Forestry Technology #3

Site Analysis and Outplanting

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More than ever, reforestation and afforestation projects worldwide are expanding at a tremendous rate. FAO surveys indicate an increase in planted area from 18 million ha. in 1980 to 44 million ha. in 1990. Much planting takes place in areas that exhibit a broad range of site qualities. However, many sites are have been degraded by inappropriate agriculture, exploitation and, particularly, excessive grazing. Forests are rarely planted on top-quality sites as these are typically reserved for agriculture. As a result, forested sites range from serviceable to severely degraded. They may be characterized by poor drainage, thin soils, steep slopes, salinity, or previous heavy use.

Usually, there is little that can be done to alter or improve a given project site; but nonetheless, the forester can be aware of potential problems -- and opportunities. The forester must learn to differentiate sites that can be worked with from those that are marginal and others that must be avoided entirely. By recognizing a site's limitations, the forester can better direct his limited resources toward optimal site preparation to ensure both desired production and long-term plant survival.

This bulletin, the third in the forestry series, addresses the specific needs of the field forester. It provides some basic measures to guide the forester in analyzing and preparing a site for outplanting. In addition, it outlines the requisite steps for developing a successful outplanting operation.

(Bulletins Nos. 1 and 2 describe how to collect good seed and methods for growing quality nursery stock).

Site Analysis

The forester must understand the site's capabilities and limitations both to ensure proper establishment and because of the long-term investment in tree growth. He can gain this understanding through an analysis of the site's properties. The analysis is best completed prior to collection of the nursery tree seeds in order to confirm the selection of species. In addition, the analysis must be as thorough as possible. Otherwise, decisions based on incomplete information or guesswork will greatly increase the chances of error. A thorough analysis examines four main site properties: soils; site biology; climate; and physical characteristics.

Soil is a key element

Soil is the main indicator of a site's tree growth potential. The soil's physical properties determine the flow and retention of ground moisture and either enhance or hinder proper root development.

The forester should examine the primary soil properties including texture, depth, organic matter content, and pH. He can chart these properties on a soil map of the area as each is explored. Texture is determined by varying combinations of sand, silt and clay and influences the rate at which water and oxygen move through the ground. Optimum texture is essential for root growth enabling trees to take up nutrients and water. A high clay content in the soil inhibits moisture retention and proper root development. Such soils are subject to sealing and surface crusting when exposed to raindrop impacts. Light, sandy soils tend to lose moisture quickly, yet permit rapid root development. Sandy clay loams provide the superior medium for moisture and root growth, but are only found on the best sites.

Texture and depth together determine how much ground moisture can be stored for tree survival through the dry seasons and growth during the wet seasons. Depth alone also affects a tree's ability to anchor itself and influences the total amount of available nutrients. Furthermore, areas with shallow soils should be carefully noted as root development will be hindered on these sites. Simple test holes can be dug with an auger to discover any heavy clay layers or compacted layers or "pans" near the surface. Such layers will restrict rooting and infiltration of rainwater. Soil profiles can also be viewed at nearby road cuts or from ant mounds because ants bring up the subsoil. Other soil properties that are important, but more difficult to measure, include organic matter content and soil pH.

Determining soil texture by hand

A simple test can be used to identify soils in the field. Take a small, damp soil sample and rub it gently between the thumb and forefinger. The feel of the soil will indicate its texture and type.

Individual sand grains can be felt and seen in sandy clay loams. When squeezed the sample will form a fragile cast that breaks easily. *These are the preferred soils.* A loam soil will feel somewhat gritty, yet fairly smooth. It will form a more durable cast when the sample is squeezed. Clay soils are entirely smooth and can be squeezed into long, flexible ribbons that will not readily break. These soils must be avoided as they will inhibit proper root development.

Possibly one of the easier methods of soil texture analysis is to take a sample and place it in a cylindrical glass container (a measuring cylinder is ideal but tall jam jar or wide mouth bottle can be used) and fill the container with water. Vigorously shake the container and place it to stand upright on a horizontal surface. Heavy material such as gravel will sink to the bottom, next sand, then clay and finally silt. Organic matter will probably float on the surface of the water. The layers can be measured and expressed as percentages.

Acting as a sponge, organic matter promotes better moisture retention and reduces surface evaporation. Because of this, the top organic layer is an important zone for initial growth of small outplanted trees. Unfortunately, in many sites, the topsoil which contains most of the organic matter is lost and residual organic matter is low. Testing for the presence of organic matter is simple; estimating the organic matter volume is more complex, requiring a laboratory analysis. To test for the presence of organic matter, put a few drops of hydrogen peroxide on a small amount of soil in a narrow container. Organic matter is present if the hydrogen peroxide bubbles and foams. In addition, the strength of the reaction relates to the amount of organic matter present.

