should be used.

KEYWORDS

alien plants, arid lands, degraded areas, drylands, ecology, introduced plants, landscape restoration, native plants, planting, planting strategy, plant material choice, pollution, re-vegetation

1 | INTRODUCTION

There is a long-standing but still burning question amongst practitioners, academics and consultants regarding landscape and restoration planting around the world. This query centres on the choice of native versus non-native (alien or exotic) plant species. This debate is not new, but not having been resolved, it remains a key and controversial question regarding general landscape projects and it is particularly important and contentious for restoration measures particularly in degraded as well as marginal/edge use areas. The issue of using native versus non-native species is also more critical in areas that are fragile as is the case for many dryland areas, where water is a primary

limiting factor, where changes in any aspect of the environment may create a tipping point towards decline of productivity/biodiversity. Of particular note is the issue of the degradation of food webs that support insect and animal diversity, brought about wholly or in part by the introduction of non-native plant species. The most convenient solution is probably to postulate that only native species should be used in restoration and re-vegetation projects in order to restrict potential undesirable effects from introducing non-native plants. However, due to the large variety of differing aims and goals that are desired under the terms 'restoration' and 're-vegetation', this principle may only easily be achieved for areas that are protected by legislation for their outstanding value, for nature conservation, or landscape beauty and so forth. But, the boundaries for native versus non-native plant species use become blurred when the motives for the conservation of areas are less well-defined and/or where land degradation is not the major issue.

Finding suitable plant species for restoring degraded habitats, particularly in drylands, is not easy or simple. In some places like Cape Verde, exotic plants have been introduced where native planting has failed. The raison d'être being that something is better than nothing (B. Kotzen, personal communication, University of Greenwich and Cristina Branquinho, Universidade de Lisboa, 2016). But this is not always the case as is evidenced by the later undesired spread of invasive species introduced with 'good' intentions in Cape Verde (Duarte and Romeiras, 2009) and across the world. The situation is further complicated by the fact that 'native' has a geographic dimension that is often neglected. A species that is 'native' to a defined region may be genetically differentiated in the north of a region compared with the south due to adaptation to very local environmental conditions. Therefore, native plant material is not always easily and readily available for the desired region and/or in the required amounts whereas exotic species may be. Additionally, using native species can be more complex and finally more expensive if compared with the use of non-native species (Nunes et al., 2016) and where the use of native species may require planning years in advance, and also where native plant use may be less effective than using exotic species (Nunes et al., 2016). Additionally, cost will always be a key determining factor and, in some instances (in less wealthy countries and areas), the costs of non-native species is less than the native ones (Nunes et al., 2016). But even if costs are higher using native species would that justify the use of non-natives?

The question that needs to be asked is whether undesirable effects can be regarded as being free of costs? In many cases, the quick answer is no, as is evidenced by the direct economic consequences brought about by terrestrial as well as aquatic invasive species where every continent has 'horror' stories to tell.

Although the following discussion may be relevant in any of the world's biomes, the focus of this article is drylands (includes semiarid and arid lands) as this discussion has been initiated through COST Action ES1104[1], which focused on the restoration of degraded dry and arid lands. It is meant to provide support for decision making by providing some general principles. However, general principles always have to be treated with caution as doctrine always needs to be adjusted to the specific region, local conditions and goals. Therefore, this article focuses on overarching principles and we thus would like to highlight that all the principles suggested below need additional scientific input (monitoring of the real situation) and adjustment prior to their application with regard to a specific task.

This discussion can also be seen in the context of a new type of assessment approach, the so called 'nature's contributions to people' (NCP), where NCP is described by Díaz et al. (2018) as 'all contributions, both positive and negative, of living nature (diversity of organisms, ecosystems, and their associated ecological and evolutionary processes to people's quality of life'. Whilst Díaz et al. (2018) note the beneficial ecosystems services, such as 'food provision, water purification, and artistic inspiration', that nature provides, they also note 'detrimental contributions' that 'include disease transmission and predation that damage people or their assets'. In the context of this article, severe detrimental contributions can indeed stem from planting the wrong plants in the wrong places. The NCP approach considers that 'a range of views exist' where on the one hand 'humans and nature are viewed as distinct' and on the other hand 'humans and nonhuman entities are interwoven in deep relationships of kinship and reciprocal obligations…In addition, the way NCP are coproduced by nature and people is understood through different cultural lenses'. In this assessment process, it is apparent that the NCP approach 'recognizes the central and pervasive role that culture plays in defining all links between people and nature' and secondly, it 'elevates, emphasizes, and operationalizes the role of indigenous and local knowledge in understanding nature's contribution to people' (Díaz et al., 2018). In the case of plants and planting, there has to be a consideration and a real role for local stakeholders as part of the NCP approach.

