# Biodiversity and Ecosystem Management: The Role of Forest and Conservation Nurseries[1]

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Abstract.--Nurseries offer unique opportunities for ecosystem management because they offer the opportunity to not only preserve, but actually increase biodiversity levels. In addition to the traditional commercial timber species, nurseries are propagating a wide variety of diverse plants - from sedges and grasses to woody shrubs and riparian trees. Natural resource specialists are using nursery stock for innovative planting projects: gene conservation, resource protection, ecosystem restoration, wildlife habitat enhancement, rehabilitation of recreation sites, and forest health.



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# 1.0 INTRODUCTION

## 1.1 Basic concepts

In the last few years, natural resource management has been going through some revolutionary changes due to increasing public pressure to manage wildlands in a more "natural" manner. Management practices, such as clearcutting, that primarily focus on commodity production are under attack and managers are reevaluating many traditional policies.

Biodiversity and ecosystem management are two of the most important natural resource issues at the present time, but very little has been published on how forest and conservation nurseries can participate. For example, a recent Task Force Report on Biological Diversity in Forest Ecosystems contained no mention of nurseries at all, although it did state that "forest regeneration is a key element in maintaining and enhancing diversity in forest ecosystems" (Society of American Foresters 1991). Therefore, our objective in this paper is to demonstrate how forest and conservation nurseries are already being used to promote biodiversity and ecosystem management. Hopefully, this will lead to a better appreciation of the potential and stimulate discussion of some new possibilities.

Biodiversity is a contraction of the term "biological diversity" and can be defined at three different levels (Wilson 1988):

- The genetic level - the number of alleles or genotypes within a species.
- The species level - the number of species within a population and the number of these populations within a community or ecosystem.
- The ecosystem level - the number of communities and ecosystems in the world.

Nurseries are unique in that they can affect biodiversity at all three levels,. but particularly the first two. While most of the current dialog concerning biodiversity has been how to preserve it, nurseries offer the opportunity to not only preserve, but actually increase, biodiversity at both the genetic or species levels.

Ecosystem management can be most simply defined as those practices that are oriented towards the entire biological system instead of one particular species or commodity. Natural resource managers have begun to question the tradition of favoring one activity or commodity, such as timber harvesting and livestock grazing, especially on public lands. In contrast, the ecosystem approach recognizes that interrelationships between organisms are critical and stresses ecological structure, function, and processes. The political pressure to convert natural resource management to an ecosystem basis has been steadily growing. For example, issues like the spotted owl controversy in the Pacific Northwest have spawned several new forest management approaches such as "new forestry", "new perspectives", and "adaptive forestry" (Adams 1992). Although they differ slightly in detail, all of these new philosophies reflect the change from commodity-based to community-based management.

Biodiversity and ecosystem management are interrelated and are ecologically important for several reasons (Landis 1992):

1. High species diversity contributes to ecosystem stability. Although there are exceptions, communities and ecosystems with more functionally diverse species tend to be more stable than those with fewer. Sudden decreases in biodiversity are also sensitive indicators of environmental stresses, such as pollution. Some apparently insignificant species may serve as our "canary in a coal mine".

2. Diverse ecosystems provide many services. Humans are dependent on a multitude of plants and animals at lower trophic levels for vital "ecosystem services" such as maintenance of the atmosphere and climate, generation of soil, recycling of wastes, and regulation of pests. Although we take them for granted, these services depend on reasonably diverse and stable ecosystems.

3. Conserving biodiversity preserves unique genetic information. Each species contains unique genotypes and therefore has ecological as well as potential economic value. The genetic resource represented by the 10 million species on earth is a collection of successful environmental adaptations which have intrinsic value beyond their potential usefulness to mankind.

Vascular plants constitute only about 2.6% of the species in the world, and trees and other woody plants make up an even smaller percentage (Pimentel and others 1992). Large woody plants, however, are considered "keystone species" because of their sheer size and longevity (Noss 1991). These structurally and functionally dominant plants play a pivotal role in terrestrial ecosystems because they generate physical structure and create ecological niches for many other species. By creating a variety


Figure 1.--The Bessey Nursery was established by the USDA Forest Service in 1902 (above), to provide seedlings for the afforestation of the Sand Hills of western Nebraska (right).

of microenvironments, trees and other woody plants affect the distribution of many other plants and animals and therefore control the biodiversity of a particular community. Plants are also the primary producers that fix sunlight and provide a food base for all the organisms that are higher on the food chain. Even after they are dead, woody plants continue to provide the habitat for many animals and plants, and in the case of microorganisms responsible for decomposition, a stable food base.

People in the nursery and reforestation business haven't traditionally had much political influence in defining natural resource issues, but here is a real opportunity to play a leading role. Forest and conservation nurseries can supply plant materials for the wide range of planting projects that will be generated by the biodiversity and ecosystem management issues and nurseries need to make this fact known. However, before we take a look at where we are going, let's look back at where we've been.

## 1.2 Traditional roles of forest and conservation nurseries

In the United States, forest and conservation nurseries have been producing tree seedlings since the early 1900's, when the first nurseries were established by the federal government. The USDA Forest Service established the Bessey Nursery in 1902 to provide seedlings for the afforestation of the Nebraska Sand Hills (fig. 1A/B). In 1909, the Wind River Nursery was started in Washington and the Savenac Nursery in Montana with the primary objective of growing seedlings to reforest after large fires and protect watersheds (fig. 2A/B). In addition to resource protection, these nurseries had secondary goals of commercial timber production and the testing of exotic hardwoods.

In 1924, the Clarke-McNary Act provided cooperative federal funding to establish state government nurseries. Federal work programs in the 1930's, such as the Civilian Conservation Corps and the Shelterbelt

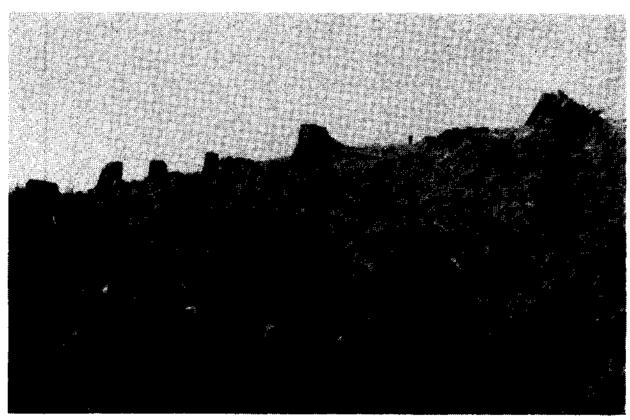


Figure 2.--In the West, the USDA Forest Service developed nurseries, such as the Wind River Nursery in Washington in 1909 (left), to reforest large burns with the primary purpose of watershed protection (right).

Project, led to an increase in tree planting for a variety of conservation purposes (Steen 1976). These programs continued through the Second World War. After the war, reforestation following timber harvest became the principal market for forest nursery stock in the West. That trend. has continued to this day.

