Forest Restoration Management Plans in West Bekaa, Lebanon

TECHNICAL GUIDE

Preface & Credits

This document builds on the experience of the Forest Science and Technology Centre of Catalonia (CTFC, Spain) with participatory afforestation and forest management and the practical lessons learned in the project REFORLEB - Building-up a participatory governance framework for the sustainable development of forests and rural territories in Lebanon (EuropeAid/135-358/M/ACT/LB) 2014-2018. This document is complemented by the guide “Participatory Territorial Forest and Rural Development Framework - Good governance practices for Forest Restoration and Management Plans” (Plana et al., 2019), produced at the same project and presenting the steps to consider for the successful governance of a forest restoration project.

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Table of content

0. Introduction and definitions 4
- 0.1. Aim of this guide 4
- 0.2. Rationale of the Forest Restoration Management Plan (FRMP) 4
- 0.3. Content of FRMP 5
- 0.4. Definitions 6

1. Site assessment 7
- 1.1. Site selection 7
- 1.2. Site characterization 8
- 1.3. Site zoning: Patches and Blocks 9
  - 1.3.1. Restoration patches 9
  - 1.3.2. Restoration blocks 10
  - 1.3.3. Site zoning outcomes 10

2. Restoration design 11
- 2.1. Vegetative materials choice and management 11
  - 2.1.1. Species choice 11
  - 2.1.2. Sowing or planting? 13
  - 2.1.3. The importance of seed/seedling origin and quality 14
  - 2.1.4. Seedling handling, transportation and management until planting 16
  - 2.1.5. Sowing / planting period 17
- 2.2. Density and planting frame 18
  - 2.2.1. Density 18
  - 2.2.2. Planting frame 19
- 2.3. Afforestation techniques (I): soil preparation 20
  - 2.3.1. Pit dimensions 20
  - 2.3.2. Soil preparation techniques: areal vs. punctual; mechanic vs. manual 20
- 2.4. Afforestation techniques (II): tackling drought 21
  - 2.4.1. Techniques applied prior to planting 22
  - 2.4.2. Techniques applied during planting 23
  - 2.4.3. Techniques applied after planting 25
- 2.5. Afforestation techniques (III): preventing browsing damage 26
- 2.6. Afforestation techniques (IV): competing vegetation 29

3. Monitoring, tending and management of a restoration 30
- 3.1. Monitoring plan 30
  - 3.1.1. The importance of monitoring 30
  - 3.1.2. Monitoring timing 31
  - 3.1.3. Monitoring techniques 31
- 3.2. Tending plan 32
  - 3.2.1. Irrigation 32
  - 3.2.2. Weeding 34
- 3.3. Management plan 35

4. Preparing the Forest Restoration Management Plan 37
- Annex 1. Description of the restoration polygon 39
- Annex 2. Description of the restoration patch /block 40
- Annex 3. Example of monitoring scoreboard 41

References 43

0. Introduction and definitions

0.1. Aim of this guide

This technical guide presents the methodology for the sustainable and participatory implementation of Forest Restoration Management Plans (FRMP) in Lebanon, focusing on the particular conditions of west Bekaa. The aim is to ease the planning, design, implementation and management of future forest restoration initiatives in the area.

The target users of this guide are forest restoration developers: technicians from the Ministry of Agriculture, NGOs, municipalities, free-lancers and SMEs.

Forest restoration is an expensive and complex process where a wide range of technical and social factors are involved. The long-term success of a forest restoration project depends upon the successful achievement of all factors, while the lack of adequate consideration of a single one may lead to the failure of the project. This guide aims at facilitating the decision-making of the most critical steps of a forest restoration project.

0.2. Rationale of the Forest Restoration Management Plan (FRMP)

The preparation of a FRMP starts with the assessment of site conditions and involves an iterative process of decision-making involving many interdependent factors: restoration design (vegetative materials, afforestation techniques), tending, management, available budget (in terms of quantity and timing) and technical skills, as described in Figure 1.

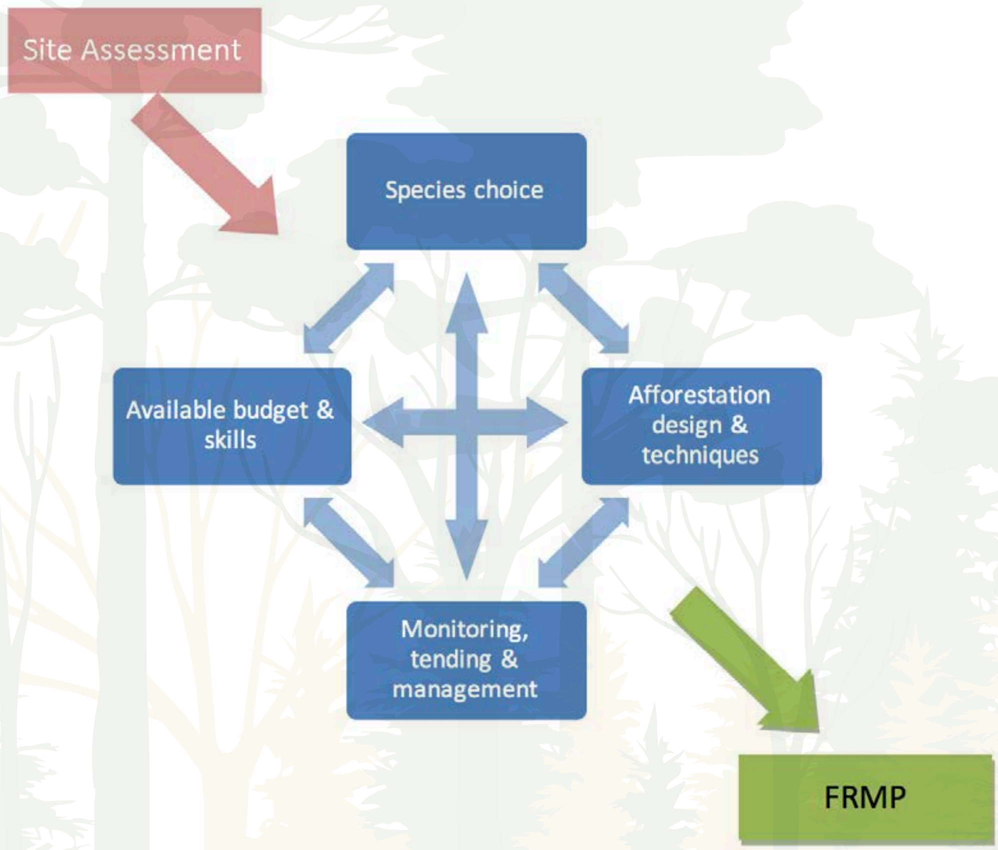


Figure 1. Process of FRMP preparation.

0.3. Content of FRMP

The FRMP should include the following information, whose content is described in detail throughout this technical guide

A. Objectives

Description of the aims of the FRMP and the specific goals that the restoration promoter (municipality, other public authority, NGO, private owner, religious entity, other) wants to achieve: generate employment, production of goods and services, income opportunities, landscape improvement, reduce erosion, etc.

B. Previous forest restoration experiences in the area

Description of previous forest restorations: site description, area, vegetative material used (species, age, format, nursery), afforestation techniques and tending applied (soil preparation, irrigation, weeding), summary of results (survival rate for each species) and interpretation (factors of failure / success).

C. Site description

Maps and forms resulting from chapter 1. Site Assessment.

D. Restoration Design: vegetative material choice and density

At patch/block level: indication of the chosen species, format (seed or seedling; seedling age, dimensions, container type and quality criteria), planting frame and density, based on chapters 2.1 and 2.2.

E. Afforestation techniques: soil preparation, plantation techniques

At patch/block level: indication of the soil preparation methods (pit dimensions, type of tools or machinery to use) and planting techniques against drought, browsing damage and competing vegetation (chapters 2.3, 2.4, 2.5 and 2.6).

F. Monitoring Plan

At patch/block level: monitoring protocol and timing (chapter 3.1)

G. Tending Plan

At patch/block level: tending protocol and timing (chapter 3.2).

H. Management Plan

At patch/block level: management protocol and timing (chapter 3.3).

I. Risks and Contingency Plan

Description of potential conflicts with stakeholders, actions aimed to prevent conflicts and contingency plan.

J. Workplan

Diagram showing the timeline of the forest development plan, including the afforestation implementation, monitoring, tending and foreseen management.

K. Budget

Structure of the foreseen costs of all the components of the FRMP, including the expected support by contributors.

0.4. Definitions

Table 1 shows the definitions of the main technical terms used throughout the document.

Table 1. Definition of the main technical terms utilized in this guide.

Term	Definition
Afforestation	Establishment of forests on lands which have been without forests for several decades (Watson et al., 2000). In this document we use this term as a synonym for "reforestation".
Beating up	Substitution of the dead seedlings for alive ones or seeds.
Forest Landscape restoration (FLR)	Re-establish the presumed structure, productivity and species diversity of the forest originally present at a site, involving stakeholders in all affected land-use sectors, as well as participatory decision-making processes. Afforestation is a part of FLR.
Forest Restoration Management Plan (FRMP)	Operational document describing the details of the complete afforestation cycle: design, implementation and management.
Pruning	Cutting branches to improve the shape of the tree with regard to technical (e.g. timber or fruit production) or safety (e.g. reduce the risk of browsing damage, ease access…) reasons.
Restoration polygon	Area within the restoration promoter selected to be afforested.
Restoration patch	Area with homogeneous ecological features, which are different from surrounding areas. The polygon is divided into patches of at least 0.5-1 ha.
Restoration block	Group of patches with similar ecological features. A restoration block is suitable to host a single type of restoration in terms of species, soil preparation, plantation techniques and management.
Thinning	Reducing the density of a forest stand to decrease the competition for water and other resources and promote the vitality of the best trees.

