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LEBANON REFORESTATION INITIATIVE

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A GUIDE TO REFORESTATION BEST PRACTICES

2014

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1. GENERAL INTRODUCTION

The Lebanon Reforestation Initiative (LRI), a program funded by the United States Agency for International Development (USAID), and implemented by the United States Forest Service (USFS), aims to restore Lebanon's native forests and to instill a national commitment to reforestation and wildfire prevention and response, through capacity building of local communities and organizations.

LRI activities include building increased capacity to sustainably manage and expand the country's forests, catalyzing the planting of several hundred thousand native trees on sites throughout Lebanon. The project favors a decentralized approach to engaging communities at the municipal level and focuses on:

- Assisting native tree nurseries with technical improvements and enhanced business planning;
- Developing comprehensive forest mapping to help identify existing forest resources and priority areas for the reforestation of native tree species;
- Promoting the importance of reforestation and biodiversity through community-led activities that foster local ownership and forest sustainability;
- Supporting the planting of quality native seedlings, and especially threatened species, throughout Lebanon;
- Strengthening capacities to prevent and respond to wildfires through technical assistance and specialized training of communities and firefighting agencies.

This manual was developed by LRI as part of the program's capacity building strategy. The purpose of this manual is to summarize best practices in reforestation and provide clear and concise guidance for future reforestation managers on planning and implementing reforestation projects. The choices of practices recommended in this manual are based on the long experience of the US Forest Service and the more localized experience of LRI in more than ten reforestation sites across the country, with a total surface area exceeding 700 ha of variable soil and climatic conditions.

2. INTRODUCTION TO KEY PRINCIPALS OF SEEDLING SURVIVAL AND GROWTH

Successful reforestation in Lebanon presents many challenges. A Mediterranean climate, rocky, thin soils, grazing and fire issues are just a few of the issues confronting managers. The Target Plant Concept, developed by Thomas Landis (Landis 2009), provides a detailed and proven approach to planning and implementing reforestation projects and is well-suited to these challenges. The concept is based on three simple ideas;

1) Understand the key characteristics of the planting site to inform choices on seedlings.

2) The partnership between the nursery and reforestation client is critical to success of the project.

3) Always maximize seedling quality and assess based on performance in the field and not on its appearance and price at the nursery (Landis 2009).

Outplanting success (i.e., seedling survival and growth) depends on the last three factors in the Target Plant Concept outlined in Figure 2.1. below.

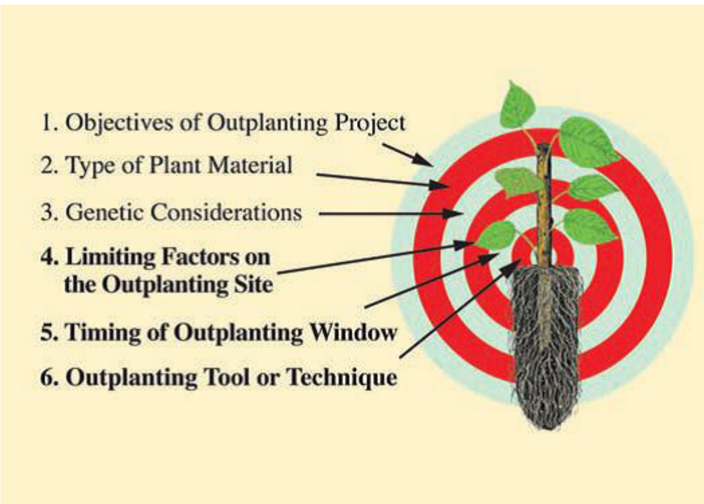

Fig.2.1. Target Plant Concept (Landis 2009)

Limiting factors on the outplanting site. Each reforestation site is different in terms of soil, slope, aspect, environmental conditions, vegetation cover, etc. It is critical at each site to identify all the factors that can strongly influence plant survival and growth. Temperature and moisture are usually the most limiting. Aspect, slope and soil type can also be limiting in extreme conditions. For example, a steep south-facing slope can dry out quickly and may require additional shade and irrigation to limit mortality.

Timing of the outplanting window. The outplanting window is discussed in more details in section 4.1.4 below. The timing of the outplanting window dictates the proper sowing time at the nursery for each species to allow for good physiological conditioning before planting.

Outplanting tools and techniques. Close coordination between the nursery and reforestation manager is needed to ensure that seedlings grown can be planted with the tools identified in the reforestation project planning phase. If using a hoedad, root plugs should be narrow and short for better results. When planting cylinders are used, root plug size and cylinder size should match. If root plugs are larger or smaller, the cylinders become useless (see details under section 5.4 below).

Consequently, it is very important for every reforestation manager to plan reforestation activities at least a year ahead and to pre-order seedlings targeted to the reforestation site in question. Nursery managers usually collect seeds as early as October-December of every year.

Seedling orders should be placed before or during seed collection time to allow the nursery manager to acquire enough seeds to cover the needs for reforestation.

3. SITE ASSESSMENT AND SELECTION

A good site selection procedure constitutes the first step towards successful reforestation. Site selection and assessment should be conducted from an ecological and a socio-economic perspective.

Site selection can start prior to visiting the site by choosing potential locations from a reforestation suitability map such as the LRI Potential Reforestation Sites Map available on the mapping platform of www.lri-lb.org. This map of potential reforestation sites was developed by LRI using advanced GIS and modeling techniques based on environmental and soil criteria. As a result, sites shown on the map are those where reforestation can be successful from an ecological and scientific point of view. However, it is important to note that the map is not exclusive and one can find suitable sites for reforestation that do not appear on the map. In such cases, consultations with those knowledgeable about a particular area can help the reforestation manager learn more about best species to plant and other site-specific characteristics.

In the absence of digitized land ownership data for Lebanon, ownership of potential sites of interest selected from the map should be first verified. Although in some cases private land might be chosen for reforestation under agreement with the owner, it is usually preferable to conduct afforestation/ reforestation activities on public land to avoid subsequent land use changes that might affect the presence and survival of the planted seedlings. In Lebanon, public lands are of two different forms: private public land, which are owned and managed by the local government (i.e., the town municipality), and public or republic land, which are owned by the Republic of Lebanon and managed by the local government under approval from the Lebanese Ministry of Finance. Getting the right approvals from the municipality and/or the Ministry of Finance, and in some cases from the union of municipalities, is crucial for the success and longevity of the reforestation project.

Once land ownership is clarified and corresponding authorities' approval acquired, a thorough site assessment should be conducted well in advance of the planting season (see sample field assessment form in Annex 1). The site assessment process can change with the goals and objectives of the reforestation manager. Standard site evaluations include several criteria divided into primary and secondary criteria based on their importance and contribution to the final decision on site selection. The primary assessment criteria include:

- **Soil depth**: Successful seedling establishment requires a minimum of 40cm of soil. Thinner soils can lead to high mortality rates. In some cases, such mortality may not be observed until a few years after planting. To assess soil depth, try to dig 40cm deep holes in several areas across the site.
- **Vegetation cover and natural regeneration**: The purpose of reforestation is to restore pre-existing forests that have been cut or burned and weren't able to regenerate on their own. A thorough assessment of current vegetation cover should be completed if such cover exists. If natural regeneration of native pre-existing species is happening, reforestation is no more needed and could even be harmful to the natural environment through the disturbance created both by the frequent activities on site as well as the introduction of new seedlings. Protecting regenerating vegetation in such a case exceeds in value any reforestation activity. If the site used to be a forest and no regeneration is observed, and if it is currently dominated by invasive species and/or other non-tree vegetation, then reforestation is highly needed to restore the ecosystem. If the site itself shows no signs of previous tree vegetation, looking in the general area for signs of past vegetation (stumps) or for nearby trees or forests can help guide the manager's decision both on suitability of the site for reforestation as well as the choice of appropriate species.
- **Land use**: Before planning reforestation activities, it is important to check current and future land uses both at the municipality and the Ministry of Internal Affairs. In some cases, local municipalities may not be aware of other plans at the ministry level at odds with reforestation.

- **Presence of security concerns:** When planning a reforestation project in Lebanon, it is important to check for security issues on the proposed planting site. Prohibitive issues include the presence of landmines, presence of bases for armed forces, or location in a conflict zone. Sites that are close to a conflict zone or with cleared landmines should be approached with caution.

- **Rockiness and distribution of rocks:** Very rocky sites might be hard to plant and manage. Sites with surface rocks require a good assessment of soil underneath. Sites should be chosen only if good soil exists under the rocks, and in such cases, heavy machinery may be required to break the surface rocks to access the soil layer.

- **Interest and level of engagement of the local community:** Successful reforestation cannot be achieved unless all stakeholders are engaged and interested in conducting reforestation. Gauging such interest from the beginning and setting a unified vision for the reforested area among all stakeholders is crucial for the long term success and establishment of the planted forest. A community engagement strategy should be set and followed for each reforestation activity from the beginning of the decision-making process and should continue in parallel with the technical activities on the site to insure those activities are responding to the needs of the actual owners of the future forest. This process influences largely decisions on planting area, access road location, choice of species, spacing or seedling density, and fencing, among others. More community engagement can be achieved by creating socio-economic incentives such as hiring local people for planting activities, including economic species that can benefit the local community on the long run, or including in the reforestation plan specific areas within the site for recreation or community activities that can encourage local residents to visit the reforestation site.

Secondary site assessment criteria are those needed to guide the manager's choice of species and practices to be used on the reforestation project. Those include:

- **Elevation:** Species selection is highly influenced by the site elevation. For guidance on species that are best adapted to a given elevation, refer to the new vegetation map of Lebanon (available on www.lri-lb.org).

- **Slope:** Steeper slopes can be hard to manage and risky for labor. If some slopes on the site are steep, concentrate reforestation efforts in the more gradual topography. When using machinery, it is important to understand the slope limitations of equipment to ensure safety and efficient operations. Small excavators (Poclin) can only work on gradual topography(less than 30 ˚); while larger excavators can operate on slope between 30˚ and 60˚. Slopes steeper than 60˚ become too risky for machine operators and should be prepared by hand.

- **Aspect:** North-facing slopes usually have better soil and more shade, which favors seedling growth. In contrast, south-facing slopes are dryer and more exposed to direct sunlight. Species distribution on the site should consider the aspect of each slope. For example, species that require shade should be planted on the north-facing slopes or in the shade of shrubs and rocks, while south-facing slopes should be planted with lower densities and only with drought and light tolerant species.

- **Soil type and texture:** Soil type should strongly influence species selection for planting. In Lebanon, soil type varies considerably between sites and even within sites. Checking soil type in several locations across the site is important. The current arrangement of species composition may provide some indications of the soil types, and inform species selection and where to plant. A detailed soil type of Lebanon (1:200,000) is available for purchase from the National Center for Scientific Research- Remote Sensing Center (CNRS).

- **Water availability:** Until now in Lebanon, reforestation success has been tightly linked with summer irrigation. While seedling production techniques are improving and planting without irrigation is being tested, insuring water availability is still very important. Irrigation systems and watering can be very expensive. Having an adequate water source for irrigation in close proximity to the site minimizes additional costs and ensures success of reforestation.

- **Accessibility:** Access is considered an important selection criterium because it influences directly project costs. Most public lands are situated in the remote mountain tops. Access roads are needed if mechanical soil preparation is planned, for transportation of seedlings, and for transporting workers to the site. Access roads are also important for post-planting maintenance and fire prevention and suppression. If access roads are not available, they should be opened well in advance of the planting season. Maintenance work on dirt roads should occur before the planting season to insure good access. It is not recommended to pave reforestation site roads but rather keep them as natural as possible to minimize disturbance, costs, and to preserve aesthetics. If roads are deemed necessary, careful planning of their location and construction is critical to minimize environmental impacts, ensure efficient site operations, and reduce costs. For large sites, fire experts should be consulted when designing access roads so they can also function as fire breaks and provide adequate access for suppression. If fencing is planned, the access roads should follow the fence line to facilitate installation and maintenance and to serve as an external fire break.

