I.

Introduction

1 Problems and Perspectives of Dryland Restoration

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Introduction

Forest degradation was probably necessary for human cultural evolution, especially for the development of agriculture and animal husbandry. Quite early, however, our ancestors realised the essential asymmetry underlying deforestation and desertification. It is easy to destroy forests, but their recovery is agonizingly slow, if they recover at all. This is nowhere more evident than in the Mediterranean and circum-Mediterranean lands, where some of the first human experiments in transformation of land, urbanization and stable governments were carried out. As early as the fourth century BC, Plato eloquently described widespread and profound human impacts on forests: *"Hills that were once covered by forests and produced abundant pasture now produce only food for bees"*. The degradation-regeneration asymmetry referred to just now is caused by the increased entropy of ecosystems related to the loss of organisation that had evolved over long periods of time. Therefore, while human or non-human disturbances may cause sudden ecosystem (forest) degradation, repair and reconstruction require a long time (fast out, slow in, for example in organic carbon budgets). When positive feedback processes of degradation appear after disturbance, leading to irreversible loss of ecosystem integrity, artificial inputs of energy are needed to stop and reverse degradation.

The recognition of the need for forest restoration is also far from new. Attempts to reforest degraded lands are documented as far back as the Middle Ages (Manuel Valdés and Gil 1998), and deliberate introduction of non-native forest species is known from much earlier times, especially during the Roman empire. Throughout the 18th – early 19th centuries, the so-called Age of Enlightenment, European administrators attempted to preserve and promote forests. However, only since the late-19th century did afforestation efforts attain significance at national scales, finally becoming widespread – if not yet fully developed – during the 20th century.

During the first half of the 20th century, many large afforestation and reforestation projects were conducted in the Mediterranean region, and elsewhere. As an example, the

Spanish National Reforestation Plan, initiated in 1939, led to tree planting – mostly pines – on more than 4 million hectares, in the course of a century (Fig. 1). The results of these efforts were diverse, but nowadays we are able to enjoy, and benefit from, many magnificent forests on formerly degraded land as a consequence of these efforts (Vallejo 2005). Similar efforts were made in France (Vallauri et al. 2002), Portugal (Campos Andrada 1982), Italy (Hall 2005) and further east and south as well. In the last quarter of the 20th century, huge advances were made in the field, both conceptually or technically, as part of the wider, indeed global, movement to begin investing more time, energy and financial capital into the restoration and rehabilitation of degraded and ill-used ecosystems on which all human economies are ultimately dependent. In the 21st century, new challenges – notably climate change, and ongoing human population growth, will require new strategies. We will address these issues at the end of this chapter

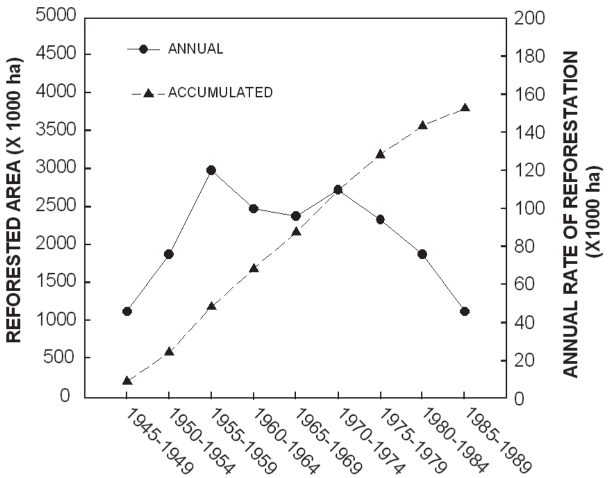

FIGURE 1. Spanish National Reforestation Plan (approved in 1939) (Ortuño 1990).

Here, and throughout this book, we address wildland restoration in a wide sense. In the Mediterranean Basin, as in other seasonally dry regions, the distinction between forests and shrublands is not straightforward. There are frequent and subtle transitions among open woodlands, low forests (sometimes coppices) and tall shrublands (*maquis, garrigue, etc.*), perhaps especially at the drier end of the range of Mediterranean bioclimatic conditions (Aronson et al. 2002). In addition, many sclerophyllous shrubs may attain tree-size if allowed enough time and space to grow. In ancient Roman times, *silva* (forest) was clearly distinguished from *saltus* (uncropped forest region and other wildlands used for grazing). Under the Spanish legislation, however, forest lands include all wildlands under the term *monte*, even those without continuous tree cover. For the Inter-governmental Panel on Climate Change (IPCC), in its efforts to establish carbon budget accounting, "forest" is defined in very broad terms as a minimum area of 0.05-1.0 ha with tree crown cover of more than 10-30%, including trees with the potential to reach a minimum height of 2-5 m at maturity (UNFCCC 2002), also including young stands resulting from plantations or regenerating after disturbance. According to that definition, a great number of plant formations of arid lands – including open woodlands and tall shrublands, could be considered as forests under the Kyoto Protocol. Considering these peculiarities of the drylands, hereafter we will use land and forest restoration in the wide sense of assisting the recovery of degraded lands as per the SER International's Primer of Ecological Restoration (SER 2002) towards any natural wildland type, such as shrubland, woodland and forest *sensu stricto*.