Soil pH is a measure of the soil's acidity. Although it is not always necessary to test pH, the forester must be aware of certain species' sensitivity to the pH level. For example, many leguminous trees are pH sensitive. Some simple methods such as litmus paper are available for measuring pH in the field. However, these results should be checked against a laboratory analysis to ensure accuracy. With the above soil information, the forester can rank the suitability of sites for planting. Ideal sites will:

- have a sandy loam textured soil that is deeper than 50 cm;
- have an organic matter content;
- be neutral or slightly acidic;
- not form surface seals or crusts;
- not have restrictive layers in the top 50 cm.

Conversely, some sites will have soils that are unsuitable for tree planting. These areas must be avoided as efforts will be better spent on sites with greater potential.

Vegetation, typography provide clues

Typography and vegetation also indicate site quality.

In terms of typography, extreme slopes and shallow depressions may present undesirable moisture conditions. Typically, as slope increases the soil becomes thinner and poorer, which is an inadequate planting medium. Shallow depressions may have standing water most of the year. As for vegetation, indicator plant species provide clues to soil type, pH, and past use. For example, *Tristania spp*. and *Ericaceae* are indicators of acidic soil conditions.

In other instances, some vegetation will grow only on sites that have been heavily degraded by intensive agriculture. Imperata grass is a case in point. This fire climax species thrives on nutrient-deficient soils and renders vast areas of land unproductive. Furthermore, barren sites must be examined to explain the absence of plant growth. Such an absence may be due to harvesting, overgrazing leading to soil compaction, or lack of seed. Or, the soil may be totally devoid of organic matter, which means the essential soil flora and fauna have been lost.

In any case, the factors that have hindered establishment of natural vegetation must be corrected prior to tree planting and establishment. Also, an inventory of current vegetation must be completed as native and non-native vegetation can pose a threat to tree establishment.

Site structure and use

The area's available space and current use are an integral part of the analysis. Available space is defined by designated boundaries, soil limitations, and typography. Drainage patterns, too, are a critical component of this analysis. Activities on adjoining lands should also be noted. In addition, if the proposed area is already in use under agriculture or rangeland, the question must be raised, "Will the forestry project improve, disrupt or displace the existing activity?"

In consulting with local users, the foresters must plan to either sustain the existing goods and services (fuel, fodder, food, medicine, etc.) or provide for acceptable substitutes (e.g., tree fodder for grass; cash income for food, and so forth). Also note, future earnings from plantation products are only attractive to those farmers and villagers whose immediate needs are met. Even industrial plantations may need to provide other products and services. For example, in China local people will collect all fallen leaves, needles and branches, leaving the site bare and disturbing the nutrient cycle unless their fuel needs are otherwise met.

Small projects have potential

Aside from the main project, the forester should consider opportunities to use small sites, such as those around the home, school areas, along farm borders, riverbanks, along streets or roadsides. Such sites can be planted easily and quickly. And such plantings often fit very well with the farming system.

Small-site projects might include small orchards, streamside gully buffers, intermittent field trees, wind and water erosion breaks around farmlands, or shade trees. The "four-a-side" tree planting in China provides an excellent example of success in this field.

Planting Dates, Timing

As in agriculture, weather is either the handmaiden of success or messenger of failure. Favorable weather conditions during planting season are often extremely short, which demands adequate planning and an uninterrupted work schedule.

Timing and duration of the planting period is critical to the project's success. Growth and preparation of nursery stock must be completed when favorable planting conditions near their peak. If seedlings are not ready on time, the duration of this favorable period is shortened, which jeopardizes the seedlings' proper establishment or survival. Conversely, delays in field preparation can have an adverse affect as a seedling's vitality is significantly reduced when kept too long in the nursery.

Soil moisture is a key

One key indicator used to determine the optimum planting period is available soil moisture. Good planters monitor soil moisture and only plant when it reaches an adequate level. In areas where soils are severely compacted, planting during the season's first rainfall may not be the best choice as these sites may have to absorb the first several rains before enough soil moisture is available. In fact, early rain on compacted sites is often lost due to surface run-off. This loss can be overcome with suitable site preparation such as plowing along contours, deep ripping, hole digging, etc., to reduce the speed of run-off and increase water percolation into the soil. Planting dates may also be influenced by several other factors, such as soil condition or species requirements. In another instance, the selected species might be better planted in a dry season planting with limited irrigation. For some areas, a dual rainy season permits an initial planting, with a follow-up planting during the second rainy season. The second season can also be used as an in-fill for areas where the primary planting failed to establish.

