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LARGE-SCALE REFORESTATION

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Proceedings of the
International Workshop on
LARGE-SCALE REFORESTATION

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A hearty thanks to all -- JKW, PES, and MJK

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INTRODUCTION

Jack K. Winjum

BACKGROUND

The purpose of this workshop was to identify and explore major operational and ecological considerations for successfully conducting large-scale reforestation and afforestation projects internationally. Interest in this subject by the U.S. Environmental Protection Agency stems from the global warming issue.

Projections for global warming resulting from "the greenhouse effect" have led to growing public concern about the consequences of increasing climatic temperatures. Although experts continue to debate the credibility of the model-based projections, it is certain that the concentration of the earth's atmospheric CO_2 has increased by about 30 percent since the 1850 level of 280 ppm. Much of this increase is attributed to CO_2 emissions caused by ever-increasing human activities. If this trend continues unchecked, the preindustrial level of atmospheric CO_2 is predicted to increase another 30 percent in 50 years and double by about the year 2100 (Abrahamson 1989). Likewise, other greenhouse gases such as methane (NH_4) and nitrous oxide (N_2O) are also increasing for anthropogenic reasons. Thus, within decades, and likely by 2100, global warming could be significant, unprecedentedly rapid and, initially, has the potential to hold many detrimental effects for humankind (Smith and Tirpak 1989).

Forest ecosystems play a pivotal role in the global carbon cycle. Not only are tremendous amounts of carbon stored in forest vegetation and soil (i.e., the biomass), but global forests also account for some 90 percent (~90 Gt) of the carbon flux to and from the atmosphere from terrestrial systems annually (Waring and Schlesinger 1985). This suggests that forests are a primary control point in the cycle and that through management, they can possibly contribute to increased carbon conservation and sequestration to offset a part of the CO_2 build-up in the atmosphere. As a major management tool, large-scale reforestation would likely make a significant contribution. Definitive estimates of that contribution are the subject of longer term, in-depth studies by EPA and other agencies. Thus, this topic was not an agenda item, although several of the invited authors gave it some consideration (e.g., Walstad, Hughes, Cailliez, and de Jesus).

Workshop speakers included prominent forest managers and scientists who have had experience with large-scale reforestation projects in ten diverse world locations and situations. These experts, many of whom participated in the follow-up discussions, provided the international coverage sought.

In this publication, which is the outcome of the workshop, two initial papers based upon U.S. experience outline fundamental considerations for large-scale reforestation success. The first, by Owston and Turpin, addresses operational concerns; the second, by Walstad, ecological considerations. Subsequent papers expand on these fundamentals according to eight case studies representing other situations (*Table i*, page *xvi*). "Large-scale" for this workshop means projects where, by human effort, approximately 100,000 hectares or more of new forests have been established or are planned annually for about a decade in an individual country or region.

KEY FINDINGS

Operational Considerations

From the USDA Forest Service in Corvallis, Pete Owston, a senior reforestation scientist, and Tom Turpin, an experienced silviculturist, focus on operational considerations for plantation establishment based on U.S. national forests, primarily those in the temperate region (pages 1-10). Important operational considerations discussed are:

- an overall commitment by the sponsoring organization to making reforestation projects succeed;

- thorough reforestation planning;

- respect for seedlings as living organisms during handling and planting;

- effective supervision of work by knowledgeable foresters;

- the value of follow-up steps such as survival surveys and replantings were necessary.

Ecological Considerations

Jack Walstad, Head of the Department of Forest Management, Oregon State University, has had considerable experience in reforestation research and operations in the eastern and the Pacific northwestern forest regions of the U.S. On pages 11-28, he points out fundamental ecological considerations such as:

- matching species and stock type to site conditions;

- use of well-adapted genetic stock;

- anticipation of insect, disease and weed problems;

- corrective soil treatments, such as fertilization or mycorrhizal inoculations;

- intensifying operational and ecological effort as reforestation progresses from very productive lands to lands with more marginal growing conditions.

Case Studies

The basic operational and ecological considerations noted above, while common to most reforestation projects, must be tempered to accommodate other considerations unique to specific locations. The workshop was structured to address the three broad latitudinal regions of the world; i.e., boreal, temperate, and tropical. Further, examples of reforestation using native versus exotic species were represented as well as large-scale projects consisting of many solid, contiguous block plantations for timber production, or distributed small patches of trees supporting social forestry land use. Authors present eight different combinations and describe reforestation considerations unique to each one.

Boreal, Native Species, Block Plantings

Denis Lavender, reforestation scientist at the University of British Columbia, drawing on his long research career including experience in northern British Columbia, notes on pages 113-122 these important considerations for boreal conditions:

- there are only a few weeks of frost-free conditions favorable to planting;

- compressing large-scale work into a few weeks requires careful planning;

- cold, poorly-drained soils require special site preparation techniques;

• bioclimatic zones are useful guides to species selection.

Temperate, Native Species, Block Plantings

Joe Hughes, a third-generation North Carolinian and forest scientist for Weyerhaeuser Company, has spent many years researching the establishment and management of loblolly pine plantations in the southern U.S. His list (pages 51-65) of priority considerations for successful reforestation in a region with high potential for growing timber crops include the following points:

• organizational commitments must be consistently maintained to take full advantage of a favorable growing environment and a very versatile conifer species such as loblolly pine;

• public agencies must develop favorable economic incentives so land managers can sustain investments in reforestation;

• reforestation technology must be backed by a steady program of research.

Temperate, Exotic Species, Block Plantings

Ian Hunter, reforestation scientist for the New Zealand Forest Service, summarizes on pages 39-50 almost a century of reforestation experience in New Zealand which exemplifies a classic case of the successful use of an exotic tree species, radiata pine. Reforestation considerations learned by New Zealand foresters from this perspective are:

• don't let early successes develop into overreliance or over-confidence on one exotic species;

• be aware of the risks of a too-narrow genetic base;

• support the program with sustained and adequate research and development.

Temperate, Native and Exotic Mix, Block Plantations

Douglas Malcolm, Head of the Department of Forestry and Natural Resources, University of Edinburgh, outlines on pages 66-77 the history of the forest cover of Great Britain and the efforts to re-establish conifer plantations of native Scots pine and exotic Sitka spruce many years after the lands had been cleared for farming. Important considerations for success in this afforestation situation are:

• public education is required before people will accept a change in scenery and land use they are not used to, even if it is afforestation of bare lands;

• government lawmakers must develop long-term economic incentives to maintain large-scale reforestation programs.

Temperate, Native-Exotic Mix, Block Plantings and Social Forestry

A. N. Chaturvedi, a Senior Fellow at TATA Energy Research Institute in New Delhi, presents on pages 106-112 a survey of reforestation in India which dates back to the mid-1800s. India has, in general, favorable growing environments for forest crops. Their foresters have developed effective technology for establishing plantations of native teak and bamboo as well as exotics represented by several species of *Eucalyptus,* other hardwoods and some conifers. In addition, there is a long-standing public interest in reforestation. Nevertheless, these positive factors must be considered in light of social-political considerations such as:

• requires a strong coalition by public agencies, industrial groups, environmental interests, farmers, etc., because all have their individual expectations which must be coordinated since space and money are limited;

- plantation protection where human and animal (particularly goats) densities are high.

Tropical, Exotic Species, Block Plantations

Francis Cailliez, who directs the French Centre Technique Forestier Tropicale, informs us about large-scale afforestation in the Congo (pages 84-92). Large plantations of *Eucalyptus* have been established on savannah lands for the purpose of growing wood to serve a newly-developing pulp manufacturing industry. Here, with favorable growing conditions and a low population density, the important considerations are:

- use of local labor in plantation establishment as much as possible rather than mechanization, thereby providing jobs, family incomes, and greater support by the Congolese people;

- employment of women in seedling nursery production accentuates the above result;

- multiclonal hybrid *Eucalyptus* is recommended for plantations to achieve both low-risk genetic diversity and high productivity;

- plantations on savannahs require intensive weed control for fire protection.

Tropical, Exotic Species, Social Forestry

Renato de Jesus, a tropical forest research coordinator and executive in Brazil, stresses (pages 78-83) that in his country, while reforestation trials date back to the 1800s and operational-scale projects with *Eucalyptus* and *Pinus* exotics began in the 1960s, a broader need is restoration of deforested lands. Plantations for carbon sequestration has little meaning; rather, planting in a social forestry sense is much more urgent. The objectives are to help make farming sustainable, control erosion and siltation, stabilize water tables, and produce wood for energy. Special considerations, therefore, from this present-day approach in Brazil include:

- expanding the use of native species to more fully tap the potential of tropical growing environments and retain biodiersity;
- increasing silvicultural research to develop the use of native species;

- implementing forest management practices which maintain land productivity and forest health.

Tropical, Native-Exotic Species Mix, Social Forestry

Mark Trexler is Director of the Carbon Sequestration Forestry Project for World Resources Institute. He reports (pages 94-104) on a new and innovative reforestation project in Guatemala. The Applied Energy Service of the U.S. has provided start-up funding to promote enough tree planting in Guatemala over the next 30 years to sequester carbon equivalent to the emissions of a new electrical power plant in Connecticut. The project has revealed that large-scale reforestation in developing tropical countries calls for unique considerations; that is:

- working with local people so that the people who need the most help in improving their living conditions get it and are involved with and committed to the reforestation;

- the need for assistance of people with experience in tree planting;

- where the expertise is not provided by government agencies, then available sources are often the representatives of non-governmental organizations (NGOs) which are already active in the areas targeted for reforestation;

- production of seedlings in nurseries dispersed in communities and planting for woodlot and agroforestry production.

CONCLUSIONS

The key findings are backed by many additional considerations in the texts of the ten papers. In addition, the proceedings of the one-day follow-up discussion contributed additional information (pages 113-142). Altogether, they form a rich assemblage of reforestation information which has broadened EPA's knowledge base on international reforestation.

As with most gatherings of people with both experience and fertile minds, serendipitous results emerge. This workshop followed that course, and four points are noteworthy:

1. The potential of large-scale reforestation as a means to aid mitigation of increased atmospheric CO_2 depends on how much land in the world is available. A considerable pool of land exists that might be "technically suitable" for reforestation and afforestation, particularly in the tropics. The size of this pool is estimated to range from a half-billion to almost 2 billion hectares. Such amounts, however, would likely be an upper limit. What is actually available after social and political limitations are accounted for, would be a lesser amount. A clear determination of the amounts is a priority research question.

2. Regarding economics, reforestation does require money investments. Reforestation foresters are quite mindful of this and conversations among peers usually gets around to cost comparisons. David South, Auburn University, voluntarily recorded the costs he heard mentioned throughout the workshop and presented them for a discussion topic. Quickly giving it their attention, the workshop participants offered refinements, and the results are included in Table XXXII, page 124, for reference.

3. Social and political considerations were very strongly emphasized in all eight of the case study papers. It was a particularly important point relative to developing nations. Indeed, social and political considerations for accomplishing large-scale reforestation turned out to be as major as those of an operational and ecological nature. It is good that the workshop clearly established this perspective.

4. The fourth fortuitous outcome is a subset of number 3, above. Large-scale reforestation or afforestation projects mean more than just contiguous block plantings. They can include many small, dispersed plantings as well. Examples are woodlot plantations or integral parts of agroforestry systems. All will sequester carbon, but just as important, these plantings serve people in many immediate and very vital ways.

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Table i. Outline of Categories and Topics of the Workshop Papers.

Category/Topics	Area	Author
Fundamental considerations		
Operational		
Native Species Block Plantings	U.S.	Owston and Turpin
Ecological		
Native Species Block Plantings	U.S.	Walstad
Case Studies		
Boreal		
Native Species Block Plantings	Northern B.C.	Lavender
Temperate		
Native Species Block Plantings	Southern U.S.	Hughes
Exotic Species Block Plantings	New Zealand	Hunter
Mixed Species		
Block Plantings	Gr.Britain	Malcolm
Block Plantings and Social Forestry	India	Chaturvedi
Tropical		
Exotic Species		
Block Plantings	Congo	Cailliez
Social Forestry	Brazil	de Jesus
Mixed Species		
Social Forestry	Guatemala	Trexler

OPERATIONAL CONSIDERATIONS FOR LARGE-SCALE REFORESTATION PROGRAMS: A PACIFIC NORTHWEST PERSPECTIVE

Peyton W. Owston
Thomas C. Turpin

Abstract

Planting tree seedlings seems simple enough--dig a hole, insert the roots of a seedling, repack the soil, and move on to the next planting spot. An experienced worker can manually plant 500 or more seedlings per day on rough terrain. Machine planting on level ground goes even faster. Planting, however is only one of many steps in achieving successful reforestation. The process should begin with careful planning long before a stand is harvested or an area is afforested--or soon after a disaster results in deforestation. The plan must consider factors such as environmental impacts and long-range land management objectives as well as the reforestation process itself. Economic considerations, quality control and evaluation of results must also be included in each of the separate phases of planning and operations.

History has shown that large-scale tree planting efforts can be successful (Walstad, this volume). This paper describes the broad range of factors and complexity of operations that such reforestation programs involve. We hope to increase the awareness of this complexity among policy makers and others who might be initiating new programs. We will do this by focusing in general on the western United States and in particular on the Siuslaw National Forest in the Coast Range of western Oregon. The relative importance and operational details of the various aspects of programs will, of course, be different for different ownerships, environments and sociological conditions. We believe, however, that the general aspects apply fairly broadly over mountainous regions of the temperate zones and also illustrate the complexity of large reforestation programs--wherever they occur.

GENERAL CONSIDERATIONS

Large reforestation programs are made difficult partly by the nature of tree seedlings themselves. Their needs as living organisms must always be considered. Several factors add to the problem: (1) many of the processes in reforestation are not one tree's experience in nature; (2) the remoteness of most planting sites and the large scale of operations make it economically prohibitive to irrigate forest plantations, which is the one practice that would best ensure reforestation success where moisture deficits are common during the growing season; and (3) many reforestation sites are on unfavorable soils, have high levels of competing vegetation, and have a large number of animals that can damage seedlings.

Time available for accomplishing specific tasks each year is limiting. Many operations must be timed to coincide with the time of year that seedlings are most resistant to environmental stresses, when planting sites are available, and when climate is most conducive to seedling survival. Most programs cannot be increased in size simply by planting in more months of the year.

The availability of technically knowledgeable personnel is another consideration. Prescriptions for reforestation operations should be site-specific and developed only after on-the-ground evaluations by silviculturists with authority to make decisions. Thus, programs cannot be increased merely by growing more seedlings and hiring more tree planters.

ORGANIZATION, FACILITIES AND PERSONNEL

Logically, reforestation programs are managed using the same organizational framework, facilities, and personnel as other land-based activities in an organization. This normally includes a headquarters for overall coordination and field offices that handle on-the-ground operations. Personnel must include managers and technical specialists. Operational facilities and major equipment specific to reforestation and people to operate them must also be available. Facilities include seed processing plants, seedling nurseries, cold storage buildings and transportation systems.

A successful reforestation program also requires dependable seed suppliers and a large labor pool. Commonly, actual conduct of the work on the planting sites and in the nurseries is done to rigid specifications by crews contracted to perform specific parts of a program. Their work should be rigorously inspected by trained employees of the land management organization. Other participants in reforestation programs are upper- and mid-level managers, contracting and budget specialists, and general office support personnel. Research scientists provide technical service as well as pertinent new knowledge. Professional specialists in fields such as wildlife biology, recreation and fire control participate in various phases so that work is integrated with other land management activities.

As a new approach to making the reforestation job more efficient, some organizations in the United States are using stewardship contracting as a tool (Porterie *et al.,* 1986). A contractor takes responsibility for successful establishment and early maintenance of a plantation--not just individual steps of planting or applying protective treatments. This places the emphasis on living seedlings rather than on numbers planted or amount of area treated.

In the U.S. Department of Agriculture Forest Service, most of the land-based activity is centered on 159 national forests, which are commonly 400,000 to 800,000 hectares or more (1 to 2+ million acres) in size. The forests are subdivided into ranger districts, which are often 40,000 to more than 80,000 hectares (100,000 to 200,000 acres). People who conduct or manage the actual on-the-ground activities are based on the ranger districts. In our example, the Siuslaw National Forest consists of 255,000 hectares (630,000 acres) divided into four ranger districts. In any given year, approximately 0.8 percent of the Forest is reforested, additional sites are prepared for future planting, and young plantations are weeded and thinned.

Their program focuses on manual planting of conifer seedlings on prepared sites, a method that has been the mainstay of reforestation programs in the western United States for the past 25 years or so. The Siuslaw has a successful program that last year resulted in planting of almost 3 million seedlings on more than 2,600 hectares (6,500 acres) on some of the most productive forest land in the world. Similar annual totals have occurred for most of the past 20 years. This is not a large program by world standards, but it is thorough and effective.

Each ranger district on the Siuslaw employs a professional silviculturist who must pass a comprehensive certification examination. The silviculturist is responsible for developing site-specific reforestation prescriptions and has a staff of three to five people responsible for completion of the various tasks. The Forest headquarters has a staff silviculturist who provides expertise and overall direction for completion of the reforestation program. This person works closely with the silviculturists on the ranger districts as well as with research organizations and contracting sources.

PLANNING

The need for careful, thorough planning

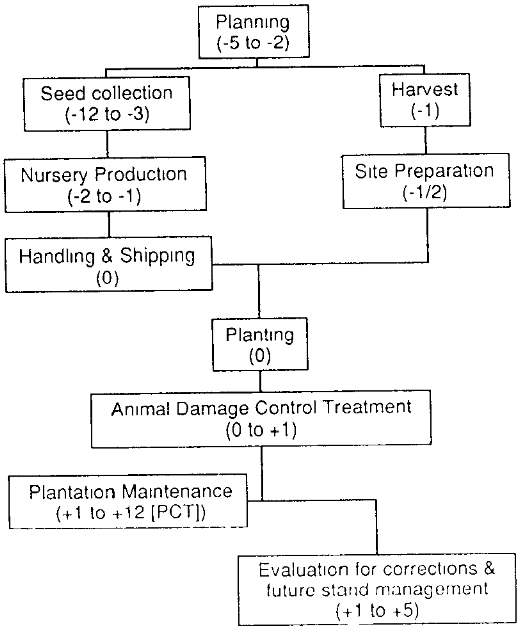

Figure 1. Major Steps in the Reforestation Process for Typical Harvested Sites in the Western U.S.

cannot be over-emphasized (Cleary *et al.*, 1986; Williams et al., 1990). Reforestation is a complicated process that involves coordination of many different steps that, in turn, have their own complications (Figure 1). Mistakes in any one of many phases can mean failure for the whole effort. Furthermore, reforestation has to be conducted in concert with overall land management objectives and be coordinated with other management practices. Land management objectives could be production of wood products, watershed protection, improvement of wildlife habitat, recreation or combinations of several objectives. Each of the options might call for different reforestation strategies.