1. Site Assessment

Aim: evaluating and mapping the potential of the area to be restored in terms of site conditions and constraints.

1.1. Site selection

Aim: identifying the area to be restored.

The restoration promoter may own a large area available to be restored, but because of economic constraints only a part can be implemented. Some criteria to prioritize the plots to restore are:

- Lack of foreseen conflicts: the perimeter of the area must be clearly delimited and free of ownership conflicts. The area should not be exposed to possible land use changes (housing, agriculture, infrastructure development) in the medium or long term.

- Vegetation cover below the site's potential: there are records of the area sustaining a much denser vegetation cover in the past but at present it is degraded because of mismanagement (excessive grazing and/or unsustainable harvesting).

- Cost-effectiveness: the most accessible sites in terms of both distance and road access should be prioritized over remote sites.

- Visibility from the villages and nearby roads, where it is intended to maximize the positive scenic impact.

- Connectivity with other forest areas, in order to create corridors for biodiversity.

The outcome of site selection process is a map with the delimitation of the polygon/s to restore.

1.2. Site characterization

Aim: providing the baseline information for the design of the restoration (see Section 3).

Table 2 shows the variables to collect as well as a proposal of sources of information.

Table 2. Variables considered for site characterization

Variable	Description	Possible source
Polygon	Geographical coordinates of the perimeter of the polygon; cadastral code	GPS / Google Earth / cadaster
Area	Total surface of the polygon	GPS / Google Earth / cadaster
Altitude	Minimum, mean and maximum altitude above sea level	Google Earth
Climate	Main climate features: annual and summer temperature and precipitation	FAO New LocClim 1.10[1] / Safi 2012[2]
	Other climate features: prevailing winds (aspect, speed, moisture), snow risk, thermal inversion…	Local consultation
Bioclimate and series of vegetation	Bioclimate and potential vegetation series	LRI interactive maps[3,4]
Soil features	Main soil features: texture, pH, electrical conductivity, organic matter, active lime, calcium carbonate	Laboratory analyses
	Stoniness, rockiness, depth	On-site evaluation
Slope, aspect, physiography	Slope steepness, site aspect(s) and vertical and horizontal convexities / concavities	GoogleEarth
Accessibility	Easiness to reach the perimeter of the plot and to move within; potential for gravity-based irrigation.	GoogleEarth, on-site evaluation
Current and past land uses	Existing vegetation, potentially conflicting land uses around and within the plot: grazing, bee-keeping, etc; availability of irrigation infrastructure	Local consultation and on-site evaluation
	Past use of the land: previous vegetation and uses	

1 http://www.fao.org/land-water/land/land-governance/land-resources-planning-toolbox/category/details/en/c/1032167/

2 http://lri-lb.org/sites/default/files/Lebanon-specific%20Vegetation%20Classification%20System.pdf

3 http://lri-lb.org/mapping.php#mapping

4 http://lri-lb.org/sites/default/files/Lebanon-specific%20Vegetation%20Classification%20System.pdf

All these variables are studied at whole-polygon level, with the exception of soil stoniness, rockiness and depth; slope, aspect and physiography and accessibility. The changes in these variables within the polygon must be identified, to enable the identification of homogeneous areas with respect to these variables, as described in the next chapter, Site zoning.

1.3. Site zoning: Patches and Blocks

Aim: identification and mapping of homogeneous areas within the polygon to restore.

The previous section (Site characterization) showed how to describe the main features of the polygon to restore. However, when the polygon is large or heterogeneous it is necessary to identify relevant changes of site conditions within, particularly with regard to: i) soil stoniness, rockiness, depth; ii) slope, aspect, physiography; iii) accessibility. These factors have a major effect on the micro-site conditions (exposure to sunlight, runoff concentration / diversion, snow accumulation, thermal inversion, wind dynamics), and therefore affect the choice of species, planting techniques and tending. This process can also lead to the identification of areas that are unsuitable to afforest because of major limitations: rocky outcrops, gullies, etc.

Site Zoning consists on dividing the area of the polygon in Restoration patches and Blocks.

1.3.1. Restoration patches

Restoration patches are areas with homogeneous features, whose boundary can be delimited. The minimum area of a patch should be around 0.5 - 1 ha. See example in Figure 2.

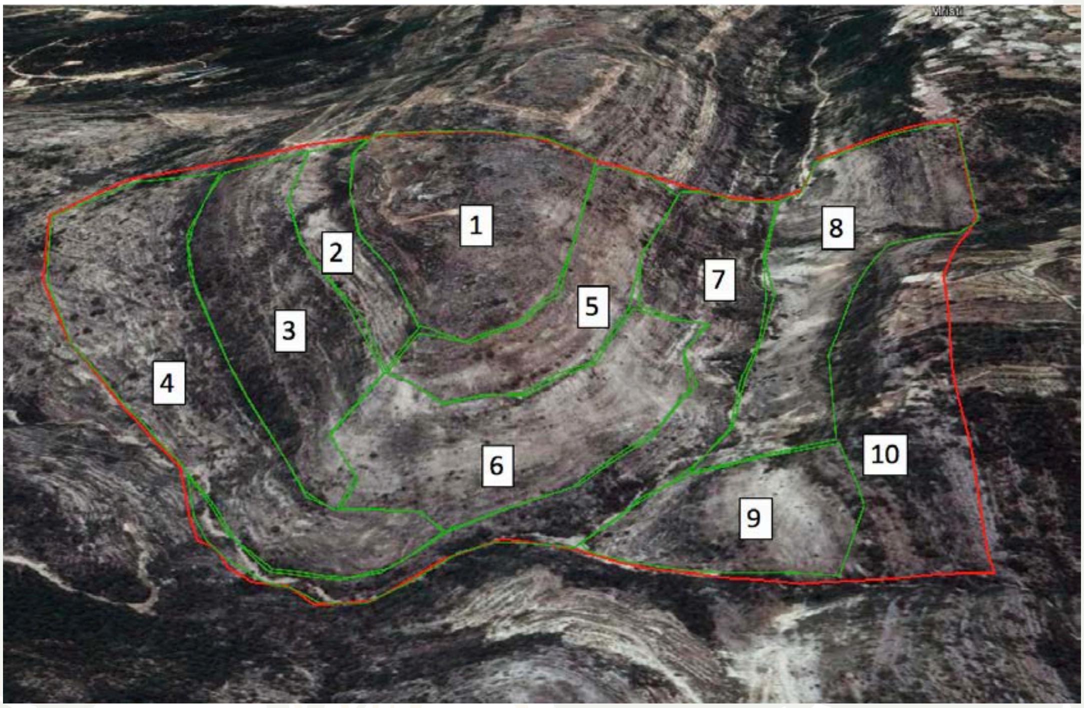


Figure 2. Example of polygon (red line) divided in 10 homogeneous restoration patches (green lines, numbers): **1**: crest; **2**: upper slope (concave) SW aspect; **3**: mid slope, SW aspect; **4**: low slope (convex), SW aspect; **5**: upper slope (concave) E aspect; **6**: mid slope, SE aspect; **7**: valley bottom (concave); **8**: mid slope, shallow soil, W aspect; **9**: mid-slope, deep soil, W aspect; **10**: mid slope, W aspect.

Nowadays there are many user-friendly free softwares to ease map production (Site selection, characterization and zoning), such as Google Earth or QGIS. These tools should be complemented by on-field GPS delimitation and cadaster maps.

1.3.2. Restoration blocks

A restoration block is the result of aggregating patches with similar ecological features. A block can host a single afforestation scheme (species, planting techniques, tending) in all its patches.

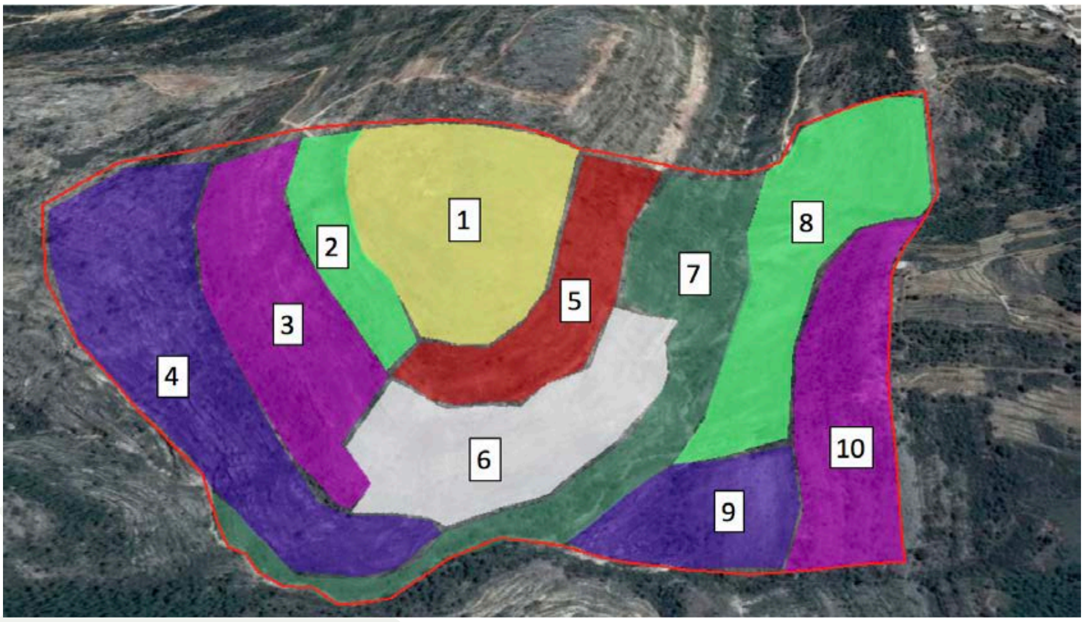


Figure 3. The 10 homogeneous restoration patches (numbers) are aggregated in 7 Blocks (colors): Block A, yellow: crest; Block B, pale green: shallow soil slopes with W aspect; Block C, violet: mid slopes with W aspect; Block D, purple: low slopes with deep soils, W aspect; Block E, red: upper slope E aspect; Block F: mid slope, SE aspect; Block G, dark green: valley bottom.