2 | MATERIALS AND METHODS – THE ISSUES AND THE EFFECTS

The philosophical starting point for this discussion centres on the concept of pollution and the question: 'Can non-native plant use be considered as pollution, if pollution is considered as matter out of place?' The concept of dirt being matter that is out of place is usually attributed to the renowned anthropologist Mary Douglas, in her book *Implicit Meanings* (1979), where she notes that it was in fact Lord Chesterfield who first said that 'dirt is matter out of place'. Douglas (1979) comments that this concept implies multiple conditions as there are degrees of dirt or pollution as there are of cleanliness, and thus 'dirt then is never a unique, isolated event. Where there is dirt there is system'. Interestingly, Douglas (1979) also says that 'pollution beliefs protect the most vulnerable domains, where ambiguity would most weaken the fragile structure'. Robust beliefs and laws have thus been devised to protect key social traditions and customs, but within the realm of plant use no such directives have been agreed. These concepts could as we suggest be transferred to the native versus non-native planting debate. Mccauley (2006) notes that 'nature has an intrinsic value that makes it priceless, and this is reason enough to

TABLE 1 Determining native versus non-native plant use according to landscape quality and vulnerability

Landscape quality/vulnerability	Action	Native or Non-native use?
High/very vulnerable	Protect	Native only
Medium high/vulnerable	Protect	Native only
Medium/vulnerable	Protect	Native only
Medium low/low vulnerability	Enhance	Native and non-native
Low/little vulnerability	Enhance	Native and non-native

protect it' and that 'the time is ripe for returning to the protection of nature for nature's sake'. Taking this argument forward, where nature has not been adequately protected and where dryland environments have become vulnerable, these 'valuable' areas (they must be valuable as they are recognised as being vulnerable) must be planted, restored or re-vegetated using native species unless there are over-riding reasons. (This may also require the removal of non-native species.) However, where the status of the environment is ambiguous, the argument for native only planting becomes weak and then this opens up the native versus non-native debate. Thus, for example, high value, high quality and/or vulnerable areas need to be protected and planted with appropriate native species, whilst a mix of native as well as non-native species may be suitable in those areas that have ambiguous and lower values/quality (Table 1). The table needs to be seen in the context of decision making of whether to use native or non-native species or perhaps both. High-quality landscapes and/or those that are very vulnerable refers to landscapes that have high value for numerous reasons but mostly because of their intrinsic characteristics as ecosystems and the ecosystem services that are under threat. In some cases, planting may not be the solution and more passive restoration measures may be more appropriate. This will depend largely on the degree of degradation and an overall long-term strategy to restore the appropriate ecosystem services.

We recognise that the concept of plants being part of pollution or the idea of a 'good plant' or the antithesis a 'bad plant' presents a pure anthropocentric perspective and it is not scientific or based on ecological principles, biodiversity and ecosystems functioning, but it is most likely that the scientist, ecologist and biologist will find that this anthropocentric stance helps to reinforce their scientific position when it comes to a planting strategy.

2.1 | What is pollution?

Dictionary definitions of pollution consider the condition to be the presence, or introduction of contaminants into the natural environment that cause adverse change or harm. *The Oxford English Dictionary* (Oxford Living Dictionaries) defines pollution as "...the presence in or introduction into the environment of a substance which has harmful or poisonous effects"(https://oxforddictionaries.com/definition/pollution). However, in much simpler terms, a pollutant is considered as something that is located or introduced into an environment where it does not belong. In its home environment, it may be 'beautiful' or functional, or even go unnoticed, but in an alien environment, it can be considered 'dirt' or polluting. The question that needs to be asked is: if dirt or pollution is matter that is out of place, then is it reasonable to argue that a plant that is found or deliberately positioned in the wrong place may be considered dirt and polluting? Is it polluting because it does not fit within the normal context or most importantly because it can cause adverse changes, harm and contaminate the environment in what may end up being irreversible? To complicate matters, whether something is beneficial or adverse (pollutive) may be based on proportionality. Too much of something can be detrimental, whilst having it in balance is necessary for the health of any system, whether this is human or environmental. Using the same rationale, it may be the case that a plant located in a place in one proportion may be considered to be appropriate, but in a much higher proportion than normal it might be considered as pollution. The issue then is how does one determine the appropriate proportion? The further question is whether this is the case everywhere and in every situation? Like Mary Douglas' discussion of dirt being part of a system, the native (clean plant scenario) and non-native (dirty plant scenario) situation is not clear-cut. Thus, there is the need for a system or systems that can rationally define where native plants should be used and where exotic plants can be used so that this works for the benefit of the environment as well as people.

This discussion will argue that the imposition of non-native species, particularly in fragile areas such as drylands, for most purposes, may be considered polluting and thus a new paradigm is required to inform the selection of plant species.

2.2 | Introducing the problem

The willing, intentional introduction, and sometimes inadvertent, unintentional movement of alien or introduced 'exotic' faunal and floral species from one location to another was at its peak during the 18th, 19th and even the first half of the 20th century when thousands of species were transferred from one continent to another (Roy et al., 2012). The dominance of Europe, the attitudes of imperialism as well as the desire for new scientific knowledge expanded the transfer plant species in particular from one continent to another; usually from the New World (the Americas), as well as the East (China and Japan) and a number of other Far Eastern countries into Europe and its colonies, including the Americas. In most cases, these transfers, by plant hunters and other gentlemen adventurers, were based on the desire for knowledge and the excitement and allure of a new discovery and the kudos this brought, as well as on the potential financial rewards. But the history of plant transfer is, of course, much older than this. The Romans, for example, transferred many edible and non-edible plants across the continent of Europe and England. It is probably fair to say that as long as mankind could travel, he transferred plants willingly as well as unwittingly from one place to another (Figures 1 and 2). For example, it is assumed that the early gatherers and hunters may have supported the re-colonisation of Central Europe by hazel (*Corylus avellana*) after the last ice-age by sowing the species during their