- **Suitable planting area:** The land area available for reforestation can differ from the total area of the plot on the cadastral maps. Past land use has degraded some areas to the point where reforestation is not possible or practical. In some cases, small structures are built within the site. In others, the local government had planned to leave a recreational area within the land. In all cases, an estimation of the plantable area is needed to determine the number of seedlings needed and costs of treatments. Access roads, very rocky areas, picnic areas, human structures and other non-plantable areas can be mapped and substracted from the total plantable area.
- **Grazing pressure:** In parts of Lebanon, unregulated grazing presents serious challenges to successful reforestation. Determining likely grazing pressure, including number of shepherds and herds and origins (local vs. foreign) can guide in the decision whether a fence is needed to protect seedlings. Fencing types and costs vary widely (see section 5.1.2). There are many on-site indicators of grazing (species composition, size and shape of vegetation, presence of tracks and scat) that can be examined to further assess trends.

Even though some of the criteria described above are already included in the reforestation model developed by LRI and are thus taken in consideration in the map of suitable reforestation sites, *in situ* verification helps to ensure accuracy of information and improves chances of success.

On heavily degraded sites such as quarries, unstable sandy slopes, and old terraces, additional site assessment should be conducted to determine the need for soil stabilization and hydrological works before outplanting. In some cases, tree seedling planting may be delayed of several years until other preparatory activities are carried out to ensure soil stability and worker safety.

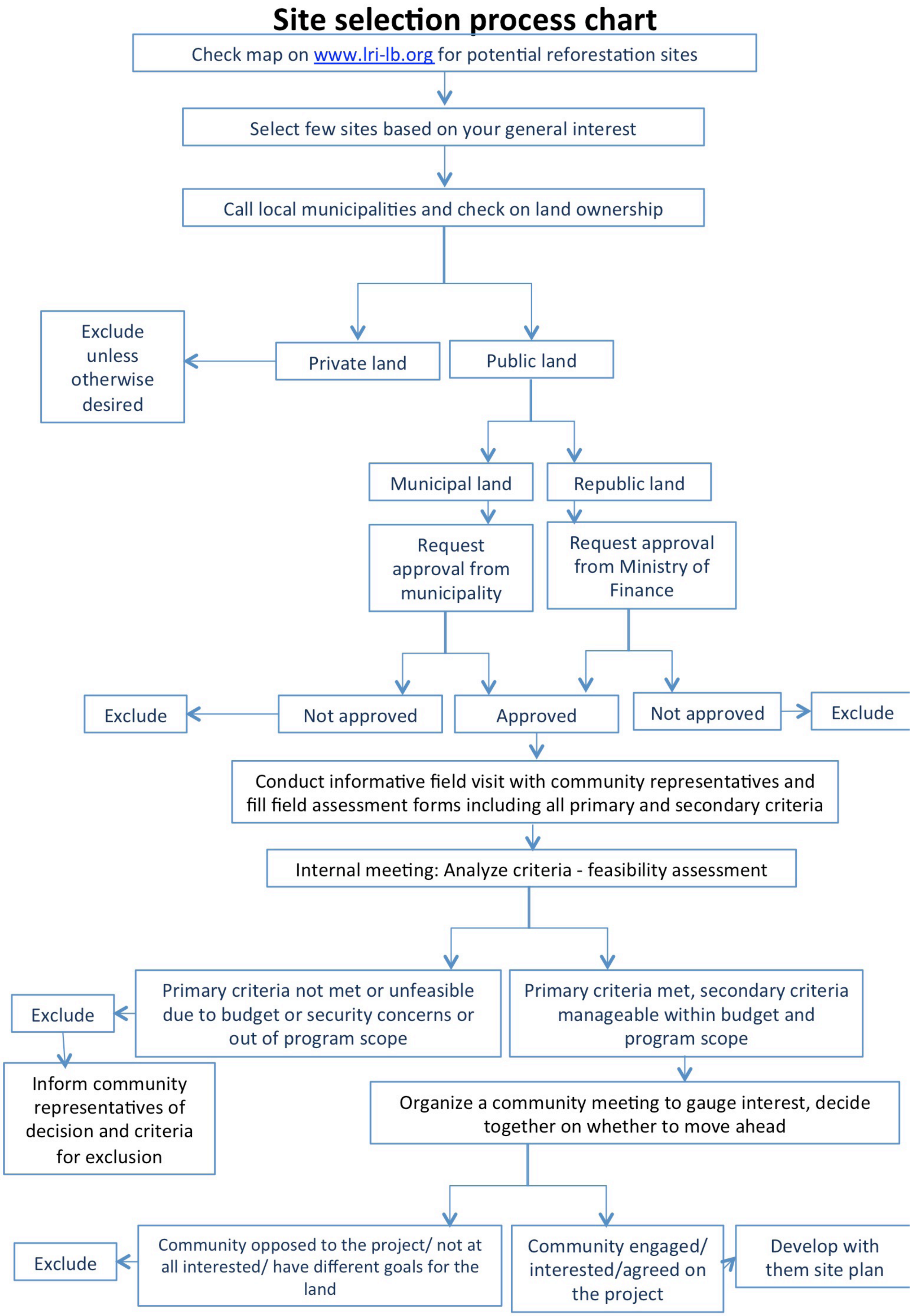

Figure 3.1. Site Selection Process

4. SITE PLANNING

Once a site is selected based on the criteria mentioned in section 1, a detailed site plan should be developed. Reforestation activities could be very expensive and in some cases irreversible (e.g. opening access roads in wrong locations). Planning all steps of the reforestation project helps reforestation managers reduce unnecessary costs, cut down losses and insure sustainability of the planted site. Reforestation projects conducted on public lands should involve all local stakeholders from the early phases of planning where project goals are set and approved.

A standard site plan includes:

- A general description of the selected site with the criteria used in the selection process.
- General and detailed objectives of the reforestation project. Those are set in stakeholders meetings and can vary a lot from one project to another.
- A technical plan including species to be planted, stock types, planting configuration and density, planting window, planting sequence, soil preparation, planting protocol, moisture conservation techniques, irrigation, protection from grazing, protection from fire, maintenance and long-term activities and access.
- A community engagement plan including a list of stakeholders, community engagement activities during the timeframe of the project, and a plan for the development of a long-term community action plan to be implemented by the local community after the project timeframe (for details refer to the "Lebanon Reforestation Initiative: A Guide to Community Engagement Approach for Reforestation").

4.1. *Technical Reforestation Site Plan*

4.1.1. Selection of Species

The LRI potential reforestation sites map provides an indication of the suitable vegetation series for each potential reforestation site, based on the updated vegetation map of Lebanon (see www.lri-lb.org). However, this information is coarse scale and may not represent all conditions found on the site. For this reason, the applicability of the vegetation series should be verified on-site and adjusted as needed. From this vegetation series, species that are more drought and light tolerant are planted on exposed and south-facing slopes. For example *Pinus brutia* can be planted on the south facing slopes while *Pinus pinea* is better suited on north- facing slopes. *Abies cilicica* seedlings are hard to grow under direct sunlight and thrive better when placed in the shade of a rock or an existing tree or shrub.

Aside from the technical criteria, species selection depends on the preferences of and goals set by the local community and the potential to grow such seedlings at the nursery. Selection of species is one of the most important steps in the planning process that should be done in close coordination with the local community. Some species are preferred by the community either for their economic importance, (e.g., stone pine, carob and laurel) or for their symbolic value such as cedar. Other species might be rejected by the community such as cypress which is associated in some Lebanese towns with cemeteries. Some species are also hard to grow at the nursery and might not be available.

It is very important to plant as many of the species included in the vegetation series corresponding to the site as possible to maintain biodiversity of the growing forest and increase wildlife habitat.

4.1.2. Stock Types and Containers

The success of a reforestation project depends largely on the quality of the planted seedlings. Seedling quality is affected by seed provenance and genetics and by nursery production practices including type of propagation environment, growing media, container type, irrigation and fertilization. Quality is simply assessed by looking at the seedling color and measuring seedling height and diameter, health and container types used during production.

Seedling height and diameter vary by species. Optimal seedling heights range between 10 and 30cm. Optimal diameter is measured on the crown right above the surface of the soil and should range between 2 and 4mm (for more details, see Lebanon Reforestation Initiative: Native Tree Nurseries Culturing Practices and Results).

4.1.3. **Planting Configuration and Density**

Planting configuration and planting density are dictated by project goals and by site conditions (rockiness, soil depth and aspect). Planting could be done either randomly or following a more uniform pattern.

Random or non-uniform planting configurations with moderate planting densities are usually preferred when restoring natural forest ecosystems because they result in a more natural appearance of the growing forest and create a higher biodiversity by allowing for a higher complexity of habitats with various sizes of clearances versus shaded areas. Non-uniform configurations are obligatory on rocky sites where planting spots are dictated by the distribution of rocks and in sites with harsh topography where steep slopes, rock protrusions or depressions prohibit the uniform distribution of seedlings. On high elevation sites with clay soil where melting snow can create temporary water ponds, deeper valleys should be avoided when planting since stagnant water in those valleys will cause seedlings to suffocate or get infected with various types of molds. This again results in less uniformity in the planting configuration and higher spacing between trees.

For inspection and monitoring purposes, non-uniform planting configurations result in higher variation and increase the sampling error, resulting in less accurate data than in uniform plantations.

On the opposite side, uniform planting configurations with high planting densities (in the order of 1,000-2,000 seedlings/ha) are preferred for economic forestry because they facilitate cultural practices and result in a more uniform wood production. In such cases, planting is done in parallel rows with very high density within the rows and large enough spacing between rows to facilitate mechanical thinning, weed management and harvesting activities. Uniform planting is easier and faster for workers to accomplish on less rocky sites. Uniformity of seedling distribution on the site also facilitates data collection and enables more accurate inspection and monitoring results.

In Lebanon, most previous and ongoing reforestation projects are done to increase the forest cover and restore natural ecosystems and are thus preferably done with a random planting configuration. Based on the growth patterns of Lebanese species, preferred planting densities range from 400 seedlings per ha for species like cedars wherever the wide shape of the Lebanon cedar tree is desired to 600-700 seedlings per ha for hardwood species such as oaks and wild almonds.

Planting density could also be dictated by project resources. If resources and time are limited and the reforestation manager can only afford to conduct planting activities once during the project lifetime, higher densities could be targeted to account for later potential mortality and keep the final density at the desired level.

Planting configuration and density of local reforestation or restoration projects are also often guided by the specific goals set by the local community. This is one of the reasons why project goals and detailed objectives should be set at the beginning of the site planning process.

Reforestation projects developed for the purpose of improving the ecotouristic value of a site should consider the need to leave open trails for hiking or mountain biking, areas with largers clearances to be used as picnic or rest areas and higher density spots for biodiversity, shade and to improve habitat for wildlife. In such cases, planting configurations should be mapped and approved by all stakeholders prior to planting to avoid later removal of trees. In areas with high fire risk or grazing pressure, strips of unplanted land may be left for the creation of fire breaks or herd passage.

4.1.4. **Planting Window**

The outplanting window is a critical step of the Target Plant Concept. At the time of ordering, the reforestation manager should inform the nursery owner of the planned planting window to ensure seedlings are hardened and dormant by the time they need to be transported to the site. Good hardening and seedling dormancy are known to decrease seedling susceptibility to the stresses of harvest, storage, shipping, and planting.

The outplanting window is defined as the period of time during which environmental conditions on the site most favor survival and growth of nursery stock (Landis et *al*. 2010). **Start and end dates of an outplanting window are defined mostly by soil moisture and temperature.** Following outplanting, seedling roots should be able to take sufficient water from the surrounding soil to meet the demands for shoot transpiration and photosynthesis. If soil moisture is insufficient, seedlings can experience serious drought stress that results in reduction in growth and increased mortality. Ideally, soil water potential in the top 25 cm (10 in) should be greater than -0.1 MPa at the time of outplanting (Cleary and others 1978, Krumlik and others 1984).