Arid and semi-arid lands are highly sensitive when faced with anthropogenic forces of perturbation and degradation. Plant cover is scarce and especially vulnerable to disturbances, unpredictable and prolonged periods of drought. In addition, plant recovery after damage is very difficult under these stressful conditions, and this applies both to natural regeneration and to artificial restoration. Therefore, as plant regeneration is the major driver of ecosystem recovery, land restoration is especially necessary and, at the same time, difficult in arid and semi-arid lands.

Major difficulties of reintroducing plants in Mediterranean degraded lands are related to a combination of high water stress and regimes of high risk of varied post-plantation disturbances, including fire and grazing by domestic or wild animals, combined with relatively moderate impacts from competition (Fig. 2). In moister environments, stress is lower and competition higher. Therefore, restoration of Mediterranean ecosystems would especially require addressing ways of overcoming water stress and avoiding or mitigating the impact of disturbances.

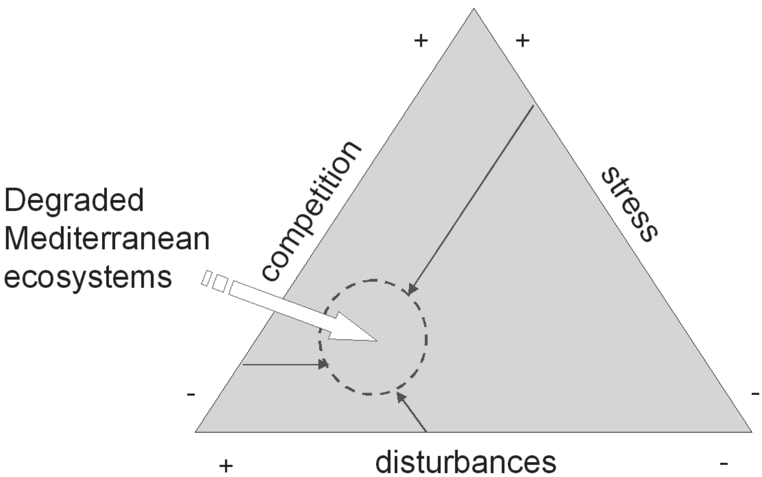

FIGURE 2. Main limitations for reintroducing plants under Mediterranean conditions. Triangle inspired by Grime's work on plant life history strategies (1979).

Old *vs.* new approaches

Traditional reforestation projects conducted in the Mediterranean countries were not, strictly speaking, ecological restoration projects as we understand this term nowadays. However, they embraced the broad aims of restoration, such as reducing soil erosion and runoff, or recovering natural forests, though sometimes exotic species were used as intermediate stages in the rehabilitation process (e.g., Vallauri et al. 2000, Hall 2005). In Mediterranean countries, most afforestation projects addressed watershed protection, reducing floods and soil erosion, and, in coastal areas, stabilization of mobile dunes. In addition, a common goal was to increase forest surface and productivity, while improving rural economies through the creation of jobs and livelihood opportunities provided by the project execution investments and the expected increase in timber and non-timber forest productivity.

Strong socio-economic development in southern European countries during the second half of the 20th century lead to profound changes, with rapid and dramatic depopulation of many rural areas, changes in land use – agricultural land abandonment, reduction of grazing and firewood collection, etc. – and a decreasing dependence of rural people on forest resources. Slowly, a new perception of nature was growing in the EuroMediterranean countries and elsewhere that lead to new demands on wildlands, leaning more towards recreation, and ecological, cultural and landscape values. Of course, these new demands required, and still require, a corresponding adaptation of forest restoration techniques to meet these demands. The transition between old and new objectives is best characterised by a shift from reforestation, tree-oriented interventions based on the planting or seeding of both native and non-native trees, followed by silviculture, to ecosystem-oriented, ecological restoration of native ecosystems within vibrant cultural landscapes. This requires the diversification of plant species used in restoration projects, and making better use of the large pool of native species available, as well as considering fauna, microorganisms and soils along with plants.

