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Monitoring Guidelines for the Implementation of Forest Restoration Projects in Mediterranean Regions

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Introduction

It is generally understood that ecological restoration is still young and evolving (Hobbs and Harris 2001, Winterhalder et al. 2004, Clewell and Aronson 2006). However, the restoration of degraded lands has become increasingly important worldwide, leading to growing demand for ecological restoration expertise, practitioners, and eco-technological products, as well as research in restoration ecology (Dobson et al. 1997, Dudley et al. 2005, Young et al. 2005).

In the Mediterranean Basin, forest restoration is a long-standing practice, which experienced a particularly intense period from the end of the 19th century to the mid-20th century (see Chapter 1, this volume). Restoration of degraded or damaged forest ecosystems includes many restoration activities of which planting is almost always a key component (Harrington 1999). Historically, large-scale tree planting activities constituted the sole restoration action in the Mediterranean basin. Nowadays, the restoration of forest lands includes the use of herbaceous, shrub and tree species, as well as activities aimed at enhancing the autogenic restoration of ecosystems (Vallejo et al. 2006), and there is an increasing interest in working toward the exploration of sustainable forest landscape restoration practices (Boyle 1999, Holl et al. 2003).

Forest landscape restoration has been defined as: “a planned process that aims to regain ecological integrity and enhance human well-being in deforested or degraded landscapes” (Dudley et al. 2005). According to this concept, developed by The World Conservation Union (IUCN), The World Wildlife Fund (WWF), and some of their partners, restoration should not try to re-establish the “pristine” forests of the past. Furthermore, restoration projects are dynamic and their inherent uncertainty needs to be managed; resulting in a process rather than a planned product (Fulé et al. 2002, SER 2004, Saint-Laurent 2005, Falk 2006).

An essential part of any restoration project is an effective monitoring system, which allows the status and trends of selected indicators to be measured and helps to identify the corrective actions and modifications needed (Vallauri et al. 2005). Monitoring increases our understanding about ecosystem and landscape response to restoration treatments and thus plays a major role in reducing and managing uncertainties in restoration actions.

In the Mediterranean basin, due to the historical degradation of forest ecosystems and to the current complexity of a situation in which society demands multiple uses for these ecosystems, together with increasing land use pressure and wildfire occurrence, there is a critical need to assess the results of restoration activities and establish standard monitoring practices as part of the restoration efforts. The aim of this chapter is to provide monitoring guidelines to be applied to forest restoration efforts in the Mediterranean. A methodology for improving monitoring procedures in forest restoration is proposed which includes four monitoring phases –Baseline, Implementation, Functional Assessment, and Long-term monitoring– within an adaptive management framework. Additionally, limitations to monitoring in the Mediterranean region are discussed and solutions anticipated. As a frame of reference, two restoration projects in Andalusia (southern Spain) are used as examples of implemented monitoring activities.

Monitoring of forest restoration projects - An adaptive management approach

Restoration monitoring is the systematic collection and analysis of data that provide useful information for measuring project performance at a variety of scales. It is designed and conducted to provide useful data to understand why some restoration techniques and practices work, and, equally important, why some fail (Thayer et al. 2003, Saldi-Caromile et al. 2004). Monitoring can be a powerful tool if the objectives are clearly stated and the monitoring action is well-designed, rigorous and scientifically-based (van Diggelen et al. 2001). Monitoring must be scaled spatially and temporally to the response variables assessed (White and Walker 1997, Block et al. 2001). Additionally, to provide unbiased estimates of significant response variables, the monitoring design needs to include statistical considerations, such as the distribution of sampling sites and the number of replicate samples to be collected (Gibbs et al. 1999).