1.3.3. Site zoning outcomes

As a result of this process the polygon is divided in one (homogeneous site) or more patches, which can be aggregated in blocks, if necessary. The outcomes of this process are:

a) Map showing the polygon, divided if necessary in patches and blocks.

b) Form describing polygon features (Annex 1) and, if necessary, the patches/blocks (Annex 2).

Picture 1. This is how nature works: the different species occupy different site conditions at small-scale level. Restoration should mimic this process by a careful site zoning. ©CTFC

2. Restoration Design

This section shows how to define the technical aspects of the implementation of a restoration, from its concept to its establishment. The decisions on all the aspects related to the restoration design (vegetative materials, density, afforestation techniques) must be taken according to a coordinated plan, where the local stakeholders must be involved to achieve a successful accomplishment.

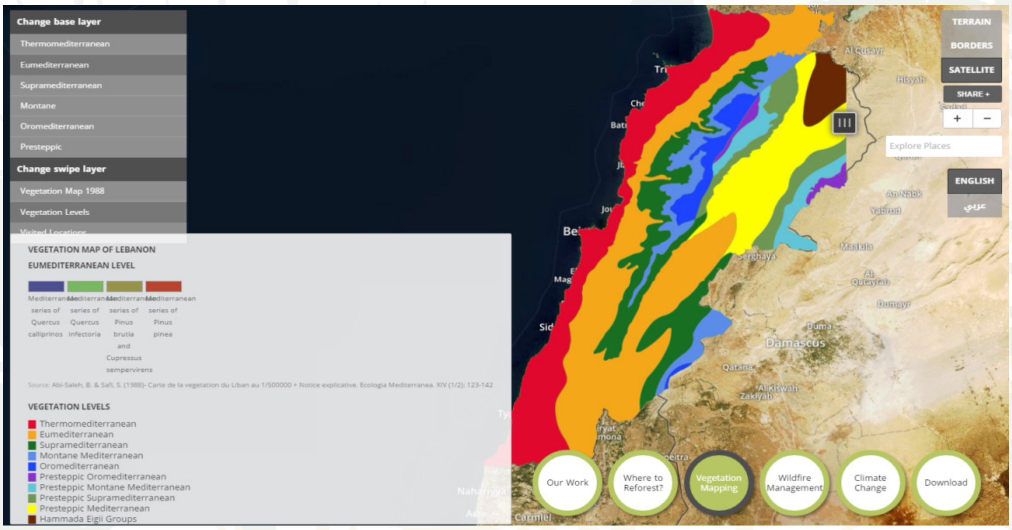
2.1. Vegetative materials choice and management

The success of the restoration depends to a large extent on the right selection and management of the vegetative materials.

2.1.1. Species choice

The choice of species is based on two factors:

- Demands by local stakeholders: planting species of their interest (from the productive and/or cultural and/or aesthetic points of view) is the best manner to ensure their involvement and sense of ownership.
- Ecological suitability: only the species that are well adapted must be considered. In the current framework of climate change, the eligibility criteria should be conservative, as it is expected that the drought conditions will get harsher in the upcoming decades. During the site assessment the present and past vegetation in the area are checked, which should be a suitable starting point to decide on the possible range of species. This information should be complemented by the consultation of botany publications and of experts on the existing and past vegetation in ecologically analogous areas.



The LRI vegetation maps (http://scryptech.github.io/lri-mapping/vegetation/) provide valuable information to support decision-making on species suitability. Like any other source of information, these maps should be considered an orientation and not an absolute truth.

Once the range of suitable species is available, the afforestation based on a mixed composition (including more than one species) should be favored over pure afforestations (single species), for various reasons:

a) Higher probabilities of success: the risk of dramatic mortality rates in the case of an unexpected problem (extreme drought, problems during tending operations, forest fire, etc.) can be higher if only one species is chosen. It is therefore recommended utilizing some species that are adapted to the worst possible scenario, so that at least a part of the restoration is always suitable. In this sense, it is also recommended using species from different functional groups: seeders (species that reproduce only by seed dispersion) and sprouters (species that are able to resprout after a severe damage such as browsing, fire, etc.). It is also recommendable combining tree and shrubs species, for creating a more complex and resilient ecosystem since the early years.

b) Enhanced biodiversity, both in the short term (more species present) and in the medium and long term, because of the diversification of conditions for fauna and flora species.

c) Higher landscape value and opportunities for economic diversification for various uses (e.g. species with interest for honey production, medicinal plants, etc.).

Picture 2. Mixed forest in autumn. © CTFC

Picture 3. The scattered trees can provide a good indication of the potential of the site. This area is covered by few *Juniperus excelsa* trees. This is a species to consider in this restoration. © CTFC

2.1.2. Sowing or planting?

The main options for establishing a tree or shrub species are sowing seeds or planting seedlings.

The main **benefits of sowing** are:

- Lower costs, not only of sowing compared to planting but also with regard to vegetative material purchase (cheaper and not requiring a pre-reservation many months in advance) and transportation as well as soil preparation.

- Social aspects: possibility of involving staff that are often excluded from forest restoration works: unlike planting, sowing is done with small tools that can be handled by staff that are not particularly vigorous, allowing the participation in the restoration process of a wider range of the population.

- If available, it is very easy to use local provenances, by gathering seeds close to the area to restore. In the case of planting, the restoration developers must rely on the availability of materials in nurseries, which may not have local provenances.

- In some cases, sowing results in higher quality and more resilient seedlings: it is the case of species with a tap root (a very powerful and deep central root) and large seeds, as it is the case of Mediterranean oaks (*Quercus spp.)*. When sown in autumn, the oak seeds (acorns) take advantage of the wet season (autumn, winter, early spring) to develop a deep tap root, while the aerial shoot is developed slower. At the arrival of summer, the resulting seedling may be a few centimeters high (low transpiration area) and has a deep root able to reach more than 50 cm in depth, and therefore can access deep soil moisture resources to withstand summer drought. In the case of nursery seedlings the tap root cannot be fully developed at the moment of planting.

Picture 4. Social benefit of sowing: women prepare the seeds within a Seedshelter® device. © F Martínez

Despite these benefits, **sowing has some limitations** compared to planting:

- Uncertainties on seed availability (many species show a strong inter-annual variability with regard to seed production) and performance (high variability in the germination rate).

- Need for a flexible, and often more expensive planning: the ripening status of the seeds must be monitored regularly, to collect them as soon as they are ripe and then sow them as soon as possible. Moreover, the sown area requires consistent monitoring during the first year to assess seedling germination and, if necessary, protect the emerging seedlings before they are browsed in the case that no perimeter fence is installed.

- Some species require complex pre-germination treatments to activate germination.

- In areas with high densities of mice and birds there is a high risk of predation, especially in the case of large seeds. There are devices like the SeedShelter® that can reduce notably this threat.

Pictures 5 and 6. Left: biodegradable Sheedshelter® device to reduce seed predation. Right: a high quality seedling, well provided with water and nutrients, guarantees the future of the tree if adequate tending is applied. © F Martínez.

2.1.3. The importance of seed/seedling origin and quality

The **provenance** (origin of the seeds or seedlings) and the **quality** (viability, vigor) are as important as the species choice with regard to the probability of success.

The provenance is particularly important for species with a wide distribution, which can grow with various types of climates and soils. The ideal provenance is the same area as the restored site. If there are no local materials available, then the most similar conditions (which sometimes are not the closest ones) should be chosen, prioritizing those provenances which are more limiting in terms of drought over those that are wetter.

Seed quality is defined by the ripening status (specific to each species) and seed viability. There are viability tests specific for each species, although the easiest and most common one is the flotation test: all the seedlings floating on water should be discarded.

Seedling quality can be assessed visually. The main features of a high quality seedling are:

- High vigor, healthy, well provided with nutrients (greenness), with no visible signs of pests, diseases or damage.

- Balanced root:shoot ratio; the shoot must consist of a single stem, well lignified, with healthy buds.

- They must be served in containers made of solid plastic, with an open bottom or drainage holes to allow air circulation and root pruning, and with a system to avoid root spiraling. The minimum container volume is 300-400 ml.

- The growing media must have a balanced texture (preferably with a high proportion of peat) and be free of animal manure, insects and weeds. At the moment of being served, the rootball must be well hydrated and remain intact (keeping all roots within the growing media) when removing it from the container.

- The seedlings should be preferably one year old.