Planning requires considerable lead time due to such varied reasons as the need for environmental analyses and the need to collect sufficient quantities of seed. Plans must also be flexible enough to allow for changes as conditions warrant. When disasters such as the eruption of Mount St. Helens or the Yellowstone fires occur, the planning process must be compressed in time. No matter what constraints there are, however planners must never forget the ecological requirements of the living organisms, the tree seedlings with which they are dealing.

Planning is becoming more complicated as time goes on: legal and other societal constraints are increasing; many more resources must be considered than in the past; reforestation is becoming more a science than an art; and now we have an additional management objective to consider -- mitigation of global climate change. Economic objectives and constraints must also be accounted for in the planning process.

In addition to strategic planning, a tactical plan must be written for each site. If a stand is to be harvested, the plan must include a complete analysis of the harvest method. From a silvicultural standpoint, this is based largely on the ecological requirement of the desired species and on whether the area is to be planted, seeded, or regenerated from natural seedfall. Site characteristics (e.g., elevation, soil type, steepness and slope aspect, and microclimate) are very important for both the logging and reforestation practices. Plans must also deal with seed source selection and seedling production; site preparation; planting; methods of protecting seedlings from heat, drought, and animal damage; plantation maintenance; and evaluation of results in such terms as stocking levels and growth. Timing of the various practices must also be planned so that they are properly coordinated.

REFORESTATION PRACTICES

Careful planning increases the chances for success, but conducting large-scale reforestation programs is nevertheless challenging. The sections below describe the main steps in the process.

Sources and Handling of Seed

Selection, production, collection, and storage of seed are other stops in the reforestation process that must be considered long before planting time. Foresters must use species and genetic sources that are well adapted to the sites on which they are to be planted. Research and testing of new species or seed sources, done properly, is a long-term proposition (Zobel *et al.*, 1987).

Managers should always resist using untried species or seed sources--even when disasters cause sudden, unplanned, and extensive deforestation of land that must be rehabilitated quickly. Plantations composed of poorly adapted species or seed sources have survived and grown for a few years, but many of them deteriorate long before they mature (Walstad, this volume). They also pose the risk of introducing more genetically undesirable material by pollinating native trees and by establishing natural regeneration from poorly adapted parents (Ching and Lavender 1978).

These ecological considerations on use of species and seed sources introduce further operational complications. Sub-programs must be developed to collect, test and store sufficient quantities of proper and viable seed to meet the needs of production nurseries (Stein *et al.*, 1974). Since some major tree species such as Douglas-fir (*Psuedotsuga menziesii* ((Mirb.) Franco) produce good seed crops irregularly (Owston and Stein 1974), it can take a number of years and sophisticated storage facilities to accumulate and maintain sufficient seed stocks for large programs.

Furthermore, seed-source integrity must be maintained by carefully labeling and tracking seedlots from the time cones are collected until the seedlings are planted. A seed and seedling certification program should be strictly adhered to, and plantation records that include seed source identification should be maintained.

The Siuslaw National Forest collects all of its Douglas-fir and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) seed from grafted seed orchards developed over a number of years. Seeds of other species are gathered from parent trees in the forest that have been carefully selected for favorable growth and form characteristics. These are clearly marked and mapped for long-term use.

Seedling Production

The inability to irrigate plantations, vegetative competition, temperature extremes and damage from animals make it imperative to plant healthy, vigorous nursery stock. Forest nursery practice is a complex, intensive "farming" business. A balance must be struck between production of large, vigorous stock and conditioning that stock to withstand the rigors of planting on harsh sites with little follow-up care. Insects, diseases, and weather extremes are constant threats. Considerable research, engineering development and operational advancements have been invested in nursery practices in the past 20 years. Seedlings now being produced are much better able to withstand environmental pressures than those grown in the past, and improvements are continuing (Duryea and Landis 1984).

Most of the tree seedlings used in the western United States are grown as bareroot stock for one to three years in outdoor nursery beds. The seedlings are dug from the ground during the dormant season, and protected from drying and overheating until planted. Some seedlings, particularly in north-temperate and boreal regions, are produced in small containers in greenhouses or similar structures that modify the environment to allow production of plantable seedlings in one growing season (Tinus and McDonald, 1979). These seedlings are usually pulled from their containers and planted with a plug of potting mixture around their roots. In the tropics, large containers are often used; the seedlings grow rapidly and need the protection of a container and root ball because they don't have a true dormant period that would allow handling them as bareroot stock.

The Siuslaw National Forest uses mostly two-year-old seedlings grown in outdoor beds. To promote good communication between the nursery managers and land managers, silviculturists visit the nurseries several times a year. The Forest pioneered the practice of having a representative present at the nurseries during the times their seedlings are being lifted from the ground to ensure that moisture stress in the stock is at an acceptably low level and that proper grading, packing and storage procedures are followed. Improper treatment in any of the steps could result in high seedling mortality. Production of high-quality nursery stock in large quantities will be one of the major challenges of greatly enlarged reforestation programs. Capacities of current tree nurseries cannot come close to meeting the needs of the greatly enlarged programs that would be necessary to help mitigate climate change (Walstad, this volume). Owners and manager of private nurseries now growing ornamental stock would have to learn how to produce seedlings conditioned to survive and grow on remote forest sites with much less follow-up attention than most ornamentals receive. Developing new nurseries for large programs requires careful site selection, considerable financial investment, and several years to construct (Morby, 1984). If reforestation programs do expand dramatically, we would anticipate an influx into the nursery industry of untrained entrepreneurs hoping to make money quickly with little investment. This happened in the Pacific Northwest during the nineteen-seventies when seedling needs expanded and container seedlings came into use. Temptations to use poor stock from these types of nurseries would have to be resisted.

Site Preparation

Preparation of planting sites is often necessary. The purposes are to reduce unwanted vegetation that would compete with the planted trees, reduce debris from harvesting that physically hinders planting, and create microsites favorable for seedling survival. On steep terrain, common in the Douglas-fir regions, use of controlled burning and/or herbicides has been the general practice, but recent concerns about possible adverse environmental or human health impacts of burning and herbicide use has resulted in both legally mandated and voluntary efforts to reduce or eliminate their use. This has caused a shift to preparing sites by mechanical or manual methods, which have their own sets of operational needs and coordination requirements. On the Siuslaw National Forest, current emphasis is to use the logging operation as the major site preparation activity. Planting is now done without burning on 45 percent of the area. Ten years ago, only ten percent of the area was planted without burning.

Careful integration of practices is necessary. For example, the method of site preparation will affect the population level of animals that could potentially damage planted seedlings. If a site is burned, seedling-damaging rodents would be reduced in number but large browsing animals may find the open area attractive because of the easy access. If a site is left unburned, large animals might be hindered in reaching the seedlings but rodent populations may be high enough to jeopardize the success of the planting. Thus, the size of seedlings planted and protection treatments applied should be coordinated with the type of site preparation conducted.

Any large-scale reforestation effort is bound to require substantial site preparation efforts. Much of this would probably have to be accomplished by mechanical or manual means, because relatively inexpensive use of chemicals and burning are becoming less socially and environmentally acceptable.

Handling and Planting

Organizations operating large-scale reforestation programs pay close attention to the biological needs of the seedlings. They are lifted from seedbeds when they are most resistant to stress, and they are planted when soil is moist enough to allow establishment of root systems. Complexity is increased by the need for coordinated timing of the steps. For example, seedlings should be ready for planting soon after the site is prepared. Delay of planting allows development of potentially competing vegetation or damaging rodent populations. If seedlings are ready for planting before the site is available, seedling quality may deteriorate if lifting is delayed or if seedlings are stored too long.

Handling between lifting and planting has become highly sophisticated in many places. Nurseries have used refrigerated storage for some years, and it is now common to freeze seedlings for long-term storage. It is also common to have refrigerated storage at field offices such as ranger stations. Seedlings may even be transported to planting sites under refrigeration and kept there prior to planting. If refrigeration is not available, the seedlings are usually kept in insulated trucks or under reflective "space" blankets until given to planters. The planters carry the seedlings in waterproof bags that keep the root systems moist until planting. Each of these steps introduces further equipment and coordination needs.

On relatively flat ground, machine-assisted planting gives rapid and fairly uniform results. Nevertheless, machine planting cannot be used in much of the western United States. The steep, rough terrain makes it necessary for individuals to carry seedlings in shoulder bags and plant them with hand tools such as shovels, spades or special planting hoes. Crews are trained to select good planting spots and to plant them properly. It is common for on-site inspectors to dig up sample seedlings to make sure planting quality is maintained. On the Siuslaw National Forest, virtually all planting is done by contractors according to strict specifications.

Almost all organizations now have standards of acceptable soil moisture and weather conditions. Temperature, humidity and wind speed readings are taken periodically during planting. When conditions become too drying, planting is suspended for the day. This results in additional operational complexity because schedules for seedling deliveries, crew locations and duration of contracts can be seriously disrupted.

Planting rows of the same species at close spacing is certainly the most efficient operational technique. Social opposition to this sort of plantation forestry is growing in many parts of the world, however; single-species plantations also tend to be more susceptible to pests (Walstad, this volume). Conducting large-scale reforestation so that it gives a natural appearance or to reduce the potential for pest problems (mixed species and/or non-uniform spacing) is technically feasible. It adds to the operational complexity, however because it requires more careful planning and more on-the-ground supervision if it is to be successful.

Protective Treatments and Plantation Maintenance

High-quality nursery stock, planted well and at the right time, can significantly reduce the need for expensive treatments to retard competing vegetation and discourage animal damage; i.e., vigorous seedlings are less apt to be overtopped by competitors and can grow beyond the size where they are most susceptible to animal damage sooner than mediocre stock. Once planted, however, seedlings receive only infrequent attention. Thus, precautions are often taken at planting to better ensure survival and good early growth.

Treatments may include shading stems near the groundline with cardboard or plastic material on hot, dry, southerly exposure; mulching or scalping away competing vegetation to conserve soil moisture; and protecting from animal damage by enclosing the seedlings in plastic-mesh tubes.

Follow-up treatment is often necessary to keep competing vegetation from seriously retarding seedling growth or even taking over the site. Treatment is done by mechanical, manual, or chemical means depending upon such factors as site conditions, legal or environmental constraints, and the management objectives. The treatments may be applied in a broadcast manner over a site or around individual seedlings. Several applications may be necessary before a plantation becomes fully established. These require reliable crews and close inspection, because the potential of damaging the seedlings in the process is high.

Surveys of survival and growth are also part of the reforestation process. Examinations are used to determine how well management objectives are being met and what subsequent treatments may be necessary to ensure plantation establishment. They also provide valuable feedback for planning future projects. These surveys must involve statistically sound sampling schemes, because sheer numbers make complete surveys prohibitive (Stein 1984).

On the Siuslaw National Forest, the goal is to have 95 percent seedling survival one growing season after planting and to require replanting on no more than five percent of the area planted. In the past five years, the replant rate has ranged from 1.4 percent to 9.4 percent; the five percent goal was reached in three of those years. Other areas have different problems (e.g., drought rather than overtopping by noncrop vegetation) that require different practices. However, the experience on the Siuslaw show that well-planned and well-conducted programs can be highly successful--the principles should apply widely.

Timber Stand Improvement

Following establishment, new stands may be precommercially thinned to keep them growing vigorously and to select for the fastest-growing well-distributed trees. Thus, this is often considered as the last step in the reforestation process. Approximately 70 percent of the young plantations on the Siuslaw National Forest are precommercially thinned--usually between the ages of 10 to 12 years. A second thinning may follow at about age 35 and will commonly produce a marketable tree as well as help keep the stand growing vigorously. On sites where timber production is the main objective, final harvest on the Siuslaw occurs between 60 to 80 years of age, and the reforestation process begins anew.

REFORESTATION COSTS

Reforestation can require substantial econ-

Table I. AN EXAMPLE OF REFORESTATION COSTS: 1989 COSTS PER HECTARE REFORESTED ON THE SIUSLAW NATIONAL FOREST IN WESTERN OREGON[1].

Reforstn. Component	Cost/ HA	Area Treated	Average Cost/HA
Surveys (pre- & post-plant)	$ 22	100%	$ 22
Site prep.[2]			
Hand-slash	370	20%	74
Brdcst.burn	618	55%	340
Nsy.Stock (400 sdlgs./ac.)	148	100%	148
Planting (incl admin.costs)	425	100%	425
Animal damage control	408	80%	326
Release	309	60%	185
TOTAL	$2300[3]		$1520

[1] *These costs are an example and are for a specific location, organization and yr. They should not be construed as typical of all organizations or all situations--even within western Oregon.*

[2] *Costs of burning are sometimes charged wholly or partially against reducing the hazard of wildfire. The full costs are included here because of the frequent necessity of site prep. to obtain successful reforestation.*

[3] *This total cost represents the maximum cost for acres on which all treatments are applied and charged against reforestation.*

omic investment. For example, the Siuslaw National Forest program cost an average of $1,520 per hectare ($615 per ac.) in 1989 (Table I). For sites on which all possible treatments were applied, the cost was $2,300 per hectare ($930 per acre). The cost of nursery stock and planting combined--the items usually considered to be the major reforestation costs by those not familiar with the complexity of the process--constituted only 38 percent of the average and only about 25 percent of the maximum per hectare (acre) costs. The point again is that there is more to reforestation than planting trees.

The Siuslaw comprises some of the most productive forest land in the world, but reforestation costs are high, regardless. Even in areas where costs are substantially lower, economics must be carefully considered before launching into large-scale programs.

Reforestation economics, of course, involve much more than summing initial costs. Willis and Affleck (1990) and Tunner (1982) describe methods of evaluating alternatives from economic perspectives.

SCIENTIFIC ADVANCEMENTS

Reforestation technology is becoming less art and more science through time. Research by federal, university and private-industry scientists has, for example, resulted in greater knowledge of how tree seedlings react to environmental stresses and in development of new nursery systems (Tinus and Owston 1984). Scientists are currently striving to learn how to produce seedlings specifically tailored by size and condition to the types of sites on which they are to be planted. Additional attention is being paid to producing uniform nursery stock (Tinus 1989) and to improving the quality control in forest tree nurseries (Owston *et al.*, 1990). Instruments and procedures for testing physiological quality of seedlings have been devised and are becoming widely used; root growth potential (Ritchie, 1985) and cold hardiness (Glerum, 1985) are two of the most common tests.

These efforts have good potential for improving the performance of planted seedlings, but they also introduce further complexity to reforestation programs. The new technology requires additional expertise, equipment, more careful monitoring and closer coordination of activities. Outcomes of tests may also result in having to change operational plans on short notice; e.g., a lot of seedlings determined to be poorly conditioned may have to be held longer in a nursery or given additional protective treatment after planting.

Some level of testing or research should be another important part of any on-going reforestation program. This can range from simple trials installed out of curiosity to full-fledged research programs for long-term support on large programs.

SUMMARY

Successful large-scale reforestation programs are attainable, but they are neither simple nor inexpensive to conduct. Reforestation requires commitment to planning and action by a large number of people with an array of different skills. If deforested areas are not reforested promptly, the growth of competing vegetation and build-up of animal populations significantly increase the difficulty and expense of the process. Breakdown at any one point can often doom plantations to failure at a higher cost of dollars and time.

Success must be measured in terms of established plantations--not the total area or numbers of trees planted. This requires an established infrastructure, both strategic and tactical planning, attention to timing and careful implementation of the various steps, and follow-up care and evaluation. The steps between planning and evaluation may include harvesting, seed collection, seedling production, site preparation, seedling handling, planting and post-planting protection treatments to reduce vegetative competition, animal damage, and temperature extremes.

Another of the keys to success is having professionally-trained decision makers involved with on-the-ground observations and prescriptions on each planting site. As more trees are planted on more land, the commitment to site-specific treatment must continue. Attention should also be paid to emerging technologies and research information that can make the task more efficient and successful.

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FEASIBILITY OF LARGE-SCALE REFORESTATION PROJECTS FOR MITIGATING ATMOSPHERIC CO_2 -- ECOLOGICAL CONSIDERATIONS

John D. Walstad

Abstract

Prospects for establishing and tending new forest plantations on a large scale to help mitigate CO_2 buildup are discussed with respect to suitable land area available, technical know-how, operational experience, ecological factors, vulnerability to pests, and socio-economic considerations. The analysis indicates that most of the enormous land area required will necessarily come from marginal and nonforest sites, including some agricultural land. Because such lands are not naturally conducive to growing trees, extraordinary measures will be required to establish, protect and sustain artificial plantations. Nevertheless, the technologies and information exist to install and manage plantations on a large scale provided sufficient funds, expertise and willpower are available. Considerable planning and analysis should be done before initiating such ventures in order to minimize the inherent risks and to maximize the potential for success.

INTRODUCTION

This paper deals with ecological considerations in establishing large-scale reforestation projects to help mitigate the buildup of CO_2 in the atmosphere. Because of the broad connotation of the term "ecological considerations," it is necessary to describe what will and will not be covered. First, three questions which will *not* be answered to any great extent.

1) Can sufficient carbon be sequestered in artificially established plantations to have any appreciable effect on the CO_2 concentration of the atmosphere? As a partial answer to this question, Sedjo (1989 *a, b*) calculated that a minimum of 1.15 billion additional acres (0.47 billion hectares) of plantation would be needed to stabilize atmospheric CO_2 concentrations at current levels. This is an area equivalent to approximately 1.5 times the total forested area of the United States, or about 75 percent of the nonforested land area. And it represents a scale five times greater than the current 230 million acres (93 million hectares) already under plantation culture throughout the world.