Although Mediterranean countries have long-standing experience in reforesting degraded lands, assessment and monitoring have rarely been done, and when they were done, they were essentially based on a few early assessments of seedling survival. Consequently, scientific and technical information on past reforestation projects is scarce (see Chapter 4, this volume). Some recognised reasons for this limited monitoring of forest restoration actions in the Mediterranean region include economic and political constraints as well as scientific and technical limitations. Thus, for example, there are many tree species for which our knowledge is still extremely limited (Méndez et al. 2008), and there is still a lack of understanding of the effects of reforestation on various system processes and components (Maestre and Cortina 2004), which compromises the selection of response variables and critical values for monitoring. Monitoring of forest restoration should be carried out over a a long enough time to address the processes and dynamics of interest, and to take into account the variation in environmental conditions (Block et al. 2001). Unfortunately, there are imposed constraints associated with political turnovers and the time frames for agency budgets. Consequently, monitoring efforts are not supported with the funding required to implement long-term monitoring plans. Despite the recognised constraints, monitoring needs to be a routine practice and an integrated component of restoration planning. Effective monitoring results in greater efficiency and lower cost for future restoration activities, provides technical bases to demonstrate the effectiveness of public expenditures, and informs funding agencies so they can refine their funding priorities over time (Gaboury and Wong 1999).

Though the uncertainty in forest restoration can probably never be fully overcome (Gomez and Elena 1996, Pemán 1997, Navarro et al. 2003b), periodic estimates of the magnitude and trajectory of suitable response variables provide an ongoing evaluation of the restoration strategy and, thus, a basis for decisionmaking under an adaptive management framework. The restoration activity can thus be improved, creating a feedback loop of continuous learning (Gibbs et al. 1999, Gayton 2001), where the problems addressed, the objectives, the design and implementation of the project and the monitoring program are adjusted to reflect the understanding gained through the monitoring action (Fig. 1). Actually, the monitoring action should permeate the whole restoration process, from problem assessment and project design to evaluation and adjustment. Thus, for example, to assess initial conditions for the target area, pre-restoration (baseline) monitoring must occur. Monitoring procedures for evaluating project implementation and project results must also be established. Monitoring includes decision making. Thus, monitoring programs should incorporate all the procedures that connect the monitoring results to the decision process (Noon et al. 1999), and decisionmakers should be involved in the planning and application of the monitoring programs (Noble and Norton 1991).

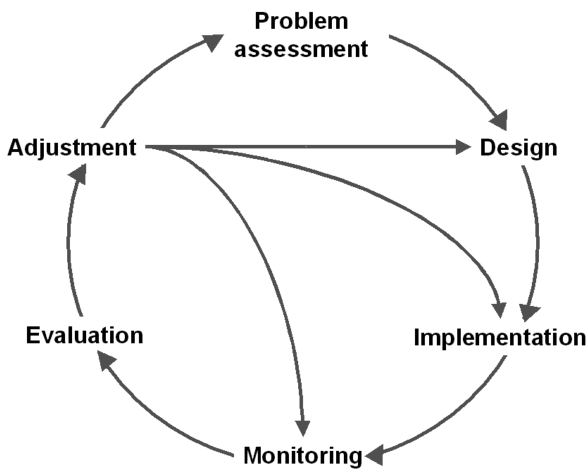

FIGURE 1. An adaptive management framework for ecosystem restoration (adapted from Gayton 2001).

Monitoring phases: baseline, implementation, effectiveness, and long-term monitoring

The herein-proposed monitoring methodology to be applied to forest restoration in the Mediterranean region follows the general monitoring approach suggested by Holl and Cairns (2002), and can be described as an adaptive management-based method articulated in four key phases: Baseline, Implementation, Effectiveness, and Long-term monitoring. Baseline monitoring primarily addresses the assessment of baseline, pre-restoration conditions. Parallel to the planning of the restoration project, monitoring objectives and questions, and a strategy to answer these questions, are also established during this first phase of baseline monitoring. Frequency and duration of monitoring measurements, spatial scales for monitoring, and budget opportunities and constraints are key elements to be considered while designing the monitoring plan. Implementation monitoring is used to assess whether the previously established quality control conditions for the project implementation are being met. This phase serves as a checklist for implementing and managing the restoration project, and for assuring compliance with the contract prescriptions. Effectiveness monitoring assesses the effect of the restoration action on target attributes previously selected as suitable indicators for evaluation purposes. This phase helps in determining the degree to which restoration activities attain the specific objectives set out in the planning phase. Finally, long-term monitoring aims at assessing trajectories and trends in the restored area, determining whether the ultimate restoration goals can be attained or whether the key assumptions underlying the restoration project were valid. Table 1 describes some primary tasks for each of these phases. Each task can also be considered a contingency factor that influences the quality of the implementation of the next steps in the monitoring program.