In addition, soil temperatures below 5˚C prohibit root growth. The ideal soil temperature range for root growth is 5 to 20 °C (41 to 68 °F). When transpirational demands are high but cold soils limit water uptake, plants may experience a "physiological drought" that can limit survival and growth (Mitchell and others 1990).

In Lebanon, planting windows vary by the geographical location of the site. High elevation sites and sites in the Northern Bekaa valley experience quick drops in soil temperatures early into the fall season. This results in much shorter planting windows in those areas as compared to coastal and southern sites where moisture and moderate temperatures are available for most of the fall and winter seasons. Despite those differences, three major rules apply overall Lebanon for determining the planting window:

1. **Planting should be conducted in the fall season** for several reasons, including among others seedling quality and sufficient root growth:

   a. With the adoption of the new seedling production practices in Lebanon, good quality seedlings are ready at the nurseries around early October. Seedlings can be kept dormant and conserve their quality through the cold season but will start growing back, developing higher shoot-to-root ratios and consequently loosing their hardening once temperatures start increasing in early spring. To plant good quality seedlings, planting activities should be limited to the fall season when seedlings quality is at its highest. Leaving seedlings too long at the nursery also increases seedling production costs and subsequent seedling prices, thus increasing the cost of outplanting.

   b. Planting when soil moisture is high allows for good expansion of seedling roots in the ground before the dry season, which later limits the need for surface irrigation if roots are able to reach the below-ground moisture.

2. **Planting should not start until the soil has built sufficient moisture (usually equivalent to more than 50ml of rainfall).** The start of the outplanting window is thus site-specific and one date cannot apply to all locations across Lebanon. Local weather stations should be consulted to determine the good time to start planting. In the absence of such stations, continuous on-site monitoring of precipitation and soil moisture should be conducted. Continuous monitoring is mostly critical in high elevation sites where the planting window can be as short as few days after the first rain and before the first snow and the quick drop in soil temperatures. In fall 2012, the outplanting window in some high elevation Lebanese sites was limited to 10-15 days since it snowed shortly after the first rain.

   Don't start planting too early!!! It is always tempting to start planting after the first rain, but it might not rain enough or rain could be followed by a long dry period. In those cases when the planting window is expected to be too short to complete planting and resources are available, planting can start after the first rain even if moisture is not enough and seedlings can be watered right after planting to complement available soil moisture.

3. **Planting should be completed during the rainy season** and as early as possible before the onset of drought and high temperatures. Planting in the last days of rain will only lead to seedling mortality since roots have not had the chance to develop enough before the dry season. This is

mostly criticial in Bekaa sites where weather tends to shift quickly from cold to very hot and dry.

Be conservative!!! Finish planting as early as possible and let the roots grow well enough during the rainy season.

It is important to differentiate between the outplanting window and conventional planting dates. Numerous volunteer-based reforestation activities in Lebanon are organized in the spring and summer when volunteers are readily available. However, both for the nursery and the planting sites, conditions in spring and summer do not favor seedling survival. Soil temperatures can be too high and continuous irrigation would be required to keep seedlings from experiencing severe drought stress. Recent experience with LRI and its partners has shown that survival rates increased dramatically when seedlings are planted within the site's planting window. For example, in Rachaya el Wadi in the Bekaa valley, seedlings planted in November after the first rain and while temperatures were still conducive to root growth exceeded 85% survival. In contrast, almost all those planted later in the season (in February-March) died.

Even within the planting window, daily weather conditions and forecasts should be checked. Waves of higher temperatures and drought are not uncommon during the fall season in Lebanon. Those should be anticipated by preparing the needed equipment to irrigate planted seedling through such a wave. Fast winds can also cause surface dessication by seriously lowering air humidity. Therefore, planting is best done during the early morning hours when air temperatures are cool and wind speeds are low. When weather is sunny, windy, or dry it is necessary to take extra protective measures to minimize plant stresses. In extreme cases, the planting operation may have to be suspended.

4.1.5. Planting Sequence

The planting sequence refers to the chronological sequence of planting a reforestation sites, both from a geographical and species perspectives.

The planting sequence can vary considerably with changing site conditions and logistics. In hilly sites with various aspects, it is recommended to plant the south-facing slopes earlier to benefit from a longer rainy period before they are exposed to drought.

To facilitate inspection during planting and record keeping, it is better to completely plant a section before moving to another, and to follow site topography. If access to a site is from one side only, it might be easier to start with the furthest location and plant back towards the roads. Working from back to front reduces chances of workers stepping on planted trees and maximizes worker energy.

If different species are planted in clearly different locations, starting with the more vulnerable, drought intolerant species might give those a higher chance of survival. In cases of site restoration, the planting sequence can expand over several years where soil stabilizing plant and shrub species are planted first and tree seedlings are only introduced to the site once the soil is deemed stable or enough organic matter has accumulated. For sites where reforestation activities are conducted in parallel to construction, infrastructure, or recreational area development activities, the planting sequence should be developed in coordination with the engineering plans, taking into account the disturbance caused by those activities to avoid seedling damage during the process. In cases where slow-growing shade intolerant species are mixed with fast-growing shade tolerant species in high density planting configurations, the shade intolerant species should be planted a year or two in advance to give them enough time to grow and avoid being outcompeted.

5. PROJECT IMPLEMENTATION

Project implementation issues described below provide guidance to reforestation managers on how to implement step-by-step reforestation projects.

Although soil preparation, planting, moisture conservation, irrigation, protection from grazing, protection from fire, maintenance and long-term activities and access should all be included and decided upon in the planning phase, they are included under project implementation to avoid repetition.

5.1. *Site Preparation*

Site preparation includes all physical activities conducted on the site pre-planting to facilitate and speed up the planting process. Site preparation varies according to initial site conditions and purpose of reforestation.

In general, restoration projects require more complex and time consuming site preparation techniques and strategies (see section 5.1.5. below).

More standard reforestation projects can be prepared for planting in a relatively short period of time, prior to the planting season. Standard site preparation includes:

a. Developing/improving access to the site

b. Protecting the site

c. Installing main parts of the irrigation system

d. Vegetation control and soil preparation

5.1.1. Site Access

Access roads are crucial to facilitate transportation during planting and later maintenance activities, allow efficient fence installation if needed, and create fire breaks and fire truck access. Access roads on natural reforestation sites are usually dirt roads that require regular maintenance after each winter season. In the absence of such roads, opening new access roads should be done after satisfying environmental impact considerations and any needed mitigation measures, followed by consultation with a civil engineer experienced in road safety standards. Access roads location should in all cases meet the access needs described in the site plan. Roads on hilly sites should be designed and maintained to ensure proper water drainage, safe use and access by different types of equipment planned for use on the site. In some cases culverts may need to be installed.

5.1.2. Site Protection

Potential threats to the newly planted seedlings should be identified in the project planning phase and measures to respond to those threats should be decided upon in consultation with the local community and based on available resources.

Common identified threats for reforestation sites include:

- Grazing by domestic or wild animals
- Human activities such as off-road driving, snow activities in high elevation sites, etc.
- Fire

Grazing is one of the major issues that threaten successful reforestation in Lebanon, mainly because it is poorly regulated. Overgrazing has contributed to the rise and dominance of spiny shrubs and plants that are unpalatable to goats and sheep. In these conditions, newly planted seedlings are highly attractive to all animals, both domestic and wild.

In case grazing pressure was identified in the assessment phase as a serious risk on the reforestation site, measures to protect the site from grazing should be decided upon in the planning phase upon consultation with the local shepherds and the municipality. In ideal cases, an agreement would be reached between the local municipality and the shepherds either to provide them with alternative grazing areas or to involve them in the reforestation activities. If no such agreement is possible or alternatives are not available, fencing the reforestation site becomes a necessary procedure, despite its high cost. However, decisions on fencing must be taken in close coordination with the local municipality and community stakeholders.

Fencing can be applied at three different levels, as individual seedling fencing or individual shelters, cluster fencing or full site fencing. Table 5.1 below describes each of the fencing options and analyzes its advantages and disadvantages.

Table 5.1. Fencing options for reforestation sites

Type of Fencing	Description	Advantages	Disadvantages
Individual fencing (Fig. 5-1)	Fencing each seedling individually with a metal wire fence fixed on iron rods	-Can be customized to the size of the growing seedling -Allows recycling of old fence material if available -Protects seedlings without affecting herd movement -Reduces fire risk on site by allowing grazing animals to eat the growing weeds between the planted seedlings	-In the absence of recycled fencing material, the cost of individual fencing is much higher than full site fencing -Time consuming to set on the site -Should be set during planting right after seedlings are planted- delays might cause losses of seedlings -If site is irrigated with a full drip irrigation system, individual fences make irrigation system maintenance harder and expose a large part of the irrigation system to damage by herd movement or animals chewing on pipes -Better used coupled with mulching and no irrigation. Scalping harder to accomplish with individual fences

Plastic mesh tree shelters (Fig. 5-2)	Plastic ready-made shelters that can be purchased from international companies. They usually come in different heights and diameters but are rarely wide enough to sustain several years of growth. They're held by iron or wooden stakes	-Protects seedlings without affecting herd movement by concept. -Reduces fire risk on site by allowing grazing animals to eat the growing weeds between the planted seedlings -Provide good protection from wild boars (tested by LRI in Tannourine) and rabbits and other small sized wild animals -Tested by LRI in Qlaiaa, they were found to be also effective for sheep. -Allow for scalping around the seedling and drip irrigation since diameter is narrow.	-Cannot be customized- diameters were found to be too narrow and seedling branches start going out of mesh the first year after planting. Can cause branch girdling. -Made of plastic- considered a pollutant in natural systems - Expensive and time consuming to install- require later labour and time for removal as well. - Tested by LRI in Qlaiaa, more than 95% of shelters held with either one or two wooden stakes were removed by goats à doesn't effectively protect seedlings from goat grazing. -Weeds growing right next to seedling are hard to reach
Plastic solid shelters (Fig. 5-3)	Plastic shelters that come in the same shapes and sizes as the mesh ones but are made of a full sheet of plastic, only perforated at the base to allow for air movement	-Protects seedlings without affecting herd movement by concept. -Reduces fire risk on site by allowing grazing animals to eat the growing weeds between the planted seedlings -Provide good protection from wild boars (tested by LRI in Tannourine) and rabbits and other small sized wild animals -Tested by LRI in Qlaiaa, they were found to be also effective for sheep. -Allow for scalping around the seedling and drip irrigation since diameter is narrow. -Based on the color and material used, have the potential to limit evapotranspiration and create shade around seedling base	-Can cause seedlings to grow weak trunks when trying to reach the light faster (grow taller lower diameter seedlings) (Mechergui et *al*. 2012). -Made of plastic- considered a pollutant in natural systems - Expensive and time consuming to install- require later labour and time for removal as well. - Also not effective against goat grazing -Weeds growing right next to seedling are hard to reach -In most of LRI sites, they were used by wasps and other insects as nesting areas or protection à potential additional insect damage for seedlings.

Cluster fencing (Fig 5-4)	Fencing small areas within the site inside which planting is done at slightly higher density, instead of fencing the whole site.	-Protects planting seedling while allowing grazing to be done between the fenced areas. -Grazing in this case creates fire breaks between the planted tree clusters. -Allows to preserve biodiversity within each fenced area -Weed management can be done within the fenced areas -Does not affect seedling growth or branching patterns	-More expensive than full site fencing because it requires additional fencing length and installation costs. -Results in a clustered pattern of the forest with relatively large overgrazed clearances in between - Allows harvesting of forest by-products, such as herbs and others, by local community, without damaging the seedlings
Full site fencing (Fig 5-5)	Installing a metal fence around the whole site perimeter.	-Protects the whole site from grazing, allowing biodiversity to reestablish over the whole site -Protects also from human activities such as off-road driving and snow activities. -Protects all irrigation and other equipments installed on the reforestation site -Based on materials used, could be the least expensive of all alternatives above and the faster to install -Does not affect seedling growth or branching patterns	-Prohibit access to the site except for site managers – can cause serious issues to shepherds and local community members who collect forest by-products -Increases fire risk by building up weed biomass due to grazing prohibition -Requires more elaborate weed management procedures both to preserve moisture for seedlings and to prevent fires. -Allows for all types of planting configurations.