Picture 7. Seedling nutritional status can be assessed visually: left: *Quercus calliprinos* with a poor nutrient content. Right: the same species, with the seedlings well provided with nutrients. © F Martínez

Pictures 8 and 9: Poor quality plants. Left: very poor root system ©F Martínez. Right: seedlings in plastic bags: they should not be accepted for planting because of the high risk of root spirallization. ©CTFC

Pictures 10 and 11, Good quality plants © F Martínez. Left: dense and healthy root system. Right: balanced root:shoot ratio, tree lignified with deep green needles.

Both the provenance and the criteria of seedling quality should be included in the purchase contract with the nursery, in order to guarantee the provision of high-quality seedlings, together with the conditions of transportation and the conditions for seedling rejection.

2.1.4. Seedling handling, transportation and management until planting

Once the species and the vegetative materials have been chosen, they must be kept in adequate conditions until the moment of sowing/planting. A negligent handling, transportation or management of the vegetative material can lead to the failure of the restoration.

Seeds are in general easy to store and manage. In general, they should be stored in a cold, ventilated and dark place until the moment of sowing, protected from possible predators and from severe changes in air humidity. Storage time should be as short as possible. There might be specific pre-germination treatments (stratification in wet sand, exposure to cold cycles, etc.) to be considered in certain species.

Seedlings are more delicate:

- Handling: the containers must be piled only in trays adapted to the containers and seedling dimensions to avoid bending or damaging the shoots.

- Transportation: it must be done in an adapted vehicle that protects the seedlings from direct sunlight, wind (especially caused by the movement of the vehicle) and keeps them undamaged and unbent during loading / unloading and transporting.

- Management until planting time: the time between seedlings delivery and planting must be as short as possible. Therefore, the seedlings should be provided when all the means for planting (soil preparation, material and staff) are ready. Once unloaded from the vehicle, and until the moment of planting, the seedlings must be stored in a cold place, protected from sun and wind, and watered regularly (especially before being planted) to keep the rootball moist.

Pictures 12 and 13. Left: transportation in open vehicles is only accepted for short distances. © F Martínez. Right: a negligent unloading and storing of seedlings can cause major damages and the failure of the restoration. ©Cortina et al, 2006.

Upon delivery, the seedlings must be evaluated by the restoration manager to ensure that the whole batch meets all the agreed quality criteria. If more than 5% of seedlings do not meet the quality requirements the batch should be discarded.

2.1.5. Sowing / planting period

Mediterranean conditions are characterized by a mild wet season from autumn to spring and a hot dry season that can extend for more than 5-6 months. This dry season, particularly during the first years when the root system of the seedlings is underdeveloped, is the most limiting factor for the successful establishment of a restoration. It is therefore recommended to <u>maximize the number of wet months during which the seeds/seedlings are in the ground</u>. Ideally, the sowing or planting should take place **after the first autumn rains**, with the soil being moist (neither dry nor waterlogged). The root system can then develop during this favorable season and grow as deep as possible to reach soil layers that will keep moisture during most of the dry season.

Only in the case of sites with long-lasting freezing temperatures and low snowfall it could be considered to plant in spring time, in order to reduce the number of weeks/months during which the newly planted seedlings are exposed to extremely low temperatures. However, in cold areas with consistent snowfall the risk of frost damage is reduced by the temperature buffering effect of snow, so it would be recommendable to plant in autumn.

Apart from the above mentioned seasonal recommendation, two further rules must be respected:

- seedlings must be in complete vegetative dormancy.

- days with temperatures below 0°C, strong winds or rainfall should be avoided.

Picture 14. Flushed seedling: it should not be planted. © F Martínez

2.2. Density and planting frame

2.2.1. Density

The choice of the **initial density** of an afforestation is a decision of primary importance, as it has a major economic impact, both before, during and after the afforestation takes place. The number of trees is proportional to the cost of: i) vegetative materials and plantation techniques purchase; ii) soil preparation (if done individually for each tree); iii) planting/sowing; iv) application of planting techniques; v) tending (irrigation, weeding) and management (thinning, pruning) operations. Moreover, a high density implies involving more workers (with increased difficulties in their coordination) and/or a longer time required for completing the afforestation (increased difficulties for planting or sowing during the optimal season).

On the other hand, despite this economic impact, there are also benefits associated with high initial densities: fast achievement of a green cover, with positive implications from both the social-aesthetic and the functional (restoration of ecosystem services and dynamics) points of view.

The decision on the initial density is a decisive aspect in the economics of a restoration. The initial density is decided together with the choice of vegetative materials (planting or sowing; number and type of species), soil preparation techniques, plantation techniques (e.g. individual or collective protection) and tending and management activities. This decision can also affect other stakeholders (beekeepers, collectors of medicinal and aromatic plants, , shepherds, etc) as it determines the time to reach a closed forest.

There are two general approaches for deciding on the initial density for a given area and budget:

a) Low to intermediate densities (300-600 trees/ha) with a high investment per tree (plantation techniques and early tending). This option makes it necessary to increase the monitoring investment to keep a low mortality rate, and to implement beating up (replacing dead seedlings by new, alive ones) in order to keep an adequate vegetation cover.

b) Intermediate to high densities (800-1,200 trees/ha) with a low investment per tree. This option may reduce the need for beating up in the case of low to moderate mortality rates. However, if the resources available for tending are scarce there is a high risk of a total failure of the afforestation in the event of a major disturbance (i.e. severe drought).

2.2.2. Planting frame

The planting frame is the spatial distribution of the seedlings. There are basically four types of planting frame (Figure 4), for a constant density:

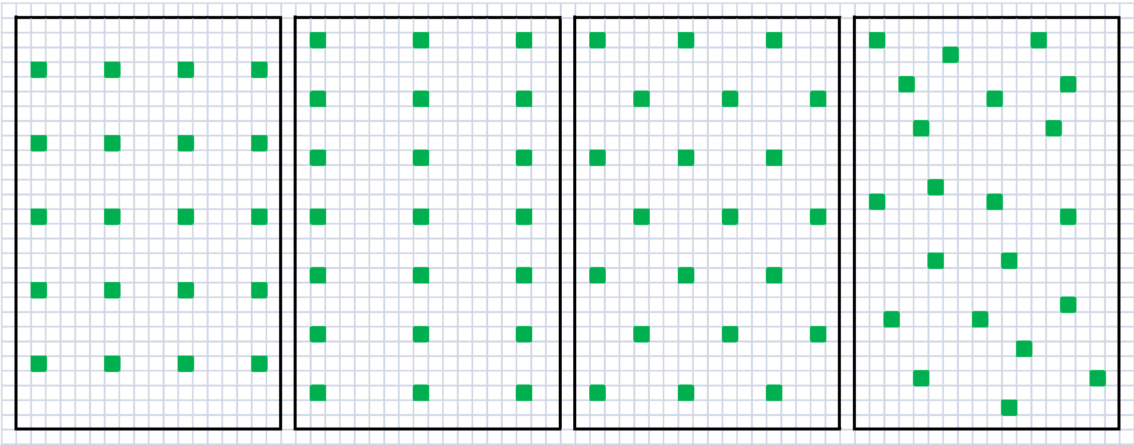


Figure 4. Different planting frames for a similar initial density (580-620 trees/ha)

Each of these designs has specific benefits:

- Square: easy to implement.

- Rectangular: the application of tending operations (irrigation, weeding and pruning) is cheaper as the distance to cover is lower than in the case of square designs. Moreover, this is the preferred design in the case of restorations aiming to control erosion. In this case the rows with less distance between trees should be oriented following contour lines.

- Quincunx: although being regular, it allows achieving a sense of natural tree disposition. It is also an interesting choice for restorations aiming to control erosion. It implies a slight increase in afforestation density (15% more trees than a square design for a similar planting frame).

- Irregular: it provides the workers more freedom to plant / sow only at the best micro-sites and leads to a natural aspect to the restoration, and is the preferred option in uneven terrains. In this case it would be needed to establish a minimum and a maximum distance between two consecutive trees, in order to avoid the accumulation of seedlings in one part of the site and large gaps in other areas. A negative aspect of this design is the increased complexity of tending, as it is difficult to go through all trees.

Calculating the density of a regular design frame (square, rectangular, quincunx):

Square and rectangular: Density = 10,000 / (distance between rows * distance between columns)

Example: 4x4 m frame ⇨ 10,000 / (4*4) = 625 trees/ha

Quincunx: square density * 1.154. E.g. 4x4 m frame ⇨ 1.154 * 10,000 / (4*4) = 720 trees/ha

The implementation of regular frames should be flexible enough to allow the choice of the best micro-sites for each tree, even when they imply small deviations from the foreseen frame. Only in very homogeneous sites the regular design must be strictly followed, which should be therefore marked prior to planting or sowing to ensure regular lines

2.3. Afforestation techniques (I): soil preparation

Soil preparation consists on modifying the soil volume where the seed or seedling is installed in order to ease its acclimation to the new conditions and its successful early establishment.

2.3.1. Pit dimensions

The choice of pit dimensions, and in particular the depth, determines the time that the roots will need to reach deep soil layers, where the moisture is available for longer time during the dry season. Pit **depth** should be therefore maximized. The minimum depth in drought-prone areas is 40 cm, although it should be ideally increased to 50 or 60 cm, if possible. In the case of sowing it is possible to reduce the pit depth to 20-30 cm

2.3.2. Soil preparation techniques: areal vs. punctual; mechanic vs. manual

There is a wide range of soil preparation techniques available:

Areal techniques: they consist of preparing the whole area to be restored, or the complete length of planting/ sowing rows. The most common technique is sub-soiling with a ripper (3-5 blades reaching 40-60 cm depth) installed in a tractor or bulldozer. The aim is to break the soil at depth without mixing the horizons. If possible, it should be applied in two perpendicular directions, to plant or sow in the points where the central blade of the sub-soiling trajectories collide.