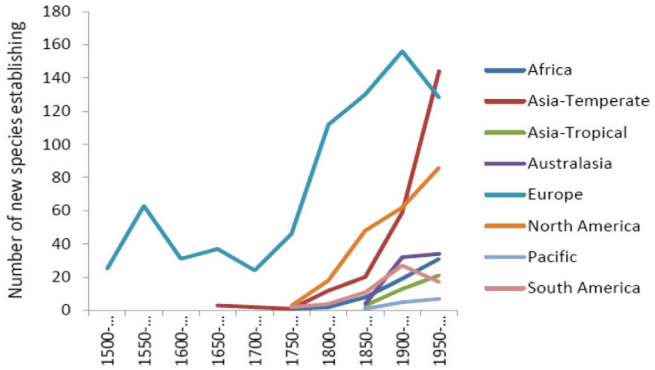

FIGURE 1 Number of established non-native species in the United Kingdom originating from different regions – after Roy et al. (2012). The graph shows significant increases from Africa, Temperate Asia and North America from the 1750s [Colour figure can be viewed at wileyonlinelibrary.com]

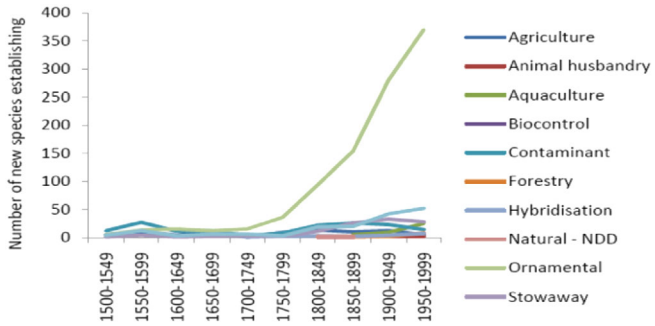

FIGURE 2 Number of established non-native species in the United Kingdom arriving through different pathways against date of first arrival – after Roy et al. (2012). The numbers of plant species arriving appears to have been more or less static from the 1800s onwards except for aquaculture purposes where the increase is much greater [Colour figure can be viewed at wileyonlinelibrary.com]

summer hunting trips to the north of the continent. The later systematic transfer of plants into Europe, the Americas and elsewhere helped to develop the scale and scope of agricultural products, which we now take for granted, (e.g. peaches, apricots and persimmon from China into Europe) and a crossover of plants from Europe to the Americas and vice versa, called the 'Columbian Exchange', after Christopher Columbus who voyaged to the Americas in 1492 (Nunn & Qian, 2010). This movement of plants also determined the extravagance of gardens based on the enormous number of plants that have become available. van Kleunen et al. (2015) after Drake et al. (1989) and Lonsdale (1999) note that 'there are many presumptions about alien species regarding their distributions and pattern of spread', where it has 'frequently been suggested that Old World species have spread more widely outside their native ranges than New World species, owing to human colonisation history or intrinsic evolutionary superiority'.

Until 2016, there was no 'comprehensive analysis of global alien species accumulation' due to a lack of data. This was rectified by van Kleunen et al. (2015) and GloNAF (Global Naturalized Alien Flora) who used a database on naturalised alien species from 481 mainland and 362 island locations to note that 'in total, 13,168 plant species, corresponding to 3.9% of the extant global vascular flora, or approximately the size of the native European flora, have become naturalised somewhere on the globe as a result of human activity', where North America has added the largest number of naturalised species, with the fastest increase in species in respect to land area in the Pacific Islands (van Kleunen et al., 2015).

2.3 | The polluting effects of non-native species introductions: a broad view

2.3.1 | Economic effects

It would be remiss not to mention the positive side of plant introduction. The introduction of non-native species, in the main, provided the mainstay for world agriculture. These world-wide introduced species, amongst others, include maize (*Zea mays*), wheat (*Triticum* spp.), rice (*Oryza sativa*), potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum*), soybean (*Glycene max*), the domestic chicken (*Gallus* spp.), cattle (*Bos taurus*) and so forth. They provide 98% of the world's food (Pimentel et al., 2001), and thus without using some exotic non-native species, most parts of the world would have even greater problems feeding itself. The question to be asked here then is if the introduction of species for food is reasonable, why should introductions for other practical reasons, for example, soil stabilisation, not be acceptable. In answer to this question, we have to acknowledge that alongside the positive effects of food plant introduction numerous mishaps, physical impacts and ecological disasters initiated by introductions have been observed. There are many well-known, high profile as well as lesser known introductions that have gone horribly wrong, with extreme damage to local ecologies and with significant costs. The international partnership, the Global Invasive Species Programme notes that 'the spread of invasive alien species is now recognized as one of the greatest threats to the ecological and economic well being of the planet' (Burring & van der Walt, 2006). They also note that the 'vehicle responsible for the introduction of the majority of these…whether intentionally or by accident, is humankind' (Burring & van der Walt, 2006). Pimentel et al. (2001) estimated that the global annual costs of damage caused by invasive species is greater than US$1.4 trillion (US$336 billion per annum for the United States, United Kingdom, Australia, South Africa, India and Brazil combined[2]) and this does not include the losses in ecosystem services, which includes biodiversity and aesthetics. In fact, since the 17th century, invasive alien species (IAS) have 'contributed to nearly 40% of all animal extinctions for which the cause is known' (SoCoBD).