Figure 5-1.Individual seedling fence – (Photo from: Phillips et al. 2007)

Figure 5-2. Mesh tree shelters

Figure 5-3. Plastic Solid Shelter

Figure 5-4. Cluster fencing withing reforestation sites. (Photo Courtesy: Al Shouf Biosphere Reserve)

Figure 5-5. Full site fencing with wire fence.

While individual fences and shelters should be set in parallel to planting, cluster and full site fencing should be planned ahead and implemented as part of site preparation to ensure good protection and to facilitate future reforestation steps. Fencing designs should take into account adequate access for workers and machinery if needed. Fences and access roads should be mapped prior to implementation to ensure good access for the installation and maintenance of the fence.

LRI Research findings on shelters

A study conducted in three regions of Lebanon, on Aanjar, Rachaya and Qlaiaa LRI reforestation sites, in 2012, showed that mesh tree shelters combined with mulching have a positive effect on survival but not on growth parameters of seedlings, in dry sites like Aanjar. No such effect was observed in either of Rachaya or Qlaiaa where soil moisture was higher (Chahine 2013). More research is needed to determine the effect of shelters on seedling survival and growth in different site conditions in Lebanon.

Mesh Treeguards (Purchased from Acorn Planting Products, © Fiberweb Geosynthetics Ltd, Blackwater Trading Estate, The Causeway, Maldon, Essex, CM9 4GG) were tested in the town of Qlaiaa in collaboration with a local goat and sheep shepherd. Treeguards were 75cm high, fixed with a 1m high (1cm x 1cm) wooden stake inserted half way (50cm) in the soil. In the first trial, 19 out of 23 shelters were completely displaced by goats that went by the area. 18 out of the 19 exposed seedlings were eaten. The test was repeated with 2 wooden stakes per shelter; the result was still the same. When 3 stakes were applied the goats weren't able to remove it. However, the time needed to set 3 stakes for every shelter was too high to justify their use on a large scale. Sheep on the other side went by the shelters without trying to displace them.

Fencing Material

Fencing material used either for individual, cluster or full site fences can vary based on location, pressure on the fence and resources available. Common fencing material types and designs include:

Mesh wire fences (Fig. 5-5) are the most commonly used across Lebanon. The mesh wire comes in diamond (most common) or square shape and is held with either round, angular or Y-shapes 2m high posts, inserted 50cm in the ground and usually placed every 2.5m. These fences are typically 1.5 m tall. In areas of high snow, posts are fixed underground with cement. Diagonal support posts are usually used counter-slope on corners to protect the fence from falling in snow or heavy run-off areas.

Barbed wire fences are an effective and lower cost alternative to mesh wire but are less visually attractive (Fig. 5-6). This fence type is constructed using 3-4 parallel lines of barbed wire secured with similar posts to those used for mesh wire fences. Lines of barbed wire are spaced evenly on the 1.5m fence height to prevent animals from escaping between the lines.

Figure 5-6. Barb wire fencing. (photo from www.moyne.vic.gov.au)

Concertina barbed fences, (Fig. 5-7), are also used in some reforestation projects. They are a less expensive alternative to the other two fence types but can be hard to maintain and risk becoming compacted under heavy snow if material quality is not adequate. They come in different diameter sizes ranging from 30 to 90cm and in rolls of 10-12m that should be extended and held by small iron poles. They require fewer iron poles than the other fencing types, which makes their installation less expensive and less time consuming. Workers installing barbed wire fences of any kind should wear protective gloves to avoid injuries.

Figure 5-7. Concertina wire fence (photo from www.diytrade.com)

Other fencing types

In low grazing pressure areas, lighter fences can be used with warning signs. Fences with poles and 2-3 lines of straight wire have been used in some locations. More natural material, including wood, cut shrubs, spiny bushes, and others have been used on a smaller scale.

All fence types need to be frequently monitored to ensure they remain fully functional.

Human activities can also cause serious damage to the planted seedlings. All types of fencing can contribute to reducing the risk of human activities either by limiting access or by warning people of the locations of planted seedlings in case of individual seedlings. Snow activities are trickier because in most high elevation sites where those activities are held, snow pack can be higher than 1.5m and all mentioned types of fencing could be completely covered and unseen. In such sites, poles high enough to have warning signs should be placed around the site to prevent entry. Local guides and managers and organizers of snow activities should be familiar with the site boundaries and should be involved in the whole process.

Fire is another serious threat in reforestation sites. A combination of individual or cluster fencing with grazing can seriously reduce this threat. In fully fenced sites, however, the risk of fire becomes greater due to the substantial increase in grass and shrub populations, leading in the summer to a build up of combustible fuel within the site. Opening access roads within the site during the site preparation phase can help limit the expansion of fires in case they happen and facilitate fire response activities. Fire prevention could also be done through weed management techniques discussed in section 5.1.4 below.

5.1.3. Irrigation Systems

Where irrigation is determined to be needed, it is important to work with an irrigation expert during the planning phase to design the appropriate irrigation system for the site. The water source, locations of water tanks and mainlines should be mapped before planting begins to ensure those areas are left free of seedlings and that planting is starting close enough to the water source and low enough beneath the tanks to maximize water pressure. Some areas are very hard to irrigate and those should be designated before the project to allow for an informed decision on whether to plant them. In low elevation sites, irrigation systems could be set prior to planting to prevent future potential delays in irrigation as well as to ensure that all seedlings are planted in areas that can be irrigated. In high elevation sites, setting the irrigation system before or during the planting season could reduce its shelf life by exposing it to severe weather conditions before even being used. In such cases, systems are better set after snow melt.

The type of irrigation system to be installed on a reforestation site is decided upon also in the planning phase. Irrigation systems vary considerably in their cost, complexity and efficacy. Table 5.2 provides a summary of the two main irrigation systems used in Lebanon and their specifications.

Table 5-2. Comparison of drip and hand irrigation systems

Irrigation system type	Description	Average cost per seedling	Advantages	Disadvantages
Drip irrigation system	System composed of water tanks set on the highest elevation points of the site, mainlines, smaller pipes and one dripper per seedling. Pressure compensation valves are used to regulate pressure on the slopes.	$3.37	-More guaranteed access to all seedlings -Faster -Saves water -Requires less hand labor	-Harder to achieve good pressure for all sections of a hilly site -Expensive -Requires continuous maintenance
Hand watering irrigation system	System composed of water tanks set on the highest points of the site with mainlines distributed on the major axes and few irrigation pipes that can be connected to the mainlines by taps to irrigate by hand seedling by seedling	$1.00	-Less expensive than drip irrigation - Requires less maintenance than drip irrigation	-More time consuming than drip irrigation -Requires more hand labor -Workers might miss seedlings. -Uses more water than needed

Aside from these two systems, other means of irrigation can be used such as solid water or deep pipe irrigation. Since those irrigation types are not installed until planting or after planting, they'll be discussed along with the irrigation schedules in section 5.7 below.

5.1.4. Vegetation Control

Deciding how to manage existing vegetation is often challenging, but following a well-designed plan is critical to project success. The most effective vegetation control is usually completed prior to planting because it limits damage to seedlings, reduces planting costs and enhances early seedling growth. Spot treatments are always preferable to full site treatment in reforestation projects aiming at restoring natural ecosystems, because they preserve the natural biodiversity and cause limited impact on non-target organisms. Spot treatments require a well-trained crew to determine planting spots and guide other workers to conduct weed management and later training practices on those specific spots.

The approach to vegetation control varies with the planted seedling needs for light and moisture. Species that are weak competitors against existing vegetation should be planted in as clean as possible of planting spots. Other species might benefit from the shade of existing shrubs to survive the heat of the summer. Knowing the appropriate species and their requirements for survival and growth defines the techniques used in the soil preparation phase. Mixed species plantings should consider the feasibility of implementing different types of vegetation control.

There are two main vegetation control site preparation techniques, aside from the use of herbicides that is not recommended under USAID regulations. These are scalping and shrub removal with excavators.

Scalping. Scalping is the physical removal of grasses, forbs, and small shrubs, around planting holes and is best applied on sites with grass and forb-dominated sites and can be inefficient and very expensive on shrub-dominated sites. It reduces vegetation competition, conserves soil moisture, and makes planting easier. It can be done using common planting tools such as a spade, hoedad or a combination tool. Scalping is more efficiently done prior to planting. However, when crews are limited, the same worker can scalp right before digging the planting hole and then plant it. Scalping should be done deep enough to remove roots of surface vegetation and for at least 1 m radius around the center of the planting spot (Fig. 5-8).

Figure 5-8. Scalping around planted seedlings

Weeds growing at the perimeter of a $1m^2$ scalped area in Rachaya were found in the spring 2012 to have extended their roots right next to the newly planted seedling, less than a month after scalping (Fig. 5-9).

Figure 5-9. Roots of weeds growing next to seedling rootseven after scalping was performed over 1m2 around the seedling.

Site preparation with excavators. Excavators are often needed in shrub dominated sites. Conventionally, a large excavator with a 1-1.5m wide bucket was used to remove shrubs and rocks and dig large planting holes. This practice is problematic for the following reasons:

1- The inversion of soil profiles can result in soil nutrient losses.

2- The loss of deep soil moisture by exposing these areas to air and heat.

3- The creation of air pockets in the soil layer where roots cannot enter, mostly problematic in high clay soils subject to frosting and/or drought.

4- The creation of large holes that are hard to manage by planting workers and that can pool water that freezes around seedlings on some higher elevation sites.

An improved practice recently adopted is to use smaller 40cm –bucket excavators to scalp and decompact the soil without inverting soil layers or creating large holes. The excavator first cleans the surface vegetation and then inserts its bucket in the soil and removes it back in the same direction. No holes are created and the moved soil can be further refined with the dents of the bucket (Fig. 5-10). This approach provides effective control in areas of heavy vegetation and may aid in seedling root growth. In LRI sites, planting holes prepared following this practice were found to provide a complete weed control in the first year of planting and to limit weed growth even in the second year.

Figure 5-10. Excavator-prepared planting spot being refined with bucket dents

5.1.5. Preparation of Highly Disturbed Sites

In Lebanon, the most common restoration projects are those that deal with old abandoned quarries. Because Lebanon lacks, in application, universal standards and environmental impact mitigation procedures, most quarries have a legacy of very steep cliffs with bottom plains cleaned to the bedrock. Creation of check dams and wide terraces, ponds and drainage areas, and the addition of soil are practices needed in most quarries before initiating planting activities. Severely destabilized sand quarries might require stabilization with bio-engineering structures or in less severe cases, through the planting of small plants and shrubs, before being reforested. Several native shrub species can be used for such stabilization projects. Once the soil is stabilized, standard soil preparation techniques can be applied. The soil stabilization and initial site preparation process might take more than a year to be completed. An interdisciplinary team including a hydrologist, a bio-engineer, a civil engineer and a forestry/species expert might be needed to develop a comprehensive site preparation plan for such sites.

5.2. *Seedling Shipping, Handling and Storage*

Seedlings can be severely damaged if improperly shipped, handled and stored. Best handling and storage practices differ by stock type and seedling growing conditions and storage at the nursery.

In Lebanon, seedlings are commonly delivered either in their containers or in plastic bags. Some nurseries store seedlings in cold storage at the end of the hardening phase and seedlings are then delivered cold and dormant to the planting site. However, the majority of nurseries keep their seedlings under normal growing conditions until the planting date.

Good seedling handling practices start at the nursery where seedling stock should be sorted, and should be followed through transportation and on-site storage.