Areal soil preparation is applicable in areas that are flat or have a gentle slope, where there is a compact horizon that should be broken to allow root penetration (petrocalcic horizon, compact horizons below tillage depth) and where there is a horizon that should not be stirred with the rest of soil (gypsum soil layer).

Punctual techniques: they consist of preparing the soil only in the volume to be occupied by the seedling roots during the first years. In order to prevent the loss of soil moisture and to ease filling up the pit with earth it is recommended to stir the soil within the pit but not removing the earth completely. The main techniques for pit digging and their features are:

- Excavation with backhoe (excavator): the volume of stirred soil is high. Suitable only in areas where there are no rocky outcrops.

- Pneumatic hammer (excavator or compressor): it is faster and has a lower impact than the backhoe excavation, and can be particularly interesting in areas with rocky outcrops. A deep soil layer can be more easily reached than in the case of the excavation.

- Drill connected to a tractor: this technique consists of opening a cylindrical pit (spiral drill). Its application is restricted to flat soils with low stoniness and with a moderate or low clay content.

- Manual pit digging (hoe, pick): characterized by a poor productivity. However, it can be the only choice in areas inaccessible for machinery (steep slopes, remote areas) and when one of the aims of the restoration is to generate employment opportunities.

The soil preparation should not be done when the soil is too wet or too dry, as the risk of soil compaction and of causing a stress to the seedlings is notably increased.

When choosing the plantation techniques (soil preparation, techniques against drought, browsing damages and competing vegetation), the following three criteria must be considered: (i) Cost-effectiveness; (ii) Autonomous and sustained effect, not requiring maintenance; (iii) Environmental and visual impact

Pictures 15 and 16. Left: sub-soiling with 50-60 cm deep blades; right: backhoe excavator. ©CTFC

Pictures 17 and 18. Left: Excavation with a pneumatic hammer on an excavator; right: manual pit digging. ©CTFC

Preventive vs. curative restoration approaches: a preventive restoration approach consists of increasing the investment per tree based on long-lasting techniques that reduce the dependence of seedlings on tending operations. The curative approach consists of reducing the initial investment per seedling while increasing the subsequent costs of monitoring (as seedlings are susceptible to disturbances) and tending (irrigation and weeding) to avoid the mass failure of the restoration. The first approach seems to be more adequate.

2.4. Afforestation techniques (II): tackling drought

Water availability is the most limiting abiotic factor for the restoration of forest cover in Mediterranean conditions. Mediterranean climate is characterized by a dry season coinciding with the highest temperatures of the year, resulting in severe evapotranspiration rates. The most critical periods are thus the first dry seasons, when the root system is underdeveloped and can only explore a limited soil volume. Other factors having a direct negative effect on drought impact are high soil stoniness/rockiness, low organic matter and a coarse texture (rich in sand).

As water availability is a limiting factor for vegetative growth in many areas of the world, besides the Mediterranean, there is a wide range of techniques to reduce the negative impact of water shortage in an afforestation. These techniques can be classified according to the moment in which they are applied: prior to planting, during planting and after planting.

2.4.1. Techniques applied prior to planting

Deep soil preparation

As previously mentioned, a deep soil preparation allows the seedling root system to reach deep soil layers, which are protected from desiccation, thus increasing notably the seedling chances to withstand the dry season.

Pictures 19 and 20. Left: planting pit deeper than 50 cm © F Martínez. Right: pneumatic hammer of 80 cm. ©CTFC

Nursery techniques

The most relevant ones, besides the production of vigorous seedlings, is the use of long containers and mycorrhization with fungi that can help the tree withstand harsh conditions.

2.4.2. Techniques applied during planting

Micro-basins

This technique consists of modifying the soil profile around the tree in order to concentrate precipitation and runoff. In flat areas this technique consists of rising the rims of the planting pit to collect precipitation. In slopes, micro-basins are done as follows (Figure 5): the original soil profile (black line) is modified (blue line) to create a slight counter-slope: the downslope rim of the pit is higher than the upslope rim, to collect precipitation and runoff. The micro-basins are done with manual tools and the work must be supervised to achieve a high efficacy.

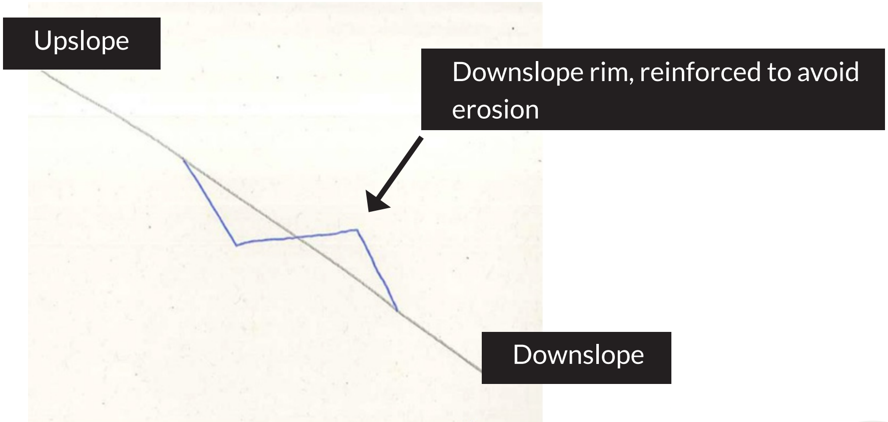


Figure 5. Scheme of a micro-basin on slope to concentrate runoff and reduce erosion.

Picture 21. Micro-basin on a slope. ©CTFC

Runoff diversion / traps

This technique is normally applied as a complement of the micro-basin on slopes, and consists of increasing the runoff collection capacity of the micro-basin through small modifications of the soil profile to divert water towards the seedling. This shape is also achieved manually.

Picture 22. Micro-basin on a slope with a runoff diversion system. ©CTFC

Soil conditioners and organic amendments

These techniques allow correcting a limiting soil feature, normally an excessively filtrating soil (coarse texture, excess of sand) or a poor soil (low nutrient or organic matter content).

Soil conditioners are applied at planting pit level (micro-site conditions improvement) and normally include water absorbing polymers that retain water, keeping it available for trees for longer periods. This product reduces water losses because of percolation and evaporation. Besides these polymers, soil conditioners may include other ingredients such as fertilizers, humic acids and root growth precursors, achieving a synergistic mixture improving soil quality, thus working as a temporary substitute of soil organic matter. Soil conditioners are particularly beneficial in coarse-textured soils (sandy, loamy-sandy), provided that they are applied at a correct dosage and are properly mixed with the soil. This product enhances early tree establishment and reduces the need for irrigation, being particularly effective during the first 1-2 growing seasons.

Organic amendments consist on applying a product rich in nutrients (fertilizer, compost, humus, manure, sewage sludge, etc.) to a poor soil. This application is normally done at areal level (whole planting plot), in flat areas. The choice of the organic amendment is based on the local availability, while the dosage and depth of application must be decided based on a good knowledge of the soil, in order to prevent an excessive alteration of soil conditions.

Pictures 23 and 24. Left: soil conditioner TerraCottem Universal ©CTFC; right: its application prior to planting/sowing ©F Martínez)

All the plantation techniques against drought can be applied alone and combined with others for an enhanced performance. However, they do not avoid completely the need for irrigating during the first years, especially in the case of warm and dry vegetative periods. However, they can extend notably the lapse between two consecutive irrigations thus reducing the number of watering interventions throughout the year.

2.4.3. Techniques applied after planting

Mulching

This technique consists of installing a cover on the ground around each tree to reduce soil water losses because of evaporation and transpiration by competing vegetation. This cover can be made of a continuous layer (plastic, biofilm, textile) or of particles (stones, woodchips, straw). Each mulch (defined by its composition, size, thickness, particle size) has particular properties:

- permeability: capacity to allow rainfall water reaching the soil and to prevent soil moisture evaporation. For example, a stone mulch is much more permeable than an impervious plastic layer or than a woodchips layer. For a similar material, thicker layers are less permeable than thin ones. In the event of a slight rain, permeable mulches allow most water reaching the soil. On the contrary, these models will also lead to higher evaporative losses of soil moisture.

- effect on soil surface temperature: dark film mulches can increase the temperature of soil surface, which can be dangerous in warm, sun-facing sites. White stones mulches, however, can reflect a large part of the radiation therefore limiting soil warming and water losses.

The choice of mulch type is based on its local abundance or availability, while its exact features (size, thickness, color) should be adapted to local conditions: precipitation and temperature regime, slope steepness, aesthetics.

Picture 25. Gravel mulching is the best choice in many stony sites. © F Martínez

Pictures 26 and 27. Mulching with plastic / bioplastic (left) or textile fleeces (right). ©CTFC

The guide "Soil conditioners and groundcovers for sustainable and cost-efficient tree planting in Europe and the Mediterranean - technical guide" (Coello & Piqué, 2016) presents the main features, interests and costs of application of soil conditioners and mulches. It is freely available in English (http://www.sustaffor.eu).

Establishment irrigation

This technique consists of the application of water right after planting in order to ease the acclimation of seedlings to the new conditions and to reduce the post-planting stress. This irrigation should be done if no significant precipitation (10 mm or more) is expected during the first weeks after planting. The volume of water applied should be of at least 10-15 l/seedling, to moisten deep soil layers and prevent evaporation.