2) Are the labor, capital, planting stock, equipment and energy requirements necessary to establish plantations at a scale substantially greater than what is already being done available? Again, Sedjo (1989 *a, b*) estimated that at least \$372 billion would be needed to establish plantations on the scale needed to mitigate CO_2 buildup. This is almost 10 percent of the annual GNP for the U.S. Additional funds would be required for plantation maintenance and protection.

Furthermore, the planting of large acreages will require substantial numbers of seedlings. This in turn will require the construction of new nurseries because current nurseries (at least in Oregon and Washington) are already producing at 70 percent or more of capacity (USDA Forest Service, 1990).

3) What long-term socio-economic and environmental changes (both positive and negative) might be associated with vast changes in the landscape from its natural or existing state to one occupied by plantation forests? Many of these changes are too difficult to forecast given our limited understanding of the complex array of interactions among cultural, economic and ecological forces, particularly at regional

and global scales.

In short, there are some very sobering problems of scale associated with any substantive efforts to mitigate atmospheric CO_2 buildup through plantation forestry. But the formidable magnitude of such a task should not deter us from a rational examination of its prospects. A lot is potentially at stake, and extraordinary measures may be needed to mitigate impending changes in global climate and local environmental conditions. Thus, this paper will address the following topics:

1) Opportunities for establishing plantation forests on sites where they currently do not exist.

2) Pest problems, environmental constraints, and periodic disturbances such as fire, frost and drought that can affect the success of plantations.

3) Potential problems associated with establishing so-called "monocultures" on a large scale for extended periods of time over several rotations.

OPPORTUNITIES FOR PLANTATION FORESTRY

The opportunities for establishing artificial plantations fall into three distinct categories:

1) Productive forest land not currently covered by trees;

2) Marginal forest land that is understocked or nonstocked;

3) Nonforest land that could support trees if managed accordingly.

Productive Forest Land

The opportunities for *additional* large-scale reforestation projects on productive forest land are somewhat limited because reforestation is already being done to a considerable extent. In the U.S., for example, almost 3.5 million acres (1.4 million ha.) are regenerated each year, requiring over 2.3 billion seedlings (USDA Forest Service, 1989). Thus, sizeable reforestation efforts are already underway in the U.S. and other developed countries. It is likely that such efforts will continue where the inherent productivity of the site justifies economic investment in intensive silviculture (*cf.* Farnum, *et al.*, 1983).

Some less-developed countries also have aggressive reforestation programs. Chile, for example, has been establishing radiata pine (*Pinus radiata*)[1] plantations at a rate of almost 200,000 (81,000 ha.) acres per year for the last 10 years, endowing it with the largest radiata pine holdings (2.8 million acres, or 1.1 million ha.) in the world (Jelvez, *et al.*, 1990).

Reforestation of productive forest land not only makes good economic and ecological sense, it is often required by law. For example, several of the states and provinces in the U.S. and Canada now have forest practices acts stipulating that forest lands be promptly restocked to prescribed levels after harvesting. In addition, national legislation in both countries requires that federal agencies ensure the reforestation of lands they are responsible for managing. The only exceptions are wilderness and national parks, where natural events are allowed to run their course with minimal interference by managers.

Thus, the incremental opportunities for reforestation of productive forest lands are confined to special situations:

1) Areas damaged by fire, pests, storms and pollution;

2) Areas occupied by brush and low-value or noncommercial species;

3) Deforested areas resulting from short-term agricultural and domestic uses (principally in the tropics and developing countries).

<u>Restoration of Damaged Areas</u>. Most areas in North America damaged by fire, pests, storms and other agents are promptly reforested. Programs of planting and direct seeding usually follow such catastrophes. For example, several thousand acres of burned-over land

have already been planted since the fall, 1987, wildfires in southwestern Oregon. Efforts are underway to rehabilitate South Carolina's coastal forests following the destruction caused by Hurricane Hugo on September 22, 1989. Even 42 percent (63,000 acres, or 25.5 ha.) of the devastated blast zone surrounding Mount St. Helens has been planted (Winjum *et al.*, 1986). Much of the remainder has been set aside as a national monument.

Conversion of Brushfields and Low-Value Stands. Rehabilitation of brushfields and thickets previously occupied by commercial tree species is also underway. The FIR (Forestry Intensified Research) Program in southwest Oregon has shown the biological feasibility of restoring 128,000 acres (52,000 ha.) to the timber base in southwestern Oregon (Walstad and Tesch, 1989), much of it dominated by sclerophyll shrubs and hardwoods. A program in British Columbia known as the Forest Resource Development Agreement (FRDA) is directed at reclaiming over 1.8 million acres (.73 million ha.) of nonstocked good- and medium-site land in that province (Canada-British Columbia Forest Resources Development Agreement, 1986). Similar efforts are underway in other regions of the continental U.S. and Canada.

Timber type conversion from hardwoods to conifers is also underway on selected sites in the South, the Lake States and the coastal zone of the Pacific Northwest. Whether such conversion will lead to any net gains in CO_2 balance is questionable, however. Many of these sites might be better managed for hardwood production, perhaps in perpetuity.

Type conversion is also underway in the tropics, principally in areas undergoing development. Perhaps the most noteworthy example is the Jari project in the northeastern-most region of Amazonia (Hornick, *et al.*, 1984). Originally part of a grandiose scheme by shipping magnate Daniel K. Ludwig to export high-grade pulp to international markets, over 270,000 acres (109,-000 ha.) of gmelina, eucalyptus and Caribbean pine have been established since 1968.

Another ambitious effort is underway near Aracruz, on the eastern coast of Brazil (Brandao, 1984). Inititated in 1967, the Aracruz project (Aracruz Florestal) is already producing enough high-grade eucalyptus fiber to run a large pulp mill.

Targeting for high-yield rotations of 5-9 years, the aforementioned operations hold great promise for raising the standard of living of native Brazilians while minimizing the area of natural forest converted to other uses.

Reclamation of Deforested Areas. Opportunities to restore degraded forest areas are principally located in the developing countries. Centuries of forest exploitation in Asia, the Middle East and parts of southern Europe have left a legacy of depauperate stands and wasteland (e.g., Harou *et al.*, 1985).

More recently, clearing of the tropical forest for agricultural and development purposes in Africa and South America has threatened the ecological stability of these regions. Estimates of the rate of tropical deforestation range from 17.5 to 50 million acres (7.1 to 20.2 million ha.) per year (Sedjo and Clawson, 1983), with the current total of degraded forest land estimated at about 500 million acres (202 million hectares) (Grainger, 1988). Clearly, substantial opportunities exist to rehabilitate degraded areas through both natural regeneration and plantation forestry. Fortunately, there have been some remarkable successes such as in the state of Minas Gerais in eastern Brazil, where 250,000 acres (202 million ha.) per year of degraded scrub brushland are being planted to eucalyptus and pine (B. J. Zobel, 1990, pers. comm.).

Marginal Forest Lands

The greatest opportunity to expand plantation forestry in the U.S. is on the marginal forest

Table II. MARGINAL FOREST LAND IN THE U.S.[1]

Region	Natl. For.	Other Public	Indus-try	Private	Total
		(thousand acres)*			
East	635	2,536	237	6,283	9,691
West	33120	112,110	476	47,741	193,446
Total	33755	114,646	713	54,024	203,137

[1] Data from Waddell et al. (1989), descr. as "other forest land."

*acres x 0.405 = ha.

lands adjacent to productive forests. From a silvicultural perspective, marginal lands are those where tree growth tends to be relatively poor (Wessels, 1984). High-elevation sites and those along the fringe of forested regions are two examples. The most recent estimates for the U.S. indicate that over 200 million acres (81 million ha.) are in this category (Waddell *et al.,* 1989). Most of the marginal land is located in the western U.S., and about 75 percent of it is in the public domain (Table II).

In Canada, the opportunity to expand forest acreage is more problematic because most unproductive land adjacent to forests consists of muskeg, rock barrens, marshes, etc., that is unsuitable for producing merchantable trees (Bonner, 1985). Nevertheless, there are significant opportunities to enhance the productivity of "not satisfactorily restocked" (NSR) forest land. Indeed, the acreage in this category amounts to over 50 million acres (81 million ha.), or about 10 percent of the commercial forest land base of Canada (Honer and Bickerstaff, 1985). As a consequence, federal, provincial and industrial constituents in Canada have greatly accelerated the level of silvicultural attention being given to NSR lands in recent years (*cf.*, Reed, 1986; Kuhnke, 1989).

Poor-Quality Sites. Certain tree species are adapted to existence on poor-quality sites, frequently characterized by thin, rocky soils and harsh climatic conditions. Nevertheless, a variety of silvicultural techniques can be used to increase the carrying capacity of these lands. For example, the use of vigorous, well-adapted planting stock, coupled with adequate weed control for the first few years, will permit conifers to thrive on hot, droughty foothills of southwestern Oregon previously dominated by brush (Helgerson *et al.,* 1990).

High-Elevation Sites. The regeneration of high-elevation sites poses a more difficult challenge because of the short growing season and extremely cold conditions. Where harvesting is appropriate, more complicated systems of management than simple clearing and planting may be required to successfully regenerate these areas in many instances (e.g., Atzet *et al.*, 1984). Carefully planned partial cuts designed to foster and protect periodic natural regeneration may be the most feasible approach to take in managing these sites. Subalpine forests ranging from the Cascades in Oregon and Washington to the Alps in Europe often are amenable to this form of regeneration.

Nonforest Land

Afforestation of nonforest land constitutes the final category of opportunities for plantation forestry. Indeed, if Sedjo's (1989 *a, b*) estimates are correct, a great deal of nonforest area will be needed if new plantations are to have a significant effect on CO_2 balance. It will include prairie and savannah, agricultural cropland and arid wasteland.

Fortunately, the literature abounds with examples of successful attempts to establish forests in such areas previously occupied by grass, shrubs, agricultural crops and other nonforest vegetation. Plantings have even been established in urban and suburban settings to provide recreational opportunities and to improve aesthetic conditions (e.g., Cohen, 1985).

Efforts to establish forest plantations in nonforest areas are often risky ventures because they represent unnatural situations. Maladaptation of planting stock and premature exhaustion of site resources, such as soil moisture, are problems frequently encountered in such afforestation efforts. Nevertheless, there are enough successful experiences both here and abroad to make this a feasible option in at least some areas. Recent advances in clonal propagation may facilitate the selection and deployment of stock adapted to such sites (Libby and Rauter, 1984).

Prairie and Savannah. A classic example of afforestation in the U.S. is the Nebraska National Forest, established in the sand hills of central and western Nebraska in 1902 (Hunt, 1965 *a, b*). About 30,000 acres (12,000 ha.) of plantation now exist in an area previously consisting of prairie grassland.

Another example of successful afforestation involves a project by AMCEL (Amapa Florestal e Celulose S.A.) in northern Brazil (McDonald and Fernandes, 1984). Here, close to 200,000 acres (81,000 ha.) of Caribbean pine have been established on grass savannahs in an effort designed to produce chips for export to Japan, Europe and the U.S. Considered the world's largest tropical pine plantation, it is scheduled for harvest after just 12 years from planting. Almost one million acres (0.4 million ha.) of pine have also been established in the Orinoco region of Venezuela (B. J. Zobel, pers. comm.).

In northern Europe, sand drift was a major problem in the 17th and 18th centuries because of overgrazing by livestock. This led to the establishment of large plantations as a means of stabilizing the soils in Denmark, Holland, northern Germany and Great Britain (N. Koch, 1990, pers. comm.).

Cropland. More recently, attempts have been made to establish short-rotation intensive culture (SRIC) hardwood plantations on nonforest land (particularly marginal-to-good agricultural land) in the western, midwestern and southern U.S. as a means of providing biomass for conversion to pulp, gasoline and gaseous fuels (Ranney, *et al.*, 1987). Coppice plantations of species such as tulip poplar, silver maple, sweetgum, American sycamore, black locust, alder, willow, eucalyptus and poplar have been established throughout the U.S. since 1978. Similar efforts are underway in Europe and elsewhere (N. Koch, 1990, pers. comm.).

Arid Wasteland. Even exceedingly arid regions such as the Middle East and northern Africa are amenable to afforestation if proper cultural steps are taken such as irrigation, fertilization, weed control, pest control and selection of appropriate species and stock type (e.g., Cohen, 1985; Harou *et al.*, 1985). Israel, for example, has increased its forested area from 100,000 acres (40,000 ha.) in the early 1950s to almost 300,000 acres (121,000 ha.) today (Cohen, 1985); and this has been achieved in a region receiving less than 10 inches (25.4 cm.) of rain per year in many places. These forests now provide a steady stream of products such as particleboard, fuel (including charcoal and hogfuel), lumber, stakes and fenceposts, as well as greenspace for recreation and aesthetics.

To summarize this section on opportunities for plantation forestry, viable options exist to expand ongoing efforts in three general areas:

1) Restoration of recently damaged or deforested areas;

2) Conversion of marginal land adjacent to productive forest land;

3) Afforestation of nonforest land presently covered by other vegetation. (Note: this category includes reforestation of lands that have been deforested for many decades or even centuries.)

FACTORS AFFECTING PLANTATION FORESTRY

This section will address some of the factors that should be considered in evaluating the feasibility of successfully establishing and managing plantations on a large scale with respect to the three categories of opportunity:

1. recently deforested areas;
2. marginal forest lands;
3. nonforest lands.

The discussion is divided into three parts:

a. plantation establishment,
b. plantation maintenance,
c. multi-rotation considerations.

There are positive and negative aspects associated with all three phases.

Plantation Establishment

With respect to plantation establishment, a positive aspect is that we know a lot about it, particularly in temperate forest regions. We understand the critical factors affecting seedling survival and growth. We have the technical knowledge to manipulate these factors to assure successful establishment of seedlings. And we have lots of experience in doing it on an operational scale.

For example, we know that it is necessary to carefully match species, provenance and stock type to the site to be reforested (e.g., Zobel, *et al.,* 1987). We also know that the seedlings must be cultured and handled properly during the nursery and outplanting phases (e.g., DeYoe, 1986; Ritchie, 1989). Suitable mycorrhizal fungi must be present on the seedlings or on the site to establish the critical symbiotic relationship linking the seedlings' roots to the soil microenvironment (e.g., Iyer *et al.*, 1980; Perry *et al.*, 1987). We know that site preparation and vegetation management are needed to facilitate seedling establishment and rapid growth (e.g., Walstad and Kuch, 1987). And we know that protection from excessive heat loads, herbivores and diseases are sometimes needed to maintain adequate survival and growth of seedlings (e.g., Helgerson *et al.*, 1991).

As mentioned earlier, this knowledge is sufficient to support a reforestation enterprise that encompasses almost 3.5 million acres each year in the U.S. alone. Operational programs ranging from the Civilian Conservation Corp plantations and shelterbelts[2] of the 1930s to the Soil Bank reclamation efforts[3] of the 1950s to Weyerhaeuser Company's High Yield Forestry ventures[4] of the 1960s and beyond, all attest to the success of plantation forestry. Many of the short-rotation tropical plantations are in their third generation. In the southern U.S. we are presently harvesting the "Third Forest," and planting the fourth. And in Europe, several generations of forests have been harvested and replanted. In short, we know how to plant trees and manage plantations.

The problem is that most of our knowledge and experience are limited to productive forest sites. Except for a few special cases like the Nebraska National Forest and AMCEL operations described earlier, most of our interest and activity have been directed at commercial timberland.[5] Consequently, we often lack information about what it will take to establish seedlings on marginal or nonforest land. Indeed, we may even lack species or provenances capable of surviving the rigors of outplanting in many atypical environments.

Selection of well-adapted genetic stock will be particularly important. We probably have more latitude in moving species or provenances of species across broad geographies if the topography is gentle than if it is mountainous (Silen, 1989). For example, Weyerhaeuser Company has had considerable success in culturing plantations of loblolly pine from North Carolina sources in Arkansas and Oklahoma (Lambeth *et al.*, 1984). Indeed, the provenance trials they have conducted in the mid-South region over the past five to twenty-five years indicate that the North Carolina sources of loblolly pine routinely outperform local stock, even under conditions of record-breaking cold weather (e.g., December, 1983) and drought (e.g., summer, 1980).

In highly mountainous regions, however, the flexibility to move stock is more limited (Silen, 1989). Because each 400-foot (122 m.) rise in elevation is equivalent to about one degree of latitude movement northward, severe problems can be encountered in trying to move stock from one elevational zone to another. According to Silen, the principal limitation appears to be the length of the growing season (or freeze-free period), and he cautions against moving stock where there is more than a 10-day differential (400 feet in elevation or 1° in latitude) from where it originated.

If care is taken to match species or provenance to environmental conditions, then considerable latitude exists to establish trees in exotic environments. Hermann (1987) describes the remarkable success of North American Douglas-fir, grand fir, noble fir, Sitka spruce and lodgepole pine in Europe. For example, plantations of Douglas-fir exist in 24 European countries and have become a significant component of the forest landscape during the past century. Numerous additional examples are given in the text by Zobel *et al.* (1987).

Sometimes the performance of a species outside its natural range is better than within. Such is the case for Monterey (radiata) pine, which has done extremely well in places as far away as Australia, New Zealand and Chile. Within portions of its native range in coastal California, it is a relatively short, branchy tree, but in more southerly latitudes it grows tall and straight. Consequently, it has become a major forest crop in those countries.

The success of exotics is more the exception than the rule, however (Zobel *et al.*, 1987). Silen (1989) cites numerous instances where local species and provenances have outperformed introduced stock. He also points out the importance of long-term testing of exotics before large-scale adoption. At the Wind River Arboretum in southwestern Washington, for example, it took 40 years before a Colorado variety of Douglas-fir succumbed to the environment. Species from more southerly origins often grew vigorously for 20-40 years before being killed by the "Deep Freeze" of 1955.

Thus extreme caution should be exercised as we endeavor to move species or provenances beyond their natural range. Fortunately, foresters and geneticists are cognizant of such risks and have developed appropriate measures to deal with them (*cf.*, Zobel, *et al.*, 1987; Ledig, 1988). The seed zone maps for sugar pine developed by Campbell and Sugano (1987) are one example. The clinal design for Douglas-fir seed orchards advocated by Silen (1989) is another. It should be borne in mind, however, that we are venturing into the unknown as we stretch the sites on which trees will be planted beyond their natural range. Furthermore, the uncertainty of adverse climatic changes in the future further compounds the risk associated with plantation culture, particularly using exotic species.