Starting in the 1950's, an increasing number of private and industrial firms built nurseries and began to grow conservation and reforestation stock. Seedling production in both government and private nurseries increased dramatically during the 1970's and then leveled off (fig. 3). Recent events, such as the spotted owl controversy in the Pacific Northwest, have caused a decrease in the demand for reforestation stock but the exact magnitude and duration of this trend is unknown. Although the majority of forest and conservation nursery stock in the West is still grown for traditional reforestation purposes, major changes are in the works.

### 1.3 Increasing demand for "diverse" species

The new emphasis on biodiversity and ecosystem management has created a demand for a wide variety of plant species for a number of different resource objectives, and we predict this demand will increase in the future. Forest and conservation nurseries all across the nation are responding to these new markets. For example, seedlings of turkey oak (*Quercus laevis*), which had previously been considered a weed tree, are being grown for wildlife habitat at the International Forest Seed Company's Sisley nursery in western Georgia. At the USDA Forest Service Tourney nursery in upper Michigan, little bluestem (*Andropogon scoparius*) seedlings are being produced for a grassland restoration project. The increased demand for forest and conservation species has come from some unusual places. For instance, taxol is a chemical which is found in the bark and other tissues of yew, and has been shown to be effective in the treatment of some cancers. Pacific yew (*Taxus brevifolia*), a previously ignored tree in the timber-oriented Pacific Northwest, is suddenly being propagated by the millions to respond to this demand.

Forest and conservation nurseries are responding to these new business opportunities. Existing nurseries are expanding their product line from a few traditional commercial tree species to a wide variety of plants - from grasses and sedges to woody shrubs and riparian trees. Several private nurseries have begun specializing in native and adapted plants for wildland plantings. To further examine this trend, let's take a look at how nursery

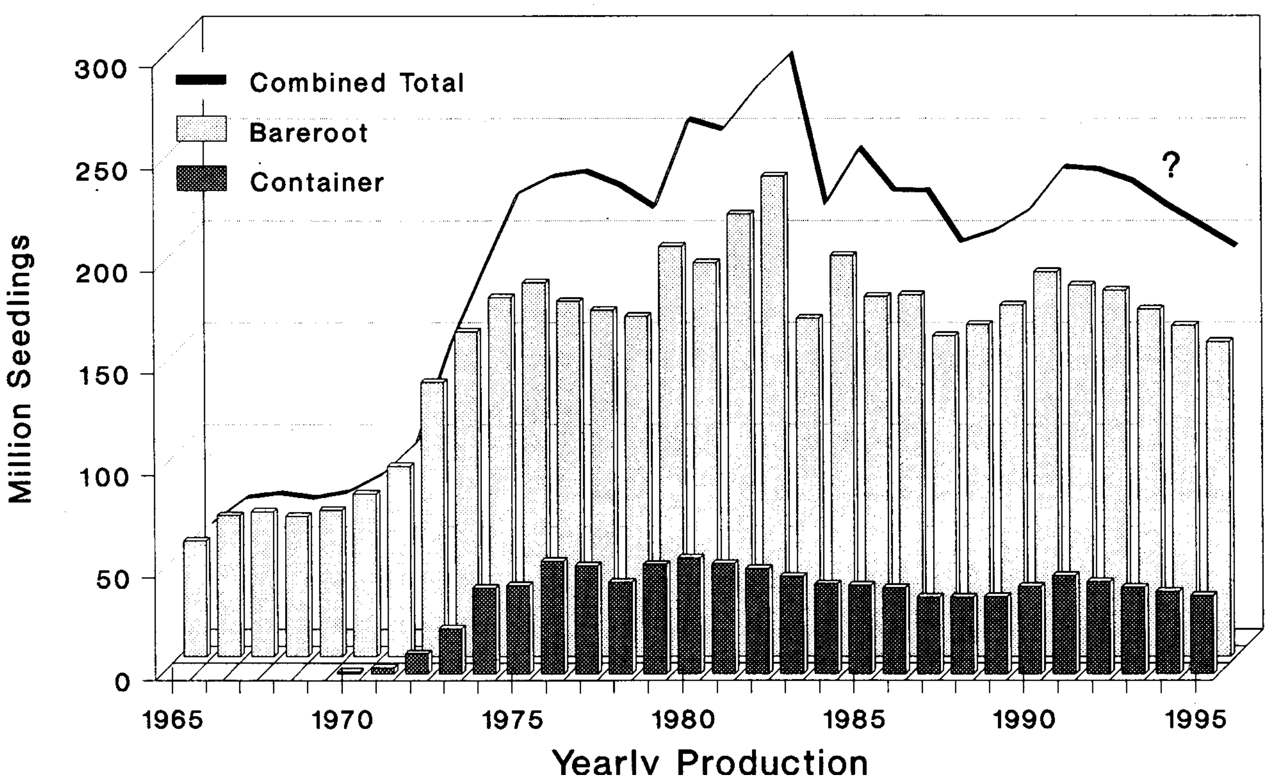



Figure 3.--Because of the political turmoil concerning timber harvesting, the future demand for commercial forest seedlings is uncertain in some areas of the West (modified from Okholm and Abriel, 1992).

stock is currently being used in planting projects that promote biodiversity and ecosystem management.

## 2.0 CURRENT USES OF NURSERY STOCK IN BIODIVERSITY AND ECOSYSTEM MANAGEMENT PLANTINGS

The following list of planting projects that use seedlings from forest and conservation nurseries is by no means comprehensive. In each category, we have listed a couple of examples of how planting "diverse" species can benefit biodiversity and ecosystem management. Hopefully, this brief introduction will stimulate additional discussion and lead to new opportunities.

### 2.1 Gene Conservation

Propagating rare species - The number of Threatened, Sensitive, and Endangered species has been steadily increasing over the past few years, from 178 in 1976 to 615 in 1991 (USDA Forest Service 1991). The list will undoubtedly continue to grow. Although the ultimate solution is to protect their habitats, forest and conservation nurseries have the unique ability to directly increase the number of rare plants or plants that are critical to the survival of other threatened, sensitive, or endangered plants or animals. Because of their isolation, the biodiversity of islands is naturally low and increasing human impacts have caused many plant and animal species to become endangered. For example, an extremely rare plant called Brighamia rockii is found only on some seacliffs on the island of Molokai in Hawaii. Apparently its insect pollinators have become extinct, and so ecologists from the National Tropical Botanical Garden have had to hand-pollinate the plants to obtain seeds. These rare plants are now being grown at their nursery and those of the Hawaii Division of Forestry (National Tropical Botanical Garden 1992).

Preserving local genotypes - Although not as newsworthy as propagating endangered species, forest and conservation nurseries have been practicing good gene conservation for many years. Most forestry seedlings are sold by seed zone - a numerical code corresponding to a geographic area that is relatively similar in climate and soil (see section 4.1). Some species that are widely distributed in geographically isolated populations, such as white fir (Abies concolor), contain high levels of genetic variability. Besides obvious differences in physical characteristics, researchers found that local ecotypes of white fir differed significantly in traits that will affect seedling survival and growth such as cold tolerance and date of bud break (Millar and Libby 1989). So, besides insuring that only locally-adapted plant materials will be used in forest and conservation plantings, the use of "source-identified" seed insures that a wide variety of local genotypes are preserved.