The application of this four-phase monitoring approach to forest restoration projects in the Mediterranean region can be further improved by using simplified but technology-sound based tools (e.g., using PERT® charts to schedule project activities – see Fig. 2; using GPS technology and GIS applications to consider and analyse spatial information), and by establishing monitoring objectives according to the existing empirical experience in Mediterranean forest restoration, and the particular environmental and socio-economic framework in the region. The following sections describe implementation examples of the various monitoring phases in the context of forest restoration in the Mediterranean region.

TABLE 1. Examples of primary tasks associated with key phases in forest restoration monitoring.

Monitoring phases	Tasks
Baseline monitoring	- Before the start of the restoration project, identify existing biophysical, social and cultural conditions and establish benchmarks (gather information on historical conditions and current land uses, identify and analyse available cartography, aerial photography, etc.) - Document project decision-making process (review available reports on site conditions and management plans) - Document project objectives and design (including time and spatial scales considered) - Become familiar with similar restoration projects - Define monitoring questions and develop a monitoring program
Implementation monitoring	- Assess implementation technique (e.g., seedling quality, site preparation, treatment application, spatial arrangement and scheduling of treatment application, etc.) - Assess compliance with the contract
Effectiveness monitoring	- Choose a standardised sampling design and monitoring variables that are based on a conceptual model for ecosystem response to restoration - Adjust monitoring design to the temporal and spatial scales of the processes addressed. Define the target sampling population and plot size and shape (consider potential for establishing a pilot study in the area), and the statistical parameters to be considered - Evaluate project results according to benchmarks and specific project objectives - Analyse, interpret, and summarise results; deliver monitoring reports and provide feedbacks for the adjustment of restoration objectives, design, and monitoring plan.
Long-Term monitoring	- Select suitable response variables for long-term monitoring - Continue the monitoring action in the long-term; establish permanent plots and sampling points. - Evaluate the ultimate goal, strategies, and cost-effectiveness of the restoration effort - Consider and propose alternative approaches in view of the lessons learned from the monitoring action

Baseline monitoring

Baseline monitoring creates an image of the existing conditions before the restoration work begins. It should include two critical steps: gathering of available baseline data and data validation. Baseline data validation aims at verifying in the field the information provided by available cartography and reports, and thus establishing the actual site conditions. Both the collection of baseline information and the validation take place before the implementation-monitoring phase. The main objectives of baseline monitoring are (1) to establish initial conditions and benchmarks to be considered in the subsequent monitoring phases; (2) in combination with implementation monitoring, to detect deviations between what has been planned and what is actually being implemented in the field; and (3) to provide the necessary background information to design the appropriate monitoring program.

An efficient software that can greatly facilitate monitoring planning efforts is Microsoft Project®, with added assistance from its Program Evaluation Research Technique (PERT) extension tool. This tool helps to plan all the tasks that must be completed as part of a program, to determine a realistic duration for them, and to monitor the achievement of project goals. A PERT analysis can also be used to compare the proposed planning of the restoration project with what actually takes place in the field, and thus to detect deviations during project implementation. The importance of these deviations is well-illustrated with the example of PERT charts created for an actual post-fire restoration project in Andalusia (Fig. 2). The application of PERT® also allows us to foresee any potential error regarding project planning and scheduling (timing, order of implementation), which can thus be corrected while the project is being implemented.

Limitations to baseline monitoring include difficulties in gathering data, particularly in digital format (e.g., readily available spatial information such as digital cartography); moreover, budgeting constraints often reduce the necessary field work involved to achieve the desired project analysis. The latter case applies to all monitoring phases.