Insects and disease can also interfere with plantation establishment, particularly in exotic or off-site situations. For example, Hodges and May (1972) describe a devastating root disease that colonized southern pines planted in Brazil, and Scriven *et al.* (1986) describe an infestation of longhorn borers introduced from Australia into eucalyptus plantings in southern California. Slow-growing, off-site ponderosa pine plantations in the western Sierra Nevada of northern California are considered more vulnerable to damage by the gouty pitch midge (Ferrell *et al.*, 1987).

Vegetation management in the form of site preparation and release from competition is a prerequisite to successful seedling establishment on almost all forest sites. Extraordinary levels of such weed control may be required to establish plantations on marginal and nonforest lands. We know this is true for the establishment of shelterbelts and short-rotation hardwood energy plantations on agricultural sites (Ranney *et al.*, 1987; Baer, 1989). It is also essential on areas dominated by shrubs and grasses (Walstad and Kuch, 1987).

Care in handling and planting of seedlings will be necessary (*cf.* DeYoe, 1986). And artificial inoculation with mycorrhizal fungi may be required (*cf.* Molina and Trappe, 1982; Perry *et al.*, 1987). This may be particularly important on marginal and nonforest sites, assuming mycorrhizal strains adapted to such sites can be found. Finally, the time required to secure successful establishment and full occupancy of the sites will depend on the inherent fertility of the site; marginal and low productivity sites will take longer to regenerate than productive forest sites.

All of these factors will make plantation establishment on marginal and nonforest sites expensive, perhaps prohibitively so. And if one factors in the fossil fuel energy required to do the job using conventional technology, the net impact on CO_2 balance may well be negative.

The task will not be much easier on the productive forest sites that have been damaged, mismanaged or otherwise degraded. The base of knowledge and biological resiliency associated with these areas makes reforestation a more probable success, however. Reclamation of the impoverished cotton farms in the southern U.S. by the natural and artificial reestablishment of loblolly and shortleaf pines is a classic example.

Plantation Maintenance

The encouraging aspect about plantation maintenance, like that for plantation establishment, is that we know how to do it. We understand the principles of thinning, fertilization, genetic selection and protection. We know how stands grow, and we can accurately forecast their development in many situations using sophisticated growth and yield models.

We also have had considerable experience managing stands for extended periods of time, approaching two-and-a-half centuries in the temperate forest regions of Europe (Zobel *et al.*, 1987). Indeed, the record of success is such that managed stands are the rule rather than the exception nowadays for many of the world's forests. In short, we know how to manage stands -- at least for timber production.

The problem is that we lack site-specific information for managing stands on marginal and nonforest sites. The principal stumbling block is the uncertainty associated with trying to grow a stand for long periods of time -- often several decades or more -- on sites where the species may not be sufficiently adapted. Once-in-30-year droughts or cold snaps have a habit of recurring every 30 years or so, and they can devastate a stand that previously had been doing quite well. The sudden topkill of mature eucalyptus trees growing on the hillsides of Berkeley, California, after a severe frost in December, 1972, is but one example of this kind of risk. Other examples are cited by Zobel *et al.* (1987) and Silen (1989).

We encountered a more subtle phenomenon during the course of the FIR Program in southwestern Oregon. A mixed plantation of Douglas-fir and ponderosa pine established on a droughty site performed quite well for the first seven years after planting. In the eighth year, however, the Douglas-fir began to die, whereas the pines continued to thrive. Upon examination, it was revealed that the roots of the pines had penetrated the saprolyte -- a fractured layer of bedrock with considerable water-holding capacity (Newton *et al.*, 1988). For some reason, the Douglas-fir roots failed to penetrate this layer and became vulnerable to drought stress by early summer as soil moisture in the upper profile was exhausted.

Other than selecting species or ecotypes naturally adapted to the rigors of adverse sites, not much can be done to overcome these environmental obstacles. Irrigation and frost protection generally are not feasible. Site preparation and fertilization are expensive.

And conventional breeding programs that primarily select for rapid growth rate at the expense of hardiness may exacerbate the problem (Silen, 1989).

Weed control will help for a time, but eventually the trees reach a size where they are competing with themselves more than with other vegetation. For example, control of manzanita extended the life of Douglas-fir in the situation described above in southwestern Oregon (Newton *et al.*, 1988). The Douglas-fir themselves, however, began to exhaust accessible soil moisture supplies by the eighth year.

Pests are also likely to be a serious problem in plantations established on marginal and nonforest sites (*cf.* Wessel, 1984; Zobel *et al.*, 1987). This is because the trees are often growing under stress, which increases their vulnerability to bark beetles, wood borers, root diseases and other pests (*cf.* Waring, 1985). In addition, the lack of vegetative diversity in such plantations often creates favorable conditions for a variety of herbivores ranging from pocket gophers to tipmoths and defoliators. If the planting stock is of foreign origin, there is the constant threat of introduced pests becoming a serious problem. This happened to radiata pine plantations in Brazil, East-Central Africa, New Zealand, and Zimbabwe when *Dothistroma* needle blight was inadvertently introduced (Zobel *et al.*, 1987).

Alternatively, relatively benign native organisms can suddenly become serious problems for exotic or off-site plantations. The destruction of eucalyptus plantations in the tropics by leaf-cutting ants is one example of this phenomenon (*cf.*, Hornick *et al.*, 1984; McDonald and Fernandez, 1984).

The issue of vulnerability of plantations (especially monocultures or clones of single species with limited genetic variability) to pest problems is a complicated one. There are numerous examples of relatively pest-free situations or situations where the pests have been easily controlled. Conversely, there are many instances where pests have virtually precluded plantation forestry or restricted its utility. Appendix A lists some of the kinds of pests likely to increase in importance under plantation forestry.

Conventional wisdom suggests that mixtures of diverse forest species are less vulnerable than pure stands (Johnson, 1976; Smith, 1990). This is because dramatic declines of multi-species forests rarely occur, whereas the sudden demise of a single species is quite common. Thus, the outbreak of virulent chestnut blight, introduced into the eastern U.S. in the early 20th century, virtually eradicated the chestnut tree for all intents and purposes, but hardly affected the overall long-term structure of eastern forests because of the presence of resistant species that filled the void. On the other hand, vast expanses of relatively pure pine stands in the southern and western U.S. have been killed by periodic epizootics of bark beetles, dramatically changing the landscape.

Nevertheless, there are cases where diverse, multi-species forests are vulnerable to pest outbreaks as well. One recent example involves the "omnivorous" gypsy moth, which has defoliated vast expanses of mixed deciduous forests in the eastern U.S.

There are also instances where relatively pure natural stands and exotic plantations have proven to be relatively pest-free. Natural monocultures of Sitka spruce growing in the fogbelt of the Pacific Northwest are one example. The sustained performance of exotic Douglas-fir plantations in Europe is yet another (Hermann, 1987). In most cases, however, it is just a matter of time before plantations, like any forest, become vulnerable to pests.

Finally, wildfire is a perpetual risk in plantations, even those established on productive forest sites. The risk is likely to be more acute, however, on marginal sites where drought is more frequent (e.g., McDonald and Fernandez, 1984; Cohen, 1985; Harou *et al.*, 1985). The problem is often exacerbated by the presence of highly flammable chaparral and grass species. The Nebraska National Forest, for example, suffered a devastating wildfire in May, 1965, that started in adjacent prairie during a lightning storm (Hunt, 1965*b*). One-third of the forest (11,000 acres) (4,450 ha.) was destroyed before the fire was extinguished.

Despite the aforementioned problems, the investments being made in plantation culture throughout the world suggest that the risks are manageable. The keys to success are maintaining a broad genetic base of the species to be planted, matching the adaptability of the stock to the site, maintaining soil fertility, controlling weeds and pests, periodically thinning the stand so the trees do not become stressed, and harvesting the stand before crop tree vigor begins to decline. Constant vigilance is required throughout the process to protect plantations from untimely losses.

Multiple-Rotation Considerations

Beginning once again on a positive note, we have had some notable successes with multiple rotations. As mentioned earlier, we are managing the third "rotation" of southern pines now and establishing the fourth (USDA Forest Service, 1988). Much of the historically cut-over and degraded countryside of central Europe was rehabilitated through "plantation forestry" in the 19th and 20th centuries, leading to a doubling and tripling of harvest levels (Plochmann, 1990). Long-term experience with rubber and oil palm plantations in the tropics and with Norway spruce in central Europe indicates that several generations of these species can be grown on the same site without loss of productivity, provided proper care is taken of the soil (Johnson, 1976; N.E. Koch, 1990, pers. comm.). Short-rotation (5-9 years) plantations in the tropics are entering their third and fourth cycles (Zobel *et al.*, 1987).

In short, plantation management designed for multiple rotations is at least a partial solution to a wood-hungry world with an ever-burgeoning population (Johnson, 1976; Ledig, 1988). Fortunately, there is little evidence to support claims that the production of multiple rotations of trees on forest sites cannot be sustained (Gessel, 1989). And if done in conjunction with agro-forestry schemes, prospects are bright for enhancing both agricultural and forest production.

The major concern with multi-rotation schemes is that marginal and nonforest sites may not be suitable for sustained production. First, relatively long periods of time will be required for the stands to reach commercial size due to the often poor quality of the sites. And the time could get longer if the "greenhouse effect" materializes as expected, making these sites even harsher.

Second, we do not have a very good understanding of the soil, nutrient and hydrologic relationships of these marginal and nonforest sites. In fact, we are just now beginning to address such questions about the long-term site productivity of our productive forest sites (e.g., Perry and Maghembe, 1989; Perry *et al.*, 1989). It may be that the marginal and nonforest sites will become impoverished after a relatively short period. Alternatively, the water table may be depleted, a phenomenon that occurred in fruit orchards in the Plains States in the 1930s.

Pest problems will likewise be serious factors during multiple rotations, particularly if the climate becomes harsher. Soil-inhabiting pathogens and parasites can be expected to become particularly troublesome on poor-quality sites (e.g., littleleaf disease, *annosus* root disease, nematodes), but endemic populations of insect pests like tipmoths, defoliators, aphids and reproduction weevils could also become serious problems (see Appendix A). For example, the build-up of pales weevils in freshly cut stumps of the previous pine forest posed a significant threat to newly planted seedlings in the southern U.S. until control methods were developed (Walstad, 1976).

For exotic plantations, the threat of introduced pests like rusts, blights, defoliators, and bark beetles will be a perpetual concern. Thus, the uncertainty of sustaining productivity through multiple rotations on marginal, nonforest and other sites is likely to be substantial. It will be difficult enough on conventional forest land.

SOCIO-ECONOMIC CONSIDERATIONS

One of the advantages of plantation forestry is that is provides a means of rapidly restoring some of the biological productivity of degraded areas. Soils are rejuvenated, hydrologic properties are restored, wildlife habitat is improved and overall ecosystem stability is enhanced.

Plantation forestry also provides an assortment of economic benefits. Wood and fiber products are the most obvious outputs. But such forests also provide a variety of recreational opportunities and other products and amenities. People travel long distances to camp and picnic in the pine and cedar groves of the Nebraska National Forest. Hunters and wildlife enthusiasts benefit from the improved habitat for game and nongame species. In many developing countries, such forests are the source of firewood, charcoal, building products and fodder for livestock. They also help reduce soil erosion and avalanche potential.

Thus, developed and developing countries alike are putting considerable emphasis on managed plantations as a means of raising their standard of living. The ability to efficiently produce wood and fiber products, while at the same time accommodating other forest and environmental values, has become an important feature of many national agendas.

The major economic dilemma with respect to plantation forests is that they are expensive to manage. As mentioned earlier, the energy and financial costs are likely to be considerable, yet many of the plantations may fail without intensive management. Plantations established on marginal and nonforest sites are particularly vulnerable.

Compounding the problem is the fact that relatively long rotations may be required to produce trees of merchantable size on marginal and nonforest sites. This is especially true for producing durable solid wood products -- the basic idea behind the reforestation venture as a means of mitigating atmospheric CO_2 buildup.[6] Yet the probability of being able to carry such plantations to maturity is low, given the impending increase in environmental stress caused by global warming and concomitant risks associated with pest outbreaks and wildfire. Even the current environment of conventional forest sites has proven too harsh for some stands and plantations carried beyond their prime. For example, Plochmann (1990) points out that about one-third of the total harvest from central European plantations comes from the unplanned salvage of trees damaged by storms, snow and insects. He advocates either shorter rotations or more diverse species mixtures if stable forests and harvests are to be achieved.

But even picking genetic stock adapted to specific sites or mixing the species used may not be sufficient, because the sites could become harsher over time if the "greenhouse effect" materializes. For example, Kimmins and Lavender (1987) discuss the implications of a warmer climate on the chilling requirements for species such as Douglas-fir. Without a cold period of sufficient intensity and duration in the winter, normal bud break does not occur the following spring. Reproductive processes such as flowering and seed maturation are also vulnerable to climatic changes.

Thus, if plantations are to be grown on such sites or under such conditions, they may need to be harvested prematurely. It may be difficult to manufacture solid wood products because of the small size and high proportion of juvenile wood that will constitute such harvests. And even if durable products can be manufactured, the large volumes involved could seriously disrupt world markets. Sedjo (1989*b*), for example, estimates the steady-state volume from carbon sequestering plantations to be about 2.5 million cunits[7], more than triple the volume of current industrial harvests. Such a flood of wood could lead to depressed prices and other adverse economic impacts.

Finally, some members of society may object to large-scale plantation forestry from an economic, esthetic or ecological perspective. Farmers and ranchers may not want their land preempted. For others, the uniform row-and-column configuration of conventional plantations may be less preferred than the more diverse mosaic of natural forests (e.g., Olwig, 1984). Such sentiments have led to the recent enactment of laws in the Federal Republic of Germany and elsewhere that actually discourage the establishment of "monotonous" monocultures (Plochmann, 1990). Instead, a more diverse, older aged, multipurpose forest mosaic is advocated that more closely approximates natural forests endemic to the region.

Perhaps the most notable case in this regard is the public outcry in the United Kingdom (primarily Scotland) against the establishment of Sitka spruce plantations on heathland. Even though the area was covered by trees in ancient times, some of the rural citizens have grown accustomed to the barren, windswept landscapes characteristic of heathland and do not want it changed -- at least not to dark, rectangular, impenetrable forests that disrupt the landscape. Thus, public sentiment can be a strong deterrent to plantation forestry in some circumstances. Carefully designed mosaics may be needed to blend plantations into the landscape.

CONCLUSIONS AND RECOMMENDATIONS

What conclusions can we draw concerning prospects for artificial reforestation efforts? First, large-scale reforestation projects are feasible. We have the technical knowledge to do it, and the world abounds with successful examples.

Second, the establishment and maintenance of plantations (including uniform monocultures) need not be an ecological problem. There are many instances where monocultures occur naturally and modern-day genetic selection, outplanting schemes and silviculture can be used to avoid the pitfalls of inbreeding, narrow genetic bases and maladaption.

Third, we can sustain timber productivity over several rotations through proper attention to soil stewardship, pest management, wildfire control, species diversity and other ecological considerations.

The dilemma is that each of the aforementioned capabilities becomes progressively more difficult and expensive as we move from productive forest sites to marginal forest and nonforest sites. Inherent productivity declines, environmental stresses become greater, pest problems increase and costs rise dramatically. Yet, because most of the productive forest sites are already under some form of management -- at least in the developed countries -- most of the incremental area amenable to large-scale reforestation projects is going to be on marginal and nonforest lands, including some agricultural sites. Although there may be socio-economic and environmental benefits associated with such ventures, there may also be serious adverse consequences.

Therefore, a great deal of thought and planning, especially land-use planning, should go into the selection of such sites before any large-scale reforestation programs are attempted. And the plantations will need to be carefully tended and protected. Otherwise, they are likely to fail, exacerbating the CO_2 balance rather than ameliorating it.

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NOTES

[1]Scientific names of tree species may be found in the General Appendix to this publication.

[2]Between 1935 and 1943, more than 200 million trees and shrubs were planted in 18,600 miles of windbreaks from North Dakota to Texas as part of the Prairie States Reforestation Project (Baer 1989).

[3]The original U.S. Conservation Reserve Program, authorized in Title IV of the Agricultural Act of 1956 and popularly known as the Soil Bank Program, led to the planting of about 1.9 million acres of highly erodible cropland in the South from 1956-1960. A comparable program was authorized in the Food Security Act of 1985 and was aimed at planting trees on some 5 million acres of marginal farmland between 1986 and 1990 (Cubbage and Gunter 1987).

[4]Since its High Yield Forestry program was initiated in 1966, Weyerhaeuser Company has treated over 2.8 million acres in the U.S. (Weyerhaeuser Company 1990).

[5]Commercial timberland is customarily defined as land capable of growing more than 20 cubic feet of wood per acre per year (Waddell *et al.* 1989).

[6]Although forest plantations established for pulp and fuel production may bolster domestic supplies of raw material, they are unlikely to mitigate the CO_2 situation. This is because the biomass is oxidized to CO_2 and other combustion products as it is burned or otherwise decomposed. In addition, the relatively intensive cultural practices employed such as mechanical cultivation, herbicide application, irrigation, thinning and fertilization require considerable fossil fuel inputs -- further exacerbating CO_2 buildup in the atmosphere.

[7]A cunit is 100 cubic feet of solid wood.

APPENDIX A
SOME PESTS LIKELY TO INCREASE IN IMPORTANCE IN PLANTATIONS

CATEGORY	EXAMPLES
Insects	
Seedling weevils	Seedling debarking weevil (*Hylobius pales*) on pines in the southern U.S.
	Pitch-eating weevil (*Pachylobius picivorus*) in the southern U. S. and Caribbean.
Tip moths and shoot borers	Nantucket pine tip moth (*Rhyacionia frustrana)* on pines in the southern U.S.
	Ponderosa pine shoot borer (*Eucosma sonomana*) in the western U. S.
	Shoot borer (*Hypsipyla grandella*) on *Swietenia* and *Cedrela* in Brazil and Colombia.
Sucking insects	Red pine scale (*Matsucoccus resinosa*) in the northeastern U.S.
	Pine scale (*Matsucoccus josephi*) on Jerusalem pine in Israel.
	Balsam woolly aphid (*Adelges piceae*) on true firs in the eatern and western U.S.
Bark beetles	Southern pine beetle (*Dendroctonus frontalis*) in the southern U.S.
	Mountain pine beetle (*Dendroctonus ponderosae*) in the western U.S.
	Engraver beetles (*Ips* spp.) on conifers in the central, southern and western U.S.
Wood borers	Poplar-and-willow borer (*Cryptorhynchus lapathi*) in the north-central U.S.
	Longhorn borer (*Phoracantha semipunctata)* on eucaplytus in Australia.
Defoliators	Pine sawflies (*Diprion* and *Neodiprion* spp.) in the Lake States.
	Cottonwood leaf beetle (*Chrysomela scripta*) in the north-central and southern U.S.