Determining these seasons can be done through consulting existing records or knowledge of the local people. Although dates will not be exactly the same from season to season, enough of a range can be determined to prepare a planting schedule of readiness. The dependability of rain can be estimated if records over a number of consecutive years are available. The information should be grouped into five-day periods and the mean and standard deviation calculated for each period over the years of records. Calculation of the variation (standard deviation divided by mean expressed as a percentage) will indicate the most reliable periods to target for planting (the higher the percentage the more the variation).

In preparing a planting schedule, the forester can devise a simple chart outlining the requisite tasks and projected completion dates. Aside from the physical requirements of the seedling stock, the forester must also account for the supportive materials and resources. For instance, the start of the rainy season is typically the more active time for field laborers. In this case, the manager or forester must be aware of local labor priorities and schedule accordingly.

Migration times and patterns of domestic herds must also be taken into account as animal hooves, and appetites, will quickly destroy a newly planted site.

Planting Site Preparation

All preparation at the planting site must be completed prior to the first rains or the prescribed planting dates. If preparation is delayed, the chances for seedling survival rapidly decrease.

Survival depends a great deal on gaining the maximum from optimum weather conditions, which may occur for only a short period. The forester must also project beyond his immediate tasks and be prepared for emergencies, mishaps, and unexpected delays. It is best to have a back-up system for the mandatory functions, such as transportation and labor, or for delays due to weather.

In addition, project success is further assured when the project scale is kept within the limits of available resources and materials. Small, lasting successes are preferable to large-scale operations that may be ill-equipped to handle high tree volumes that cover extensive areas.

Arrangements made on site

Landowners need to be aware far in advance of the desired planting schedule and required tools and materials that must be ready. At the site, boundaries must be clearly marked with posts or other types of suitable markers at frequent intervals. Fencing or animal barriers, completed beforehand, may be essential and can also serve as a border. Planting lines should also be established and marked. Typical plantations are designed in a straight-line grid. However, varying uses may require an alternate pattern, such as contour line spacing for terracing or land reclamation and staggered alternate line planting (on triangle).

Clearing planting spots for each tree to a 50 cm radius will save time and will mark individual tree planting spots. Clearing protects the tree from subsequent field burning and reduces competition from neighboring plants. Removal of undesirable plants also eliminates cover for potentially harmful pests, such as insects and small animals.

The unwanted vegetation can be slashed, chopped or burned. However, recent research suggests that it would be better to chip or at least scatter the vegetative debris on site because burning will cause an immediate loss of some nutrients and subsequent loss of others after the rains begin.

The planting holes themselves should not be pre-dug as this will dry out the mircrosite or, in the case of heavy rains, the holes may fill with water. Neither condition provides a suitable site for newly planted roots. In some countries the tradition is to dig fairly large holes as a means of site preparation then refill them, sometimes adding farm yard manure or topsoil from valley bottoms. These should be refilled and well consolidated before the day of planting.

Requirements for planting crews include transportation to the site, adequate shade for both workers and plants, ready access to clean drinking water, and proper tools. Tools include planting shovels or dibble bars and mattocks for clearing grass.

Access roads to the site must be well marked and deemed passable and in good repair. Designated alternate routes will provide an option should the primary route become impassable, a particular concern in rainy season weather.

Holding areas to receive the seedlings must be located and identified. Though temporary, these areas must still adequately shade the seedlings and protect them from roaming animals and desiccating winds.

One to two weeks prior to outplanting, a last site survey will help spot any problems or changes since the site was last inventoried. Final preparations can then be adjusted to accommodate any new conditions.

A final check of planting maps and records will ensure that the correct tree species will be delivered to the designated site.

Soil Corrective Measures

Rarely will the chosen site have the desired or adequate soil conditions necessary for a plantation program to reach its optimum production and survival. Soils often lack in nutrient content, ability to hold moisture, are too compacted, or ar*e subject to rapid desiccation.* In many cases, simple corrective measures will *help counter such shortcomings.*Several means can improve water holding capacity including use of windbreaks to slow evaporation and shading to reduce soil surface temperatures. The addition of surface organic matter, such as animal manure or leaf litter will further stem soil moisture loss.