### 2.2 Resource protection and conservation

Shelterbelts and conservation plantings - Trees and woody shrubs have been planted as shelterbelts to retard wind erosion of soil for many years. In the Great Plains, shelterbelts significantly modify the local environment, particularly during the winter, when they provide protection for livestock and farms. Other conservation plantings consist of streamside buffer strips, living snowfences, and fuelwood plantations (Schoeneberger, 1993). Although shelterbelts and conservation plantings initially consist of a limited number of trees and large shrubs, other plants soon invade these areas and so serve to increase the species diversity. In time, conservation plantings also attract a wide variety of wildlife due to the protected microclimate and presence of other plants and animals that are not normally found in these areas (Brandle and others 1988). Shelterbelt and other conservation plantings provide the structural and ecological framework for new plant and animal communities in areas that previously were dominated by large expanses of grassland, and therefore dramatically increase the biodiversity of these areas.

Constructed wetlands - Water quality is being threatened by many types of pollution. Growing plants for constructed wetland treatment systems is another way in which forest and conservation nurseries can help protect natural resources (Landis and others 1992). A few years ago the Lone Peak Conservation Center nursery, which is operated by the Utah Division of State Lands and Forestry, worked with the USDA Soil Conservation Service to design a constructed wetland to collect and treat the runoff water from their greenhouse. At about this same time, they began propagating native wetland plants for the conservation and restoration market. In an excellent example of innovation, they decided to combine the two projects. The constructed wetland treatment ponds will serve three functions: 1) biologically remove nitrates and phosphates from the greenhouse irrigation water, 2) serve as a growing area for the propagation of wetland plants, and 3) function as a seed production area. Currently, the nursery has several riparian plants under culture including care spp., Juncus spp., Scripus spp., and Eleocharis spp. (Woolf 1992). The future for constructed wetlands is great because a variety of other municipal and agricultural wastes can be biologically treated and nurseries will be asked to produce stock for these projects.

## 2.3 Ecosystem restoration

Restoring damaged ecosystems is another obvious market for nursery stock from forest and conservation nurseries. Some restoration projects, such as mineland reclamation, have been outplanting trees, shrubs, and native grasses for many years but new markets are developing rapidly.

Fire rehabilitation - As mentioned in the Introductory Section, forest nurseries were first developed to grow seedlings to rehabilitate burned-over lands and today nurseries continue to propagate stock for this purpose. Exciting changes are occurring, however. Micropropagation technology is being used to produce plants for fire rehabilitation, for example. Frequent fires have changed the dominant species composition on rangeland in southern Idaho by eliminating native shrubs, such as bitterbrush (Purshia spp.) and mountain big sage (Artemisia tridentata var. vasevana), and favoring weed species. The Forest Research Nursery at the University of Idaho is propagating two species of bitterbrush that are "fire resistant" - they sprout readily after fire. Using the latest micropropagation technology, seedlings of these special ecotypes are being mass produced and will eventually be used to help restore these degraded rangelands (Wenny and others 1992).

Restoration after natural disasters - An extreme example of ecological restoration began when Mt. St. Helens erupted on May 18, 1980 and devastated almost 150,000 acres (60,704 ha.) of private, industrial, state, and national forest land in Washington (fig. 4). Almost half of this area was owned by the Weyerhaeuser Company who decided to restore their forests as soon as possible. The first step was to quickly salvage the. down timber to prevent the build-up of bark beetles, which could spread to adjacent forests. Research trials determined that conifer seedlings would grow normally if the ash deposits were scraped away so that the roots could be planted into mineral soil. Luckily, seed of the proper origin was already in storage so that nursery stock could be grown immediately - large transplants were the preferred stock type. The dominant tree species were planted on the appropriate sites, such as lodgepole pine (Pinus contorta) on exposed ridges and black cottonwood (Populus trichocarpa) in the stream bottoms. Red alder (Alnus rubra) and other pioneer species quickly reseeded into the devasted areas. The natural resilience of these ecosystems, aided by human intervention, helped restore productive communities in less than 10 years (Rochelle and others 1992).

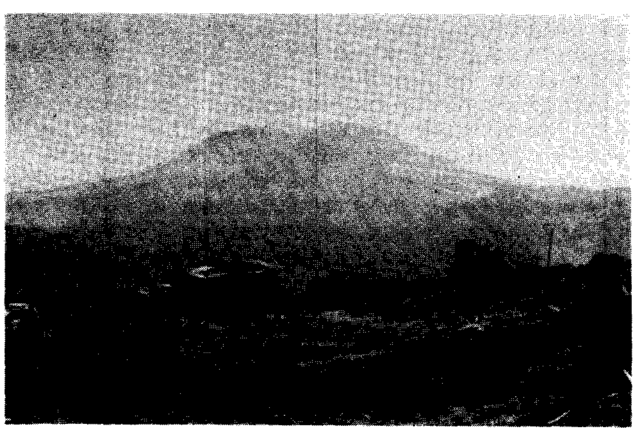


Figure 4.--Seedlings from forest and conservation nurseries have been used for a wide variety of ecological restoration projects, such as reforesting the blast zone at Mt. St. Helens, WA.

## 2.4 Enhancing wildlife habitat

Critical winter range - In many parts of the West, wildlife managers are asking nurseries to produce woody shrubs that can provide food and shelter during the stressful winter season. For example, a cooperative project between the USDA Forest Service, other federal and state agencies, and private land owners in northeastern California used broadcast burning and interplanting bitterbrush seedlings to improve the forage quality and quantity for a local deer herd. The project area on the Tahoe National Forest was dominated by woody shrubs such as sagebrush (Artemesia spp.), bitterbrush, and mountain mahogany (Cercocarpus spp.) which were overmature and senescent. Bitterbrush, in particular, is a favored deer browse but had been reduced to less than 10% of the overall species composition on the site. The prescribed burns have been carefully managed not to damage the scattered conifer overstory and the interplanted bitterbrush seedlings have prospered, with an overall survival of about 75% (Kent 1992).

Restoring sensitive habitats - Natural resource managers are also beginning to manage habitat for many nongame species, especially those which are threatened, sensitive, or endangered. As we learn more about the complex ecological relationships between organisms, plant species that are crucial to the survival of particular plants or animals can be propagated and outplanted. When the objective is to recreate a functioning, self-sustaining ecosystem, keystone plants must be identified, propagated, and outplanted to create a community with specific compositional and structural features. For

example, a riparian habitat along the San Luis Rey river in southern California is being restored to encourage the recovery of an endangered bird - the least Bell's vireo (Vireo bellii var. pusillus). Restoration ecologists carefully surveyed the plant community, identified the critical plants, and determined that the following composition created the desired structure: trees 40-60%, shrubs 30-50%, herbs 2-9%, with 3-9% left in open space. Nurseries were contracted to produce the stock for the project and six different trees and a variety of other plants were propagated. Initial surveys indicate that the project was successful as pairs of least Bell's vireos have been spotted in the restored habitat (Baird 1989).