The use of larger number of native species in particular requires the corresponding research and development on their autoecology, ecophysiology and appropriate cultural techniques. Accordingly, the recent afforestation measures for setting aside agricultural lands, promoted under the Common Agricultural Policy of the European Union, was conceived to aid in recovering native forest ecosystems. In the future, much more attention should be paid to the “hidden” part of ecosystems, particularly soil microorganisms that play such a critical role in the restoration process.

At present, differences in socio-economic development, degree of dependence on natural resources among countries around the Mediterranean, and among regions within countries, make possible the more or less comfortable coexistence of old and new approaches and techniques in afforestation. The challenge is to harmonize restoration strategies and techniques for sustainable, multipurpose afforestation/reforestation.

Local vs global

In the current era of globalisation, we widely assume the principle of thinking globally and acting locally. And this especially holds for land restoration. In science, of course, we must try to derive principles of general application. But land degradation, and the co-related land restoration, are the consequence of specific impact of local actions on local ecosystems along specific time frames. Therefore, the multiple combinations and outputs of this set of specific variables make it difficult to derive generic protocols or solutions for ecological restoration. Therefore, we recommend developing specific restoration strategies for specific regions with a shared history and biophysical setting. In this book, we focus on the Mediterranean Basin, and secondarily, on other seasonally dry lands elsewhere, assuming that transferring the guidelines to other biogeographic and socio-economic contexts will require the reformulation of approaches. However, acting locally can, to some extent, have global consequences. Local actions, such as restoration projects, if developed at sufficiently large scale, may trigger feedback processes that could influence local climate and ultimately even at the global scale, and this might be especially the case in the Mediterranean Basin (Millán et al. 2005, Clewell and Aronson 2006, 2007; see Chapter 2, this volume).

Structural mismatching of forest management policies

It is widely accepted that land and forest management must respond to social demands, and this includes forest restoration (Lamb and Gilmour 2003; see Chapter 3, this volume). The structural problem of the forest sector in industrial and post-industrial societies is that social demands, and their expression in forest policies, change faster than forest ecosystems grow and develop. Consequently, forest policies that respond to current demands from forests (or more generally from land use interests) may become obsolete in only a few decades, leaving to future generations a problem that may be difficult to reverse, or definitively irreversible. Examples of this time mismatching are: a) the clearcutting of cork oak woodlands conducted in Portugal for wheat production during the 1930s (Roxo et al. 1999), the later abandonment of many of these fields because of poor soil productivity, and the recent attempts to recover cork oak in these now degraded soils; and b) the eucalyptus plantations established in dry areas of western Spain in the 1960s, which are now abandoned, suffering frequent wildfires and, in some cases, uprooted at a large economic cost to restore the native forest. To overcome these contradictions, land use and forest management policies should have long-term perspectives, keeping ecosystems under the threshold of reversibility for any other future productive use. This is a basic assumption of sustainable and prudent land use: potentially productive lands should at all costs be protected and buffered outside of political fluctuations.

Evaluation of restoration efforts

Natural values form part of the icons of welfare in post-industrial societies, including degraded land restoration. This assumption allows and encourages widely accepted investment of public and private funds in land restoration. However, land restoration is still in a kind of early development stage where public valorisation criteria mostly rely on rough quantities (e.g., afforested surface area) with little, if any, evaluation of the quality (and persistence) of that restoration effort. Afforested/reforested acreage is easily confronted in political discussions with fire-damaged acreage as indicator of environmental policy efficiency, easily convertible in budgetary terms. Evaluating at this simple level may promote restoration actions *per se*, without sufficient justification, and hinder the prioritisation of really necessary and good quality projects. Quality control and detailed, scientifically based evaluation of restoration projects are essential elements of their performance (as in many other economic activities) that would contribute to the optimisation of restoration investments and delivery of feedback from restoration experiences into the improvement of the processes. In this spirit, the EU-funded REACTION project was launched with the primary goal of developing and propagating tools for evaluating forest restoration projects in the Mediterranean region. Quality control and evaluation of restoration projects is a major subject of this book, especially in Chapters 2 to 5.

The evaluation of restoration projects should consider ecological, technical, and socio-economic issues (see Chapter 2, this volume, and Clewell and Aronson 2006). Innovation in restoration technology often derives from sophisticated techniques that highly increase implementation costs. However, such technical developments should be accompanied by careful cost-benefit analysis so as to avoid extreme economical unsustainability (see below). Indirect, passive restoration techniques usually are much cheaper than direct interventions and accordingly they deserve greatly increased attention.