(APPENDIX A, cont'd.)

Indigenous pests of exotics	Leaf-cutting ants (*Atta* and *Acromyrmex* spp.) on eucalyptus, gmelina and Caribbean pine in Brazil.
	Termites (*Termes* and *Coptotermes* spp.) on eucalyptus and gmelina in Indonesia and Malaysia.
Introduced pests of exotics	Wood wasps (*Sirex* spp.) on radiata pine in Australia.
	Black pine aphid (*Cinara cronartii*), pine needle aphid (*Eulachnus rileyi*), and pine woolly aphid (*Pineus pini*) on loblolly pine in southern Africa.
	European pine shoot moth (*Rhyacionia buoliana*) on radiata pine in Chile.
Diseases	
Seedling Diseases	Root disease and damping-off fungi (*Fusarium, Phythopthora* and *Pythium* spp.) on conifer seedlings.
Foliage Diseases	Brownspot needle blight (*Scirrhia acicola*) of longleaf pine in the southern U.S.
	Needle cast (*Rhabdocline pseudotsugae*) of Douglas-fir in the western U.S.
	Poplar leaf rust (*Melampsora* spp.) in the north-central U.S.
	Poplar mosaic virus on clonally propagated poplar.
Stem rusts and cankers	Fusiform rust (*Cronartium fusiforme*) of slash pine in the southern U.S.
	Eucalyptus canker (*Cryphonectria cubensis*) in Brazil.
	Scleroderis canker (*Gremmeniella abietina*) of pines in the north-central U.S. and southern Canada.
	Gall rust (*Endocronartium harkensii*) of lodgepole pine in western U.S.
Root rots	Annosus root rot (*Heterobasidion annosum*) of loblolly pine in the southern U.S.
	Armillaria root rot (*Armillaria* spp.) of conifers in the western U.S.
	Littleleaf disease (*Phytophthora cinnamomi*) of shortleaf pine in the southern U.S.
Insect-transmitted diseases	Black stain (*Verticicladiella wageneri*) transmitted by beetles to Douglas-fir in western Oregon.
	Mycoplasma disease transmitted by the bug (*Cryptopeltis tenuis* to *Paulownia* plantations in Korea.

(APPENDIX A cont'd.)

Nematodes	Pine wood nematode (*Bursaphelenchus xylophilus*) of hard pines in China and Japan.
Indigenous diseases of exotics	Root disease (*Cylindrocladium clavatum*) of pines and *Araucaria* in Brazil.
Introduced diseases of exotics	Needle blight (*Dothistroma pini*) of radiata pine in New Zealand.

REFORESTATION IN BRITISH COLUMBIA

Denis P. Lavender

Abstract

This paper traces the history of reforestation in forest lands of British Columbia, the western-most province of Canada. From a slow start at reforestation in the 1930s, there has been an increasing effort at growing and planting seedlings in the cutover areas of the varied ecological zones which make up the province. Growth sites, planting techniques, survival characteristics of species are discussed.

INTRODUCTION

British Columbia is a vast and varied province. In size it is larger than any other North American jurisdiction except Alaska and Quebec. Its latitudinal range extends from 48°12' to 60° north latitude, and its elevation from sea level to 4,665 meters (15,300 ft.). The great diversity of its climates is reflected by no less than 14 major biogeoclimatic zones, ranging from the warm, dry ponderosa pine zone in the southern interior to the cold, wet mountain hemlock zone at higher elevations in the coastal mountains, which ecologists have defined to guide forest management practices, including reforestation (Pojar, 1983).

Reforestation began in coastal British Columbia in 1930 with the establishment of the first provincial nursery at Green Timbers (Knight, 1990). From this date until the mid-1960s, however, the growth of reforestation in British Columbia was very slow, confined almost entirely to the coastal portion of the province and to Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) bare-root seedlings (although there was a brief period of direct seeding during the decade of the 1950s)(Knight, 1990). The total area reforested before 1965 was 164,000 hectares, or 394,000 acres. The past 25 years, however, have seen dramatic changes in reforestation in B.C., with increasing emphasis upon planting in the interior, on planting container-grown seedlings, and on planting the major timber species of interior British Columbia -- white spruce (*Picea glauca* [Moench] Voss.) and lodgepole pine (*Pinus contorta* Dougl.).

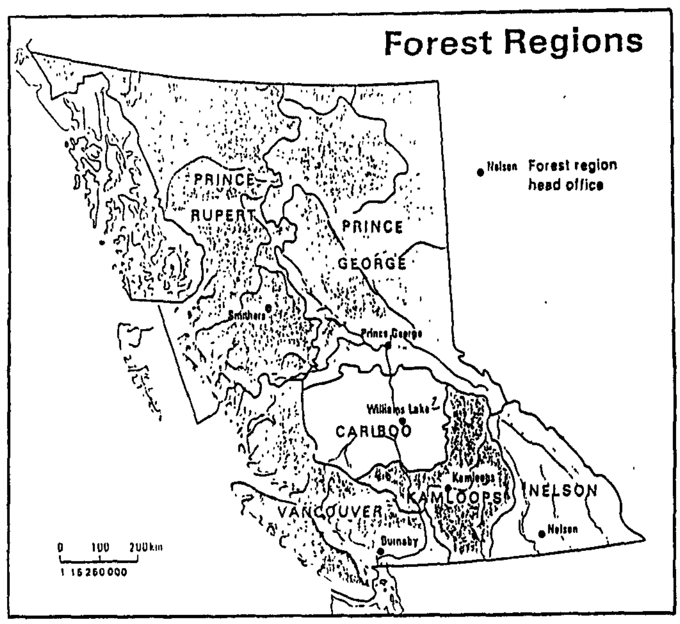

Figure 2. Forest Regions of British Columbia.

OVERVIEW OF REFORESTATION IN BRITISH COLUMBIA

The past 15 years have seen a great expansion in the reforestation effort in British Columbia and a correspondingly great change in its management and methodology. In 1975, British Columbia produced a total of 80 million seedlings, all in provincial nurseries, 63 million of which were bare-root seedlings (Lavender, 1990). In 1989, a total of 231 million seedlings, about 25 million of which were bare-root stock, were produced. And in 1980, the province allowed private nurseries to produce stock for reforestation and sold all but two of the provincial nurseries in 1988. In 1989, therefore, over 90 percent of forest tree seedlings grown in British Columbia were produced in private nurseries. Finally, the provincial government transferred responsibility for reforestation of all harvested lands, save those administered under the Small Business Enterprise Act, to companies which harvested the timber. This last action has dramatically changed the nature of reforestation in British Columbia from a program whose details were controlled by the Ministry of Forests in Victoria to one wherein the seedling parameters, planting and site preparation are administered by individual forest harvest companies through negotiations with siliviculture contractors.

The current goals of the forest regeneration programs in British Columbia are twofold:

a) the provincial government, with funding through a joint program with the federal government (the Forest Resource Development Agreement, or FRDA) expects to regenerate all previous harvested areas on medium and good sites which have been shown to be non-stocked by the year 2000; and

b) the timber harvest companies are now required to reforest all current harvest areas within five years of completion of logging.

Inasmuch as approximately 250,000 hectares are harvested each year, a production of about 300 million seedlings per year will be necessary to reforest the current cut-overs to Ministry of Forests standards.

THE HISTORY OF REFORESTATION IN BRITISH COLUMBIA

As noted above, large-scale reforestation in this province really dates from about the mid-1970s. At this time, the province moved aggressively to convert the emphasis in seeding production from bare-root stock to seedlings grown in a container system (Styroblock) developed by joint research of the Federal Forestry Service, Forestry Canada, and the provincial Ministry of Forests. The rationale for the change in the reforestation protocol was the change in emphasis in reforestation from coastal British Columbia where bare-root Douglas-fir seedlings comprised the bulk of the planting program to reforestation in the interior of the province with white spruce and lodgepole pine. Unlike coastal British Columbia, where much of the low-elevation forest land is snow-free for all but brief periods, the great majority of interior forest lands are blanketed by snow from mid-fall until late spring. Accordingly, the traditional planting season in this part of the province is relatively brief and container-grown seedlings were perceived as a more flexible solution to the logistics of reforestation than were bare-root seedlings, whose annual growth cycle was much less under the control of the nurseryman.

Although the B.C. Forest Practices Act of 1979 specifies that all harvested lands will be satisfactorily regenerated (Pearce *et al.*, 1986), in actual practice the Ministry of Forests lacked the manpower to enforce this provision. Accordingly, only about 40 percent of the nearly two million hectares harvested between 1975 and 1986 were planted. The remaining 60 percent were assumed to regenerate naturally. In some areas where species such as western hemlock (*Tsuga heterophylla* [Rafn.] Sarg.) and lodgepole pine regularly produce abundant seed crops, natural regeneration was estimated to be only 45 percent and that of planting, if no plantation maintenance was performed, 60 percent (Kuhnke, 1989). Accordingly, lands classified as non-satisfactorily restocked increased (fewer than 700 acceptable seedlings per hectare) at a rate of about 60,000 hectares per year (Pearce *et al.*, 1986).

Table III. Styroblocks Commonly In Use in British Columbia.

Styroblock	No of cavities/ block	Gross cavity volume (mL)	Cavity diam (cm)	Cavity depth (cm)	No. of cavities/ m^2
211A (2A)	240	39	2.5	11 4	1130
211 (2)	192	39	2.5	11.4	1055
313A (4A)	198	62	2.8	13 3	936
313B (4)	160	65	3.0	12.7	764
415B (8B)	112	106	3.6	14.9	527
415 (8)	80	133	4.1	15 2	441

After van Eerden & Gates, 1990.

Although reforestation in British Columbia during the past 15 years has benefited greatly from markedly increased concern by the public and land managing agencies about the future of the province's forests, it has lacked quality control throughout the reforestation scenario. (This is particularly true for seedling quality where meaningful evaluations of seedling vigor are lacking; however, this is true throughout forested areas of the world.) Further, reforestation efforts have had to suffer the exigencies resulting from a system driven throughout by competitive bidding, from the lack of sufficient funds and manpower in the Ministry of Forests to thoroughly monitor the results of reforestation effort and to modify plantation establishment practices on the basis of previous success or failure, and finally from an emphasis upon numbers of seedlings planted as a measure of reforestation rather than upon numbers of hectares successfully regenerated to the "free-to-grow" stage. In spite of the foregoing, however, the past 15 years have seen substantial improvements in the technology involved throughout the reforestation scenario, particularly in the introduction and refinement of "hot planting" of white spruce seedlings throughout the summer period and in the increasing use of larger, styroblock 415 seedlings with a concomitant lesser reliance on smaller stock (Table III).

SUCCESS AND FAILURE

As noted in the introduction, British Columbia is an extremely varied province with climatic extremes ranging from the cold, saturated soils of the boreal forests to near-desert conditions in the southern interior, particularly areas immediately east of the coastal mountains and in the Okanogan trench. The pattern of success or failure in reforestation may, perhaps, be best seen by reference to the data in Table IV.

Table IV. Total Backlog Not Satisfactorily Stocked Lands*

Region	Site class					Percent of Provincial	
	Good	Medium	Poor	Low	Total	Forest Land	Good & Medium Backlog N3R
	(area in hectares)						
Cariboo	12,297	18,450	9,062	131	39,940	13%	6%
Kamloops	13,128	61,113	20,837	8	95,086	10%	13%
Nelson	10,856	49,931	25,104	706	86,597	8%	11%
Prince George	65,925	205,822	162,532	16,789	451,068	38%	49%
Prince Rupert	10,355	96,041	44,237	7,842	158,475	20%	19%
Vancouver	1,038	8,189	4,836	353	14,416	11%	2%
Provincial totals	113,599	439,546	266,608	25,829	845,582	100%	100%
Total good & medium	553,145 Hectares						

* Backlog - areas denuded prior to 1982 (includes non-commercial brush areas). Summary for crown land only. (Crown lands comprise over 90% of British Columbia.

After Silviculture Branch, Ministry of Forests Report, 1988.

The data in Table IV clearly indicate that reforestation has been most successful in the coastal region of British Columbia. This is partly true because foresters in this area have much greater experience in reforestation since regeneration projects have been conducted in coastal B. C. for over 50 years, and partly because the cool, moist climate of this region generally favors seedling survival and growth. Probably the major obstacle to successful plantation establishment is invasion by competing vegetation such as red alder (*Alnus rubra* Bong.), salmonberry (*Rubus spectabilis* Pursh.), thimbleberry (*Rubus parviflorus* Nutt.) and salal (*Gaultheria shallon* Pursh.). These are aggressive plants with much greater initial growth potential than coniferous seedlings. Vigorous stock, however, planted immediately after harvest and site preparation treatments, can be expected to have a 90 percent or better survival. One interesting situation, which is the subject of intensive current research, is the apparent effect of salal upon the growth of coniferous seedlings in the northern part of Vancouver Island. Early growth of conifers is often good, but as salal invades the plantations, seedlings frequently exhibit extreme loss of vigor -- a condition which can be relieved, but only temporarily, by applications of nitrogenous fertilizer.[1]

Coniferous seedling survival on southerly exposures in southern Vancouver Island, on the lower mainland and in the western portion of the Kamloops region is impacted by heat and drought stress. Trials with shade cards or debris left after logging to shade the seedling microsites have demonstrated significantly higher seedling survival than that of control stock (Lavender, 1990). A combination of low rainfall, high summer temperatures and vigorous competing vegetation have resulted in a history of low survival for plantations established in the western (transition-interior) part of the Kamloops region. The role of stock quality in seedling survival in this area has not been studied in detail, although reports of root dieback of Douglas-fir stock have been related to mortality. Much of the planting stock employed in reforestation of this area has been grown in the lower mainland of British Columbia, which has a much less stressful summer climate. It is possible that production of seedlings in the interior for reforestation of this area would result in higher survival. Trials of mechanical site preparation devices and herbicides in recent years have produced erratic results. The former are limited by difficult terrain and the latter by the fact that only glyphosate, 2,4-D, and hexazinone are available for use in B.C.

The Engelmann spruce-subalpine fir (ESSF) and the interior Douglas-fir (IDF) zones in the southern interior support species such as Douglas-fir, western larch (*Larix occidentalis* Nutt.) and Engelmann spruce (*Picea engelmanni* [Parry] Engelm.), which are amenable to uneven-aged management and natural regeneration, so some form of selection management has been practiced in these zones in the Kamloops and Nelson district. A recent evaluation of regeneration success, particularly in the ESSF zone in the Kamloops region, indicates poor seedling survival at higher elevations (above 1700 m.) and on poorly drained areas. On sites at lower elevations, competing vegetation is probably the chief reason for poor plantation success. As noted earlier, registration limits the use of herbicides in B. C. The relatively steep terrain in most of the southern interior restricts the use of mechanical site preparation equipment so that the majority of site preparation is accomplished by burning, a technique which can result in warmer soils and some degree of vegetation control.

As the data in Table IV suggest, reforestation of the northern interior of British Columbia (primarily the Prince George Region) has presented the most severe problems in the province. The major obstacles to seedling survival in this area include:

a) generally cold soils, often insulated by heavy layers of organic material;

b) poorly drained, fine-textured soils;

c) aggressive, rapidly growing competing vegetation, including aspen (*Populus tremuloides* Michx.), bluejoint grass (*Calamagrostis canadensis* [Michx.] Beauv.) and red raspberry *Rubus idaeus* L.);

d) growing season frosts and cold-related desiccation events during the winter, particularly in the area east of the Rocky Mountains; and

e) the preferred species is white spruce, which naturally is a climax species, regenerates under an overstory of conifers or aspen, and which is not well adapted to the conditions which obtain in large clearcuts.

Finally, a large proportion of the seedlings planted in this region until very recently had been stored for periods as great as six months prior to planting. Such storage has been shown to adversely affect seedling physiology and root growth at low temperatures (Harper *et al.* 1989).

A significant body of research concerning factors affecting the survival and growth of coniferous seedlings in the Prince George area, particularly in the past five years, is reviewed in Scrivener and MacKinnon (1989). The results demonstrate that larger seedlings (Styroblock 415) generally have better survival and growth than those raised in smaller cavities. Positive responses have also been recorded for site preparation techniques which are designed to modify the microclimate in planting spots. Figure 3 illustrates the changes in microsite which may be achieved with machines which create patches (Leno, Bracke), mounds (Sinkkila, Bracke, Ministry of Forests) or disc trenchers (TTS Delta, Donaren 180D) and plows (Marttini, bedding, breaking), which essentially create continuous raised mounds.

The effects of such treatment vary, of course, with the climatic zone and with the depth of the litter layer and level of the water table. In the fine-textured soils, which characterize the mesic-to-hygric sites east of the Rocky Mountains between Dawson Creek and Fort Nelson, the positive effects of a raised microsite are probably related primarily to increased aeration and secondarily, perhaps, to increased soil temperatures.

On drier sites near Vanderhoof where the soils are coarser and the litter layer is only two-to-four centimeters, detailed temperature studies in the rooting zone of raised microsites do not demonstrate significant increases in soil temperature as a result of treatment. Better seedling growth on these sites, then, may be a function of better quality planting which the site preparation permits or increased available nutrients resulting from more rapid decomposition of the organic materials when they are mixed into the mineral soil.