2.3.2 | Polluting effects in ecology, biodiversity, landscape and cultural services

It is generally agreed that biodiversity is negatively affected by the invasion of alien species. In most instances, where native fauna and

flora have evolved together over millennia, non-native species fragment these relationships. It is estimated that in temperate zones there are at least 10 to 30 species of organisms that depend on each plant species and in the tropics this can be much greater (Gould, 2006). With non-native species, this is significantly reduced. There is also a significant issue regarding non-native species degrading the food web, which supports invertebrates and other animals. Narango et al. (2018) state that whilst non-natives are planted because they 'are not susceptible to pest damage and require little maintenance' they are also 'poor at supporting insects that are critical food resources for higher order consumers'. This degradation of food webs is noted by many researchers including Sanchez-Bayo and Wyckhuys (2019), who reviewed 73 historical reports on insect decline, that 'introduced species' are one of the main drivers of the decline. The importance of this issue has been highlighted in the popular press and on the web as well, including the British Broadcasting Association (BBC, 2019), *New York Times* (2018a, 2018b), *The Guardian* and the Natural History Museum (2019). The issue is compounded because whilst alien plants may be providing a substantial food resource for insect pollinators, "… a predominance of alien nectar in pollinator diets, may produce risks for pollinator health" (Vanbergen et al., 2017).

The question then relates to two hierarchical polluting aspects of plant introduction:

1. The introduction of non-native species pollutes the environment and may significantly threaten and remove biodiversity;
2. The introduction of non-native species has a secondary polluting effect, interfering with biotic relationships thereby limiting biodiversity, by, for example, reducing the number of interacting species.

The term invasive alien species (IAS) is being used more and more. The European Commission notes that these are 'animals and plants that are introduced accidentally or deliberately into a natural environment where they are not normally found, with serious negative consequences for their new environment' (EC Environment). The Convention of Biodiversity states "...for a species to become invasive, it must successfully out-compete native organisms, spread through its new environment, increase in population density and harm ecosystems in its introduced range. To summarise, for an alien species to become invasive, it must arrive, survive and thrive"(UNEP). This situation has become more complicated with climate change where some species that were not invasive have become invasive, for example, with slightly more precipitation or available moisture. Additionally, and perhaps controversially, it is possible that native species themselves become dominant ('invasive'), where one species may dominate an area because of changes in climate or changes in the nutrient content of the soils, brought about anthropogenically. There are many examples where native as well as exotic species become dominant in an area through changing, for example, the pH of the soil to suit their own species, such as with *Tamarix* sp. Hortal et al. (2017), note that plant performance is "...mediated by feedbacks between plants and soil bacterial communities." Each plant species chooses a community of soil microorganisms in its rhizosphere and "...when two plant species interact, the resulting soil bacterial community matches that of the most competitive plant species, suggesting strong competitive interactions between soil bacterial communities as well" (Hortal et al., 2017).

The question to ask then is if 'invasion' of a foreign species is not acceptable, when does it become acceptable to use foreign species? Referring back to Douglas (1979), it is certain that areas that are most vulnerable and thus most valuable will need protection and only native plants should be used. But in areas that are ambiguous, the options appear more open and either native or alien species may be used. Without doubt, this is open to debate, as why would we not also try and reinstate ambiguous areas to their former state? But if this is the case then all areas and all cases should only be considered for native planting. The answer to this is thus not clear-cut, but the concept of protecting high value and vulnerable areas and allowing greater flexibility in areas that are poor in character and quality is often used in Landscape Character Assessment (Table 1).

2.3.3 | Landscape effects

The landscape effects of alien plant introductions are most often not quantified or even qualified. It is far easier, for example, to determine the loss of species diversity. It should also be noted that the ecological lobby is far stronger than most landscape lobbies. Very few people in the European Union know of the existence of the European Landscape Convention (ELC) adopted in the year 2000[3]. Item 23 of the Convention notes that "...landscape must become a mainstream political concern, since it plays an important role in the well-being of Europeans who are no longer prepared to tolerate the alteration of their surroundings by technical and economic developments in which they have had no say. Landscape is the concern of all and lends itself to democratic treatment, particularly at local and regional level". However, changes in landscape character and landscape quality and value[4] are important as part of ecosystem services evaluations as the look and character of landscape is often an important consideration for the success of tourism and allied industries. The above statement by the ELC is a step forward in the protection of landscape but it is rather weak in its phraseology. Replace the word 'alteration' with the word 'pollution' and the statement has greater strength. Thus, people should 'no longer be prepared to tolerate the pollution of their surrounding…'. The loss of biodiversity and the increase in alien species (pollution of the landscape) significantly reduces local people's ability to live in, to adapt to and to use their environment. For some equating these kinds of alterations as pollution is way too robust, but in many cases ill-considered, development will be seen by many to be as contaminative or pollutive.

The introduction of species thus not only has adverse effects on biodiversity and ecosystem functioning but also it is reducing the beauty and often much more the uniqueness of the landscape by globalising its appearance and structure. The ubiquitous introduction, for example, of *Eucalyptus* sp., *Prosopis* sp. and *Opuntia* spp. from

FIGURE 3 *Propsopis juliflora* and *Opuntia* sp. being used to mitigate gully erosion at Baringo County, northern Kenya, 2014. Note dominant low self-seeded prosopis shrubs in the background and the taller native acacia species. Prosopishas decreased the local ground flora considerably (photograph by Benz Kotzen) [Colour figure can be viewed at wileyonlinelibrary.com]

Australia and the New World, respectively, has done considerable damage to landscape structure, diversity, uniqueness by, for example, altering environmental conditions (Figure 3). And as these introductions are relatively recent, the actual damage in the future may be much greater than we realise now.