2.5 Rehabilitation of recreation sites

Campground rehabilitation - Recreation is one of the most rapidly-growing uses of wildlands and, due to resource damage at many high-use sites, rehabilitation has become necessary. Recreation sites in quaking aspen (Populus tremuloides) stands are a notable example. Although aspen trees are highly desirable from an aesthetic viewpoint, they have thin bark and are easily damaged by campers. Fungi invade the wounds, causing cankers and killing the trees around the campsites (fig. 5). In Colorado, campgrounds in aspen stands are being rehabilitated by interplanting with conifer stock, both seedlings and larger transplants - especially in buffer zones around the campsites. Increasing the plant diversity of these stands makes them more resistant to camper abuse and subsequent pest problems (Raimo 1992). Seedlings and larger trees could be transplanted from adjacent sites but this "borrowing" depletes the vegetation and soils on the donor sites. In addition, the transplanted stock are not dormant and the root systems of larger plants are usually damaged during the operation. A much better solution is to propagate seedlings and transplants from local seed sources which can be properly planted. Nursery stock stands a much better chance of surviving the stresses of this high risk environment.

Revegetating wilderness sites - Alpine and subalpine ecosystems are particularly fragile and therefore very sensitive to adverse human impacts. Since the early 1960's, the North Cascades National Park in Washington has been experiencing heavy use by horses and backpackers in the more popular passes and trail side campsites. Although very little was known about high elevation restoration, transplanting wildlings to the restoration site was found to be unacceptable because of persistent damage to the donor site. However, propagation trials proved that subalpine

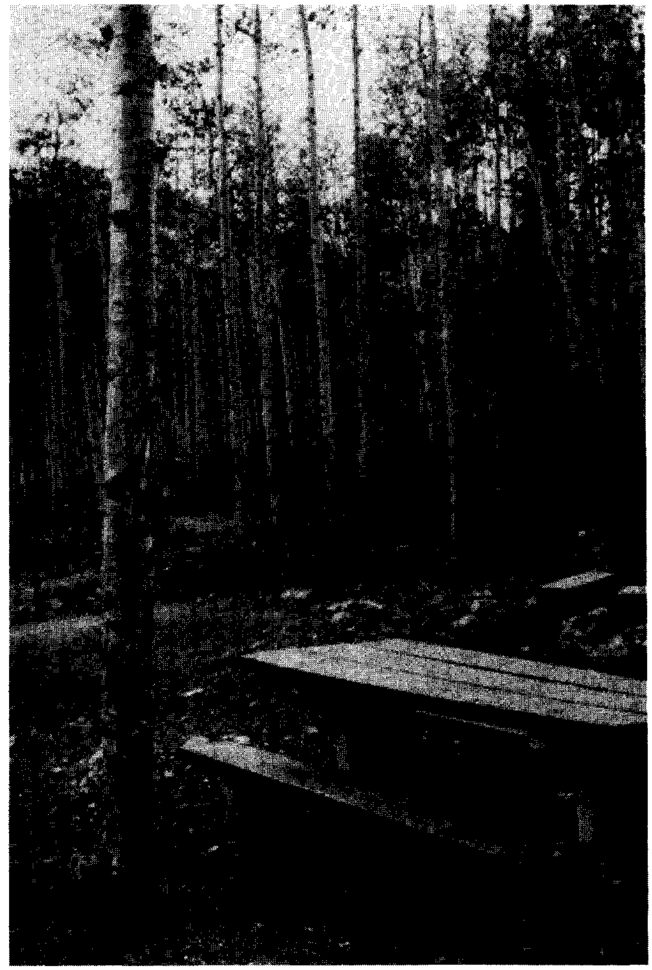


Figure 5.--High-use recreation areas, such as this campground in a quaking aspen stand, are often severely damaged by overuse, but can be rehabilitated with large nursery stock which is source-identified and locally-adapted.

plants could be propagated in greenhouses at lower elevations. Based on these early successes, a new greenhouse was constructed that can produce up to 20,000 seedlings per year by seed, cuttings, or division. Seed propagation is preferred for most species because genetic diversity can be increased and seed supply has not been limiting. Although demand for seedlings has consistently exceeded nursery capacity, over 25% of the impacted sites have successfully been restored in the Park since 1980 (Lester 1990).

2.6 Forest health

The forest health issue will undoubtedly have a profound impact on how we manage our forests in the future. The role of forest and conservation nurseries has not been fully realized as yet, but nurseries are already participating in several projects.

Breeding pest-resistant species - Since it was introduced around 1900, the blister rust fungus has spread all over the U.S. and Canada and has significantly reduced the number of white pines in many areas. Forest geneticists have developed strains of white pines that are resistant to the blister rust fungus. For example, a program to maintain sugar pine (Pinus lambertiana) in the mixed conifer ecosystem is underway in California. The goal is to provide genetically resistant seed which can be used to produce nursery seedlings and, to date, over 7,000 trees have been screened for "major" gene resistance to blister rust. These resistant trees provide an immediate source of seed and have produced an average of 175 lbs. (79.4 kg) per year. Because disease resistance is a complicated phenomenon, a second part of the program is aimed at developing trees with "slow rusting" resistance (Samman 1992). Bareroot sugar pine seedlings are grown from the rust resistant seed at government nurseries including the USDA Forest Service Placerville Nursery, and the California Department of Forestry Magalia Nursery. Rust resistant container stock is being produced at the USDA Forest Service Chico Tree Improvement Center and at CalForest Nursery. These genetically improved seedlings are then outplanted at a density of 50 trees per acre (124/ha) in a mixture with other associated trees, such as ponderosa pine (Pinus ponderosa) and white fir. Restoring white pines into forest communities across the West will take centuries but the results so far have been promising.

Developing pest-resistant forests - Most plant communities in the western U.S. developed in response to periodic burning and now many have become overgrown due to all-too-effective fire control. Species, such as lodgepole pine, that form dense stands after fire quickly become stunted and stressed, and are therefore very susceptible to bark beetle and disease outbreaks. In the Deschutes National Forest in central Oregon, over 750,000 acres of lodgepole pine forests have been decimated by the mountain pine beetle (Dendroctonus ponderosae). Absence of fire in the Blue Mountains in Northeastern Oregon has also converted many stands from open savannahs of large ponderosa pine to thickets of smaller Douglas-fir (Pseudotsuga meAziesii) and grand fir (Abies grandis) which are being defoliated by the western spruce budworm. Forest managers realize that they need to lower stocking levels and increase species diversity by converting these stands back to pine and western larch (Larix occidentalis). Unfortunately, letting natural fires burn or using prescribed burning could severely damage the existing trees because of the high fuel loads that have developed. In addition, air pollution concerns make large scale burning politically unacceptable in many areas (Gray 1992). Salvage logging and thinning will solve the stand density problem, but increasing stand diversity will require interplanting and underplanting. The public will not want to wait decades or even centuries for natural reproduction and so planting nursery stock will be the fastest and most efficient way to increase species diversity. Creating landscapes with a mosaic of different species and age classes will increase overall forest health and will help lower the potential for disastrous pest outbreaks (Schowalter 1991).