Although the data in Table V show that increased seedling growth is the initial response to raised micro-sites, it appears that the benefit gained through this type of site preparation is

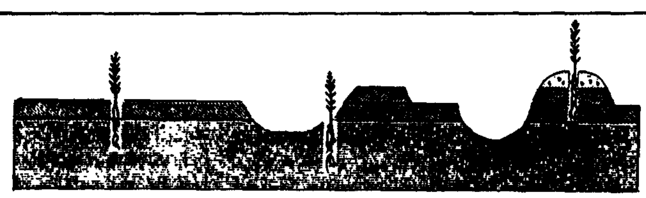

Figure 3. Diagram of Microsites and Planting Spots

Table V. TOTAL DRY WEIGHT OF WHITE SPRUCE SEEDLINGS

Site		Treatment		
		Untreated (gm)	Patch (gm)	Mound (gm)
Iron Creek		4 04	3.97	5.82
Stewart Lake	(1987)	6.09	5.14	8.56
MacKenzie		3 48	4.62	4.47
Iron Creek		6.76	6 72	10.48
Stewart Lake	(1988)	8 03	8.00	14.83
MacKenzie		4.47	6.31	6.96
Iron Creek		14.38	9 54	15 17
Stewart Lake	(1989)	22.90	12.89	24.11
MacKenzie		7.30	10.60	12.00

relatively short-lived. These results probably reflect the rapid invasion of site-prepared areas by the competing vegetation cited above and the discouraging lack of vigorous root growth demonstrated by the data in Table VI.

Present mounding machines are capable of creating several types of mounds; i.e., mounds wherein the organic material is thoroughly mixed with mineral soil, mounds with a cap of mineral soil over either a single or double layer of organic material, or mounds of mineral soil placed directly on mineral soil. Current research has shown that the optimal mounding treatment is definitely site-specific; i.e., mixed mounds are most favorable for nutrient-poor, slightly xeric soils. Further trials with mechanical site preparation treatments, particularly in fine-textured soils, production of seedlings with better root growth potential and development of scenarios to better control encroaching vegetation will be necessary for vigorous plantation establishment in the sub-boreal and boreal forests of British Columbia. Certainly, the experiences of foresters in Alberta with long-term trials of plantation establishment and growth (Drew, 1988) amply demonstrate that these sites are extremely difficult to regenerate successfully.

Table VI. SHOOT:ROOT RATIOS OF WHITE SPRUCE SEEDLINGS

Site		Treatment		
		Untreated	Patch	Mound
Iron Creek		4 93	6 81	4 13
Stewart Lake	(1987)	4 95	6 15	3 70
MacKenzie		2.26	2 42	2 58
Iron Creek		5 50	5 30	5 40
Stewart Lake	(1988)	4 80	5 10	5 40
MacKenzie		3 60	2 90	4 70
Iron Creek		7 50	8 50	9 10
Stewart Lake	(1989)	7 50	11 80	7.10
MacKenzie		5 50	6 60	9 00

Until the mid-1980s, virtually all the reforestation in the Prince George area utilized stock which had been cold-stored over winter and planted from mid-spring until early summer. Frequently, such seedlings suffered from a lack of synchrony of their annual rhythms with the environment. More recently, "hot-lifted" (seedlings planted without a storage period) white spruce seedlings are planted during the period from June through August. Such plantings may be damaged by growing season frosts but are, generally, demonstrating good survival and growth.

Table VII. SURVIVAL OF CONIFEROUS SEEDLINGS IN BRITISH COLUMBIA

Species	Cariboo		Kamloops		Nelson		P George		P Rupert		Van		Province	
	P	BR	P	BR	P	BR	P	BR	P	BR	P	BR	P	BR
	Percent Survival													
Lodgepole pine	86	77	72	63	74	70	82	73	85	75	92	81	82	73
Interior spruce**	81	59	66	57	69	55	81	65	78	59	75	67	75	60
Interior Douglas-fir	72	58	66	54	60	42	63	65	--	--	68	70	66	58
Coastal Douglas-fir	--	--	--	--	--	--	--	--	64	--	80	75	72	75
Western hemlock	--	--	83	--	35	--	--	--	77	--	76	--	68	--
Western redcedar	--	--	44	62	68	10	--	--	67	--	78	62	64	45

Forest Region and Stock Type*

* P = plug seedling, BR = bare root seedling; ** interior spruce = white or Engelmann spruce or their hybrid

After Johnson, C M 1987

Table VII summarizes survival data collected 1986 throughout the province. A weighting of the various species' survival by numbers of seedlings planted gives an average survival of 70 percent for both coastal and interior plantations. This survival, however, does not indicate the percent of plantations which are considered to be satisfactorily stocked, because the number of seedlings planted is substantially greater than the number required to fully stock an area, as an allowance for post-planting seedling mortality is made when the number of seedlings to be planted in a given plantation is determined. This allowance is predicated upon estimates of seedling survival. In interior British Columbia it is commonly believed that 1200-1400 seedlings should be planted to assure 700 stems per hectare when the plantation is judged to be free of any significant further mortality.

The data in Table VII reflect primarily first-year survival. Many of the surveys did not utilize staked seedlings, however, and therefore the error inherent in these data is greater than would be the case if only previously staked seedlings had been tallied. Current seedling survival surveys in the province are based on staked seedlings, a system which provides a positive estimate of subsequent seedling survival and growth.

FACTORS UNIQUE TO BRITISH COLUMBIA

The province has been mapped to define a range of biogeoclimatic zones, based on temperature and effective moisture parameters, which represent the major climates in British Columbia. These zones are defined by climax vegetation which occurs on mesic or zonal sites of each zone. These zones are further divided on the basis of ecological factors affecting plant distribution into subzones (Kimmins, 1987). For example, Douglas-fir is the climax overstory species found on the zonal sites in the Interior Douglas-fir zone, but is found only in the hygric sub-zone of the adjacent Ponderosa Pine-Bunch Grass zone which is characteristic of lower elevations with a warmer, drier climate. The concept of biogeoclimatic zones and subzones is that vegetation communities reflect the inherent productivity of the site and may be used to estimate the tree species which will produce the maximum yields of desired commodities. Even sub-zones, however, are too broad a classification to be used as guides for forest management decisions, so each sub-zone may be further described in terms of an edatopic grid.

An examination of Figure 4 will reveal that it divides the sub-zone into a number of sites which differ in fertility and moisture status and which are defined by different plant communities. For example, the community defined by Lichen spp., *Chimaphylla umbellata*, etc., is

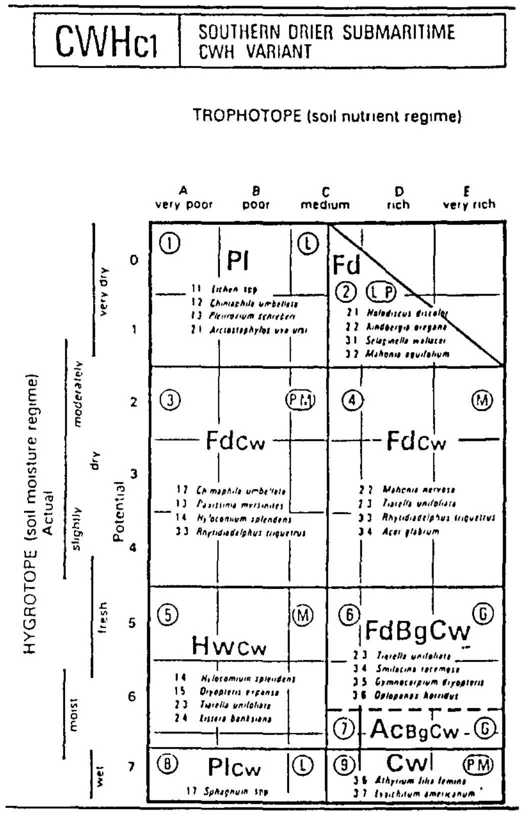

Figure 4. Edatopic Grid for the CWHcl Sub-biogeoclimatic Zone Which Occurs in Coastal British Columbia. (After Pojar et al., 1987.)

definitely drier and less fertile than the subzonal site, probably because it occurs on a ridgetop characterized by shallow, rocky soils. In contrast, the site defined by the dominance of *Tiarella unifoliata, Smilacina racemosa*, etc., probably occurs at the base of a slope where seepage water enhances the availability of both soil and nutrients and water. The significance of this detail for reforestation in British Columbia is that lodgepole pine is the recommended species for planting at the first site, and that either Douglas-fir, grand fir (*Abies grandis* Lind.) or western redcedar (*Thuja plicata* D.Don) is appropriate for the second site. Further, the figure contains a number of annotations which modify the general recommendations for suitable species; i.e., suggests that "in brush hazard sites, establishment of a mixed species stand is desirable. Pacific silver fir (*Abies amabilis* [Dougl.] Forbes) is an alternative to grand fir in the upper limits of the subzone."

While the use of guides such as shown in Figure 4 certainly assures that the species with the highest survival potential and possibly the highest productivity potential for the products desired will be planted in any given site, the usefulness of this technology is limited by the lack of authentic growth and yield data for most areas of British Columbia. Species recommendations, then, are based, at least in part, on the site quality classification by species for the vegetation communities.

Before any stand in British Columbia may be harvested, the amended Forest Practices Act of 1987 mandates that a preharvest silvicultural prescription must be prepared and signed by a registered professional forester. This prescription must detail all significant ecological characteristics of the area to be harvested, specify the harvest system to be employed and estimate the effects of the harvest on the productivity of the area for timber, water, fish and game, scenic amenities, etc., and prescribe a scenario for forest regeneration after harvest (Hadley, et al., 1990). This plan must include reference to the biogeoclimatic sub-zone, the preferred species and seedling types for planting on the sites which will be represented in the harvest area, the requirements for site preparation prior to planting and the probable effects of such activity upon long-term site productivity, and the requirements to protect the plantation from either damage by animals or adverse effects of competing vegetation. The prescription must also include a discussion of the role of the proposed harvest in the long-term forest management goals for the tree farm or timber supply area. These procedures have been mandated to assure that harvests will proceed only in areas where such practice will not have a long-term negative effect on productivity, that the logistics of the regeneration process will be recognized and provided for in advance of the designated regeneration schedule, and that necessary plantation maintenance will be scheduled and funded.

The use of biogeoclimatic zones and preharvest silvicultural prescriptions provides the basis for an enlightened forest regeneration system in British Columbia. Maximum benefits from these tools requires enhanced funding, however, and a significantly greater cadre of professionally trained, competent foresters than is currently employed.

The first step in the preparation of the propagules necessary for reforestation, unless clonal propagation is universal in the reforestation scenario, is the collection, processing and storage of high-quality seeds of appropriate species. The province of British Columbia has developed one of the leading forest-tree seed facilities in the world at Surrey. Here, cone collections from throughout the province are processed according to the most advanced methodology and stored under ideal temperature and moisture regimes most appropriate to assure continued high vigor for seeds of each species. Nurseries throughout the province must request the seeds necessary for planned seedling production well in advance of the projected time of sowing to enable the Surrey Centre to provide the stratification treatment necessary to assure the prompt, vigorous germination required to produce a uniform, healthy crop of seedlings. The detailed record keeping maintained by this central seed storage facility assures cone collection schedules which will provide the seeds of the species and sources necessary to satisfy the specifications of preharvest silvicultural prescriptions.

Reforestation costs vary widely across British Columbia. Seedling cost is dependent on seedling size primarily with stock raised in 313 styroblocks, the seedlings most commonly used, costing about 17 cents per plant. Planting costs are highest in coastal British Columbia, generally from 30-50 cents per seedling. In the interior, similar costs range from 20-40 cents per plant, but may be lower if the area is well site-prepared. Costs for site preparation vary with terrain, condition of the post-harvest area, and --in the case of mechanical site preparation -- whether or not the area had previously been burned.

Costs for burning in coastal British Columbia (by far the most common site preparation technique used) are about $220 per hectare, with costs of mechanical site preparation at about $530 per hectare. The relatively high costs of mechanical site preparation are occasioned by steep terrain and frequently heavy slash loading. In the northern interior, costs for burning and mechanical site preparation are $128 and $180 per hectare, respectively. The same costs in the southern interior are very similar: $190 and $175 per hectare. The preceding averages for mechanical site preparation are, however, the midpoints for a wide range of costs. Drag scarifiers, commonly used to prepare harvested areas for natural regeneration of lodgepole pine, cost as little as $70 per hectare, whereas mounding machines, plows and blades may cost as much as $300-$400 per hectare (Breadon, 1988).

SUMMARY

The reforestation program of British Columbia has evolved, primarily over the past 20 years, from an effort concentrated in coastal British Columbia, which employed provincial crews planting a few million bareroot Douglas-fir seedlings without regard to the ecology of the plantation areas, to a much more sophisticated, decentralized program wherein a range of species are grown largely in private nurseries and planted by silvicultural contractors according to the precept that small individual insults can accumulate to dramatically reduce the vigor of planting stock. Logistics of planting programs are now planned months or years in advance instead of the almost *ad hoc* efforts of early reforestation efforts. This is particularly apparent in the promulgation of guidelines which specify the weather conditions under which planting may occur and the parameters for proper field storage and handling of seedlings.

Given the foregoing advances, however, we have nonetheless major problems which must be solved before British Columbia will have a truly efficient productive reforestation program. These problems include:

a) production of seedlings which are capable of vigorous growth immediately after planting, particularly in the cold, hygric soils characteristic of much of the Prince George region and of the higher elevations of the southern interior (current seedling specifications focus almost entirely on physical parameters, i.e., shoot length, diameter, etc., and generally fail to recognize seedling physiology);

b) development of vegetation management systems which are sufficient to permit planted seedlings to reach a "free-to-grow" status in the minimum possible time (the severe impact of mechanical site preparation machinery on fine-textured soils which occur widely in the province and societal opposition to the use of herbicides are two major obstacles to achieving this goal);

c) the implementation of a funding level necessary to assure employment of the well-trained foresters required to conduct carefully planned, detailed reforestation projects, and the establishment of a personnel policy which encourages competent foresters to develop long-term expertise for the forest areas wherein the work;

d) increased emphasis upon quality, as opposed to quantity, in every aspect of the reforestation scenario.

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NOTE

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REFORESTATION IN NEW ZEALAND

I. R. Hunter

Abstract

Between 1000 and 1970 A.D., forest clearance by both Polynesian and European immigrants reduced the forest cover of New Zealand from 75 percent to 23 percent. Little of the timber was used. Following a far-sighted review in 1913, it was realized that the rate of exploitation was not sustainable. A policy of reforestation with exotic species was proposed, with the objective of achieving national self-sufficiency in wood. The Depression provided manpower and 300,000 hectares, predominantly of radiata pine, were planted by 1935. By 1960, this new forest matured. The local wood-using industry had no experience of utilizing the exotic softwood but came to prefer the new resource. In 1960 it was decided to expand the exotic forest with the objective of providing an exportable surplus. A total forest estate of 1.2 million hectares was established by 1990. Following substantial restructuring of the industry, however, expansion has ceased.

New Zealand's reforestation effort is characterized by a sound selection of exotic species and provenance within species. The species chosen, radiata pine, grows exceptionally well in the generally moist, warm climate. There were only a few instances of poor species selection. Generally, site selection was good and a large centralized resource was created as a result. A high degree of research input ensured knowledge of the conditions necessary to achieve success. A well-educated forest staff made the implementation of high-management standards possible. Good planning, sound species and site selection, and a highly educated workforce are necessary characteristics of any successful reforestation scheme.

INTRODUCTION

Like many countries, New Zealand went through a period of severe deforestation in which the area covered by natural forest dropped from 75 percent to 23 percent. Just before the First World War, it was realized that at the current rate of exploitation, there would be insufficient timber within 30 years to maintain economic development. An ambitious program of reforestation began, using exotic softwood species. There were very few mistakes and much solid achievement in this program, such that today New Zealand has an exportable surplus of timber. The purpose of this paper is to describe the states of deforestation, outline the stages of reforestation with exotic species, discuss the successes and failures in that program, and attempt to draw general lessons for reforestation schemes elsewhere; while noting any features that are unique to New Zealand.

THE STAGES OF DEFORESTATION

In the year 1000 A.D., most of New Zealand was covered in some form of woody vegetation (Figure 5). Probably 75 percent had a continuous forest cover (Nichols 1980). Forest was entirely absent on 15 percent of the land surface comprising areas above the tree line in the Southern Alps; areas in the central North Island recently affected by volcanic activity and wetlands were devoid of woody vegetation. The remaining sub-alpine areas and the drier parts of the country were covered in a woody scrubland.

At around that time Polynesian peoples, the *Maoris*, arrived from the Pacific. These people settled in New Zealand. The Maoris cleared forest by fire partly to assist cultivation of crops, to create a glacisital around their settlement and to assist travelling. These fires tended to be more destructive in the drier,

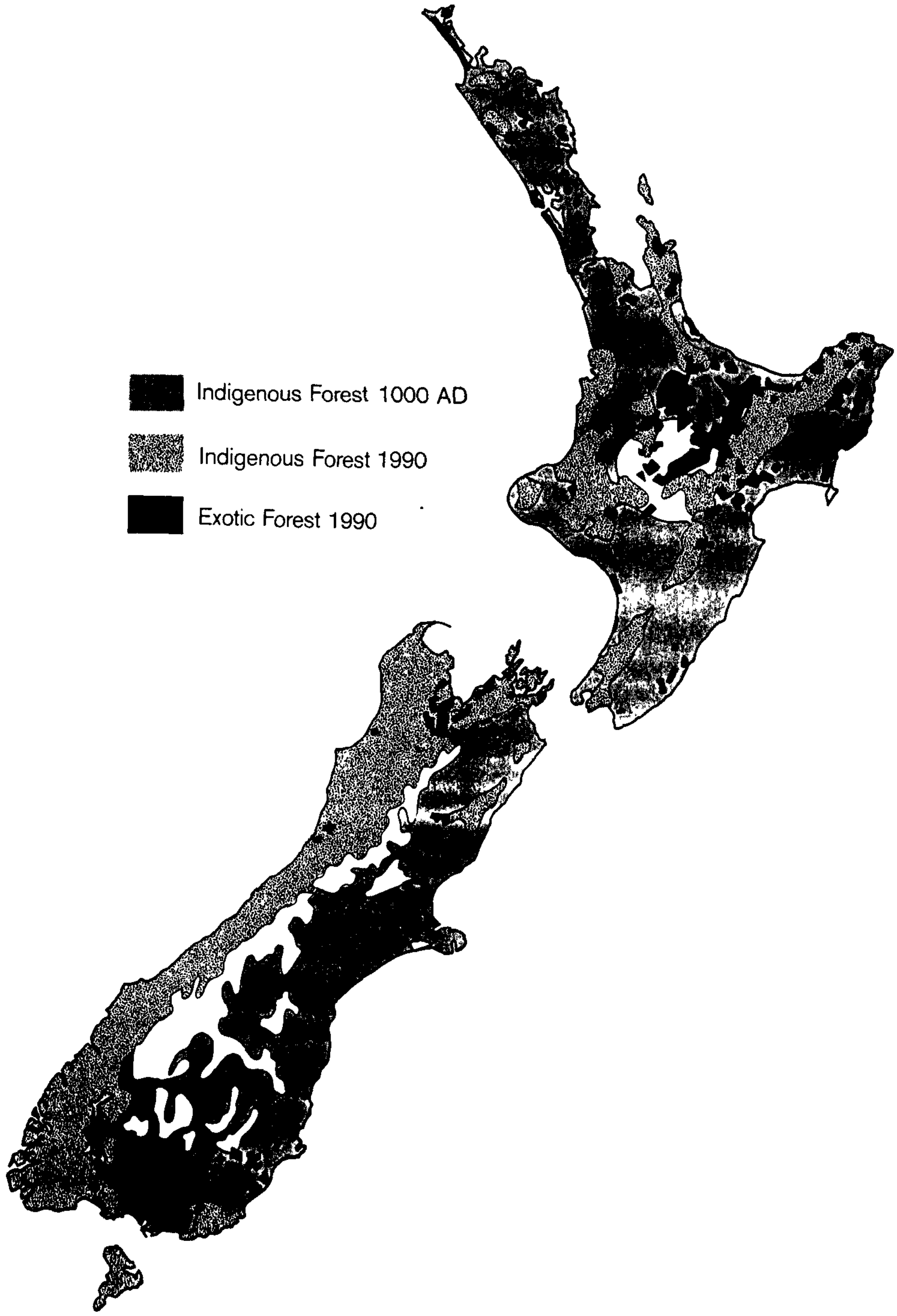

Figure 5. Indigenous and Exotic Forest in New Zealand, 1000 AD to Present.

more lightly wooded parts of the country. By 1840, when European settlement occurred, a third of the forest had already been cleared, and only 53 percent of the land surface was forested.