2.4 | The benefits of using non-native species

The benefits of using non-native species are well known and much of the world's agrarian and forestry economy as noted above relies on this use. Much of the timber that is produced for building, for industry (e.g. paper and mining crops) and for fuel where, for example, eucalyptus introduced from Australia to Africa and Madagascar is used by local people as a renewable energy source and where industry requires the forests for paper and furniture production amongst other things is from species that are grown in countries where it has been introduced. Without alien species, many gardens and gardeners and the ornamental plant nursery trade would suffer significant losses. In respect to restoration many introduced species are better at their tasks than native species. For example, erosion control with *Chrysopogon zizanioides*, commonly known as vetiver grass, from India, is more successful than the use of native species. This plant is well known in its ability to stabilise slopes and for soil carbon sequestration.

3 | DISCUSSION – THREE WAYS TO DETERMINE PLANT USE

Following on from the above, the discussion proceeds by proposing three different but interconnected ways to determine whether to use native or non-native species.

3.1 | The triple bottom line

The 'triple bottom line' argument has been used as the backbone for sustainability, where in 1994, Elkington (1997) suggested that corporations should measure success not only by the financial 'bottom line' as profit but the bottom line should also account for the benefit or profit brought to the environment and society. This tripartite view of sustainable development is often described as People, Planet and Profit. It is easy to see that this idea may well work as one paradigm, albeit simple, for determining whether exotic plants may be used. Profit through plant/crop choice is an obvious aim in agriculture and forestry, but it can also be linked to industries such as tourism where the character of the landscape, partly determined by planting or sowing could well help to determine the experience of visitors and thus financial success or not. Maintaining landscape character and quality (environment) through plant species and landscape management is important for eco-tourism and the well-being of local people especially in more rural areas[5]. A good example of this is in the Mediterranean basin areas of Portugal and Spain. *Montado* in Portugal (*dehesa* in Spain), for example, is a unique agro-silvo-pastoral ecosystem found only in the Mediterranean basin. "Shaped over millennia of traditional land use practices these multi-use forests are threatened, as are the benefits associated with the *montado*" (Príncipe et al., 2016). The changes in land management, including land abandonment, is due to many factors, but the loss in plant and animal biodiversity and landscape character affects the environment, the local people and their ability to pursue economic well-being, for example, through eco-tourism. The complexity of the situation means that both the ecosystem services and the ecosystem disservices need to be scrutinised together by all the relevant local stakeholders to ensure the appropriate actions are taken both for nature and people.

3.2 | The issue of intention

People most often make decisions based on rules and "...most of the time behaviour follows the rules" (March, 1994). Decisions are also usually made relative to intentions, purpose, aims and objectives. But in the case of deciding whether to use native planting or exotic species, there are no fixed rules. Thus, intent, purpose or aims behind planting, including restoration planting must then be a key aspect of the decision-making process. It is obvious if new planting/sowing is going to be planned and implemented then the intention behind it needs to determine the choice of plant species that are used. In agriculture, for example, the intention is to grow a crop for food or for some other useful commodity. This crop is likely to comprise non-native species as discussed above.

In restoration planting and sowing, the intentions centre on restoring the land but the question then needs to be asked is 'to what previous or other condition does the land need to be restored?' In some instances, perhaps when the land has been affected by extreme drought, fire or floods, the pre-condition is well known and thus the

intention to restore is well known and justified. However, in some cases where land degradation has occurred over longer periods of time, the answer may not be as clear-cut. Additionally, the situation is complicated because in most cases land that requires restoration is also land that is used by people for their livelihoods. In many dry areas of Kenya and in many other African countries, for example, the loss of ground flora and grasses has been inflicted by over-grazing and this in turn has increased bush encroachment, which further impedes the growth of ground flora and grasses (Vehrs, 2016; Figure 4). In this situation, the aims of restoration would be to return the land to a previous balance, with people as a central part of the equation and not to a 'virgin state'.

One of the axioms of our world, however, is that nothing has been or can ever be permanent and thus there never was nor can there ever be a permanent condition. Many would argue that climax vegetation or intermediate successional states (such as pastures and meadows) are the appropriate aim and an equilibrium state should be aimed for. Introducing the values associated with ecosystem services makes the decision-making process much more difficult, especially when introducing the needs of people into the equation. Where people are involved, they need to be a key component in determining the key intentions, aims and objectives. Those who work in the planning and the design of restoration planting want to get it right and in order to do so, it is important to understand past and current paradigms of planting in various situations and then to re-establish a set of paradigms that work for those situations.