## 3.0 METHODS OF ESTABLISHING PLANTS ON THE PROJECT SITE

The plant species used and the establishment technique will vary with the objectives of the project. "Revegetation" projects try to recreate the original terrain and re-establish plants on the site that are similar to the native plant communities.
Both "reclamation" and "rehabilitation" plantings attempt to return impacted land to some desired use, such as converting mining spoils to grazing. Because these types of projects are oriented to specific land uses, either native vegetation or adapted plants that meet management objectives may be planted. "Mitigation" involves trying to replace the natural habitats that will be damaged by development, and can be done onsite or offsite. "Restoration", the most ambitious and difficult type of planting project, involves replanting native vegetation with the end objective of recreating a self-sustaining, functioning ecosystem. See Newton (1993) for more discussion of this terminology.

Depending on the objectives of the project and the site conditions, plants can be established by transplanting wildlings, direct sowing of seed, planting unrooted cuttings or rhizomes, and propagating and outplanting nursery seedlings or rooted cuttings (Table 1).

### 3.1 Transplanting wildlings

Digging up and moving existing plants from adjacent sites and planting them in the project area is a common practice. Because of the labor involved, transplanting wildlings is an expensive option but may be justified under some conditions.

The technique of lifting many young or small plants from their native habitat and transplanting them on a new site has little merit in ecological restoration unless the operation is carried out for the purpose of salvaging unique or rare plants from an area destined to be destroyed. Note that many

TABLE 1. --COMPARISON OF DIFFERENT WAYS OF ESTABLISHING WILDLAND PLANTINGS

| CHARACTERISTIC | ON-SITE METHODS: TRANSPLANT WILDLINGS | ON-SITE METHODS: UNROOTED CUTTINGS | ON-SITE METHODS: DIRECT SEEDING | OUTPLANT NURSERY STOCK |
|---|---|---|---|---|
| EFFICIENT USE OF SEED AND CUTTINGS | ---- | NO | NO | YES |
| COST OF ESTABLISHMENT | HIGH | MODERATE | LOW | MODERATE |
| ABILITY TO ESTABLISH DIFFICULT SPECIES | YES | NO | NO | YES |
| OPTION OF USING IMPROVED GENOTYPES | NO | NO | YES | YES |
| PRECISE SCHEDULING OF PLANT ESTABLISHMENT | YES | YES | NO | YES |
| CONTROL OF STAND COMPOSITION AND DENSITY | YES | YES | NO | YES |
| MATCHING STOCK TYPES TO SITE CONDITIONS | NO | NO | NO | YES |
| DEPLETION OF ADJACENT PLANT STANDS | YES | YES | NO | NO |

rare plants are protected and a permit must be obtained before moving them (Kaye 1992). Transplanted wildlings suffer high rates of mortality and there are negative impacts to the "donor" or "borrow" sites (Table 1). In most cases, it would be impossible to sample from a large enough gene pool when obtaining the transplants to assure genetic variability in the new population. For many species, it is very difficult to time the operation properly or to get enough root system in proportion to the top to assure survival on the new site.

A recent trend involves transplanting a few large, specimen-sized plants (usually trees) in an effort to "preserve" the natural resources of the area. This makes for great publicity and is an effective technique for creating instant maturity in a landscape project. However, the ecological value of transplanting a few large museum-piece trees without the associated plant community is questionable.

Considering the negative impacts and the ease of nursery propagation, transplanting wild plants should be discouraged except for salvaging easy-to-move species or specimens of high enough ecological value to warrant the effort.

## 3.2 Direct seeding

One of the most obvious methods for establishing plant communities is to simply apply seed of as many native species found on the site as possible and wait for rain and nature to take their course. Seeds can be broadcast by either hand or machine. The effectiveness of direct seeding varies with the species of plants and the objectives and time frame of the planting project.

The principal advantages of direct seeding are that it is inexpensive, relatively easy, and allows the seedling to develop a natural root system. However, there are many drawbacks (Table 1). Native plant seed from the proper seed source is often difficult to obtain or is very expensive. Some species do not produce adequate seed crops each year and the seed of others, such as the white oaks (Ouercus spp.), does not store well. Seeds of many diverse species require special cleaning and processing before they can be sown (fig. 6). Even if seed can be obtained and properly distributed over the site, predation from birds and rodents,

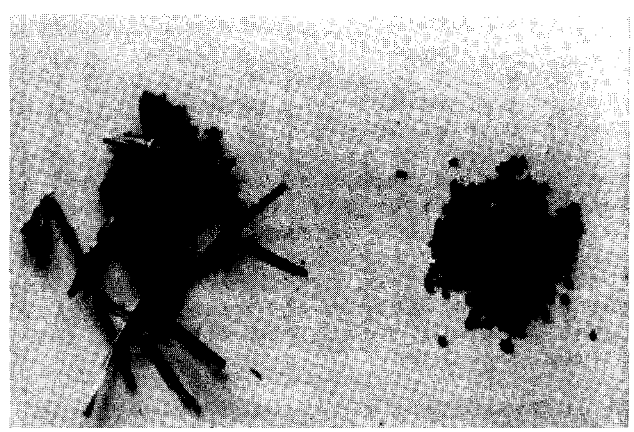


Figure 6.--A successful direct seedling project requires clean high quality seed, which can be a challenge with some "diverse" species, such as this alkali bullrush (Scirus robustus).

competition from weed species, and unpredictable weather often reduce establishment success. And finally, with direct seeding, it is difficult to control species composition and plant density over the project area.

Direct seeding is generally recommended for grasses and forbs, although certain woody shrubs and trees can also be established under some conditions. In California, direct seeding of native oaks has been quite successful and the Department of Fish & Game has direct-seeded alkali bullrush (*Scirpus robustus*) for restoration of wetland wildlife habitat in the Delta (fig. 6). Pacific Gas and Electric has also had good results with direct seeding several shrub species on wildland sites. Reduction of weed competition and protection from herbivory were certainly key factors in the success of these projects.

### 3.3 Planting unrooted cuttings

Many riparian and wetland species can be successfully propagated on site by collecting cuttings and planting them without any cultural treatment. The term "stem cutting" generally referring to traditional hardwood cuttings but also includes rhizomes and tubers, which are modified underground stems. Specialized roots, such as bulbs and corms, can also be used to propagate some plants. Under ideal conditions, planting unrooted cuttings can be a very cost effective means for establishing certain vegetation types. There are several limitations, however (Table 1). Because this is a type of vegetative propagation, care must be taken to sample from a variety of individuals and populations so that adequate genetic and sexual diversity will be represented.

Unrooted hardwood cuttings are prepared from long whips collected from shrubs or trees on the project site or from an adjacent area. The whips should be collected during the dormant season when the probability of new root formation is highest, and are subsequently cut in sections which range from 12 to 24 inches (30.5 to 61.0 cm) in length and 3/8 to 3/4 inch (9.5 to 19.0 cm) in caliper. When planted properly in moist soil and under favorable conditions, the cuttings will form new roots which follow the receding water table down as the young plant develops during the first growing season.