2.5. Afforestation techniques (III): preventing browsing damage

Browsing damage caused by domestic animals (especially goats) is a major threat for a young afforestation in Lebanon. It is therefore necessary to prevent this damage through physical barriers, which can be applied at single-seedling level (individual protection) or at restoration polygon level (collective protection), and always adapted to the type of animals present. The two types of measures to prevent browsing damage are individual and collective protections.

Individual protection

It consists of a shelter for each tree, while the restored polygon is open to be accessed by the animals and can therefore allow a multiple land use and prevent conflicts with shepherds. The minimum shelter height to prevent damages from goats is 120 cm (flat sites) or 150 cm (sites on slope). The most common models are:

- plastic mesh: there is a wide range of models on the market, with different resistance and effects on tree performance. In order to avoid damages from goats, the minimum density should be 200-250 g/m^2. The plastic must be treated to resist UV radiation.

- plastic tube: it allows the trees growing in conditions that are darker and wetter than outside the shelter. This alteration of conditions forces the tree to grow higher and thinner during the first years, becoming more susceptible to physiologic imbalances. The tubes must be double-walled in order to avoid excessive heating inside the shelter, and should also have ventilation holes at their lower part, to allow air circulation within the tube. This technique has proven to be effective for some oak species, although it should not be used with conifers.

The shelter is installed with one or more suitable tutors to ensure its long-term stability.

The guide "Protecting trees from wildlife damage – mesh tree guards" (Van Lerberghe, 2014) presents the main criteria for choosing and installing a mesh shelter. It is freely available in English (http://pirinoble.eu/en/publi.htm) and French (http://pirinoble.eu/fr/publi.htm).

Picture 28. Plastic mesh shelter, 150 cm high and 20 cm diameter, with a double structure and 250-350 g/m^2 density, able to protect a seedling from goat damages. In this case, the tutor should be one outdoor-treated wood stick at least 180 cm high and 25-30 mm diameter. ©CTFC

Picture 29. The base of the shelter can be cut in flaps to enhance its fixation. © F Martínez

Collective protection

This option consists of fencing the plot perimeter to impede the access of animals to the seedlings. Besides avoiding browsing damage, fencing allows a long-term delimitation of the plot. The main perimeter fencing options are:

- physical fence: it can consist of a continuous mesh or on a barbed wire with 3-4 lines. This second option is cheaper although it may cause injuries to animals and humans.

- electric fence, with 3-4 lines: this option is relatively cheap although it requires an electricity source, maintenance to ensure power supply and must be marked to avoid human injuries.

In both cases it is necessary to conduct a periodic monitoring of the fence perimeter, to ensure that it is effective along its entire length. A single point where the animals can access the afforestation can lead to massive damages in a short period of time.

In large restorations, the fencing should not impede the regular movement of land-users, especially shepherds, so it should be considered to leave some unfenced corridors between fenced plots. These corridors could be afforested with shelter-protected seedlings.

Picture 30. A 1.2 m high fence with a 4x barbed wire and L-shaped metal profiles. ©F Martínez

Individual vs. collective protection

Table 3. Decision criteria to choose individual or collective fencing.

	Individual	**Collective**
Afforestation density	Low	High
Plot perimeter straightness; shape	Irregular; stretched shape	Regular; circle/square-shaped
Compatible with grazing	Yes	No
Monitoring required	Low	High

Is there an alternative to protection?

Both the individual and the collective protection systems are expensive. Thus, governance alternatives should be explored, including agreements with local and visiting shepherds to avoid the herds accessing the restored sites. Among the measurements to consider, there could be compensations or small works for their benefit: small infrastructures such as water points or shelters, improvement of grassland quality though sowing, etc.

2.6. Afforestation techniques (IV): competing vegetation

Competing vegetation refers to plants growing spontaneously within the restored plot. This vegetation can have a negative impact on newly planted seedlings, as they can compete for soil water and nutrients. This threat is particularly relevant in intermediate to highly productive sites. This chapter presents preventive techniques against competing vegetation, aiming at reducing or avoiding their negative impact before they emerge. The next chapter shows how to monitor and apply tending operations against competing vegetation.

Soil preparation and competing vegetation

It is possible to prevent to a large extent the negative impact of competing vegetation, during soil preparation. Mechanical soil digging, especially when done with a backhoe excavator, allows planting the tree in bare soil, free of competing vegetation at the moment of planting. This may remain likewise for some years in poorly productive conditions, therefore not making necessary to apply any weeding technique during the first years.

Mulching

In more productive sites, or where the soil preparation affects a small surface per tree, it might be recommendable to use mulches to avoid the establishment or proliferation of weeds. This technique has an additional effect of keeping soil moisture and regulating soil surface temperature, as presented previously. From the competing vegetation point of view, the optimal mulches are large (80 x 80 cm or more) and opaque (impeding light reaching the soil).

Pictures 31 and 32. Planting pit clean of competing vegetation after mechanical soil digging. Right: mulch preventing the negative impact of competing vegetation in a highly productive site. ©CTFC

3. Monitoring, tending and management of a restoration

The establishment of trees with the afforestation techniques chosen is only the first step of the restoration process. Once the afforestation is installed it is necessary to follow it up to ensure its long-term success. This chapter shows the main tasks to ensure the adequate performance of a successful restoration at a moderate cost.

3.1. Monitoring plan

Monitoring consists of the regular control of the seedlings status, enabling an early detection of possible problems and activating the application of tending operations. This activity must be organized according to a **Monitoring plan**, a document where the monitoring techniques to apply are described, together with a foreseen timing.

3.1.1. The importance of monitoring

An effective monitoring is a cheap intervention compared to the major economic losses resulting from the failure of a significant part of the restoration because of the negative impact of drought, competing vegetation, browsing damage or any unexpected problem. Moreover, monitoring can also lead to important savings in tending: for example, it can reduce the need to apply a particular intervention (irrigation, weeding, etc.) if it is observed that the seedlings are in better condition than initially expected. Monitoring is focused on the seedling status, but also involves checking other aspects of the restoration: status of planting techniques (mulches, shelters, fence, drippers, etc.), signs of animals unexpectedly accessing the site, etc., which allow the application of an early solution. Finally, the outcomes of monitoring can be useful to improve future restoration projects in the area, as it allows improving the choice of techniques to apply.

Because of its relevance, monitoring must be coordinated by reliable and skilled staff, able to interpret the status of the trees and the restored site and assess the need to apply a particular intervention.

Picture 33. Monitoring. ©CTFC

3.1.2. Monitoring timing

The timing of monitoring is defined by its period of application during the year and its frequency. The period of application is normally during the central part of the growing season (May/June to September, in general), where most problems related to drought may occur. In intermediate to highly productive sites the spring monitoring allows assessing the proliferation of competing vegetation and the need to apply a weeding intervention. During the first years, monitoring should also be extended to autumn and/or winter months. The frequency of monitoring is proportional to the vulnerability of seedlings: it should be rather high in the beginning and will decrease over time. It should be also adapted to the weather conditions: during particularly dry and hot years the summer monitoring effort should be increased, while in wetter years it could be reduced. Table 4 shows an example of monitoring timing.

Table 4. An example of monitoring timing. Monitoring visits should be evenly distributed during the indicated period of time.

Year of plantation	Number of monitoring visits, May - September	Number of monitoring visits, October - April
1	3	2
2-4	2	1
5-10	1, in summer	-

3.1.3. Monitoring Techniques

A tree-by-tree monitoring is only applicable in restorations with few hundreds of seedlings. In larger restorations, which is the prevalent case, monitoring techniques are based on sampling, i.e. assessing a certain number of seedlings based on transects. It is therefore critical to design the sampling in order to achieve a proper representation at a moderate cost. The most relevant factor is to set the minimum percentage of seedlings to assess, keeping in mind that all the restoration patches should be properly evaluated. Figure 6 shows an example of sampling transects. Ideally, the transects should be oriented following contour lines, and changed from one monitoring to another, to not always monitor the same trees and parts of the restoration. If a fence has been installed, its complete perimeter should be also assessed during monitoring.

In practical terms, a common option to decide the percentage of sampled trees is to set this number based on the time required by a trained crew to cover the whole area in a single workday.

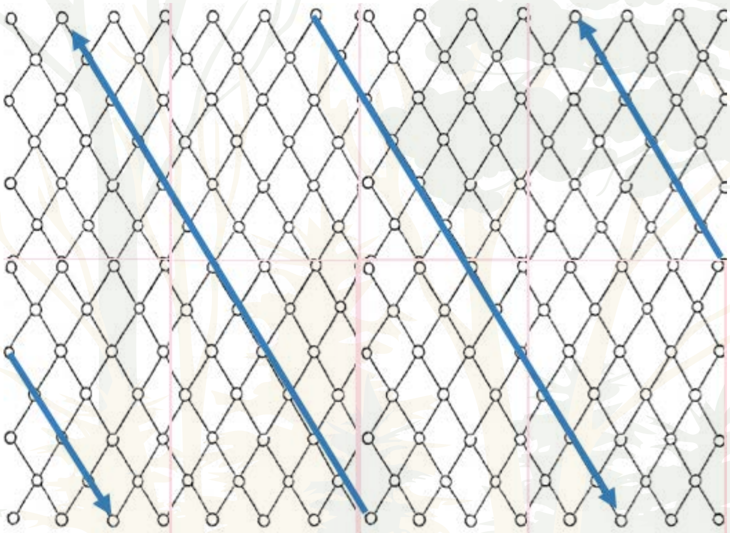


Figure 6. Example of monitoring transects covering 20% of trees (1 out of 5 planted rows) in a quincunx design. The arrows indicate the transects and their direction.