Sorting nursery stock: It is crucial to select the seedlings well and sort them at the nursery before delivery. Delivery of bad quality seedlings increases the cost of transportation and labour at the planting site and wastes time. Receiving high quality seedlings can be ensured in several ways. A buyer can visit the nursery prior to the delivery time and select seedlings needed for the planting project. A more standard practice is to specify that only good quality seedlings will be paid for in the contract terms set at the pre-ordering time and to follow it through after the delivery is completed. The seedling quality standards are available at the Lebanon Reforestation Initiative: Native Tree Nurseries Culturing Practices and Results. The inspector or planting supervisor receiving the seedlings should be aware of those standards and able to sort the seedlings accordingly and return bad quality seedlings to the nursery right away.

Transportation: In ideal scenarios, seedlings from refrigerated storage should be transported from the nursery to the site in refrigerated trucks, which should stay on-site during the planting so seedlings are not exposed to the site conditions before being planted. In this case, each truck should receive a mechanical check before use. If a different truck is used for on-site storage, the compressor should be turned on for 4 to 6 hours prior to loading for pre-cooling (Paterson et *al*. 2001).

In the absence of refrigerated trucks, covered trucks can be used that protect seedlings from direct sunlight. White painted trucks or those made of aluminum are best to keep seedlings cool. Dark colored tarps have been shown to overheat the seedlings. Trucks can be equipped with customized shelves depending on the height of the seedlings to optimize capacity without damaging the seedlings. Stacking seedling trays is not recommended as it can cause serious breakage to seedling tops and branches, regardless of tray and seedling sizes. Seedlings should be set upright, in their containers or in their storage plastic bags inside the cardboard boxes.

Truck loading and transportation is better done during the night or in early morning, when the outside temperature is low enough to avoid overheating of seedlings (Emmingham et *al*. 2002). This is particularly important for refrigerated seedlings transported in non-refrigerated trucks. If seedlings are exposed to warm temperatures for an extended period, seedling quality can be severely affected, and thus their survival once planted.

Inspecting nursery stock upon arrival to the site storage: It is crucial to inspect thoroughly seedlings upon their arrival to the site, even if a pre-sorting was done at the nursery. Many problems can occur between the time seedlings leave the nursery and arrive at the site.

Inspection should include the following details:

1. Check the temperature of seedlings to ensure they are not overheated. For refrigerated stock placed in bags, check temperature inside the bags. Temperature of refrigerated stock should be no higher than 2-4 °C (36 to 39 °F). Seedlings delivered in containers should be kept as cool as possible and away from direct sunlight.

2. Seedlings should not smell sour or sweet. Such smells indicate that the seedlings are too warm or excessively wet.

3. Root plugs should be moist.

4. Foliage, if present, should be green. For seedlings with terminal buds, those buds should still be firm.

5. Check the firmness of the bark around the root collar. The bark should not be easily removed and tissues underneath should be creamy. Brown or black tissues can indicate frost injury.

6. Check inside random boxes for signs of molds, such as *Botrytis cinerea* (Fig. 5-11). This common nursery pest can increase rapidly in storage.

Figure 5-11. Pine seedling infected with Botrytis cinerea in the middle.

7. For seedlings with foliage, spread the foliage and check for white or grey mycelia which are evidence of storage molds. Such molds usually start from the bottom (base of the crown) up toward the top of the seedling. It is important to catch such infection early on. Searching the base of crowns for growing mycelia should be performed upon delivery and regularly during storage. If mold is present, check the tissue underneath for signs of decay. Soggy or water-soaked tissue indicates advanced decay. Seedlings showing such symptoms should be removed and disposed off. Seedlings with mold and no signs of decay should be aerated well: this could be done either by planting them first (outplanting site conditions often kill such fungal molds) or by placing them in spaced container trays; or by removing them from bags and placing them on a tray if initially bagged. All boxes and bags containing seedlings should be opened at the time of receipt and kept open during storage to avoid temperature and moisture build-up.

Storage: When the nursery is close to the site and daily deliveries of seedlings are available, on-site storage is not needed. However, in most cases, reforestation sites are distant from commercial businesses, including nurseries.

- Storage periods should be limited ideally to a few days. Bad weather conditions, limited budgets for seedling transportation, remote planting sites, crew holidays or issues in finding crews can lead to delays in planting and thus longer storage periods. In all cases, storage periods should not exceed a couple of weeks.

- Good planning before the initiation of a reforestation project is crucial to ensure the least overheating and desiccation, both being the major threats facing seedlings in storage. Included in this planning is ensuring adequate storage space. If rental space is required, the rental period should start before the delivery of seedlings to ensure enough time to clean and organize the space.

- Storage spaces should be covered to avoid exposure of seedlings to sunlight and should be as close as possible to the planting site.

- Trees and other natural shade can be used if available during planting for on-site storage of small quantities of seedlings but are not adequate storage spaces for the seedling stock.

- If no storage building is available around the planting site, an artificial space can be erected on one edge of the area to be reforested. Tents made of canvas tarp or shade cloth can be effective if covered on three sides. Wetting the tarp regularly can help cool the air around the seedlings (Mitchell et *al*. 1990).

- If seedlings are packed in bags, those should be opened and kept in an upright position beside each other. Seedlings should never be stored horizontally on top of each other.

- Moisture stress is another concern with stored seedlings. Transpiration rates increase with increased temperatures. They are also affected by sunlight intensity. Root plugs should be fully moist before outplanting. Thus, if root plugs are dry upon delivery or are stored for a long time, irrigation should be applied during storage. Experience with stored Lebanese native tree seedlings delivered in deep containers(e.g. Stewey & Sons Deepots D-40) showed that irrigation two nights prior to planting keeps the root plugs moist enough to avoid moisture stress and sturdy enough to avoid breakage when removed from the container before planting (Fig. 5-12). For this, access to a water source is crucial for on-site storage spaces.

Figure 5-12. Seedling roots moisture level required at planting time (seedlings with roots similar to the photo on the left should be watered before planting).

5.3. *On-Site Seedling Handling*

Seedlings should be handled with care on site to avoid unnecessary stress before planting. Mishandled seedlings can be damaged without noticeable signs. If storage is close enough to the site, workers can carry enough seedlings for 1-2 hours and come back for refills during the day. If the storage is far enough and requires vehicular transportation, a car or covered truck can be used to move seedlings to a shaded spot on site from which workers can take hourly stocks of seedlings. On large reforestation sites that have sufficient access roads or where all terrain vehicles can be used, it might be more efficient to have a couple of workers dedicated to supplying seedlings to planting workers. Planting workers should never toss, drop or shake seedlings when moving them around.

To make the planting process easier, and reduce the amount of energy and time consumed walking around the site, planting workers can use planting bags or buckets to transport the seedlings. Containerized seedlings should be kept in their containers up until the planting time. Root exposure to the air damages the seedling. A planting bag or bucket should be used to hold and transport seedlings to the planting spot. To avoid crushing plants and to facilitate removal of seedlings planting bags should not be overfilled (Fig. 5-13). Empty containers should be returned to the planting bags and later to the storage space after planting. Most seedling containers are re-usable and should be returned to the nursery.

Figure 5-13. Worker in Rachaya using planting bags to transport seedlings and empty containers across the site.

Bad quality or dry seedlings accidentally moved to the planting site should be returned to the storage to be discarded or watered, respectively. A tally of bad seedlings should be maintained on inspection forms.

5.4. *Planting*

Good planting quality contributes largely to reforestation success. Planting quality is usually achieved through the combination of good planting spot selection, good planting hole preparation, adequate tool and good planting practices. Trained planting inspectors should continuously inspect the quality of planting to ensure all steps are implemented consistent with best practices.

5.4.1. Planting Spot Selection

The importance of choosing good planting spots (the exact location where the seedling is planted) is often underestimated. This is a skill that takes training and experience, particularly on most sites in Lebanon where rocky conditions and patchy soils predominate. Finding the best planting spot is more important than maintaining a set spacing between trees. The resulting variable spacing of trees is ideal for habitat restoration and development of an aesthetically pleasant forest. Some key guidance in determining planting spots is described below.

1- When planting on flat terrain with good soil, planting spots can be dictated by a pre-set planting configuration.

2-On most mountain sites, planting spots should be chosen carefully based on soil depth and micro-site conditions. Look for deep soil pockets. Avoid bedrock and slope edges that might erode with run-off. On steep slopes, look for flat areas.

3- Where soils are gravelly and unstable, look for a planting spot directly below a shrub or large rock which can shelter the tree from sliding rocks and soil. For example, on sites covered with surface gravel such as in Ainata (Northern Bekaa- east slopes across from the Bcharre mountain), planting seedlings in such locations resulted in higher survival and less damage from gravel run off, snow movement and foot traffic.

5.4.2. Planting Hole Preparation

Common planting hole preparation techniques include hand digging, excavators and augers. Using a combination of these tools on one site maximizes benefits associated with each, but also requires more planning and management. The timing of hole preparation is important to consider. If holes are made after rains have wetted conditions, followed by a dry period, the hole and mound dirt may be dry during planting. However, if holes are produced during a dry period followed by some moisture immediately and during planting, this may actually increase soil moisture in the hole. Hole dimensions are also important and need to be determined prior to operations and should be well-communicated to crews. Holes dug too shallow are a major cause of poor quality planting and seedling mortality.

1. Hand digging: Hand digging is a suitable method for a range of site conditions and is the most commonly used approach in Lebanon. Unlike the other two methods, the hole is dug as part of the same process as planting when hand methods are used. Hand digging is conventionally done with two tools, the pickaxe and the spade. Holes are produced by one worker carrying both tools or in teams of two workers. LRI has developed a tool that combines these two implements for greater efficiency. When digging a hole using these tools, the removed dirt should be sorted out for rocks and debris and clean soil should be piled on one side of the planting hole to speed up the planting process and minimize root exposure. Planting hole dimensions are guided by container size (see section 5.4.3 below). If slit planting, the dirt is not removed and the hole is just large enough to plant the seedling to proper depth.

Hand digging is the best approach for rocky and steep sites and provides the most labor opportunities and benefits for the community, assuming work is contracted locally. With trained crews, it usually results in better selection of planting spots compared with excavator preparation.

2. Excavators: Small excavators can be used on less rocky and less steep sites. Unless the practices described in section 5.1.4 are strictly adhered to, planting holes prepared by an excavator would be too large for a seedling and require additional hand digging work to be ready for planting. Incorrect application of this equipment creates unnecessary project costs and environmental impacts.

   Augers: Augers can be either hand operated or mounted on a tractor or excavator. Hand operated augers are most commonly used. On flat land with deeper soils, a tractor mounted auger can be used. However tractor-mounted augers tend to be wider than the needed diameter for digging planting holes and are better suited for the planting of fruit tree seedlings. Augers should be carefully chosen before purchase. Less expensive augers that are widely available work well on good sites such as old agricultural terraces or private land with low gravel and rock content but often break down and bits wear out fast on rocky sites. Only experienced workers should handle and use augers both for efficiency and safety. Workers operating augers should wear chain-saw grade chaps, eye protection and heavy duty outdoor gloves.

Augers create deep round holes of small diameter that guide the roots vertically deeper into the ground. Hand augers could be used on all kinds of slopes where there is good soil depth, and they are considered a fast and efficient soil preparation technique. One auger operator can prepare holes for a team of workers to plant behind. Another advantage of using handheld augers is that, on sites that do not require initial scalping, one well-experienced person can choose all planting holes and control hole size thus increasing planting quality and survival. Augers however can be less effective in rocky sites. LRI tested augers in ten sites around the country and they only provedeffective on the sandy site of Qlaiaa, and some fine soil areas in Qlaiaa and Rachaya. In Aanjar, first year planting was done mostly with augers. Seedling mortality was high and partially attributed to shallow planting holes that were placed above solid bedrock. This example demonstrates the importance of auger operators being well trained in choosing planting spots or trained workers should mark adequate planting spots prior to digging. Another concern raised with augers used in clay soils is that they might compact the soil around them. Moving the auger bit back and forth gently while operating can minimize compaction.

Auger holes are best prepared when the soil is slightly moist and right before planting to ensure the soil is soft during planting. In addition to the main planting hole, adjacent shallow holes can be created as a source of additional soil during planting.