The challenges of the near future: the perspectives of climate and land use change

Mitigation vs. adaptation to climate change

Future perspectives of forests and land restoration need to be considered in the perspective of land use dynamics, primarily driven by human demands on goods and services. Recently, Rounswell et al. (2006) have proposed future land use scenarios for Europe on the basis of the IPCC emissions scenarios (Nakićenović et al. 2000). Scenario changes are coincident in a generalised increase of agricultural land abandonment. This would reinforce present trends in Southern Europe with regard to the spread of wildfires, the increase of desertification processes, and more opportunities for restoring degraded lands.

Apart from the outstanding and historical role of land use change as a driver, a newly recognised process will undoubtedly have great influence on land management and restoration strategies, i.e., anthropogenic climate change. Now and in the future, global society should incorporate in the formulations of land restoration the limitations (and opportunities?) of climate change, or better the risks associated to climate change projections (Harris et al. 2006). For the Mediterranean, these projections foresee an increase of drought intensity and frequency of extreme events (drought spills, heavy rainstorms) and induced disturbances such as wildfires and flash floods for the next century or so (IPCC 2001), that is in the time window of full development of restoration projects that are initiated right now. The increase of water shortage in the Mediterranean would be especially acute in transition regions that may trigger dramatic changes in ecosystem composition and structure, e.g., from dry sub-humid to semi-arid (loss of forest cover potential), and from semi-arid to arid (strong reduction of plant cover). However, the relative effects of land-use induced degradation and climate-change induced impacts, and their interactions, are difficult to advance so as to incorporate them in the restoration practise. Of course, the combined effects of human disturbances and climate change are far from linear. Soil properties are very sensitive to land use impacts, and only slowly responsive to climate change. In fact, relict soils having supported various climate change cycles are frequent in the Mediterranean and other warm regions in the world. We can hypothesise that in extremely disturbed sites, climate change impact would be comparatively lower than in less disturbed sites. In view of these perspectives, the key question is how to design restoration projects, and what references should be used (Fig. 3). Should we accommodate our techniques and species selection to the expected aridisation of the climate, that is taking a pure adaptation approach, or should we use species and techniques trying to mitigate climate change?

According to the IPCC, mitigation is an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC 2001). Land restoration would contribute to carbon sequestration, so reducing a major driver of climate change. This area was under discussion in the negotiations of the Kyoto protocol on two headings: afforestation/reforestation and revegetation. Direct human-induced conversions of land through afforestation (on non-forest land in the past

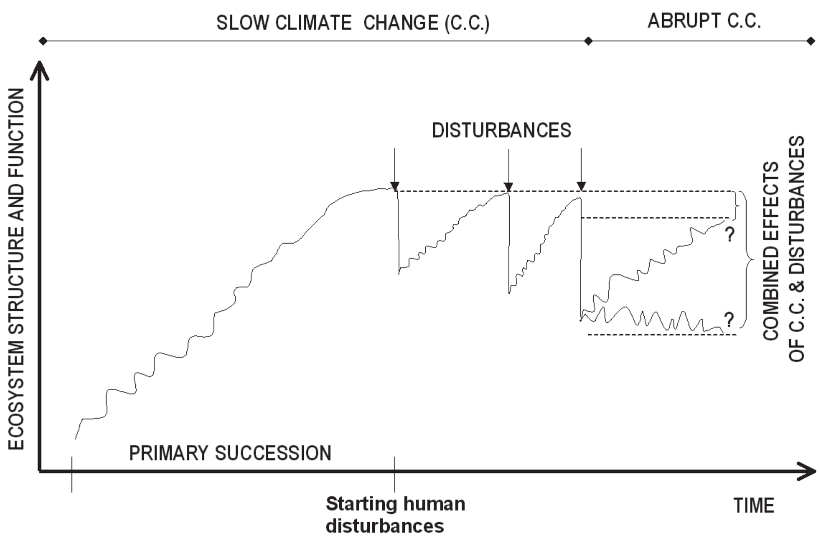

FIGURE 3. Schematic hypothetical changes of ecosystem structure and function over time. There are large uncertainties concerning the combined effects of the two main drivers – direct human disturbances and projected abrupt climate change resulting from anthropogenic modifications to the atmmosphere. How these impacts modify ecosystem structure and processes will have great significance in determining how to choose and utilise reference systems for restoration projects.

50 years), reforestation (on non-forest land for less than 50 years) or revegetation (other vegetation establishment activities) are considered to increase carbon stocks (UFCCC 2002).