An interesting type of hardwood cutting sometimes used in riparian restoration projects is called the stump or pole cutting (Carlson 1992). These poles are often six feet (1.8 m) in length and 8 - 12 inches (20.3 to 30.5 cm) in caliper, and are obtained by cutting the major branches or stems of existing cottonwood or willow trees. The top end cut or any scars where major branches were removed should be sealed with a tree pruning sealant to prevent desiccation. The key to success with these extremely large unrooted cuttings is to plant them deep enough so that the butt end reaches the water table. The soil must also be coarse enough to allow enough air exchange at these depths to support adequate root growth. Unfortunately, this does not always work. If the bottom of the pole cutting loses contact with the ground water or if soil conditions are not favorable for root production, shoots called "watersprouts" will form but quickly wither. Another drawback to the use of pole cuttings is the obvious impact to the "donor" or mother plants from which the cuttings were obtained.

Rhizomes, tubers, and some types of root sections are used for the vegetative propagation of certain grasses and wetland plants. They can either be directly transplanted or multiplied by division. Grass and sedge rhizomes and root sections have been successfully used for wildland plantings, such as a prairie restoration project at Jepson Prairie in California. The Nevada Division of Forestry is propagating several native wetland plants at their Washoe Valley Nursery for conservation plantings. In the Northwest, Teufel Nursery is working on a wetland mitigation project and using rhizomes and root sections to propagate a variety of plants (Turner 1992). The advantages and drawbacks for rhizomes and root sections are the same as those for unrooted hardwood cuttings (Table 1) .

### 3.4 Outplanting nursery seedlings

For projects where rapid and complete establishment of a desired vegetation is critical, outplanting seedlings that were raised at a nursery is usually the best method. Nursery stock is the most efficient establishment method when seeds or cuttings are in a short supply and/or expensive (Table 1). When done properly, the high rates of success make nursery stock one of the most appropriate methods for natural resource planting projects. Nursery seedlings can be inoculated with beneficial microorganisms, such as mycorrhizal fungi, which are then carried onto the site on the roots of colonized plants (St. John 1990). Nurseries can also produce plants with improved genotypes, such as disease resistance. Nursery production can be coordinated with the project timetable, so that the target species will be available at the proper size and in the outplanting window.

Utilizing nursery stock can improve on natural processes (Table 1). When forced to meet human time scales, natural reproduction is extremely slow. Some plants produce seed infrequently and others only at irregular intervals. Nurseries have the ability to collect during those rare seed production years and store it until needed. Propagating plants in nurseries can significantly improve seed use efficiency because, in nature, many seeds are eaten by predators and young germinants are lost to drought and other stresses. Plants that propagate vegetatively cannot disperse to new areas very quickly and so planting nursery stock can speed-up this process. Natural plant succession relies on chance whereas planting can assure that the desired species will quickly establish in the desired location and at the proper density. Natural seeding often results in undesirable spatial distribution, such as overly dense clumps, especially during early successional series.

The most serious disadvantages of using nursery stock include the high initial cost and the lag time between ordering the seedlings and planting them (Table 1). Nursery culture can take from as little as 6 months to as long as 4 years depending on seed availability and the desired stocktype.

### 3.5 Using a combination of methods

In order to establish self-sustaining vegetation that will develop into a functioning ecosystem, a combination of methods is often the best alternative. By carefully analyzing the project area and planning for proper site preparation, the restoration specialist can customize the project to use some or all of the methods detailed above. Operational limitations may influence the choice of method and timing of implementation. To recreate the desired plant community, a master plan should be carefully developed which details the desired species along with the appropriate establishment technique.

## 4.0 PROCURING SEEDLINGS FOR PLANTING PROJECTS

The decision of what types of plant materials to use on a specific project should only be made after consulting with nursery personnel. The project planning team should consider factors such as nursery production time and space, cost, handling, storage, and outplanting method.

### 4.1 Types of plant materials

"Plant materials" is a general term for any propagule that can be used to establish a plant: seeds, cuttings, or seedlings. A variety of different plant materials can be used in natural resource planting projects but they must be "source-identified and locally-adapted": genetically suited to the specific outplanting environment and properly hardened to withstand the stresses of handling, storage and outplanting.

Stock types - Plant materials for biodiversity and ecosystem management plantings can be characterized by the way in which they are grown. Each stock type has unique economical and biological characteristics that affect seedling survival and growth after outplanting. Potential planters should realize that, when ordering seedlings, stock type must be considered along with species and seed source. Although little is known about many plants, information on which stock types to use in reforestation is available (e.g. Iverson 1984).

Seedlings can be divided into two basic stock types: bareroot seedlings or container seedlings. Bareroot seedlings are typically grown in open fields and the soil around the root system is removed during harvesting. The distinguishing feature of container seedlings is that they are grown in some sort of enclosed vessel. Because of the restrictive nature of the growth container, the roots bind the growing media into a cohesive "plug".

Another stock type is the transplant, which is a seedling which has been physically removed from its seedbed or container and is replanted in another location for additional growth. Traditionally, most transplants have been bareroot seedlings which are grown for one or two years, and are then replanted into a transplant bed and allowed to grow for another year or two. Container transplants are a rather recent innovation in which container seedlings are replanted in bareroot beds for an additional period of growth.

Most container seedlings are grown in one season or less, and these stock types are defined by the type and size of the growth container. For example, a "styro 4" refers to a container seedling that has been produced in a styrofoam block container with cells that are 4 cubic inches (65 cu cm) in volume. For traditional reforestation purposes, most container seedlings are grown in small containers but biodiversity and ecosystem management plantings often require larger stock. The University of Idaho Research Nursery produces conifers and various hardwoods for conservation plantings in large 20 cubic inch (328 cu cm) containers. Forty cubic inch (656 cu cm) containers have been used at the L.A. Moran Reforestation Center in California for production of oaks and several hardwood species including the California buckeye (Aesculus californica), which require large containers to accomodate the big seed. Largest of all are the 810 cubic inch (13,276 Cu cm) "Tall Pots" developed by the Center for Arid Lands Restoration at Joshua Tree National Monument for production of desert species (Miller and Holden, 1993). Larger seedlings represent a trade-off, however, where positive features such as better survival and greater visual effect must be balanced against the higher cost, larger production area, and higher handling and storage costs.

"Miniplugs" are a relatively recent stock type. The small containers typically range from 0.25 - 2.00 cubic inches (4 to 33 cu cm) in volume (fig. 7A), and some nurseries have even modified existing containers to produce native plant miniplugs. For example, the California Department of Forestry, L.A. Moran Reforestation Center cut their standard 6 inch deep (15.2 cm) containers down to a 2 inch (5.1 cm) length for the propagation of blue oak (Ouercus douqlasii) and valley oak (Q. lobata). Miniplugs are typically grown for a few months in a greenhouse, and are then transplanted into bareroot beds for additional growth (fig. 7B). The California Department of Forestry, Magalia Nursery has found that miniplug+1 oaks have a larger and better distributed root system than standard bareroot seedlings or transplants.