The auger bits come in different widths. If deep root seedlings are used and if the site is somewhat rocky, the bit size should not exceed 12cm diameter. Narrow bits are easier to dig because they encounter fewer rocks, minimize soil disturbance and preserve moisture around the seedling.

Planting Tools

Although planting tools do not affect seedling survival as much as the planting technique, choosing the right implement can increase efficiency and reduce costs and worker injuries. Conventionally, Lebanese planting workers use the pickaxe to dig deeper in the ground and the spade or shovel to empty the hole. The use of these two tools has been very effective in creating the desired sizes of planting holes, which is usually standardized at 5cm deeper than the root plug. However, using two separate tools reduces average worker productivity. Several new planting tools have recently been introduced to Lebanon and are being tested.

Hoedads

Hoedads, also known as planting hoes, are widely used in the US, especially in the Pacific Northwest, for planting conifer seedlings. Hoedad blades can be flat or concave, with different sizes and shapes. The blades are connected to the handles by special brackets that can be at a 90° angle for steep ground planting or at a 100° angle for flat areas. Hoedads are best used on deep soil sites with moderate to low clay content. If planting with a hoedad, no prior hole preparation is needed. The hoedad blade is forced into the ground and a slit is made for inserting the seedling. Soil is not removed from the hole which is an efficient operation for planting. Where trained and on good soils, workers can plant up to 100 seedlings per hour with hoedads. In Lebanon, hoedads have been tried on several sites and were only successful on deep moist soils. More testing should be done with this tool under different site conditions. The hoedad is a custom tool available in the US. Replacement parts and handles have to be purchased overseas.

Planting bars

A planting bar is composed of a cylindrical bar with a wedge-shaped blade welded on the tip, and side pedals to help force the blade into the soil. The bar is forced into the ground with the side pedals, and moved back and forth to create a planting hole in which the seedling is inserted. The bar is then removed and inserted next to the hole to close it. Bars are most efficient for small narrow root plugs. However, bars cannot be used in heavy clay soils because they risk compacting the soil around the planting hole (Landis et *al*. 2010). They cannot be used for scalping and therefore lack the utility of a hoedad or combination tool.

Planting cylinders

Planting cylinders have been also tested in Lebanon and are found to be most useful on sites with well prepared deep soils. Planting cylinders are, as the name implicates, cylinders inside which the seedling is inserted and that have a specific mechanism whereby after inserting the cylinder into the soil, a hand clutch allows the planter to open the bottom of the cylinder and release the seedling into the soil. It is a very quick process but can be problematic in clay soils and soils with high rock content. In addition, cylinder size and seedling root plug size should match for this method to be effective. When using different species grown in different containers, it becomes complicated to have all the right sizes of cylinders and use them appropriately.

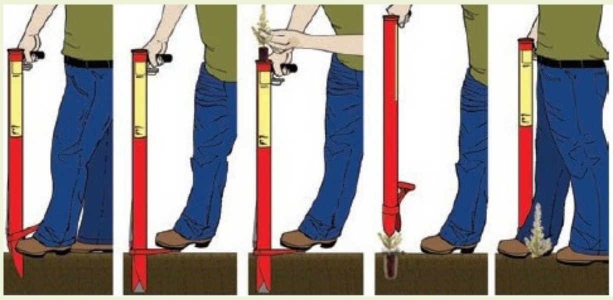

Figure 5-14. Planting with a cylinder

Combination Tool

The combination tool incorporates the pickaxe and hoe (commonly used for farming and tree planting) into one implement. It was developed to increase planting productivity using tools that workers are familiar with, that can be used beyond tree planting, and that can be produced inexpensively using readily available materials in Lebanon. Using the combination tool, a worker digs a hole just wide enough to reach the desired depth (approximately 5cm longer than the container). While digging the hole, rocks can be removed to improve root contact with the soil. This tool can also be used for scalping. A number of these tools have recently been constructed in Lebanon and are being tested on LRI planting sites.

Planting hole preparation and planting tools used or tested in Lebanon

Conventional planting tools-pickaxe and shovel.JPG

Combination tool

Handheld auger

Excavator

Planting cylinder

Hoedads

Planting bar

5.4.3. Seedling Planting

Best practices for planting seedlings involve the following steps and practices:

1- Once a planting hole is prepared, only one plant should be pulled gently from its bag or container to avoid root stripping and stem damage. Root plugs exposure to the air should be minimized. Planting workers should be instructed not to remove the seedling from the planting bag until after the planting hole is ready and a mound of clean soil is made to cover the roots. Removing more than one seedling from their bag, carrying them by their shoots around the planting site, and placing them on the ground next to the planting spot before hole is ready is a common mistake by inexperienced planting crews. Such practices can damage shoots and roots or result in seedlings being misplaced and lost.

IT IS CRITICAL TO HANDLE THE SEEDLING GENTLY AND TO MINIMIZE AS MUCH AS POSSIBLE ROOT EXPOSURE TO THE AIR.

2- At the time of planting, 2-5cm of fine soil should be returned to the bottom of the planting hole (based on planting hole depth),

3- The seedling should be placed vertically upright in the center of the hole. After planting, the seedling should be perpendicular to the horizontal plane. A common mistake is to plant seedlings perpendicular to the slope. This can result in seedling damage from run-off and wind causing contact with rocks and exposes seedlings to greater temperatures (Fig. 5-15).

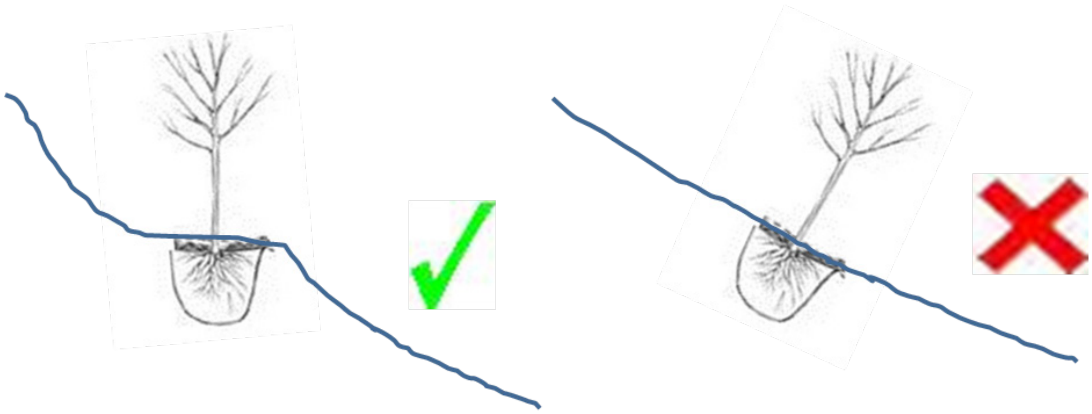

Figure 5-15. Planting seedlings on a slope

The hole must be deep enough to accommodate the plug easily. The root system should not be smashed into the hole. If the hole is not deep enough the seedling should be removed and the hole dug deeper. If proper depth cannot be reached, the hole should not be planted. Shallow holes are the main cause of J- and L-rooting (the bending for the root plug which reduces growth and can cause mortality) (Fig 5-16).

Figure 5-16. Example of a J-rooted seedling

4- After the seedling has been placed in the hole, the bottom one third of the hole should be filled around the seedling, hand-tamped gently around all sides then the process repeated in thirds until the hole is completely filled in and flush with the ground surface. Rocks or debris should not be placed back in the hole or around the planted seedling, to reduce air pockets. Instead, soils sourced from the adjacent hole dug specifically for this purpose should be used to replace rocks as needed. Upon refilling the hole, the top of the seedling plug should be buried beneath the surface 1-2 cm. On sites where settling is expected (loose soils), the seedling may be planted slightly deeper. Soil should never bury the seedling's lowest branches (See LRI Outplanting training documentary for an illustration of the whole process).

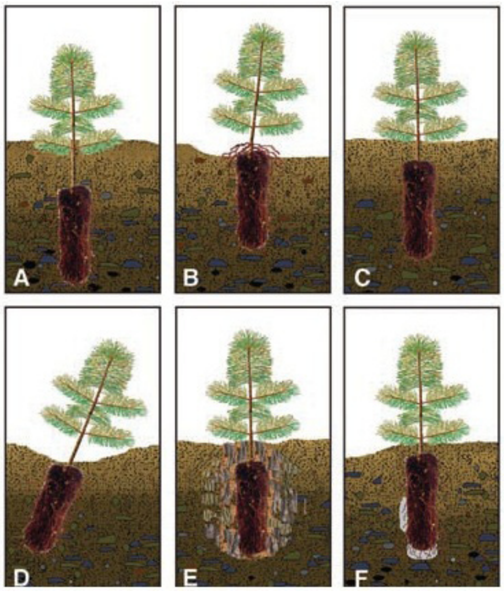

Figure 5-17.Common planting mistakes. A) seedling too deep; B) too shallow; C) well-planted seedlings; D) seedling not straight; E) debris aroudn roots; F) air pockets around roots. (Source: Landis et al. 2010)

5- When tree planting is completed, the surface around the seedling should be flat to slightly depressed compared to the surrounding ground level. Catchment around the seedling can be created if desired but must be engineered for placement of a mulch mat if those are being used.

6- The soil immediately around the seedling should be tamped lightly with a flat foot. This step will help remove any remaining air pockets and fix the seedling well in its place.

7- Finally, give a gentle tug on the seedling to assess if the seedling is well fixed in the ground. If the seedling is easily moved upward, it was not planted well and air pockets were still around the roots. The tree should be removed and hole dug deeper and seedling replanted or in the case it was not tamped, repeat step number 6. Do not attempt to just pile more soil or press the seedling deeper.

5.5. *Planting Inspection*

Use of planting inspections serves many valuable functions by providing:

A- An organized approach to controlling the quality of seedlings received from the nursery, stored locally and sent to the planted site. The planting inspector can sort the seedlings both upon arrival at the storage area and at delivery to the planting crew. He/she can recommend and ensure actions are quickly taken (irrigation, aeration or other storage related measures) to address issues.

B- A process to rapidly correct planting mistakes and provide continuous feedback to the planting crew to evaluate the quality of planting and their productivity while providing live on site training.

C- Quantifiable and up-to-date information for reporting to the managing organization to continuously evaluate the planting operation in terms of planting quality, crew planting productivity, quality of seedlings coming from the nursery, and the overall efficiency of operations.

D- A way to map planted areas and to calculate tree density.

E- Baseline records that can be used to help evaluate the planting over time including monitoring results and planting costs.

Following a well-organized and designed inspection protocol will considerably improve worker productivity and performance and result in higher planting quality and survival while reducing costs associated with failed outplanting efforts. Examples of the kinds of information that inspections provide include:

1- Percentage of seedlings planted well versus poorly.

2- Percentage of seedlings with various planting issues.

3- Seedling density and average spacing by daily planted area.

4- Total number of trees planted by species and location within the planting site.

5- Quantity and condition of seedlings from nursery including number of trees rejected due to poor quality.

6- Weather conditions associated with each planting day.

For more information on planting quality inspection protocols and procedures, please refer to the Lebanon Reforestation Initiative: Monitoring and Inspection Practices and Results- 2014.

5.6. *Moisture Conservation and Shading*

Moisture conservation in the soil around the seedling is a critical step to ensure tree survival and good growth. Grass and forbs such as thistle can quickly use all the water in the soil early in the growing season, leaving planted seedlings easily susceptible to moisture stress. Control of shrubs is not as critical unless cover is extensive. There are two main methods for moisture conservation: scalping and mulching. Whichever method or combination is used, following these practices will improve effectiveness of such treatments.

1- Vegetation control is most critical the first few years after planting as seedling roots are developing into the lower soil profile to access moisture later in the growing season.

2- Treatment should be applied for a minimum of 1 m^2 around the seedling.

3- Apply treatments early and consistently according to the prescription. Do not wait until grass and forbs are abundant around seedling.