FIGURE 4 Restoration of functional habitat with grasses on left with contrasting bush encroachment on right in Baringo County, northern Kenya, 2014. The restoration with palatable grasses was carried out with the help of the RAE Charitable Trust (http://raetrust.org/act_rese_dis.htm) to help restore grazing for local pastoralists (photograph by Benz Kotzen) [Colour figure can be viewed at wileyonlinelibrary.com]

3.3 | Defining a non-polluting paradigm through identifying different landscape natures

In *Greater Perfections, The Practice of Garden Theory*, Hunt (2000) draws attention to a tripartite paradigm for the garden or 'any piece of landscape architecture'. Hunt (2000) divides the world into three natures which is based on the ideas of the 16th century Italian humanist Jacopo Bonfadio who 'reads the landscape, with its gardens' as a 'trio of natures' (Hunt, 2000). Although Hunt divides the landscape into three separate types as (1) wilderness, (2) agriculture and urban settlement, which he calls the middle landscape, and (3) the garden (Figure 5a), it is apparent that landscapes are more complex than this. In order to be useful in understanding and determining landscape strategies as far as planting is concerned and to better illustrate the broad landscape zones apparent in our present world, it is possible to expand on and re-arrange the paradigm (Figure 5b). It can be argued that rather than Hunt's three natures, we may observe four natures as main categories with two sub-categories as follows (Figure 5b). Table 2 'Use of native versus non-native species according to nature paradigm' indicates according to the new paradigm where non-native plants may be located.

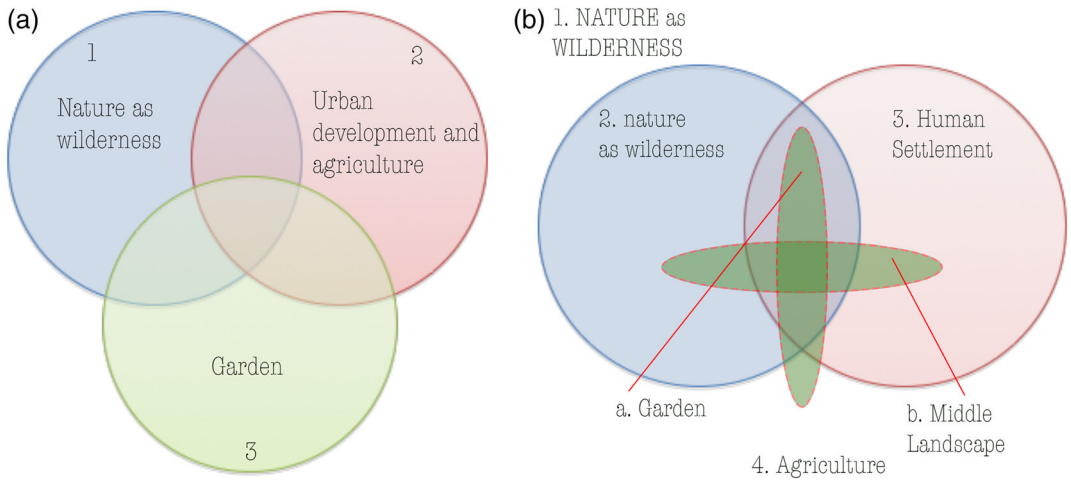

FIGURE 5 (a) Simple landscape paradigm with three main landscape categories. (b) More realistic landscape paradigm with four main categories and two sub-categories [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Use of native versus non-native species according to nature paradigm

	Categories/type of nature				
	First Nature Nature/wilderness	Second Nature Nature/wilderness	Third Nature Agriculture	First sub-category Garden	Second sub-category Middle landscape
Native plant use	Yes	Yes	Yes	Yes	Yes
Non-native plant use	Never	Only under certain circumstances	Yes	Yes	Only under special circumstances

3.3.1 | Main category – First Nature

The First Nature is Wilderness with a capital W or Nature with a capital N. The term is used in a qualitative and descriptive sense, but, is much more rigorous than that described by Porteous. For Porteous (1996), Wilderness 'involves wild, uncultivated, unspoiled land inhabited by wild creatures and where humans are only visitors'. However, for this paradigm, Wilderness describes landscape character zones as well as planting zones that are untamed, unmanaged and totally or almost totally unadulterated by man. These areas are usually extremely remote. They would include areas where man never or very seldom treads. In these areas (dryland, arid or otherwise), it would be considered unacceptable to propose any planting, that would not be native. Locating non-native species in these kinds of areas could be seen to be considerably polluting.

3.3.2 | Main category – Second Nature

Second Nature is wilderness with a small w or nature with a small n. Hunt points out how areas of Wilderness or as he calls it First Nature can be altered. He uses the example of the climbing of Mt. Everest where with its 'abandoned oxygen canisters and dead bodies', First Nature can be 'colonised physically as well as metaphysically' (Hunt 2000). Thus, these areas appear to be untouched by man but in many cases they have indeed been altered and colonised by man and polluted by man. Many of them are natural habitat areas some of which are managed as wildlife/nature reserves. They may also include military ranges and be areas of open pasture and rangelands that are utilised for grazing by local peoples. They are generally areas that are less remote than Wilderness with a capital W or Nature with a capital N, and may in fact be settlement areas and agricultural areas or be traditional pastoral areas. Some of these are open to various intensities of tourist/management activity. Despite the proximity of man, these areas still have a strong 'natural' character and thus the introduction of exotic species here is considered to be strongly polluting.

3.3.3 | Main category – Third Nature

Third Nature is agriculture. Whereas Hunt groups agriculture and human settlement together and calls this the 'middle landscape', in this part of the paradigm, agriculture is considered a landscape zone in its own right. This is because agricultural landscapes, like inhabited areas, usually have a recognisable underlying structure. These structures are generally apparent in the creation of fields and paddocks, field boundaries of walls, hedgerows, markers and drainage ditches as well as drainage and irrigation structures. The practice of growing crops and keeping animals thus creates a very different landscape character and form and is thus very distinct from inhabited areas. As most agricultural produce is exotic in nature, it would be futile to argue that most crops and orchards are polluting, although in the purest sense they are.