Finally, consideration must be given to the following fundamental questions regarding monitoring design. These questions must be answered before starting any restoration work in order to progress toward the next monitoring phases:

1. Are the monitoring objectives and questions clearly established?
2. Is there a suitable monitoring strategy developed to meet those objectives?
3. Do the proposed activities and trials properly address the questions that the monitoring is supposed to answer?

Implementation monitoring

Implementation monitoring aims both to assess whether what is being implemented is correct or not (according to the project prescriptions) and to evaluate the potential impact of the deviations observed in the degree of achievement of the restoration project goals. For common planting-based forest restoration projects, actions to be revised at the implementation monitoring stage include the selection and use of the plant material (i.e., species selection, seed provenance, plant quality, stock handling and transportation); treatment application (i.e., selection of planting sites and microsites concerning aspect, slope, soil properties, rock outcrops; field site preparation; post-planting treatments, etc.); and actual scheduling of the implemented actions.

Project implementation activities are critical to the overall success of the restoration project, and therefore they deserve careful assessment. It is often stated that immediate failure after outplanting is the result of uncontrollable conditions (e.g., climate anomalies, uncontrolled grazing, floods, etc.) affecting the area to be restored. However, the lack of

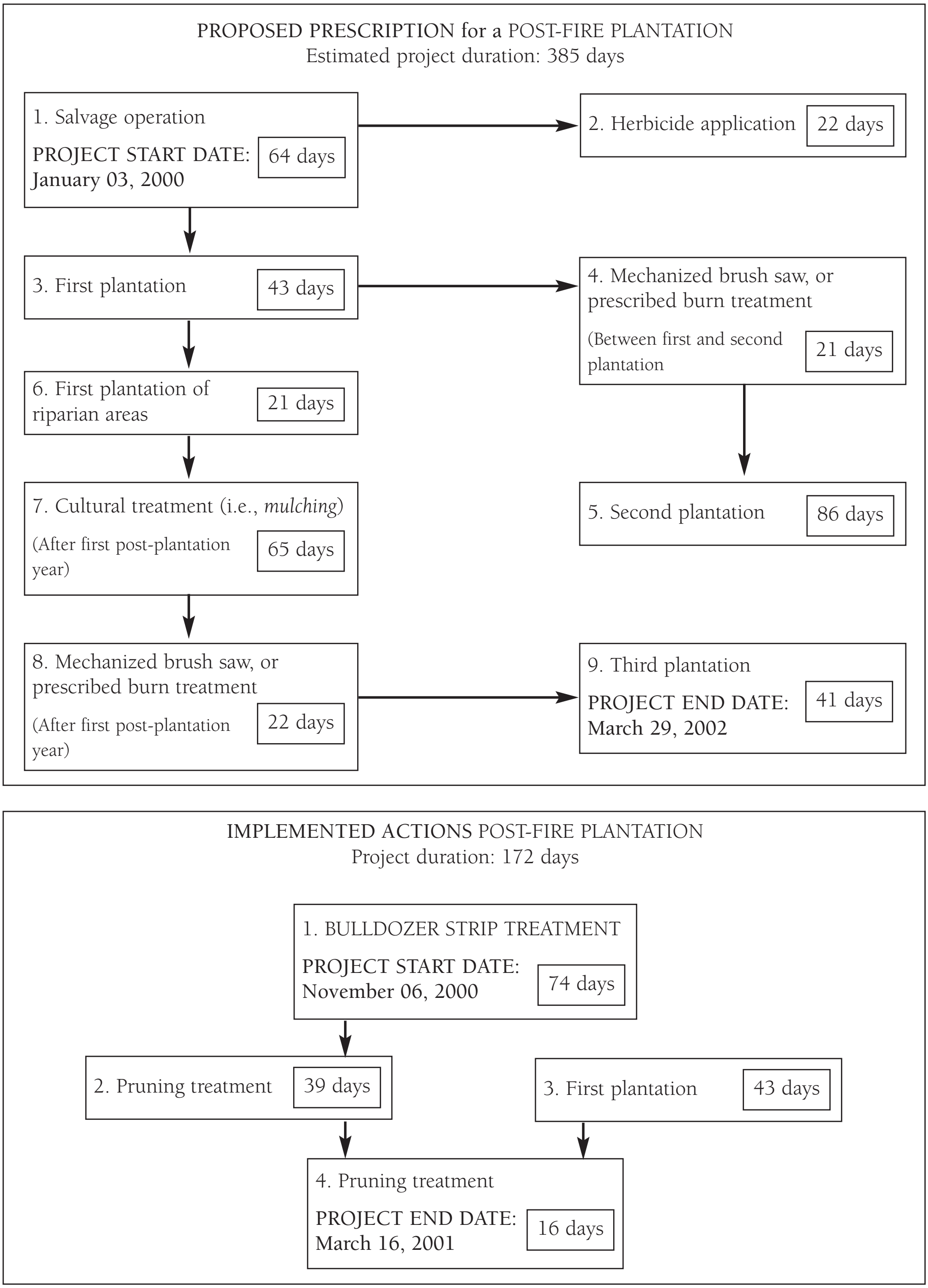

FIGURE 2. PERT chart of proposed prescription versus implemented actions for a post-fire reforestation project in El Madroñalejo (Seville, southern Spain).

implementation monitoring may leave the real causes of post-planting seedling mortality indeterminate. For example, poor quality nursery stock (e.g., unbalanced shoot to root ratios) that jeopardizes plant survival under field conditions could be identified by appropriate monitoring during the implementation phase of the project. Table 2 shows some results from the assessment of short-term post-plantation seedling survival for the various nursery stock types used in a post-fire restoration project. The assessment results help to identify species and seedling stock combinations that might not be suitable for the conditions prevailing in the area to be restored.