4- Care should be taken not to damage the seedling during treatment.

5- Monitor the conditions of competing vegetation and be prepared to adapt treatments to changing or unexpected results (e.g., weeds might regrow after a spring or summer unexpected rain. Repeated treatment might be needed in such cases).

5.6.1. **Scalping**

Scalping is often needed again as part of periodic vegetation control after planting. The process is similar to the one described in section 5.1.4 above. However, unlike the initial site preparation scalping, workers need to be careful not to damage the seedling. Though a simple process, scalping takes skilled personnel to do it effectively. Good scalping removes weeds without removing valuable top soil. Certain weeds can re-sprout from the crown and root fragments. Consequently, it is very important to remove the entire plant. If weeds are well established in the ground, it becomes difficult to remove their roots without digging deep into the soil, which may damage seedling roots.

Scalp early before weeds are well-established and dig carefully around the seedling!

Drip irrigation lines will have to be moved to allow effective scalping. At least one post-planting scalping should be done in late spring when most weeds have sprouted or germinated but are not well established and the ground is still moist. Scalping frequency will vary for each site. Monitoring weed populations closely will help determine how often and when scalping should be performed. Most average moisture sites will need a minimum of two years of scalping. Treatments beyond this will likely continue to improve seedling growth and survival but may not be financially feasible.

5.6.2. Mulching

Applying mulching around the seedling conserves soil moisture by preventing weeds around the tree and providing a barrier to water loss. Several mulch mat materials exist locally and on the international market. However, not all mulching material used for agricultural purposes are suitable for reforestation. Mulching should allow rainfall and irrigation water to get to the seedling while preventing weeds from growing through the barrier.

To better understand the effectiveness and cost of different mulching materials in Lebanese reforestation sites conditions, LRI is currently testing different types of mulch mats, including: 1- the Vispore mulch mats (a product made in the USA), Agritella dark plastic mats (available locally), fabric mats (also available locally), and low-cost mulching material such as hay, cardboard and wood chips. The trials are set in randomized block designs using several species and in several reforestation sites across the country. Preliminary results for those trials should be available by the end of summer 2014.

The following are key details for successful use of mulch mats:

1- The mat should be a minimum of 1m^2 and the seedling should be positioned right in the middle.

2- The planting spot should be leveled and scalped and protruding rocks and other debris removed so the mat can be placed flat on the ground. If mulch mats are to be used, it is critical that the worker considers and prepares this area to the specifications of the mat. Some sites or portions of them will not be suitable for mulch mats due to rocky conditions.

3- Mulch mats should be well-secured on all sides with stones and staples. Failure to secure all sides will allow weeds to grow under the mat. Contact of the mat with the tree may damage or kill the seedling. A staple should also be placed over the slit in the material that allows the seedling through the mat to reduce weed growth.

4- On excessively steep slopes that have soils prone to sliding downward, the mats may be difficult to keep secured and should not be used.

5- Inspect and monitor the mulch mats to insure proper installation.

Mulching can be expensive and time consuming. However, when the right mulching material is used, it could reduce future costs of repetitive scalping and ensure higher survival and growth. Some mulching materials are also flammable and could increase fire damage in case of fire on site. In Rmadiye, a small fire occured on-site in the summer of 2013. Seedlings with mats were more damaged and burned than those without mats and all mulch mats within the fire area were burned and in some cases completely consumed.

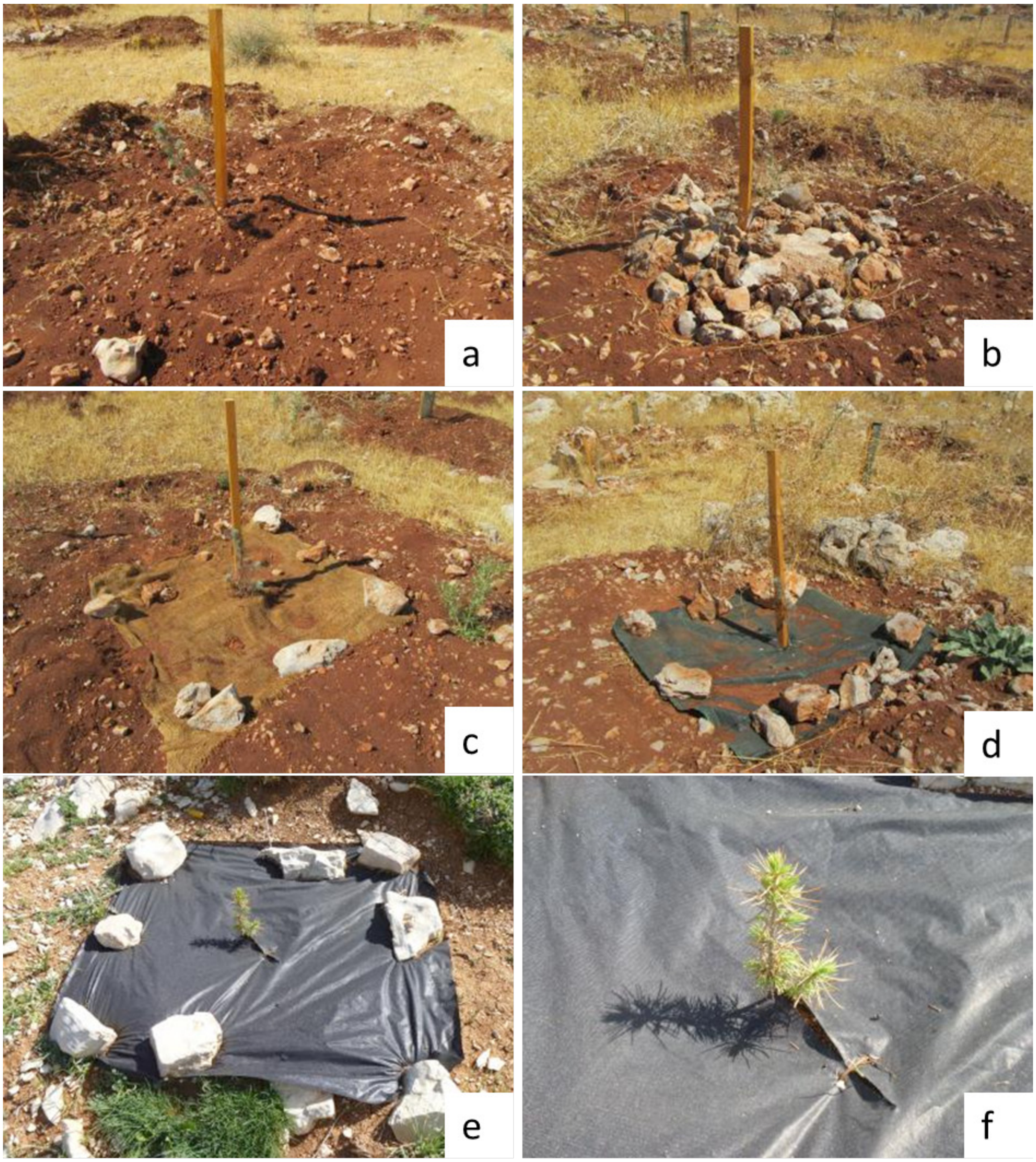

Figure 5-18. Different types of vegetation control. a) scalping; b) stone mulching; c) fabric mulching; d) Agritella dark plastic mulch mats; e) Vispore mulch mats; f) staple next to seedling to prevent weeds from growing through the slit.

5.6.3. **Shading**

Seedlings can be vulnerable to direct sunlight in the first few years after planting. In Lebanon, most potential reforestation lands are highly exposed, barren and with little shade. Seedlings on such sites, particularly on south facing slopes, can suffer from leaf sunburn and desiccation.

If large rocks or old stumps or small bushes are available on the site, planting spots should be chosen to take advantage of shade these materials provide. However, this decision should not trump the most important criteria of choosing a site with good soil depth. If mulch mats are to be used, placing trees too close to shading structures may interfere with securing this material.

In severe cases where reforestation success is questioned due to extreme conditions, use of shade cards might be considered. The eastern mountain slopes and dryer plains in the northern Bekaa (Hermel, Aarsal, etc.) are locations where shade cards might be most effective. Shade cards consist of any sturdy material that can last in the field through the dry season, such as cardboard or rigid shade cloth that is secured to a stick and placed adjacent to the seedling. Cards are placed so that they provide shade during the hottest time of the day (Fig 5-19). Shade should be directed at the base of the tree to prevent cambium damage where heat is most extreme. Shading is most critical during the first year of seedling growth. With age, seedlings develop the capacity to tolerate high sun exposure during dry summer months.

Figure 5-19. Shade card used in a pine reforestation project

5.7. *Irrigation practices and schedules*

Most seedlings currently planted in Lebanon are irrigated to improve survival. Two types of irrigation systems are commonly used in reforestation sites, the drip irrigation system whereby a dripper is set at the base of every seedling; and the hand irrigation system where mainlines are set and hand labor is required to water the seedlings using connected irrigation pipes (see details in section 5.1.3 above).

For small scale reforestation sites and for sites with sufficient access to all site sections and insufficient resources to set an irrigation system, more conventional irrigation approaches can be used, such as hand irrigation with buckets or with water trucks. Hand irrigation with buckets is only valid for small numbers of seedlings and is never recommended for large reforestation sites. Water trucks on the other hand have been used on larger reforestation sites when access allows trucks to move around the site. The disadvantages of such a method are numerous and include serious water losses, high labour and time requirements, high risk of workers missing seedlings, and serious delays in watering seedlings in different parts of the site. On LRI reforestation sites where water trucks had to be used, parts of the sites were only reached once during the summer.

In any of the cases above, a watering schedule should be agreed upon with the maintenance team to ensure seedlings are getting enough moisture. Unlike agricultural crops, reforestation projects cannot be watered based on a standard watering schedule. Irrigation dates are agreed upon after a good understanding of the site's water holding capacity and general environmental conditions and is then adapted regularly based on precipitation levels and ocurrences. Ideally, a small weather station should be set in each large reforestation site to monitor precipitation as well as soil moisture and temperature and thus guide the decision on irrigation timing. Based on LRI's experience in large reforestation sites, the first couple of irrigation times in spring and early summer are the most important. Delays in starting to irrigate might cause higher mortality than later delays of irrigation during the summer season.

In more arid areas where water is scarce and soil moisture is lost quickly due to high day temperatures and subsequent high evapotranspiration rates, such as areas in Northern Bekaa, more advanced watering techniques might be needed. The focus is mostly on getting the water to the seedling roots in the right amount while minimizing surface water losses. Some reforestation projects are currently testing the use of **solid water** to irrigate seedlings. While potentially effective in getting moisture to seedlings at the beginning of the dry season, it is still questionable how long they could last and whether the benefit from such methods justifies their cost.

LRI started also testing **deep pipe irrigation** in Lebanese conditions. Deep pipe irrigation is a rather new technique worldwide. In this approach, 1m high sections of PVC pipes are installed next to the seedling during planting, with the end of the pipe slightly above the end of the root plug. Pipes can be either punctured from the side and closed from the bottom or open from the bottom or both. Pipes would be filled with water at the start of the dry season and would lead the water directly to the soil layer around the roots. With less water amounts than those used for drip irrigation, seedlings should be able to survive and require less irrigation times per season than with other surface irrigation systems. Such method would require more labor to install the pipes during the planting season and fill them during the dry season. The efficacy and cost effectiveness of this method should be better understood by the end of summer 2014 when LRI collects all required data from field trials.

Moreover, as part of its efforts to reduce the overall cost of reforestation, and with the improved seedling quality achieved at the Cooperative of Native Tree Producers in Lebanon, LRI is currently testing ways to eliminate the need for irrigation by optimizing planting time and practices and moisture conservation techniques, hoping to realize its long-term goal to establish forests without irrigation.

Preliminary trials of no- irrigation conducted in several areas of Lebanon have shown that planting reforestation sites without irrigation can be achieved if one or more of the following conditions is available:

1. Soil with high water holding capacity such as in Qlaiaa
2. Deep soils located on northern slopes or in shaded valleys such as in Kfarzabad
3. Continuous air humidity and fog such as in Bcharre.