A numerical designation has traditionally been used to describe bareroot seedlings and transplants. The first number corresponds to the number of years in the seedbed or seed container, and the second number refers to the number of years in the transplant bed or container. Seedlings are generally produced in from one to three years (1+0 to 3+0), and transplants can take longer (e.g. 2+1) depending on the species, climate, and nursery system. Container transplants are generally held for just one year (Plug+1), although some nurseries produce Plug+2 stock.

While seed and seedlings have long been the most commonly used plant materials, new techniques such as micropropagation are now being used for some species (Wenny and others 1992). Micropropagation involves taking a piece of organized tissue, such as bud or cotyledon, culturally treating it to form roots and then buds. This has been done operationally on coast redwood (Sequoia sempervirens) by Simpson Timber Co. and Georgia Pacific, and on eucalypts (Eucalyptus spp. by Twyford Plant Labs for agroforestry plantings in the San Joaquin Valley .

Genetic considerations - One of the important differences between ornamental nursery stock and that used in natural resource plantings is that forest and conservation nurseries describe their seedlings by seed source. On the other hand, many ornamentals are named cultivars (CULTIvated VARieties) which have been selected for form or color, not source of origin. The importance of proper source identification cannot be overstated - many forestry and conservation plantings have failed because the stock was poorly adapted to the outplanting environment.

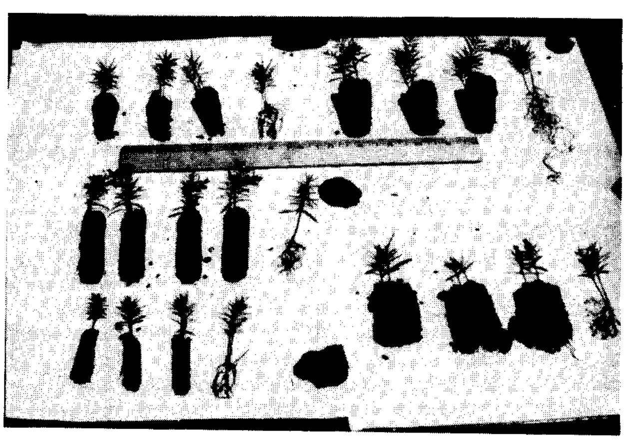


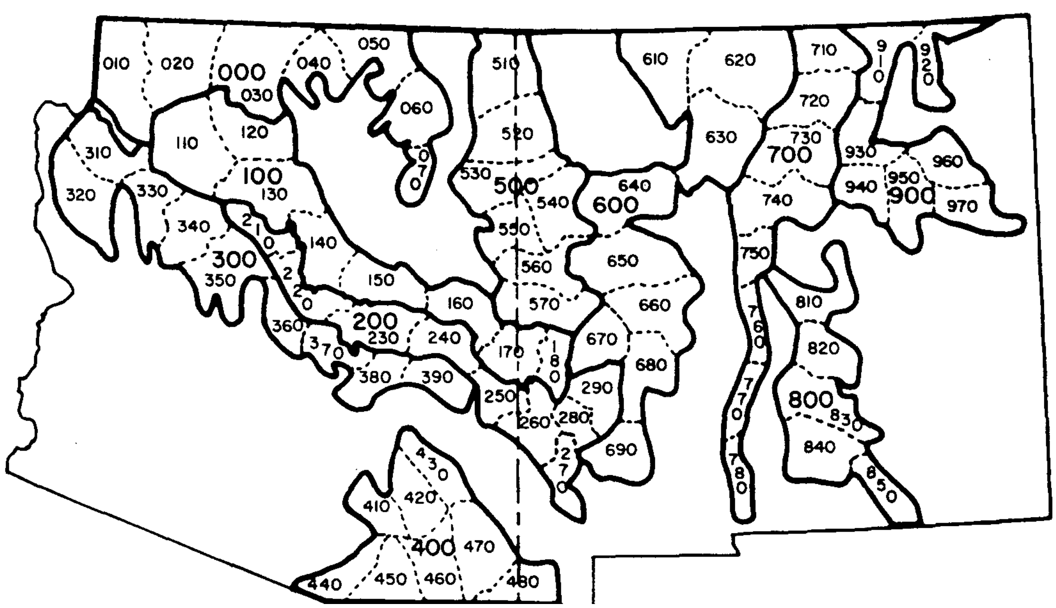
Figure 7.--Miniplugs are small container seedlings (left) which are grown for a few months in a greenhouse, and then transplanted to bareroot nursery beds for additional growth (right).

All plant materials used for biodiversity and ecosystem management plantings must be source-identified, with both geographical location (Township, Range and Section or Longitude and Latitude) and elevation specified. Foresters have traditionally used seed zones, which are geographic areas that are similar in climate and soil and are described by a numerical code. For example, the forested areas of Arizona and New Mexico have been divided into 10 physiographic-climatic regions which were then subdivided into seed collection zones that are about 50 miles wide (fig. 8). These seed zones are also stratified vertically by 500 ft. elevation (Schubert and Pitcher 1973). A geographically diverse state like California can have over 80 different seed zones with numerous elevations bands within each zone. Seed collections should also have a broad enough genetic base in terms of number of individuals, families, or stands, depending on the situation (Guinon 1993). This is of concern for both collections from the wild and for establishment of seed and cutting production areas in the nursery.

When a seedling order is sown in the nursery, this seed zone information is incorporated into a seed lot identification number. The seed lot number remains with this group of seedlings throughout the entire nursery tenure, and is labeled on the storage container when the seedlings are harvested. The process is completed when the seedlings are planted back into the same physiographic-climatic zone in which the seed was collected.

One of the central issues in the area of genetics and adaptability of plant materials is how far materials can be moved and still remain well-adapted. Usually local is assumed to be best, though it is wise to check for information that might confirm or refute that assumption. For example, giant sequoia (Seauoiadendron aiganteum) seedlings from California seed zone 534 out-grew seedlings from all other sources, even local collections. While growth is certainly one of the most obvious indicators of genetic adaptability, restoration specialists must also consider other performance aspects such as pest resistance and drought tolerance. Unfortunately, information from reciprocal transplant studies, isozyme work and DNA analyses is not often available. Still, it is worthwhile to search for ecological clues and experience that may reveal if a species is broadly or narrowly adapted.

Genetic improvement is underway for a variety of species. Selections are made to improve height growth and form in commercial conifer species such as ponderosa pine and Douglas-fir, to improve blister-rust resistance in species like sugar pine and western white pine (see Section 2.6), and to improve height growth, cold tolerance and salinity tolerance in eucalyptus and casuarina species. While local sources are almost always the best choice, genetically-improved plant materials may be appropriate for some planting projects, depending on their objectives.




Fijure 8.--Foresters use numerical seed zones, like these for Arizona and New Mexico, to insure that seedlings are adapted to the physiographic and climatic conditions on the outplanting site (Schubert and Pitcher 1973).