Adaptation is defined as the adjustment in natural or human systems in response to actual or expected climatic *stimuli* or their effects, and to degradation drivers and impacts, which moderates harm or exploits beneficial opportunities (IPCC 2001). Adaptive land restoration should adjust landscapes and ecosystems to the expected climate change, including their role as providers of goods and services. At the planning scale, one relevant question would be how to design ecosystems spatial distribution in the landscape to optimise their response to the major foreseen threats in the Mediterranean and other drylands: increased water scarcity and social water demands, protecting watersheds against flash-floods, and reducing wildfire risk. In fact, these threats are already present, though are supposed to increase in the near future. At the ecosystem level, one major question would be to what extent must we anticipate climate change introducing species or ecotypes characteristic of drier regions? Or should we preserve the ”original” vegetation as it is currently understood? Harris et al. (2006) point out the difficulties in finding or choosing references under conditions or scenarios of abrupt climate change. In the ACACIA assessment of potential effects of climate change in Europe, Parry (2000) suggested using tree provenance of more southern origin and wider spacing in plantations as adaptation measures. Fully adaptive measures may reduce mitigation effects (e.g., lower capability of sequestering carbon) and the possible feedbacks on local climate. Of course, there are many uncertainties concerning the consequences of these choices and specific research should be conducted to reduce risks of undesired outcomes. One major question to address is how ‘restorable’ are our extremely degraded ecosystems right now, and at what technological and economic cost could restoration be achieved (see Chapter 8). Answering this question would not only allow greater chances of success in restoration projects but also provide clues on how the foreseen climate change would affect restoration thresholds.

The need of integrating land restoration in the economy: Is carbon sequestration/emissions trading under the Kyoto protocol a viable strategy and tool for restoration?

Land restoration is, in many cases at least, and perhaps especially in developed countries, uneconomical in market economy terms. Restoration works are indeed often expensive or extremely expensive, and most of their direct benefits, such as improving biodiversity and habitat, reducing soil erosion, improving carbon sequestration, improving aesthetic and cultural values of the landscape and so on, are “externalities” – as defined by conventional economic measures. To date, the market deficit is assumed by public and charity funds, and these are unstable and vulnerable to other demands for resources. One promising way of stabilising and rationalising restoration economics would be to introduce the benefits in the marketplace through the economic valuation of goods and services provided by restored ecosystems (Harris and van Diggelen 2006, Rees et al. 2007) and try to include the reparation costs on the degrading agents and/or on the beneficiaries, though in many cases that approach is not possible and financial responsibility falls to the taxpayers (see Holl and Howarth 2000). European Union, Australian, and United States regulations on quarry restoration by the exploiting company are good examples of internalisation of restoration costs by the direct beneficiary of the exploited resource through assurance bonding. In any case, this is a very complex task that deserves much attention and social debate (see Aronson et al. 2007, and Chapter 2, for further discussion, in the context of a new paradigm called restoring natural capital).

Kyoto protocol agreements offer a promising opportunity for funding restoration through the possibility of linking goals of sequestering carbon with restoring degraded lands (so combating desertification (UNCCD) and even improving biodiversity (CBD)). Therefore, bonuses could be transferred from emissions to sequestration through restoration. Along these lines, the European Parliament (Rey and Mahé 2005) has suggested developing market mechanisms for member states for maintaining and increasing carbon sequestration in European forests, through funding forest externalities and promoting the use of wood for energy. However, there is much debate still as to the carbon-offset efficacy of tree-planting in extra-tropical areas as compared to tropical zones.

Concluding remarks: key issues

This book addresses key issues in land restoration that emerge from restoration science and practice in the Mediterranean Basin. On the grounds of the long-standing and well-developed afforestation experience in Mediterranean countries, we shall suggest ways to incorporate lessons learned from past experiences into new restoration approaches, to face new and old threats, and new challenges and opportunities, using new and not-so-new approaches and techniques. The first part of the book deals with missing elements in the restoration practise that are critical steps for rationalising the incorporation of restoration activities in the economy, namely quality control, monitoring and evaluation. The second part tackles specific, innovative developments of restoration techniques. These include plant selection of species and provenances, and nursery and field techniques to overcome water stress as the major limitation in drylands – now and in the perspective of projected climate change. Specific chapters are devoted to developing restoration strategies and measures for widely representative cases of desertification-threatened lands, i.e., semi-arid lands subjected to long-term degradation under high water stress, and burned forests. In a final chapter, the editors offer a summary and synthesis, and some thoughts on the way forward.

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