(Refer to the last Chapter of the Lebanon Reforestation Initiative: Outplanting Monitoring and Inspection Practices and Results)

5.8. *Monitoring Seedling Survival*

Monitoring seedling survival is essential to evaluate reforestation project successes and failures. This process allows managers to learn from their work, identify needed actions, and modify and improve practices. It also aids them in reporting. Monitoring data enables adaptive management, whereby changes can be made to practices in response to outplanting observations. For example, the survival rates and overall vigor of various species planted can help guide future planting decisions. This monitoring data has even more utility if done in conjunction with planting inspections: low survival in an area can be traced back though inspection records to a factor that caused poor seedling performance (e.g., dry conditions, poor planting quality, bad seedling handling and storage).

A monitoring protocol should be designed after defining what the key questions are to be answered by these efforts. Consider the purpose and type of reforestation project, personnel and resources including technical expertise available to conduct the work. For example, if the planting budget is limited and monitoring personnel relatively untrained, a simplified monitoring program should be implemented.

For more details on LRI monitoring protocols and results, please refer to the Lebanon Reforestation Initiative: Monitoring and Inspection Practices and Results-2014.

6. OTHER CONSIDERATIONS

6.1. *Worker Productivity*

Reforestation is a relatively new profession in Lebanon. Most projects so far have been conducted by volunteers and civil society organizations or by foreign labor hired by a Lebanese contractor. Well-trained planting crews are largely unavailable and worker productivity in general is still very low compared to the international averages. In the US, for example, one worker can plant 1,000 or more seedlings per day while the average worker productivity in Lebanon calculated on ten sites planted in fall 2012 was 51 seedlings per worker per day. These low rates are a function of shorter work days, more difficult planting conditions, more intensive planting techniques and lack of good planting tools in Lebanon. Big improvements in worker productivity are possible and will result in lower planting costs and larger reforested land area. A minimum of 200 seedlings per worker per day is an achievable goal on most sites. A strategy to improve worker productivity can include the following actions:

1- Develop worker experience level and use the same planting crew each year. With only one year of experience, average worker productivity in Rachaya increased from 25 to 36 and in Aanjar from 15 to 24 seedlings/worker/day.

2- Provide training and implement planting inspections. There is no better way to improve the skill level of a tree planter than by having inspectors provide continuous feedback and training.

3- Provide incentives to plant faster coupled with standards on planting quality. Average worker productivity should be agreed upon with the planting crew during the planning and budgeting phases.

4- Provide workers with quality planting tools (e.g., LRI combination planting tool) and training them in their optimized use, care and maintenance.

5- Integrate new workers with a peer program where they work directly with an experienced crew member.

6- Develop a planter certification program. Certified workers would be required to conduct training sessions and demonstrate outplanting skills.

6.2. *Worker Safety*

Tree planting is hard work that presents several hazards. Risks related to reforestation work include:

- Falling over moving rocks, down steep slopes, etc.
- Wild animal bites and stings: snakes, scorpions, etc.
- Back injury due to continuous bending, swinging and lifting
- Injury from auger blade for auger users and from tool edges for hand digging and planting crews
- Landmines, unexploded bombs or hunting
- General incidental hazards such as car accidents during transportation, accidental fire, etc.

Ensuring worker safety to the maximum possible is crucial. Safety measures start with workers attire: all workers should be advised to wear hiking boots, hard or sturdy hats, rain jackets in bad weather and safety glasses. Workers can be advised to do stretching exercises daily before and after work to limit back injuries. Workers should be aware of potential animal and other risks present on the site and should be given instructions on how to avoid them or deal with them when they happen. At least one car should always be available on site during planting time to transport any injured workers. A first aid kit should be kept with the crew supervisor for emergencies. Auger users should at all timeswear protective gear, including chaps, goggles and gloves. Tool users should be careful when swinging tools for passing traffic behind. Workers should be trained on using tools safely.

Areas with potential landmines or unexploded ordnance should be avoided at all costs. In case the crew encounters unexploded ordnance or other explosives on site, they should be instructed to call the supervisor, who should call the local authorities and the Lebanese Army to deal with the situation. Work should be suspended until all explosives are removed from the site and trained professionals complete a land survey and clear the area for resumed work.

If workers detect sounds of hunting close to the site, work should be suspended and the workers' supervisor should notify the local authorities to stop hunters from approaching the site until planting is completed.

Identifying the closest Red Cross center, hospital and clinic are necessary during the planning phase of the project. Acquiring phone numbers of medical centers, local civil defense and local Red Cross is also essential. Safety training should be given to all workers at the beginning of the project. A refresher should be given to new workers on site upon their arrival.

In towns where LRI has conducted fire prevention trainings, a volunteer squad is formed and tools were provided to them to deal with fires if they occur. The squad chair phone number should also be provided to the planting crew supervisor in case a fire starts on-site. Smoking is best prohibited on the planting site. An area close to the site with no weeds (old structure, road, etc) can be designated for smokers if needed.

6.3. *Cost of Reforestation Activities*

In Lebanon, the cost of reforestation is very high compared to other countries. The difference stems from all stages of reforestation, starting from higher costs of seedling production and subsequent higher purchase price, to lower worker productivity, and a greater need for expensive fencing and irrigation. On average across Lebanon, reforestation costs are estimated at $10 per seedling. The range actually reaches as high as $15 per seedling for sites with fencing and drip irrigation systems.

Across LRI sites, the cost of reforestation over two years including replacing dead seedlings and maintenance, was found to be between $5.5 in several sites to $12.4 in one site and an exceptionally high cost site for $17, all calculated per surviving seedling at the end of year two.

Further reduction of the cost of reforestation could be achieved through a combination of the following:

1. Improving quality of tree seedlings and outplanting practices to significantly increase seedling survivability and thus reduce the cost of replacing dead seedlings.
2. Seedling cost reduction, through the collaboration of nursery owners, members of the Cooperative of Native Tree Producers in Lebanon to increase capacity, decrease production costs through buying supplies in bulk quantities and reduce purchase prices based on quantities pre-ordered.
3. Improving worker productivity through continuous training and practice, refining planting practices to limit the need for large soil preparation and improvement of planting tools used.
4. Reducing the need for fencing through better engagement of local communities and improvement of local grazing regulation.
5. Reducing the need for irrigation by planting high quality seedlings, choosing the right planting spots, planting at the start of the rainy season, and choosing the appropriate planting and weed management techniques. This might not be applicable in all sites but has a very high potential of success in a good proportion of the potential reforestation sites in Lebanon.
6. Improving planning and record keeping for all reforestation projects which helps avoid unnecessary extra costs incurred and improve success by learning from previous experiences.

6.4. *Record Keeping and Lessons Learned*

A missing piece in the majority of reforestation projects in Lebanon so far is good record keeping. Inspection and monitoring forms should be developed during the project planning phase to include all information necessary to be kept. Records are helpful to understand reasons for specific outcomes such as complete or partial mortality, high survival versus high mortality, etc. For detailed examples and sample forms, please refer to the Lebanon Reforestation Initiative: Monitoring and Inspection Practices and Results-2014.

At the end of each reforestation activity, a thorough evaluation should be made and lessons learned should be recorded to be used as base knowledge for a future project planning phase. Reforestation is a highly dynamic field and learning from previous mistakes is crucial to reduce long term losses and improve seedling survival.

6.5. *Training Personnel*

In every reforestation project, success is proportional to worker performance. Training of planting crews, machine operators, inspectors, workers digging planting holes, and all personnel working on the project on best practices is very important and can positively impact the outcome. Moreover, planting crews tend to experience high turnover rates, especially when using local labor or volunteers. Continuous on-site training should be ensured to avoid failures. On-site training can be done either by the inspector, the supervisor or by more experienced workers. Training methodologies can vary according to the team or crew, to the preference of the reforestation project manager and to resources available. No matter what the methodology is, daily training should be part of the site planned activities. Reforestation managers can opt to minimize daily training resources if the choice of the planting spots and hole digging are done by experienced people and worker or volunteer teams are distributed such that experienced workers are available in every team to support the less experienced team members.

6.6. *Choice of Species in a Changing Climate*

Climate Change is becoming more and more a reality that is affecting all human activities and natural systems and that cannot be avoided or disregarded in any field. Climate change is tightly linked to Reforestation in a two-way relationship. While reforestation is considered one of the most important measures to mitigate expected effects, climate change threatens to affect the long-term success of reforestation if not well considered in the planning process. The choice of species to be planted in any specific site should be made through an informed decision making process that considers potential species displacement in the future due to climate change. Although no definitive data is available on this subject as most climate change studies depend on modeling and extrapolations, recent studies done on Lebanese native tree species show clear patterns in terms of displacement, losses or gains of some of the those species. Such studies should be consulted prior to deciding on species choice for a given reforestation sites. A recent species –specific study for multiple native tree species in Lebanon was developed by LRI in collaboration with the Spanish Center for Applied Research in Agroforestry Development (IDAF) and can be found on www.lri-lb.org.

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ANNEX 1. SAMPLE FIELD ASSESSMENT FORM

Contact Person	Position	Tel #	
……………………….	……………………….	……………………….	Completion of Data Entry
……………………….	……………………….	……………………….	---/--- /2012

Site Description		
Plot ID:		
Mouhafaza:	Caza:	Municipality:
Mayor:		
Site Physical Characteristics		

X:	Y:
Coordinates ref pt:	Coordinates system:
Altitude:	Soil depth:
Slope:	Rainfall:
Soil Type:	Total Area:

Site history
Presence of mines / UXO: ☐ YES ☐ NO Date demined: ………………………………………………
Previous fire history : ☐ YES ☐ NO Dates of fires: ………………………………………………
Previous quarries: ☐ YES ☐ NO type and date of activity: ………………………………………………
Previous/current land use if any: …………………………………………………………………………… ………
Socio-economic aspects/grazing
What is the main income activity? …………………………………………………………………………… ……… Number of shepherds/herds: …………………………………………………………………………… Type of animals (Goats, sheep, cows): …………………………………………………………………… Charcoal Production: …………………………………………………………………………………… Previous reforestation projects with dates and organizations involved: ……… ………

Water Resources and Infrastructures				
Location of closest water source?				
Type of existing water source and infrastructure, if any?				
....				
Needed water infrastructure:	☐ Ponds	☐ Reservoirs	☐ Outlets	☐ Other
Suggested number and location:	....	....	....	....

FOREST

Access to the site		
☐ Main Roads	☐ Side Roads	☐ Trails
☐ Agricultural Roads	☐ No Roads	

Neighbouring Land use		
☐ Industrial	☐ Urban	☐ Agricultural
....	....	....
....	....	....

Vegetation Types	
☐ **Type**	☐ High ☐ Medium ☐ Low
☐ Pine	☐ High ☐ Medium ☐ Low
☐ Oak	☐ High ☐ Medium ☐ Low
☐ Cedar	☐ High ☐ Medium ☐ Low
☐ Fir	☐ High ☐ Medium ☐ Low
☐	☐ High ☐ Medium ☐ Low
☐ Mixed	☐ High ☐ Medium ☐ Low
Shrubs and annuals	High Medium Low
Others (Specify)	

Local Forest Management Plan
Exist: ☐ YES ☐ NO Implemented by: Description of activities: ……………………………………………………………………………………... ……………………………………………………………………………………... ……………………………………………………………………………………...
Fire Management
Area Fire Risk: ☐ Very High ☐ High ☐ Moderate ☐ Low
Fire Breaks: Establishment of fire breaks: ☐ Possible ☐ Impossible Location of possible area to be used as fire breaks: .... Existing land features that can be used as fire breaks: ☐ Agricultural land ☐ Roads ☐ Other (specify) ....

Land Tenure conflicts: ☐ YES ☐ NO Domestic waste disposal in or near forested area: ☐ YES ☐ NO

Comments and observations