Between 1840 and the present day, a further 40 percent of the land has been cleared, paricularly of the more productive forest in the wetter parts of the country. Part of the clearance took place to generate timber resources to build a modern industrial estate and part to create opportunities for farm development. Thode (1983) pointed out that in northern New Zealand, more of the kauri forest was burnt than was ever put to use. The total land area now covered by natural stands is 23 percent of the land-surface. Eighty percent of the native forest is in state ownership. Of that 80 percent, 60 percent is in state forest land; 30 percent is in national parks and 10 percent is unoccupied Crown land (Nichols 1980). The current distribution of land-use overall is shown in Figure 6.

THE STAGES OF REFORESTATION

In 1896, a government-sponsored timber conference found that the wasteful destruction of the indigenous forests precluded a continuation of exports and required a plantation resource to be developed. An Afforestation Branch was set up inside the Department of Lands and Survey. Its objective was to establish 15,000 hectares of plantation in 25 years. By 1913, public concern for the future, both of the natural forest and for the national timber supply was such that the government set up a Royal Commission on Forestry (Royal Commission 1913). It found that the remaining natural forest resource was limited, the methods of its use wasteful, and that generally the native species were unsuited for afforestation. Future needs of timber would have to come from imports or large-scale plantings of exotic tree species. A State Forest Service was established in 1919 (Roche 1984).

In a study done in the early years of the Forest Service it was predicted that the indigenous forests would be severely depleted by 1965 and the rapid establishment by the state of

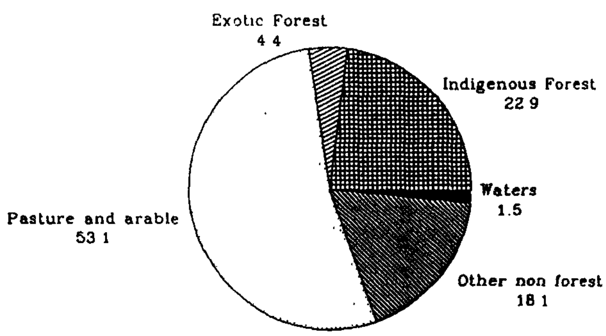

Figure 6. Percentage of Land Use in New Zealand. (Source: Anon. 1988)

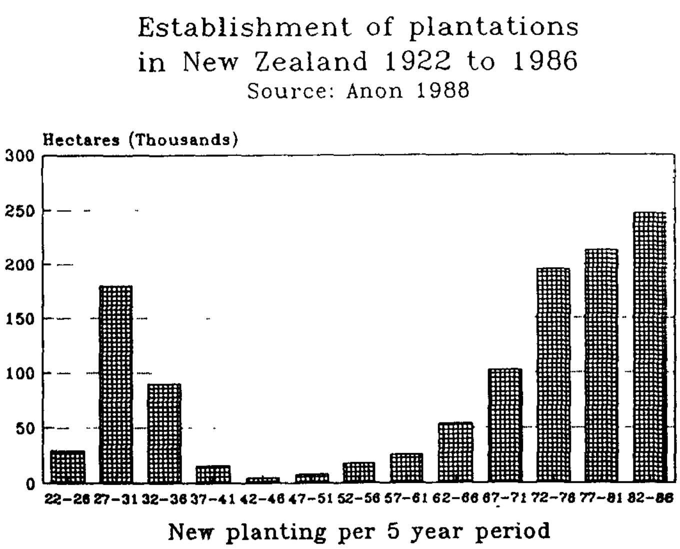

Figure 7. Establishment of Plantations in New Zealand, 1922-1986. (Source: Anon. 1988)

120,000 hectares in timber was necessary. The recommendations were accepted and rapidly put into effect using the special work schemes created to relieve the severe unemployment that occurred during the 1920s depression. The state target was achieved by 1931 (Fig. 7) and private companies planted a comparable area. By 1935, over 300,000 hectares had been planted (Sutton 1984). Radiata pine (*Pinus radiata*) was the main species used but *P. ponderosa*, *P. contorta*, *P. nigra* and *Pseudotsuga menziesii* were also used for certain sites. Having achieved an area from which it was predicted that self-sufficiency in timber could be achieved, planting of new land by the state reduced rapidly. Between 1936 and 1960 only 45,000 hectares of new land were planted. At that time, the view prevailed that New Zealand had little experience of exporting timber and could not profitably export timber to the European market (Bunn 1979). In addition, the local wood-using industry was still very inexperienced in the use of exotic softwood.

The period to 1960 saw a growing confidence in the use of exotic softwood and its substitution for dwindling native timber resources. The demonstration sawmills established by the state at Waipa and Conical Hills were very important in fostering this growing confidence. Market acceptance required the development of proven methods of conversion, grading, seasoning and preservation. The state played a leading role in their development (Sutton 1984).

In 1960, following a policy review, it was decided by the government to increase new land planting to between 8,000 and 12,000 hectares per year; to aim for an export target of 4,250,000 m^3/year and to aim for a total exotic estate of 800,000 hectares by the year 2000 (Bunn 1979). Thus the objective of reforestation was expressly modified to provide an exportable surplus. The government could control its own planting by allocating money and setting policy. It encouraged private-sector planting by a mixture of grants and loans (Forestry Encouragement Act 1962, Forestry Encouragement Grants Regulations 1970), tax incentives and export incentives. Instead of a smooth and gradual increase in planting, however, a further planting boom occurred, in which up to 40,000 hectares were planted per year, leading once again to a maldistribution of age classes. The intention was to make the export target achievable earlier, and to smooth out the age class discrepancy by silvicultural treatment. Since clear felling and replanting of the earlier planting boom occurred at the same time as the new planting, the current exotic forest estate of 1.2 million hectares is dominated by young age classes (Figure 8). Eighty-eight percent of the total area is planted in one species: radiata pine.

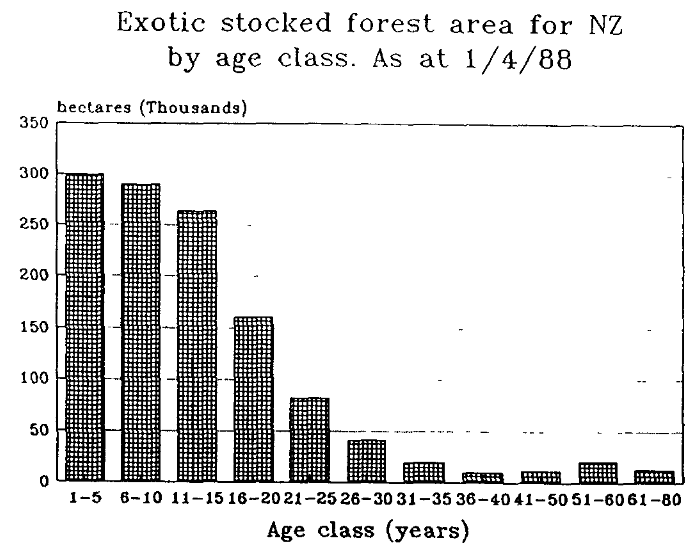

Figure 8. Exotic Stocked Forest Area for NZ by Age Class, 1/4/88.

The current situation with regard to reforestation is very different. In 1985, the government decided to create a State-Owned Enterprise to carry out the commercial activities of the Forest Service. The Forest Service had multiple land-use as one of its goals (Kirkland 1989). The new State-Owned Enterprise said in its statement of corporate intent that "the principal objective of the New Zealand Forestry Corporation is to operate as a successful forestry and wood-processing business" (Fischman and Nagle 1989). In other words, economic objectives had become predominant. Kirkland (1989) argued that it was impossible to practice a multiple-use management because of the difficulty of separating and valuing commercial and non-commercial goals. Although Kirkland (1989) showed that apparently greater financial returns were achieved by the new entity than had been achieved by the government department, government policy evolved to the point where after 30 months it passed the Crown Forest Assets Act (Government Printer 1989) and issued a prospectus entitled "the Sale of State Owned Forests in New Zealand," thereby initiating a process whereby the timber-cutting rights (but not the land itself) are to be sold to private-sector companies.

Fischman and Nagle (1989) speculate that a "corporation is not a stable institutional arrangement." Meanwhile, taxation incentives to private companies had been removed and eventually replaced by a taxation regime which most private companies view as a negative influence on new planting.

The view of the government is that the new tax regime is "neutral" (Anon., 1990). Under this new taxation regime, costs incurred in the planting and tending of a stand must be "remembered" without inflation indexation and can only be written off against income from that particular stand at such time in the future as revenue may occur. In addition, the impending sale of the state assets has caused uncertainty as to access to future wood supplies and certainty as to future cash requirements amongst the private companies. As a result, planting of new land has shown an actual and projected decrease (Figure 9). Several New Zealand companies have publicly signalled that they find overseas investment more attractive. It is necessary to point out, however, that government statistics show a slightly different picture.

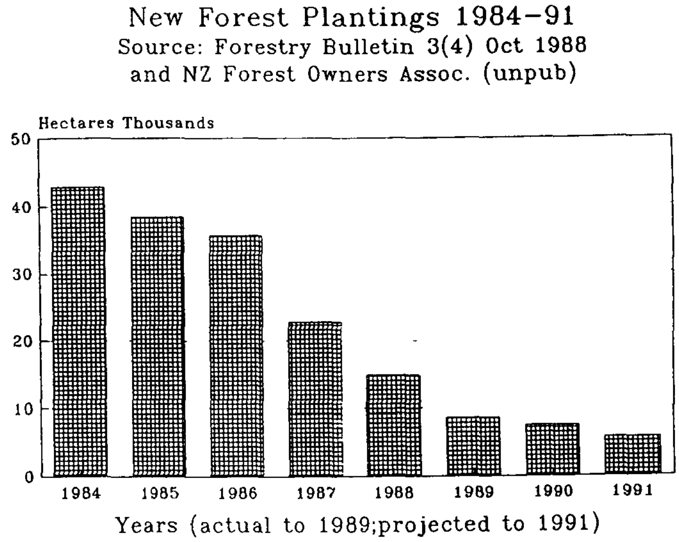

Figure 9. New Forest Plantings 1984-91.
(Source: Forestry Bulletin 3(4), Oct. 1988, and Forest Owners Assoc. unpub.)

While conceding that new planting has decreased (Anon. 1990), published figures to 1986 (Anon. 1988) give total areas of new planting up to 30 percent higher.

One aspect of the state forest sale which could have an impact on the future area planted in New Zealand is the absence of a requirement to replant. The licensee may use the land for any purpose (Government Printer 1989). Some state forests were established with too little regard for topography and siting and justifiably deserve critical evaluation before replanting. No such requirement to replant currently exists over private company land and nearly every hectare felled is replanted. There is therefore no strong reason, based on past experience, to fear that large areas of the current estate will be alienated to other land uses. It is probably fair to conclude, however, that under current policies the present size of the New Zealand forest estate will not increase greatly in the immediately foreseeable future.

Policy in the area of the native forests has moved firmly in the direction of conservation (Anon. 1989). The proposed national policy states that "the maintenance of the present area of indigenous forest is in the national interest," but that sustainable management will be allowed within tight minimum impact criteria where it is demonstrated to be technically feasible. If this policy is implemented, then the forest on the 23 percent of the New Zealand land surface which is currently under native vegetation will continue to grow, replacing the biomass removed over much of the area in past partial logging. Mature indigenous beech/-podocarp forest (at ages greater than 150 years) contains as much living biomass as a mature radiata pine stand (Beets 1980). It is worth noting, however, that the native forest of New Zealand is very slow-growing, with estimates of volume production in some of the denser stands of podocarps being as low as 1.5 to 3.5 m^3/ha/-year (Franklin 1973, Herbert 1980). The New Zealand beech may produce between 7-10.5 m^3/ha/year (Evans and Jackson 1972).

SUCCESSES AND FAILURES

It is difficult to characterize aspects of the reforestation program simply as either successes or failures because all strengths, when looked at from another perspective, can be seen as weaknesses. All successes carry the seeds of their own failure. For example, the enormous success in achieving physical targets of planting began to create apprehension in the minds of influential economists as to the future capital demand for processing plants.

A major success of New Zealand's afforestation strategy was the early recognition of radiata pine as a very flexible species capable of growing on a wide range of sites and producing outstanding volume. Radiata pine was introduced to New Zealand about 1856 and used by farmers and tree enthusiasts. By 1890 there were many plantations (Sutton 1984).

At the same time, a very wide range of species was tested informally. The Afforestation Branch planted blocks of species in the early years of the 20th century, so that by the time the big expansion came in the 1920s there was considerable experience with a wide range of species and clear evidence that radiata pine outperformed all others on most sites. The exceptions were on very cold, frosty sites and on some nutrient-deficient sites. There is general consensus that New Zealand had several strands of good fortune.

In the first place, the seed that was collected in the early days produced a land race composed of Año Nuevo and Monterey provenances which later provenance trail work has shown to be near optimal (Burdon and Bannister 1973).

Table VIII. STEMWOOD PRODUCTIVITY OF RADIATA PINE IN NEW ZEALAND.

Location	Net Ann.Growth m^3/ha/yr.	Source
Av., all forests	18.8	Collins, et al. 1988
Eastern N. Island	24.0	Collins, et al. 1988
Max. observed	44.7	Shula 1989

In the second place, some of the more severe diseases which attack radiata pine in its native range have not been introduced into New Zealand. Radiata pine is a very flexible species capable of growing well on a wide range of sites. It seldom goes into "check." Indeed, the only circumstance that appears to cause irreversible slow-down in growth is a rise in the water-table such that the root zone is often saturated.

Radiata pine produces on average significantly more than the growth of native forest species (Table VIII). At its best, radiata pine is capable of growing five times as fast as some of the best native stands, and there is evidence that after two rotations this high level of relative productivity will be sustained on most sites.

Its outstanding performance as a forest tree, however, has led to its acceptance ahead of other trees which grow well in New Zealand and which might be more acceptable as a timber either on the general world market or in specific niches of that market. Except in the Australian market, radiata pine is used chiefly for packaging (Anon. 1990).

Cryptomeria japonica, on the other hand, grows about two-thirds as fast as radiata pine on selected sites and would possibly be more readily acceptable on the Japanese market than radiata pine.

It is also widely recognized by the forestry community in New Zealand that being dependent on one exotic species, whose full range of native disease have not yet become established in New Zealand, carries risks (Chou, 1981; Bain, 1981). It is necessary to be aware of the diseases that occur on the introduced species in its native range and also to consider the possible impact of a meeting between the exotic species and a new disease unknown in its home range. A thorough risk assessment should be undertaken before commencing large-scale reforestation. Species for which there are known fatal diseases, such as elm, should be avoided.

A necessary characteristic of any reforestation scheme, however successful its main species, is that strategic research is continued to evaluate a large range of potential substitute species (Bunn, 1979).

One of New Zealand's failures concerns the attempt to plant cold, higher altitude sites on which radiata pine initially failed. *Pinus ponderosa* was one of a small group of species chosen to plant these sites, and at one time this species was second only to radiata pine in area planted. Nearly 30,000 hectares were planted in the first planting surge. Insufficient attention was paid to provenance variation. Seed was purchased fairly indiscriminately and New Zealand ended up with over 95 percent of the area being planted in a provenance from an area called North Plateau which consecutive provenance trials proved to be less than optimal (Figure 10, Moore. 1944). Four percent was planted with the very poor variety *P. ponderosa scopulorum* and less than one percent with the optimal Californian provenance. It ought to be unnecessary in the 1990s to stress that any successful afforestation program must have a thorough knowledge of the macro- and micro-genetical variation of the main species.

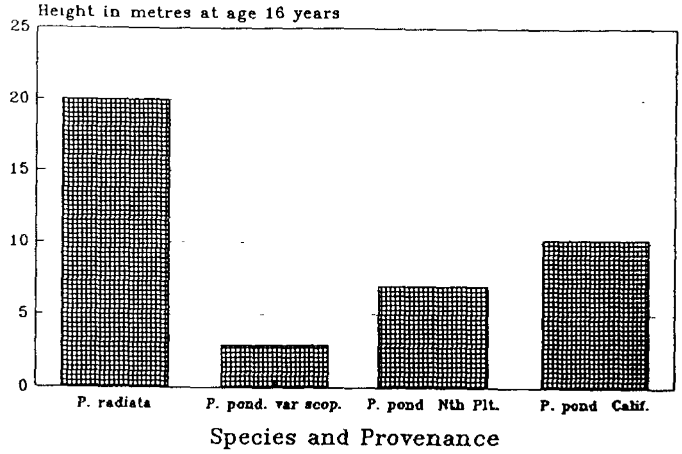

Figure 10. Height and Growth of Radiata Pine and Ponderosa Pine on Cold Sites in New Zealand.