Subsoiling, a deep breakup of the soil, at the planting spot is a highly effective practice that will encourage water infiltration and improve root development. Loosening the upper crust is also helpful. Note, however, that crust formation is caused by slaking and will re-occur unless the soil surface is kept moist, is protected, or *is amended with lime or gypsum.* Addition of compost is beneficial on many sites, particularly in the tropics and subtropics. However, in these countries compost is either difficult to obtain or is expensive d*ue to its use in agriculture.* In these cases, the compost must first be developed, maintained, and then transported to the planting site in large volumes. An abundant source of organic matter must also be close at hand for developing the compost mixture. The

Berkeley method of *composting is highly recommended*. Cover crops, too, will act to stabilize the site, adding nutrients, organic matter and enhancing the water storage capacity of the soil. Depending on the selection, the crop may provide a cash income or short-term food source for humans or animals.

Nursery Preparation, Transporting

As preparations in the field are being made, equal emphasis must be given to the preparation of nursery stock. The nursery manager's goal is to have an adequate supply of seedlings ready to be outplanted when favorable conditions occur. (See Forests and Forestry Bulletin No. 2, Essentials of Good Planting Stock, for ideal nursery operations.)

Outplanting is a time of critical care for nursery stock because it is exposed to various conditions, transport and handling. Each step of the process, if not monitored carefully, can potentially damage the seedlings or allow desiccation of the plants. For both bareroot and container stock, adequate root-to-crown ratios must be maintained. Inattention to this detail will invite problems such as stems that are too large for their root structure, or the development of large root masses that will be subject to damage during outplanting. The root-to-crown ratio can be periodically monitored by exposing the roots of sample seedlings throughout the nursery. Proper ratios will vary by species. For containerized plants it is critical that a fibrous root system develops firmly, binding the potting mixture into a plug.

However, bareroot stock requires extra precautions. Root pruning is needed during development and growth, and so nursery operations must include undercutting. Roots that grow too deeply will be severely damaged during lifting. Although growing bareroot stock is an option, it is advisable to consider using root trainers, a system that uses rigid or semi-rigid containers with internal vertical ribs. The ribs direct root growth downward, which prevents spiraling, and the containers permit air-pruning of the roots, which controls root length. In effect, root trainers provide superior root systems that are ideally suited to the rigors of outplanting and stand establishment. This relatively new technology has proven highly effective wherever it has been applied.

Hardening off mimics field conditions

Hardening off is a measured reduction in watering just before outplanting takes place. Typically done over a four- to six-week period, the process readies the seedlings for the lower moisture conditions that can be expected in the field.

Watering can be limited to once daily, followed by watering every second day in the final weeks. However, care must be taken not to proceed too quickly as this might induce wilting or plant stress. If wilting occurs, water the plants immediately.

Just before removal and outplanting, the seedlings should undergo a final culling. Remove individual trees that are misshapen, poorly formed, diseased, too small, or of poor vigor. Also take out trees that are oversized. Culling must be taken seriously and based on measurements of seedling variation. The objective is to send to the field seedlings that are all of the same size and quality.

Again, care must be taken with bareroot stock. Use a shovel or other tool to ease the undesired tree from the ground. Pulling the tree out may damage the roots of neighboring seedlings.

Conversely, root trainers separate individual seedlings and separation is easy once the root plug has properly formed. This simplifies culling with little or no damage. If the planting site has adequate water supplies, the forester might consider lifting the plants out early and placing them in a temporary mini-nursery. The early move saves time and is helpful in areas where seasonal rains make roads impassable. Of course, the mini-nurseries have to be managed with great care.

In moving bareroot stock, the seedlings must be dug carefully to avoid unnecessary root damage. Once lifted, the seedlings are bundled in groups with the roots packed and wrapped in a water-saturated compost. In temperate countries, these bundles are often stored at low temperatures over winter prior to spring planting. Moving root trainer stock is much simpler. An adequate means of transportation is needed to keep the containers level and neatly stacked. Also, containers must be handled carefully to prevent crushing or damage to the seedlings.

How To Plant, Microsite Selection

Although the work must be done quickly during tree planting there is no reason for slackened quality. Subquality work at this point will negate all previous efforts, resulting in high plant mortality. Through whatever means possible, the forester must ensure that workers follow proper planting techniques and handling.

Proper spacing gives adequate coverage

Tree spacing, or trees per hectare, depends on the severity of the site, mature tree size, projected survival rate, available soil moisture, desired result, cover crops, intercropping, and so forth. For example, a plantation established on severe, dry sites calls for wide spacings, whereas windbreaks or live fencing demand a tight spacing.

Experiments over many years in the tropics and subtropics indicate that trees need between four square meters and nine square meters of space at the time of planting depending on their growth rate (faster means wider).