Adaptability - In addition to selecting the proper species, seed source, and stock type, seedlings must be properly acclimated so that they will survive and grow under the climatic conditions at the site. The question of whether plant materials will be hardy on the outplanting site is sometimes overlooked, however, especially by people who are inexperienced. Obviously, species that occur naturally on the outplanting site will be best adapted and so the primary -mphasis has been on "natives" for biodiversity and ecosystem management plantings

Although native species are usually best, there is still a role for site-tested exotics in certain situations. This is particularly true for afforestation projects, such as the windbreak and homestead plantings in the Great Plains and Intermountain areas where there are no native trees. On sites where cold, salt, alkalinity and/or drought are problems, exotics like poplars and casuarinas may be the best choice. However, when using non-native plant material, special care must be taken to match the species and seed source characteristics with the site. There are numerous examples where poor cold tolerance caused problems (Merwin 1992). Finally, the plant materials, even if locally adapted, must be properly hardened at the nursery prior to planting.

## 4.2 selecting a nursery

Natural resource specialists who are interested in purchasing plant materials should visit local nurseries and talk to the nursery personnel. Take a walk around the operation and look at the current crop. Remember to check out the quality of the root systems as well as the tops. Search out others who have purchased seedlings and inquire about the reputations of the local nurseries, including the success of outplantings.

On the business side of things, there are two basic ways to obtain nursery stock for your planting project: speculation stock, and seedling contracts.

Buying speculation stock - Some nurseries sow a certain percentage of their annual production for the speculation market. Usually, these are species and seed sources which are adaptable to a wide geographical area or have proven to be marketable in the past. The other source of speculation stock results from surplus nursery production. Because of the variation in seed quality and weather, most forest and conservation nurseries oversow their seedling orders and therefore have some seedlings available each year for open market sales. The quantity and seed source of this surplus stock varies from year to year, however, and so seedling users must contact different nurseries each season to learn what species and seed sources will be available.

Contracting for seedlings - Forest and conservation nursery stock is a specialty product and also perishable. The market is also notoriously changeable, and so economics dictate that most nurseries grow a large proportion of their seedlings on contract. As discussed earlier, seedlings for natural resource plantings are different from ornamental nursery stock in that a specific seed lot is only biologically suitable for a relatively few planting sites. Therefore, most foresters and other seedling users procure their stock by contract and specify the appropriate species, seed source, and stock type. This assures that high quality plant materials will be ready for their planting project when they need them.

## 4.3 Nursery Services

The increasing emphasis on biodiversity and ecosystem management is changing the role of the forest and conservation nursery. Traditionally, nurseries merely grew seedlings, but the current trend is to go beyond propagation to a broader range of services (Table 2). Seedling users should consider the nursery as a partner in the planting project and involve them early in the planning process.

In particular,. government nurseries can serve as a plant materials clearing house, and refer project managers to sources of plant materials. Federal and state nurseries have a long tradition of providing

*TABLE 2.--LIST OF POTENTIAL NURSERY SERVICES*

- *ANALYZE PLANT MATERIAL NEEDS AND PREPARE PLANTING PROJECT PLANS*
- *COLLECT, PROCESS, AND STORE SEED AND VEGETATIVE PLANT MATERIALS*
- *PROVIDE SEED TESTING AND PRESOWING SEED TREATMENTS*
- *MAINTAIN SEED ORCHARDS AND CUTTING HEDGES*
- *GROW VARIETY OF SPECIES AND STOCK TYPES*
- *DEVELOP NEW PROPAGATION TECHNIQUES*
- *STORE AND DELIVER NURSERY STOCK*
- *OUTPLANT STOCK AND PROVIDE FOLLOW-UP CARE*

seedlings for reforestation and other conservation plantings, and they understand the biological and operational aspects of growing, handling, and storing plant materials. Their personnel are willing to help natural resource specialists who are considering planting projects make intelligent decisions about how to obtain appropriate plant materials, handle and store them, and transport them to the outplanting site. Government nurseries also offer specialized services, such as seed cleaning and testing, for a variety of diverse species (fig. 6).

Private forest and conservation nurseries offer a variety of services, depending on their facilities and expertise. An increasing number of progressive nurseries provide a full range of services - from seed collection and processing, seedling propagation and storage, through outplanting and follow-up care (Table 2). Because of available seedling inventories and technical experience, planting project managers may find out that working with a combination of nurseries is the best alternative.

## 5.0 CONCLUSIONS AND RECOMMENDATIONS

Forest and conservation nurseries are going to be asked to play a greater role as natural resource managers begin to implement biodiversity and ecosystem management programs. Although they have been traditionally associated with timber management and reforestation, nurseries should be viewed in a wider context - as a vital part of all vegetation management activities. Forest and conservation nurseries are willing and able to respond to any need for plant materials for a wide variety of natural resource uses.

### 5.1 Effects on nursery culture

The change towards biodiversity and ecosystem management will have several effects on forest and conservation nurseries. The following are our predictions:

More species - Obviously, nurseries will be growing a greater number and variety of plants than they have in the past.

Smaller orders - As natural resource specialists focus on smaller management units, the average seedling order will decrease. Greater recognition of the need for locally-adapted, source-identified plant materials will also contribute to this trend.

Higher costs - Compared to the large volume orders grown for traditional reforestation projects, the trend towards smaller, more specific crops will cause an increase in seedling cost. However, the price of nursery stock will remain a relatively small part of the overall planting project budget.

Different propagation techniques - Currently, the vast majority of plants grown in forest and conservation nurseries are propagated by seed. The need to propagate a greater variety of plants will necessitate innovative new seed propagation techniques as well as more types of vegetative propagation. Micropropagation, and other newly developed propagation methods, may also become more common.

New stock types - Plantings that are made to increase biodiversity and fulfill ecosystem management goals will require a greater variety of seedling stock types than have been used for traditional forestry projects. More species will be grown in containers because of the relative ease of propagation and the shorter rotations. More transplants will also be used because of the competition from other vegetation and the need for rapid establishment and growth. Container transplants, especially mini-plug transplants, will become more common because they produce larger plants with better root systems.

Source-identified and locally-adapted seedlings - Plant materials that are to be used for biodiversity and ecosystem management plantings must be genetically suited to the specific outplanting environment and properly hardened to withstand the stresses of handling, storage and outplanting. Resource managers will demand source-identified seedlings, and forest and conservation nurseries will need to develop cultural regimes, handling, and storage techniques that result in hardy stock that not only survives, but thrives, after outplanting.

Trend towards full service nurseries - Nurseries that can provide a full range of services from seed collection and processing to seedling storage and outplanting will receive a higher proportion of business. Natural resource managers are specialists who do not want, or have the time, to work with a series of different businesses and so will prefer to work with one full-service facility.

### 5.2 Reaching beyond the nursery

Gone are the days when nurseries can expect to sit back and expect customers to come to them. Successful nurseries will devote a significant amount of time to marketing their products and services, and establishing better communications with natural resource managers and planners. The increasing emphasis on issues like biodiversity and ecosystem management mean that nursery managers will no longer just be dealing with traditional reforestation personnel. Many more resource professionals will be needing plant materials and so nursery managers will be communicating with wildlife biologists, recreation specialists, and other new, inexperienced customers. Nurseries that can provide high quality seedlings and a full range of services will be in great demand.

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