Although quality standards for seedling nursery stocks do exist for many of the Mediterranean species used in common restoration projects, they are frequently ignored. As a result, the quality of the seedling stocks produced for planting-based projects is often very poor. Implementation monitoring checks whether these seedling quality standards have been met or not. Also, regardless of the degree of compliance with the standards achieved, it comparatively assesses the effect of the various stocks used on early seedling performance (Table 2).

TABLE 2. Average survival rate (percentage) for contrasting nursery stocks (various combinations of species and container sizes) used in a post-fire restoration project in Guadiamar, south-western Spain (Navarro et al. 2003a). Data obtained 3 months after outplanting.

	Volume of seedling container				
Species	**200 cc**	**210 cc**	**300 cc**	**400 cc**	**500 cc**
Arbutus unedo		0 %		5 %	
Crataegus monogyna			40 %		
Pyrus bourgaeana			15 %		
Pistacia lentiscus		95 %	90 %		35 %
Retama sphaerocarpa	95 %	100 %		100 %	

Temporal and spatial scales for project monitoring are key aspects to be considered when scheduling the monitoring program, and the implementation monitoring in particular. Both the monitoring design and the size, number and shape of the monitoring plots must be scaled to the extent of the target area, and the questions being addressed (Holl and Cairns 2002). Depending on the size of the project and the degree of regularity of the activities performed, the frequency of monitoring (when and how often monitoring activities will occur during project implementation) can vary from intensive quantitative data collection during certain periods of the implementation phase to more infrequent and regularly scheduled measurements (Gomez and Elena 1996, Pemán 1997, Navarro et al. 2003b).

Although the implementation phase of a restoration project is critical to the achievement of the project goals, deviations from project design and implementation schedule are very common (Fig. 2). Reasons that account for such deviations include: (a) lack of continuity between planning and implementation, since the manager implementing the project in the field is not usually the designer of the project; (b) lack of adequate baseline data needed in advance to design the restoration project to properly match the site conditions; and (c) budgetary constraints that preclude making needed adjustments to address unforeseen problems that emerge during the implementation phase. For example, Figure 3 illustrates the within-site spatial variation in the degree of implementation (relative to the planned actions) for a particular post-fire restoration project, with a spatial arrangement of treatment units that ended up differing considerably from the planned units due to the challenges of field implementation.