Early crown closure reduces weeding costs but care must be taken not to plant trees too closely as this leads to competition among trees for nutrients and water. This is particularly important with eucalyptus. Conversely, spacing trees too far apart may leave gaps in the crown. In addition, spacing requirements must be determined well in advance to ensure that an ample supply of seedlings is planned for.

During planting, workers will space the trees accordingly by following the pre-marked planting spots. To prevent error along the planting line, a pole of the proper length can be used as a measure between plants.

Microsite selection, clearing, moisture concerns

Workers must be able to judge the exact planting spot, or microsite, within the designated spacing. For example, a suitable distance should be kept from pathways to prevent damage by foot traffic. Also, extremely rocky spots, minor ground depressions, and shallow soils must be rejected. This may lead to plantation gaps, but cannot be avoided.

As noted previously, competing vegetation should be cleared away from each seedling for a distance of 50 cm. Other competing vegetation can be cut low to the ground and piled on the contour. This practice promotes improved soil and moisture conservation versus total site clearance, which causes increased runoff and erosion.

Rainwater catchment basins may be necessary in particularly dry areas to ensure seedling survival during the first years of establishment. These basins, built around each tree, divert the surface rainflow from a large area to irrigate the tree. But note, these may only be used in areas that have well-drained soils.

Soil between the tree rows should be cultivated to encourage water infiltration. Also, cultivation with dust mulching around individual seedlings will help lower surface evaporation.

The planting hole must be dug deep enough to allow straight root placement. Curling or bunching the roots is unacceptable; this practice will destroy the tree. Seedlings must also be planted to the root collar and the roots must not be exposed nor should they be planted too deeply. Backfilling the hole and tamping the soil against the lower roots will remove any air pockets. Water should not be applied before the tree is planted as this will also create air pockets around the roots. If the holes are too large, roots take too long to anchor in undisturbed soil, resulting in deformation of the butt-log.

When using bareroot stock, handle only a few seedlings at a time keeping exposure to sun and wind to a minimum. Seedlings not used immediately must be kept moist and under cover. When using poly-bag plants the bags should not be squeezed too tightly and should be cut cleanly from the entire root plug before planting.

Also, as they plant, workers will have a final chance to cull any seedlings that exhibit disease, poor form, or other signs of substandard quality.

A Case Study: Crops Keep Soil Problems Under Cover

Research is showing hopeful signs that legume cover crops can infuse renewed vigor into Thailand's weary forest soils. Long subjected to intensive use, the region's soils are exhibiting dramatic declines in crop yields and productivity. "Like most tropical soils, our Thai soils suffer severe degradation as a plant growing medium after cutting of the natural forest," said Tom Brummer, managing director of Thai Stora Agroforestry Co., Ltd. in Bangkok.

Problems are readily apparent. The soils become compacted and reduce water infiltration by as much as 60 percent. Organic matter and mineral content declines and erodibility increases. The overall effect has resulted in crop yield reductions of up to 40 percent over several years, with further reductions projected. Alarmed at the rate of soil degradation, Brummer's company took action. "It was decided that the best soil improvement and protection method may be by planting a legume soil 'cover crop' under the trees," Brummer said.

To be successful, however, the crop would have to satisfy several criteria. Brummer's team devised the following:

- No climbing and strangling of plantation trees;
- No negative competition for the trees;
- No barrier to foot access;
- No fire danger during the dry season;
- Be able to suppress weed growth;
- Be able to tolerate some shading;
- Grow fast to occupy the site;
- Be able to survive the dry season and regenerate afterward.

In searching for candidate species, the team procured legume seed both commercially and from naturally occurring sources within their own plantation. The goal was to discover those species best suited as a cover crop, rather than testing for dry matter production or soil nitrogen enrichment.

In all, nine species were tested. The first year's efforts were limited to small plots under two-year-old plantation stock. Building on these preliminary results, the team selected four crop species and planted these in larger "operation sized" areas across a wide range of tree age classes. Species not chosen were deemed too large or not vigorous enough in growth.

First-year results of the second elimination trial showed good survival during the dry season. Drawbacks of species not selected in the second trial included inability to resist weed invasion, slow initial growth, lack of commercially available seed, and attractiveness of the plant to grazing animals. The chosen likely candidate species, Centrosema pubescens, closely matched the given criteria, with the added advantage of readily available seed. From the tests, Brummer's team further concluded that although one species proved preferable, a species mix would be more effective in the long run. For future studies, the team hopes to expand its tests to include more potential species.

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