3.3.4 | Main category – Fourth Nature

Human settlement is the Fourth Nature in this paradigm and the landscape character of these developments. These are characterised by an organised and sometimes ad hoc infrastructure of roads and civic, public, commercial and domestic buildings as well as open space areas including public parks. Within this nature, there are two types of planted spaces apart from, for example, allotment gardens and other forms of urban agriculture.

Recently, the concept of Biocultural Diversity (BCD) was applied to urban green spaces (Elands et al., 2019). BCD builds upon the idea that nature is socially constructed and gives expression to the idea that biological diversity and cultural diversity are intertwined – they are 'made' together and imply each other, they are inextricably linked. The concept of BCD also accentuates the dynamic, constantly evolving, nature of interactions between humans and natures which is particularly relevant in urban areas.

3.3.5 | Sub-category – garden

This sub-landscape character area corresponds to Hunt's Third Nature. It is the Garden. There are many definitions of what constitutes a garden. As with art, it would be futile and unwise to try and limit its scope and intent. [6] But for the purpose of this article, the garden is seen to constitute areas that generally have ornamental horticultural elements[7] and are purposefully designed, created and maintained by individuals or groups as aesthetically pleasing spaces. Garden design and plant use often follow fashionable trends, such as the use of prairie planting derived from the United States. In some areas, there is a trend towards the use of native plants and associated with this use, waterwise gardening and xerophytic gardening have evolved to reduce water usage in dry and arid lands, but this does not

mean that native plants are always used. Native plant use has yet to become fashionable. But like art, it is proposed that the form and content of gardens should not be restricted, although it is quite possible to use native species quite effectively. Garden as illustrated in the alternative paradigm diagram (Figure 5) shows that it can be located within settlements, as well as within agricultural areas but should not be located in wilderness (nature) and most definitely not in Wilderness/Nature.

3.3.6 | Sub-category – middle landscape

The middle landscape is a sub-landscape character zone that relates to those external places within urban areas, agricultural or settlement and wilderness/nature (small w/small n) areas, which are treated as gardens, but which, if treated differently would be of benefit to the environment and some principles of sustainable development (lower cost, using local materials, ecologically sound, wildlife friendly, etc.) In most areas and particularly dryland areas, they would also be more sustainable in terms of reduced water demands and inputs. In many cases, they are secondary-use areas (but not exclusively so) and their uses can be seen to be secondary as opposed to primary. They are thus areas that usually support other spaces with primary functions and include areas of transition, passage and border/margin/boundary zones as well. They include, for example, tracts alongside roads and within the grounds of institutions: hospitals, universities, research establishments, industrial zones, business parks, military bases and recreation areas. These are also fringe areas, ecotone areas between development and landscape. Within this alternative landscape paradigm, this is the 'middle landscape'. In most cases at present, these middle landscape areas are treated as Garden and where they are treated as Garden (where anything can be planted), they are unnecessarily high cost and high maintenance. In cases where they are transition zones and they provide the ecotone[8] between areas influenced by man and wilderness, treating them as Garden can have a detrimental effect on the ecological character and quality as well as the landscape character and quality of the landscape.

This argument suggests that these areas in the middle landscape should not be treated as Garden but as something else. Treating these areas as habitat only with native planting also has advantages in creating ecological and landscape character benefits and as ecological buffer areas to other wilderness areas.

Thus, the realisation and understanding of the middle landscape is a key issue in providing a background and theoretical methodology for planting in dryland areas and indeed for other arid areas around the world and for general landscape architecture and landscape planting.

In the 1990s, Kowarik (1992) similarly suggested landscape typologies to help determine whether to use native or non-native species in restoration projects in central Europe. He described (a) remnants of the landscape prior to human interference, (b) agricultural landscapes, (c) symbolic nature (gardens and parks) and (d) urban and industrial nature. Kowarik, determined the following that in (a) only native species are to be used, in (b) natives are preferred, but for good reasons some non-natives are acceptable, in (c) both native and exotic species are acceptable depending on the fashion of the day and in (d) mainly non-natives are to be used because they manage better with the strongly altered environment than native plants. Whilst Kowarik's determination is similar to the authors', we propose that natives have a key role in urban environments.

4 | CONCLUSIONS

Whilst there are numerous reasons to advocate the planting of native species, at present, there are no well-grounded arguments on how to determine whether non-native plant use is a viable option for restoration or other planting in drylands and more temperate areas. In the first instance, it may be useful to determine plant use by applying the triple bottom line where the actions need to benefit People, Planet and Profit. A further useful way to determine plant use is to match the use against intention and objectives. If restoration planting is the aim, the restoration team will determine the state that it needs to be restored back to. An additional approach is to look at the type of landscape and their 'nature', and if possible treat the 'middle landscape' as nature and thus use native species. There is one other rather complex way of determining plant use and that is through landscape assessment and Environmental Impact Assessment methods, where landscape character, landscape quality and landscape value, sensitivity to change to non-native planting as well as the more complex interaction of Sensitivity to Change relative to the Magnitude of Change that may be caused in the landscape can be assessed.