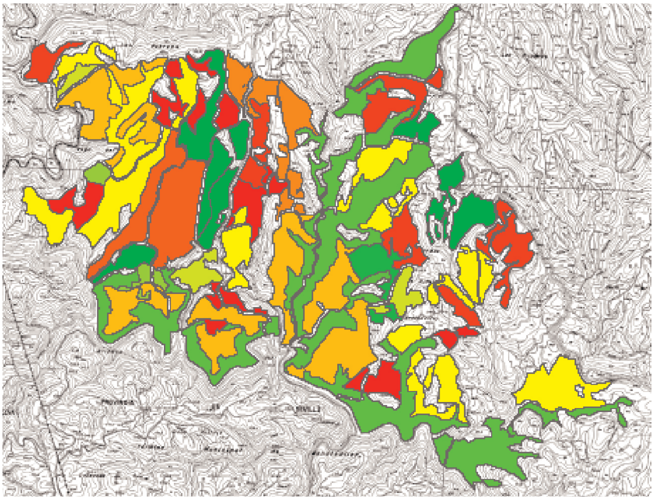

FIGURE 3. Differences between planned and implemented restoration actions and project stages in the El Madroñalejo post-fire restoration project, Seville, southern Spain. Different colours represent different degrees of implementation success.

Feedbacks from the implementation monitoring to managers must serve to determine if the modifications produced are significant and relevant and whether they should be reversed or altered. The modifications accepted, and the respective changes in the associated specific objectives, will result in a new (modified) framework for designing and implementing the subsequent monitoring phases.

Effectiveness monitoring

During the effectiveness monitoring phase, changes and trends over time in one or more of the selected indicators are assessed and evaluated (White and Walker 1997). Effectiveness monitoring is used to determine whether the restoration project achieved the specific project objectives. In reforestation and afforestation projects in the Mediterranean region, effectiveness monitoring is typically performed during the first few years after the implementation phase of the project and, therefore, is focused on the initial response of the target area and species, assuming that this short-term response is a good indicator of the long-term trends. Effectiveness monitoring requires data collection to follow a repeated sampling approach, in order to provide preliminary information regarding the potential dynamics in the target area. This is particularly applicable in the context of adaptive management, where the implementation and management of the restoration efforts depend on monitoring feedback. Furthermore, established monitoring plots may act as study sites that provide observational data for future consideration.

Field measurements of seedling survival and growth are the first steps in evaluating the degree of success of most planting-based restoration projects in the Mediterranean region (Maestre and Cortina 2004). These measurements aim to evaluate the degree of seedling establishment as well as the seedling response to the conditions prevailing during the first post-planting years, with special emphasis on the critical period corresponding to the first summer season. Survival and growth values are then analysed in relation to meteorological and site conditions, site preparation, microsite location, treatments applied, and data available from the previous monitoring phases. These analyses should provide insights into cause-and-effect relations between environmental stressors, treatments applied and seedling response (Machmer and Steeger 2002). For example, seedling survival was the key success indicator for the Guadiamar post-fire restoration project (Table 3). By comparing this project with similar restoration projects and previous experiences in similar areas, and taking into account the weather conditions during the first post-planting year, we used these survival values to estimate future project outcomes regarding ecosystem functioning and plant population trends.

As in to the implementation-monitoring phase, the schedule of the effectiveness-monitoring plan can be adjusted to allow more intensive, quantitative data collection to take place during pre-determined critical periods, such as the first post-summer season. After this initial period, the frequency of monitoring can be reduced to address long-term dynamics and silvicultural needs rather than initial success (see below).

Preparation of data summaries and interpretive reports, and associated feedbacks to management are also key components of effectiveness monitoring (Gaboury and Wong 1999, Mulder et al. 1999). Appropriately analysed information should be rapidly accessible to a wide audience, particularly to decision makers. Data summaries should be brief, comprehensive reports on the essential data collected; periodic interpretive reports should evaluate the significance of the status and trends emerging in the monitoring data. The resulting information can thus be used to change plans and directions, as well as budgetary decisions.