The results of the monitoring are recorded in a scoreboard adapted to the restoration features, with specific fields to identify the different patches, species and plantation techniques. Annex 3 provides examples of monitoring scoreboards. If the data is gathered on paper it is recommended to use a simple method for recording (and reading) several data in a single sheet (Figure 7). It is also possible to record the information in electronic devices (tablet, smartphone, etc.), adapting the scoreboard for fast data gathering.

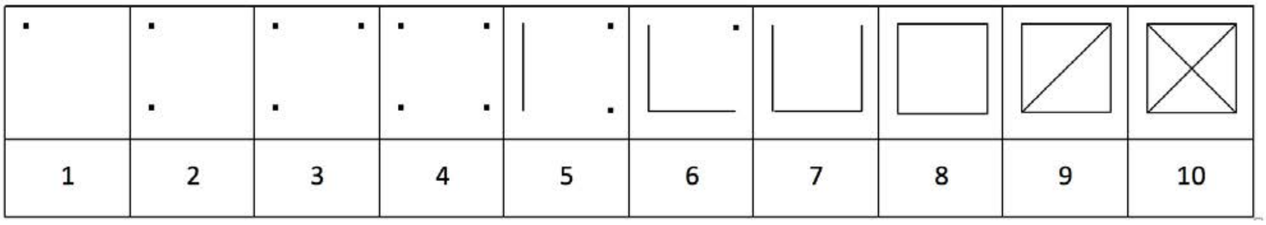


Figure 7. A possible method for short-handed progressive recording of numbers from 1 to 10 on a paper scoreboard.

The data collected must be interpreted as soon as possible, especially if the results of the monitoring make it necessary to conduct a tending intervention, such as weeding or irrigating.

3.2. Tending Plan

Tending makes reference to all operations conducted in the early years of the restoration and aims at enhancing early tree performance. The main tending operations are irrigation and weeding. The tending activities must be programmed in a **Tending plan**, a document where the tending techniques to apply are described, together with a foreseen planning of application over time, as well as a brief protocol to ease the decision-making on how, where and when to intervene. The exact techniques to apply depend on the restoration features: species, density, site properties. Moreover, these techniques and their timing depend on unforeseeable factors, such as weather during the first years, and therefore this plan must include a list of contingency measures to apply based on the monitoring (see previous section).

Tending operations must be applied with a double criteria: they must be foreseen in the tending plan but they must also be applied with some flexibility, based on monitoring, provided that the need for application depend on the actual afforestation performance, weather and unexpected situations.

3.2.1. Irrigation

Irrigation is one of the most expensive tending operations as it often implies installing or building specific infrastructure, including water deposits, pumps and pipes. Moreover, it is a recurrent and hard to foresee intervention. The type of irrigation affects how the tree develops its root and aerial system. There are two general recommendations related to irrigation with this regard:

a) Period: it should be applied preferably as an emergency operation, restricted to the most critical moments of the year. The spring irrigation may seem effective (fast increase in tree aerial size) but can be detrimental in the long term because: i) the root system is not forced to grow deep and ii) the overdevelopment of aerial organs increases transpiration rates.

b) Dosage: it is much more favorable to apply a low number of consistent irrigations (10-15 l/tree) than frequent slight irrigations (3-5 l/tree), for the same reason stated above: slight-volume irrigations only moisten the upper soil horizons and the root system is not forced to grow deep. Another problem of slight irrigations is the risk of competing vegetation proliferation.

There are mainly two manners of irrigating: manually and semi-automatically.

Manual irrigation

It consists of applying water to the seedlings by using hoses connected to pre-installed or wheeled water deposits. This option has very low initial and maintenance costs but increases notably the cost of each irrigation, the risk of damaging the seedlings during hose dragging and of applying a very variable volume of water in each seedling. This option would be therefore the main option in restorations with low density that are foreseen to need very limited water support: species chosen with conservative criteria regarding their ecological needs and supported by various planting techniques against drought (see section 2.4).

Semi-automatic irrigation

This system is based on the installation of drippers around each seedling, and the water is transported directly to them from pre-installed water deposits. This option should be chosen in sites where it is feasible and necessary to irrigate often and where the planting techniques against drought were applied only in a limited manner.

Pictures 34 and 35. Left: water deposit. Right: dripper. ©CTFC

A useful tool for planning the irrigations, which should be included within the Tending Plan, is the use of an irrigation protocol. This protocol helps to decide when it is necessary to establish an irrigation, based on easily measured indicators, among which rainfall is the most important one. Other variables to consider are the performance of the vegetative material (based on Monitoring), soil features, temperatures, aspect, wind and plantation techniques installed.

An example of **irrigation protocol** is proposed for two bioclimatic levels: Subhumid and Semiarid (Safi, 2012). An irrigation of 10-15 l/tree is applied after a prolonged period without effective rainfall (>10 mm rain in 24 h) (Table 5).

Table 5. Example of irrigation protocol for subhumid and semiarid conditions. The numbers indicate how much time without significant rainfall (>10 mm in 24h) can pass before the application of an irrigation becomes necessary.

Year of plantation	Subhumid	Semiarid
1	**2 months** (Jul-Aug) OR **3 months** (May-Jun or Sep-Oct)	**1.5 months** (Jul-Aug) OR **2 months** (Apr-Jun or Sep-Oct)
2	**3 months** (May-Sep)	**2 months** (Jul-Aug) OR **3 months** (Apr-Jun or Sep-Oct)
3-5	**5 months** (Apr-Sep)	**4 months** (Apr-Sep)

3.2.2. Weeding

Weeding consists of avoiding the negative effect of competing vegetation that grows besides the newly established seedling. Because of its fast development, competing vegetation can limit the access of the seedling to soil water (thus enhancing the negative impact of drought), soil nutrients and even light. As mentioned before, competing vegetation is a major threat to young restorations in intermediate to highly productive sites, while in sites of low quality it might be of less relevance. As the trees grow they become less dependent on weeding because their root system is able to explore a larger and deeper soil volume and their crowns are able to progressively shade the soil, therefore limiting weed proliferation.

There is a range of weeding techniques available in forest restoration, with their own strengths and weaknesses (Table 6).

Table 6. Evaluation of the most common weeding techniques in afforestation. Adapted from Coello & Piqué (2016).

Technique	Description	Cost-effective	Environmental impact	Durable effect; possible tree damage	Suitable in poorly accessible areas
Hand-operated mechanical weeding	Destroying competing vegetation manually, with small tools or with machines (e.g. brush cutter)	X	O	X	O / ✔
Tractor-operated mechanical weeding / tillage	Destroying competing vegetation with flail mower or tillage tools	O	X	X	X
Chemical weeding	Application of herbicides to prevent the germination or to suppress competing vegetation	✔	X	X	O
Mulches	Covering the area around the tree for impeding weed development or establishment	X / O / ✔	O	✔	O

X : Negative O : Intermediate ✔ : Positive

In the case recurrent weeding techniques (mechanical or chemical) are necessary the most suitable period of application is spring, before the competing vegetation produce flowers.

The need for weeding depends on the proliferation of competing vegetation, and therefore is linked to the meteorology, especially, to spring rainfall. This intervention is, however, more foreseeable than irrigation.

Pictures 36 and 37. Left: mechanical weeding with brush cutter ©CTFC. Right: tractor-operated mechanical weeding with flail mower ©M Burguess

Pictures 38 and 39. Left: chemical weeding with herbicides ©Crop protection Unit, Catalan Department of Agriculture. Right: plastic mulch preventing that weeds grow near a newly planted seedling in a productive site. ©CTFC

3.3. Management Plan

Management makes reference to the long-term operations conducted to achieve the restoration objectives: production of goods and services, generate income opportunities, landscape improvement, reduce erosion, etc. It is therefore necessary to draft a **Management Plan** while designing the restoration, setting the foreseen tasks to apply with this regard.

Provided that the restoration should result in a forest that will remain for decades, its objectives may vary during its different stages of development. For example, during the early years the restored area is open and fully exposed to sunlight, while it becomes more and more shaded as trees develop. Because of the evolution of the restoration/forest over time, the management plan should be reviewed and updated every 10-15 years to adapt it to the status of the forest and the emerging demands.

Multi-functionality: an intrinsic feature of any forest is its capacity to simultaneously provide a wide range of goods and services. In the management plan and in its updates a multifunctional approach should be considered.

The main management interventions related to the trees are pruning and thinning, while any further activity to be conducted in the forest (beekeeping, walking trails, collection of wild fruits, etc) should be also considered in the Management Plan.

Pruning

Pruning consists of removing branches with a wide range of objectives, which are compatible between them:

a) Reducing vulnerability to forest fires: the low branches that are shaded by the upper ones tend to shed their leaves and thus are not productive for the tree. In the case of a forest fire, these low dry branches result in the continuity of fuel from the ground level to the upper crown, therefore increasing the risk of high intensity fire. The removal of these low branches (up to 2 m high) allows breaking fuel continuity and thus reducing the risk of forest fire affecting the upper crown of the trees.

b) Enhancing the walkability: the above-mentioned pruning (up to 2 m high) allows that the different users can access the forest.

c) Reduce the risk of damage caused by animals: the browsing of low branches may cause wounds that can result in diseases. The pruning of these branches prevents their potential damage.

d) The pruning may also have a productive purpose, as it can increase the production of fruit and the quality of timber products.

The percentage of leaves eliminated in a pruning intervention should be less than 33%, to avoid causing an imbalance in the tree.