Returning to the start of this article, to the issue that non-native plants as being considered as pollution, as contamination and as matter out of place, this article suggests that in order for us to better protect vulnerable dryland, arid as well as other environments, we need to understand that plants can be polluting. This article suggests that landscape is a key determining factor whether non-native plants can be used or not. However, we realise that in some situations, where landscape restoration is required, the problems may be so severe that native plants do not offer a part or complete solution. In these cases, we suggest that a phased programme of planting may offer solutions but plant use must be well managed and monitored over a period of time to ensure that landscape changes are not more detrimental to the land relative to the problem that is being fixed. Cost is also a key determining factor on most projects but has not been a focus of this paper as expenditure varies according to location, size, type of project, resources and so forth. Our belief is that although cost needs to be considered throughout the decision-making process, it is not the key driver. This discussion has revealed a number of landscape derived methods for determining non-native versus native plant use. This is an attempt to provide some rules/methods to assist decision making but should not be used in a way that avoids considered and balanced approaches where the problems are solved but at the same time take due account of the needs of local people and the overall environment.

A number of final points need to be made: (a) firstly, that landscape and plants form part of greater and more complex ecosystems

and the introduction of non-native plants as well as native species will affect other life forms, the invertebrates and then higher trophic levels. The introduction of non-native species is part of the accelerating decline of species where the United Nations (U.N.) predicts the extinction of 1 million species and they pinpoint the 'five direct drivers of change in nature with the largest global impact so far'. One of these five is 'invasive alien species' (U.N., 2019). The food web is thus a key aspect of ecosystem functioning and should always be considered when planting occurs. As our world is changing so rapidly, it would thus be wise to not only protect ecosystem functioning in rare or threatened areas but also to protect ecosystem functioning everywhere. (b) In a similar vein, non-natives intentionally introduced can be a primary source of serious invasive species and that this negative potential needs to form part of the decision-making process. (c) However, all landscapes are vulnerable not only to non-native species but also to native species that are imported from elsewhere, for example, from Continental Europe to the United Kingdom, because supply does not meet the demand or because the imported plants are cheaper than the home grown ones. This can lead to devastating effects as in United Kingdom with ash die back (*Hymenoscyphus fraxineus*), with an estimated cost to the United Kingdom of £1.5 billion (US$1.84 billion; Kinver, BBC). Nunes et al. (2016) note that in restoration projects non-EU countries depend 'more on non-native plant species than EU countries, thus deviating from ecological restoration guidelines' and that 'nursery-grown plants… were mostly of local or regional provenance, whilst seeds were mostly of national provenance'. The Forestry Commission in the United Kingdom notes that plants should be sourced locally and should relate not only to geographical position but elevation as well (Hubert & Cundall, 2006). In restoration, the use of seed or plants of local provenance is not only preferable but it should be essential. Finally, (d) there are those who use the philosophy of 'panta rhei', literally translated from ancient Greek, (attributed to Haracleitus), to mean everything flows and that everything is for ever changing and all things are in flux (Meriam–Webster; https://www.merriamwebster.com/dictionary/panta%20rhei) Gröning and Wolschke-Bulmahn (2010) say that nature is in flux and we should accept these changes and not be dogmatic about the use of native plants. With respect to the world being continuously in flux and in particular to the potential changes in regional and seasonal climate patterns due to the concentrations of greenhouse gases, Bakkenes, et al. (2002), modelled 1,400 plant species across Europe to predict plant diversity distributions by 2050. The model predicts 'major changes in biodiversity by 2050' (Bakkenes et al., 2002). Using grid cells across Europe, an average of 32% of species that occurred in a cell in 1990 'would disappear from that cell' and the area in which these 32% or more of the 1990 species that will disappear is across 44% of the modelled European area (Bakkenes et al., 2002). Although it is inevitably the case that change is going to occur and that there is a constant dynamism in nature and people and their interactions together, we need to use the precautionary principle in any planting in drylands and elsewhere as we would use with any project that may have the potential to impact on the environment and cause pollution.

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ENDNOTES

[1] COST Action ES1104 Arid Lands Restoration and Combat of Desertification: Setting Up a Drylands and Desert Restoration Hub, was set up in April 2012 and will run for 4 years. The main remit of the Action is to ascertain current best practice in drylands restoration, to initiate new initiatives and innovation. Benz Kotzen was Chair, Cristina Branquinho was a Working Group Leader and Rudiger Prasse was a Management Committee and Working Group Member.

[2] Figures vary in different publications – The Secretariat of the Convention on Biological Diversity of the United Nations notes that this is US$100 billion but also notes that the loss is in the trillions of US$ worldwide and not just US$1.4 trillion.

[3] Also known as the Florence Convention, it promotes the protection, management and planning of European landscapes and organises European co-operation on landscape issues. The convention was adopted on October 20, 2000, in Florence (Italy) and came into force on March 1, 2004 (Council of Europe Treaty Series no. 176).

[4] Landscape character refers to and describes the type of landscape, for example, steep wooded valley or open, rolling calcareous hills. Landscape quality refers to the land in terms of a hierarchy from very high down to poor quality. Landscape value refers to the value people place on the land. Thus, a World Heritage Site has a very high value whilst a local site that is used for dog walking may be considered having local value.

[5] Of course there are always exceptions, where for example the island of Madeira is renowned for its exotic flora.

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

[7] Some gardens may indeed not have plants, for example, an electronic garden where light and electronic images may be used.

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

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