TABLE 3. Survival rate (percentage) for the target species used in the Guadiamar post-fire restoration project in south western Spain (Navarro et al. 2003b).

	Number of seedlings		**Survival (%)**
Species	Estimated (to be planted)	Actually planted (2002)	1 year after planting (2003)
Arbutus unedo L.	1650	985	46
Celtis australis L.	1672	797	44
Ceratonia siliqua L.	494	256	41
Chamaerops humilis L.	144	41	21
Cistus salviifolius L.	550	389	64
Cotoneaster integerrimus Medicus	1700	420	19
Crataegus monogyna Jacq.	1150	563	46
Fraxinus sp.	1902	918	23
Genista sp.	888	378	36
Lavandula angustifolia Miller	2550	1245	38
Lonicera sp.	300	55	14
Myrtus communis L.	2050	1259	56
Nerium oleander L.	200	161	79
Olea europea L.	2435	1491	60
Pinus sp.	575	383	47
Pistacia lentiscus L.	814	456	48
Populus sp.	478	361	59
Pyrus bourgaeana Decae	1200	736	51
Quercus ilex L.	460	281	56
Rosa sp.	1100	577	49
Rosmarinus officinalis L.	550	422	74
Rubus fructicosa L.	600	95	2
Salix atrocinerea Brot.	250	227	80
Tamarix sp.	150	115	69
Teucrium fruticans L.	888	476	43
TOTAL	**24428**	**11305**	**47**

Long-term monitoring

Long-term monitoring may be necessary to evaluate the results of many restoration projects. In fact, the final outcome of a reforestation project can only be assessed comprehensively in the long term, after several decades. However, funding sources for long-term monitoring are very limited. Therefore, for the majority of forest restoration projects in the Mediterranean region, monitoring programs rarely last more than four-five years, despite many of these projects consider long-term projections (e.g., 50–100 years for common forest restoration projects based on plantations of tree species).

Long-term monitoring builds upon the previous effectiveness-monitoring phase by increasing the number of parameters assessed and the temporal scale of the measurements. Monitoring plots installed during the first stages of a restoration project can be used to establish a permanent monitoring structure. The purpose of longer-term monitoring in such established plots is to assess the recovery trajectory and self-maintenance of the target area after the implementation of the restoration project, and to evaluate the effect of the silvicultural treatments applied in the area. The feedbacks provided by long-term monitoring are of particular interest for adjusting post-project management practices aimed at modulating the succession processes to ensure that long-term conservation and restoration goals are met (Harrington 1999).

In addition to the common variables used for the short-term effectiveness monitoring, such as seedling survival and growth in planting-based projects, a wide range of structural and functional indicators are appropriate for long-term monitoring (see Chapter 4, this volume). For example, plant cover, density and biomass, diversity of plants and fauna (including wildlife abundance and diversity), and indicators of ecosystem processes, such as biological interactions (e.g., pollination, dispersal), fire incidence, forest pests, and soil organic matter, have often been used to evaluate restoration success (Ruiz-Jaén and Aide 2005).

Conclusions

The growing number of restoration projects worldwide has increased the interest in monitoring and evaluating of these efforts. However, monitoring still seems to be carried out in only a small proportion of restoration projects, only a small number of projects require or mandate performing project monitoring, and in most cases the monitoring effort only addresses compliance with the contract prescriptions. Environmental and economic constraints on forest restoration make it necessary to place more value on project monitoring. The monitoring approach presented in this chapter can easily be applied to common forest restoration projects in the Mediterranean region in the context of an adaptive management framework. If monitoring is well-designed and conducted, it helps to reduce uncertainties, assisting and improving the restoration practice. Project sponsors, funding agencies, and managers must ensure the implementation of appropriate monitoring programs, which may be critical to future progress and funding of forest restoration in the region.

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