Thinning

The initial density can be higher than 1,000 trees, but as they grow it becomes necessary to apply thinning. This intervention allows reducing the competition between trees, and must be done with criteria of stand improvement:

a) Trees showing low vigor or that are affected by pests and pathogens

b) Trees that compete with the most interesting ones

c) Trees that lead to the vertical fuel continuity

d) The last criterion would be to remove trees while keeping the representation of all the species and a predominantly regular distribution of trees.

Picture 40. Overdense afforestation. ©CTFC

Picture 41. Thinned forest. ©CTFC

4. Preparing the Forest Restoration Management Plan

Based on a participatory approach, the document describing the afforestation and the subsequent management should be compiled in a **Forest Restoration Management Plan** (FRMP, hereinafter).

The three sequential steps could be as follows:

1st step. Participatory scoping workshop: It aims at introducing the outcomes of the site assessment to the stakeholders involved in the participatory process and discuss on afforestation aims and potential species. It is therefore necessary to conduct the identification of all the potential stakeholders involved should be carried out based on, for instance, land ownership and uses, potential conflicts, neighbors and land managers' demands, etc.

This workshop should be coordinated by a person skilled in participatory processes, and requires normally the involvement of, at least:

- Local stakeholders;

- Forest restoration experts including those involved in site assessment;

- Representatives of the municipality and restoration promoter.

The base documents to discuss are the outcomes of the site assessment (maps + forms) and the estimated available budget, which should be sent to all participants well in advance. Previous afforestation experiences, identification of main constraints – especially grazing or land occupation, should be considered.

As a result of this workshop the following decisions should be made:

a) Choice of prevalent **aims** of the afforestation at polygon level, and at patch/block level if relevant.

b) Choice of **species** and broad outlines of afforestation design and management.

c) Identification of potential **conflicts** and preliminary contingency options.

d) Identification of potential **contributors** to the afforestation implementation, either as co-financers or providing material or staff (e.g. youth associations, schools, NGOs, etc).

These decisions must be put in a Diary document, to be agreed by all participants.

2nd step. Interim Forest Restoration Management Plan: Preparation of the first version of the FRMP (afforestation + management) project.

The FRMP contains all the specifications of the forest restoration and the subsequent management, particularly: objectives, previous forest restoration experiences in the area, site description, stakeholders' description and demands, afforestation design, afforestation techniques, tending and management plan, risks and contingency plan, workplan and budget.

The interim version of FRMP is prepared based on the information collected in the site assessment, the participatory scoping workshop and the available budget. This interim or preliminary version must be therefore presented and validated by the stakeholders at the Validation Workshop (see next step).

3rd step. Workshop for adopting the Forest Restoration Management Plan and dissemination of the final version: Presentation the Interim FRMP to the stakeholders and discuss possible adjustments for its final validation.

As in the first step, this workshop should be coordinated by a person skilled in participatory processes, and requires the involvement of, at least:

- Local stakeholders (at least those participating in the scoping workshop);

- Forest restoration experts including those involved in the preparation of the Interim FRMP;

- Representatives of the municipality and restoration promoter.

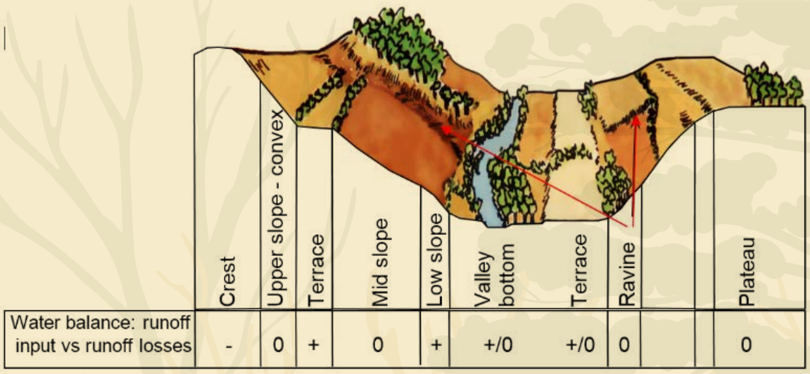
The base document to discuss is the Interim FRMP, which should be sent to all participants well in advance. The topics to discuss should include the overview of the content of the Interim FRMP, potential alternatives and amendments to the document.

The agreements must be put in a Diary document, to be agreed by all participants. The agreed **Forest Restoration Management Plan** will be finally produced and adopted after a reasonable period of public exposition for final amendments.

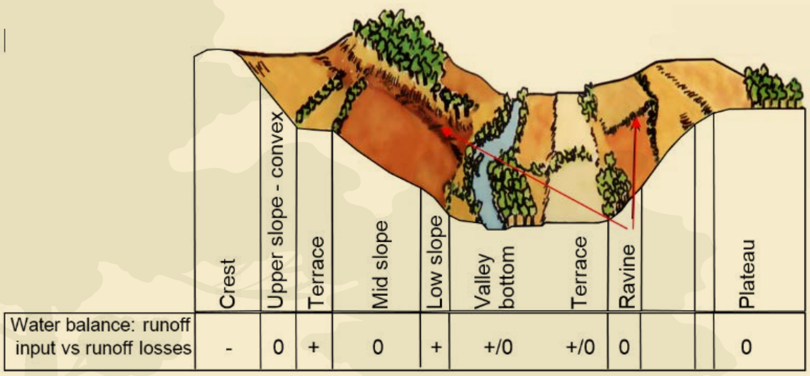
Active dissemination of the final version among citizens and stakeholders is recommended.

For more information on participatory approaches and governance please refer to the manual "Participatory Territorial Forest and Rural Development Framework - Good governance practices for Forest Restoration and Management Plans" (Plana, 2019).

Annex 1. Description of the restoration polygon

Polygon cadastral code		**Polygon area (ha)**	
Geographical coordinates		Range of altitudes	
CLIMATE INFORMATION			
Mean annual rainfall (mm)			
Mean summer rainfall (mm)			
Mean annual temperature (°C)			
Other climate features: prevailing winds (aspect, speed, moisture), snow risk, thermal inversion…			
BIOCLIMATIC INFORMATION			
Bioclimate/s		Vegetation series	
SOIL			
Depth(s) (cm)	<30 / 30-50 / 50-80 / >80	Stoniness (Ø0.2-20cm) %	0-15 / 15-40 / >40
Texture		pH	
Conductivity (dS/m)		Organic matter (%)	
Other chemical soil features: active limestone, calcium carbonate, N, P, K			
Rocky outcrops (%)	0 / 1-15 / 15-40 / >40		
PHYSIOGRAPHY			
Steepness range (%)	<10 / 10-30 / 30-60 / >60	Main aspect(s)	N / NW / W / SW / S / SE / E / NE / flat
Vertical physiographic position(s) (see figure below)			
			
Horizontal physiography(ies) (concave, flat, convex)			
ACCESSIBILITY AND LAND USE			
Accessibility to the perimeter	All vehicles / 4x4 & caterpillars / inaccessible		
Accessibility within polygon	All vehicles / 4x4 & caterpillars / inaccessible		
Tree and shrub species present in the area or in the vicinity at similar conditions			
Coexisting land uses			
Past land uses			
Water collection and/or storage facilities			
OVERALL EVALUATION			
Brief description of the potential of the polygon			

Annex 2. Description of the restoration patch /block

Patch/block code		**Patch/block area (ha)**	
Patch geographical coordinates / Number of patches within the block		Range of altitudes	
CLIMATE INFORMATION			
Other climate features: prevailing winds (aspect, speed, moisture), snow risk, thermal inversion…			
SOIL			
Depth(s) (cm)	<30 / 30-50 / 50-80 / >80	Stoniness (Ø0.2-20cm) %	0-15 / 15-40 / >40
Rocky outcrops (%)		0 / 1-15 / 15-40 / >40	
PHYSIOGRAPHY			
Steepness range (%)	<10 / 10-30 / 30-60 / >60	Main aspect(s)	N / NW / W / SW / S / SE / E / NE / flat
Vertical physiographic position(s) (see figure below)			
			
Horizontal physiography(ies) (concave, flat, convex)			
ACCESSIBILITY AND LAND USE			
Accessibility within patch		All vehicles / 4x4 & caterpillars / inaccessible	
Tree and shrub species present			
Coexisting land uses			
Water collection and/or storage facilities			
OVERALL EVALUATION			
Brief description of the potential of the patch/block, especially, its feasibility for being afforested			

Annex 3. Example of monitoring scoreboard

Example of monitoring scoreboard (empty).

Patch 1	Alive					Dead				
Species 1										
Species 2										
Species 3										
Species 4										
Plantation techniques status										
Other comments										
Patch 2	**Alive**					**Dead**				
Species 1										
Species 2										
Plantation techniques status										
Other comments										
Patch 3	**Alive**					**Dead**				
Species 1										
Species 2										
Species 3										
Plantation techniques status										
Other comments										

Example of monitoring scoreboard (filled up).

Patch 1	Alive	Dead
Species 1		
Species 2		
Species 3		
Species 4		
Plantation techniques status		
Other comments		
Patch 2	**Alive**	**Dead**
Species 1		
Species 2		
Plantation techniques status		
Other comments		
Patch 3	**Alive**	**Dead**
Species 1		
Species 2		
Species 3		
Plantation techniques status		
Other comments		

It can be seen at a glance that in Patch 3 there are 37 alive trees of species 1; 30 of species 2 and 38 of species 3, while the dead trees are 20, 19 and 0, respectively. Moreover, it can be calculated the share of sampled trees of each species with respect to the total.

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