By the time that the first crop was felled, research conducted by field foresters and by the Forest Research Institute had shown that, with cultivation and weed control to speed initial growth and reduce frost risk, radiata pine could be grown on the high plateau areas (Washbourn 1978). Figure 11 shows that radiata pine is capable of a much higher growth rate on the same sites.

Radiata pine is a remarkably flexible tree; New Zealand climate is generally mild and moist. As a result, the growth of radiata pine is fairly even over the whole country. There is a trend towards slower growth in the more southerly parts of the country and dry, high-altitude sites in the South Island can produce very slow growth (Figure 11).

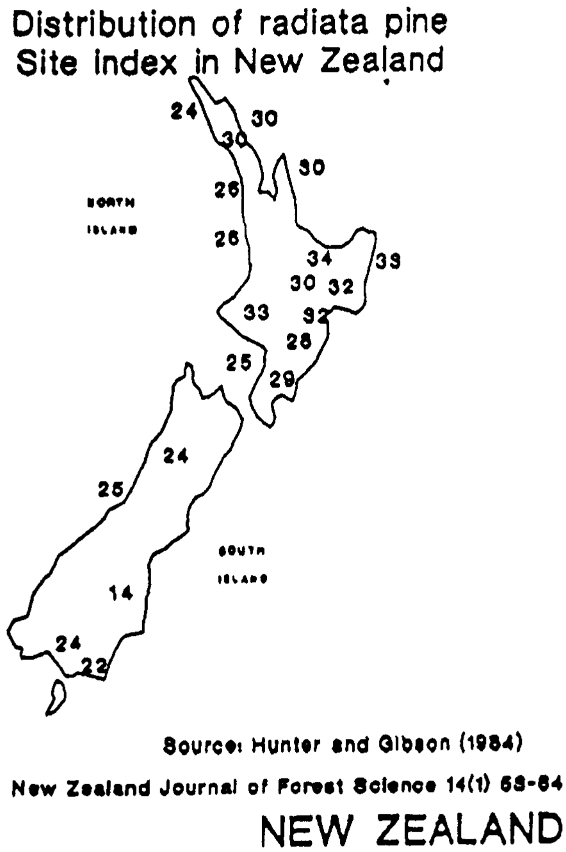

Figure 11. Distribution of Radiata Pine Site Index in New Zealand. Source: Hunter and Gibson, 1984

New Zealand's afforestation program contains both successes and failures in other aspects of the choice of site. The failures came about partly through lack of knowledge about site productivity relationships, partly through not considering the economic considerations rigorously enough and mainly because choice of land was constrained by land-use planning procedures. Of the 75 percent of the estate for which original land use is known, over 70 percent was planted on land described as unutilized or reverting farmland, 9 percent was planted on land with varying erosion problems, 12 percent was directly converted from native forest, and only 7 percent was planted on land considered to be viable farmland at that time (D.J. Evans, pers. comm.). Thus the expansion of the plantation estate was not directly at the expense of the native forest. There are good historical reasons for the concentration of the estate on unutilized or reverting land. The state was constrained up to the 1970s by a Land-Use Committee made up of Government Department representatives who normally allocated any land bought by the state with agricultural potential to the state land development agency (Fenton, 1965). When land-use decisions became the prerogative of local government, these bodies generally moved to place forestry land use in a subordinate position to pastoral land use: specific local authority being required to afforest more than tiny parcels of land (Rockell, 1980). The forestry sector experienced considerable hostility from the farming community and there were several successful appeals against large-scale forest expansion onto farmland. Smith and Wilson (1984) showed that forestry was not one of the more publicly favored options for land use. Respondents to their survey gave environmental concerns, life-style concerns and general land-use preferences as their reasons for opposing conversion of land to forestry. A really successful reforestation program would control the choice of site pro-actively. To do that, however, it would need to take public opinion with it by confronting and dealing with issues of public concern.

Despite these constraints on land availability, there is nowadays a satisfactory concentration of forests in the Central North Island (Figure 12). The soils in this region are deep pumice

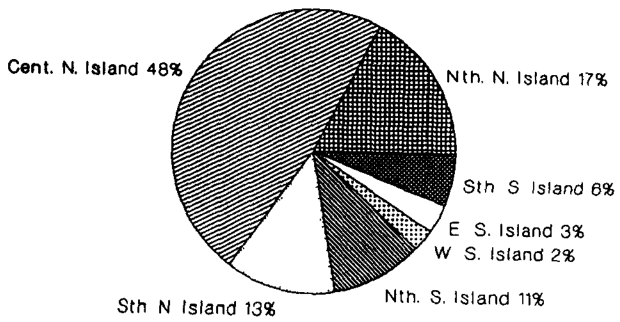

Figure 12. Distribution of Exotic Forest in New Zealand. (Source: Novis, et al., 1989.)

ash, with high water-holding capacity. The climate is moist. Radiata pine growth is rapid. Nevertheless, part of the estate was planted on land that proved to be chronically nutrient-deficient. Annually about 30,000 hectares are fertilized with boron, phosphorus, potassium, magnesium and/or nitrogen fertilizers. Moreover, in the second planting boom, planting was distributed around the regions and some minority of forests were planted on very steep slopes in inaccessible areas (Bunn, 1979). Logging on these steep sites will pose severe problems (Carson, 1983).

Latterly, very high standards have been achieved in the establishment (e.g., Hunter and Skinner, 1986) and management of the plantations (Sutton, 1984). This situation contrasts with that in the first planting period where there were some failures due to inadequate technology. A Forest Research Institute was established in 1947. Staff training through in-house, sub-professional and university-based, professional training accelerated through the 1950s (McKelvey, 1984). Research concentrated on practical outcomes. Scientists were given considerable freedom to focus on medium-term opportunities rather than on short-term problems, however, in an environment where long-term stability of budget was guaranteed (Sutton, 1984). The phrase "scientific effectiveness," used by a past director of the Institute, encompassed the successful practical application of research results to field situations. Particularly successful were efforts in nursery techniques, site preparation crop establishment, crop tending and utilization of the timber. These results were communicated to managers through research symposia (e.g., Chavasse, 1981), by face-to-face communication (Balneaves, 1983), and by practitioner-oriented publications (e.g., Hunter and Skinner, 1986).

The combination of applied research effort and a highly trained staff who understand and applied that effort was particularly successful. Over the last few years, however, the Research Institute has been required to earn an increasingly high percentage of its costs from commercial activity. Although mechanisms have been found to ensure continuation of widely available practical research through the founding of research cooperatives, some of the research effort has been diluted and diverted by proprietary agreements. In addition, the number of staff employed in forest management has declined sharply (D.J. Evans, pers. comm.) to the point where the remaining staff feel unable to put as much time into technical matters as was previously the case. A successful reforestation program needs the underpinning of an adequate research and development agency, a highly trained workforce and a high level of communication between the two.

A weakness of New Zealand's afforestation program was that the "Forest Service nurtured a fraternal cadre of foresters who made management decisions largely insulated from political or judicial pressure" (Fischman and Nagle. 1989). The management concentrated too greatly on physical goals (number of hectares planted for example) and not enough on financial goals (Grant, 1979), making it vulnerable to financial inquisition. It also paid insufficient attention to the changing and growing tide of urban opinion which was firmly against the destruction of native forests.

UNIQUE FEATURES

New Zealand's economy is moving from a highly regulated one to a more free-market approach. The government has introduced a tax regime which has been negatively received by industry. There are large areas of land in New Zealand potentially available and suitable for afforestation (Table IX), but recent new land plantings have fallen to a 30-year low. The state is removing itself from afforestation by the sale of the state forests. If the area planted in trees is to increase in the short term then a mechanism will have to be found to encourage private enterprise to plant more trees than their current economic appraisal considers desirable.

New Zealand has developed silviculture into a considerable science (Sutton 1984). Years of intensive field research culminated in a modelling phase which sought to bring the empirical knowledge into one framework. Sutton (1984) summarized the main conclusions of that modelling effort thus:

* site productivity is the most important determinant of profitability;
* topography and distance to market can have a major impact on profitability;
* overhead costs can often be more important than direct costs;
* for any one site, the choice of final crop stocking is most important;
* low final crop stocking is most important;
* low final crop stockings and stem pruning produce the highest value output. New Zealand's forestry practice is overwhelmingly influenced by these ideas, to the extent that it might be difficult to obtain increased planting in areas or in ways that contradicted this body of knowledge. For example, Sutton (1984) points out that it is almost impossible to maximize both volume production and value in the same regime. New Zealand's forests tend to be managed for maximum value, which means less than maximum volume. Less than the potentially immobilizable carbon would be immobilized by such a silvicultural regime.

Table IX. POTENTIAL LAND AVAILABLE TO EXPAND EXOTIC FORESTRY (HARRIS, 1979).

REGION	AREA IN THOUSAND HECTARES
North, North Island	351
Center, North Is.	705
East, North Is.	777
South, North Is.	632
North, South Is.	590
East, South Is.	1041
South, South Is.	1520

Afforestation can be a very capital-intensive operation (Fenton, 1965). Following planting, radiata pine plantations are usually live-branch pruned and thinned (without commercial yield) several times. These operations place a severe cash-flow constraint on owners. The objective of such operations is to produce high-quality clear timber at rotation age. There are incidental benefits from such treatment. Plantations so treated are healthier than those left untended (Sutton, 1984). The first crop, which was mostly untended, was badly damaged by a wood wasp, *Sirex*. Needle cast fungi such as *Dothistroma* and *Cyclaneusma* are more severe in untended plantations as well. The costs of establishing the plantation are small, however, when compared to the capital costs of the utilization plant. It is estimated that capital investment of 6 to 7 billion N.Z.$ would be required to process all the wood available over the next 20 years (Anon., 1990). For a small, relatively capital-poor country like New Zealand, these capital costs can be a significant constraint on plantation expansion.

New Zealand has a small population (3 million) and historically high wages for manual labor. It has a very strongly regulated labor market with very strong labor unions. The cost of getting logs to the market amounts to 50 percent of the costs incurred in the whole 30-year rotation. Labor availability and cost are therefore significant factors in the expansion of afforestation (Anon., 1990).

New Zealand has a land area equal to the United Kingdom, or equal to the state of Colorado. It has a low population density, yet it has a very high degree of investment in economic infrastructure and in education of its people. It has a mild, moist climate capable of growing one of the highest producing conifers in the world. It has plentiful land that is both suitable and potentially available for an afforestation program (Table IX). It has the capacity to make significant world contributions to net afforestation.

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A BRIEF HISTORY OF FOREST MANAGEMENT IN THE AMERICAN SOUTH: IMPLICATIONS FOR LARGE-SCALE REFORESTATION TO SLOW GLOBAL WARMING

Joseph H. Hughes

Abstract

The American South provides perhaps the best case study of large-scale plantation forestry in the United States. The primary objective of this paper is to present this reforestation case study within the broader context of southern forest history. A secondary objective -- the potential use of southern forest plantations for carbon storage as a means to slow global climate warming -- is considered in the final sections of the paper.

INTRODUCTION

Forestry and forest products have been significant and locally dominant in the southern economy for more than 250 years. Southern forest history over this time span is symbolically divided into four eras -- the **first**, **second**, **third** and **fourth forests** (SFRAC, 1969; USDA, 1988). In reality, the eras overlap in time, both across the South and locally, but are useful to illustrate the historical development of timber utilization and forest management. The eras of southern forestry also provide comparisons to forest management and forest exploitation in other regions of the United States and of the world. The virgin, old growth **first forest** provided the "seed" for the second-growth **second forest**, which in turn provided the "capital" for the pine plantations that are the **third forest**, which in turn provides the "hope" upon which we will establish the future **fourth forest**. The **third** and **fourth forests** are the models for potential carbon storage in southern pine plantations. We will consider each forest sequentially in time, beginning with the **first**.

THE FIRST FOREST

Coastal North Carolina, including my home town of New Bern, located in Craven County, is representative of the longest forest history in the South. I will use this area as an example throughout the paper. Savannah, Mobile, Pineville or a hundred other locations could be used. The first forest -- the original, virgin stands of longleaf and other southern pines, upland and bottomland hardwoods, cypress and white cedar -- powered the economy for more than 200 years, until about 1930.

An early example of the importance of forest products to this area is from the export records for Port Beaufort for the shipping year ending October, 1764. Naval stores were the principal exports -- nearly 40,000 barrels of pine tar, turpentine, pitch, spirits of turpentine, and rosin were shipped that year. Most were probably extracted from the longleaf pine stands of Craven County (Watson, 1987). Naval stores put the South on the map of world trade. The British navy was no longer hostage to northern Europe for these vital materials. The dominance of naval stores in the coastal Carolina economy continued for more than 100 years.

The 1860 census for Craven County indicates that 47 of 68 manufacturing firms produced turpentine products, accounting for three-quarters of the value of all manufactured products from the **second forest**. Incidentally, only one sawmill operates on the New Bern waterfront today. Additional forest products such as sawn lumber increased this to 88 percent of the total value for the county (Watson, 1987). Similar statistics were applicable to Florida, Georgia and Alabama as the naval stores industry assumed dominance in those longleaf and slash pine areas, especially after the Civil War.

The Southern economy was depressed for a few years as a result of the war, but unprecedented demand for forest products forced a turn around. Waves of immigration into the United States after the Civil War resulted in a building boom that placed a tremendous demand on timber supplies throughout the country. This demand, coincident with internal access provided by railroads, opened up vast stands of southern timber which were previously untouched. The result was a logging and sawmilling boom across the South that lasted from about 1870 until 1930. Craven County shared in the boom. By the turn of this century, the New Bern waterfront was crowded with sawmills. The Neuse and Trent Rivers were filled with log rafts and lumber cargo vessels. About a dozen lumber companies were operating in the area (Watson, 1987). John L. Roper Lumber Company, with more than 200,000 hectares of timberland, a railroad system and several mills in coastal North Carolina, owned a sawmill complex in New Bern, including the largest planing mill in the Carolinas and Virginia (Krinball, 1956). Blades Lumber operated seven mills in the area. Lumber production across the South peaked at nearly 50 million cubic meters in 1909 (SFRAC, 1969). The 1920 census included 16 lumber mills in the New Bern area (Watson, 1987). The timber harvest level was not sustainable. Remnants of the **first forest** were rapidly depleted. The virgin forest was mostly gone by 1930, by the beginning of the Great Depression. The few remaining stands were harvested by about 1945. Sawmill capacity reflects this loss. In New Bern, the number by 1940 had declined to 7 sawmills and 4 planing mills (Watson, 1987). These mills were progressively being supplied from the **second forest**. Incidentally, only one sawmill operates on the New Bern waterfront today.

Timber harvest during the last 50 years of the **first forest** provides a good example of rapid exploitation of a natural resource -- of "cut-and--run," of "boom-and-bust." Was this the equivalent of tropical rainforest destruction today? Probably not, although there are similarities. The survival of some plant and animal species was put at risk. Rainforests are, however, much more complex systems. We also have the advantage of hindsight. The **second forest** did rise to replace the South's first forest, but we do not want to manage the southern or any other forest that way again.

THE SECOND FOREST

The **second forest** is the second-growth timber that arose from the cutover timberlands and degraded, abandoned farm fields across the South. This forest is the product of exemplary human effort and changing land use patterns. Organized efforts to naturally regenerate the cutover **first forest** were begun in the early 1900's. The regeneration period extended for perhaps 50 years -- from about 1900 until about 1950. The **second forest** resulted from natural regeneration, not from tree planting. Primary limiting factors to forest establishment were wildfire and uncontrolled grazing that destroyed young seedlings and tree sprouts. Wildfire and unregulated grazing were gradually reduced by the various state and federal forestry agencies that arose during this period. An early fire-control campaign was the Dixie Crusades of the 1920s (SFRAC, 1969). The culmination has been the Smokey the Bear campaign begun in the 1950s.

A world class infrastructure for forest utilization and management has evolved in the South during the last 70 to 80 years. Individual state forestry agencies, the national forests, federal and state experiment stations, more than 30 major forest product companies, and the southern forestry schools helped to create the **second forest** and, perhaps as importantly, are here because there is a **second forest**.

Transition from the **first** to the **second** forest as a source of timber must have occurred for more than 20 years -- from the 1920s into the 1940s. From 1935 to the present, total lumber production southwide has averaged about 26 million cubic meters per year, and has been in the range of 19 to 31 million cubic meters per year. Pine is 60 to 80 percent of this volume on an annual basis; the remainder consists of hardwoods and softwoods other than pine (USDA, 1988). Second growth southern pine gave rise to a structural plywood industry in the early 1960s with a current annual capacity of nearly 1,000 million square meters. But most impressively, the **second forest** is also the raw material base for perhaps the largest regional pulp and paper industry in the world. The southern pulp industry, with very modest beginnings in 1891, had a 10-fold expansion in pulp tonnage between 1920 and 1940, followed by an 11-fold tonnage expansion between 1940 and 1984 (USDA, 1988).

Amazingly, until perhaps 1980, the expansion of the industry did not keep pace with the growth and expansion of the wood supply. Consider our example of New Bern and Craven County. Weyerhaeuser built a 545-metric-ton/day pulp mill at New Bern in 1968; expansions have brought the capacity to 690 tons/day. By 1987, southern pulp production included 106 mills with a total capacity of 111,890 tons/day (Hutchins, 1989). The South is now the leading region in pulp and paper production with 70 percent of United States production and ranks high in other forest products (USDA, 1988). The **second forest** serves us well. With increasing demand for forest products and a shrinking forest land base, however, **second forest** growth rates of 2 to 7 m^3/ha/yr will not be enough. Raw material for sawmills, plywood plants, pulp mills and other manufacturers of forest products is increasingly coming from the **third forest**. Even so, the South's **second forest** is one of the greatest forest recovery success stories of all times. The **second** and now emerging **third** forests may be providing a sustained supply of forest products at a higher rate today than did the **first** forest at the height of exploitation in 1909. Applied technology and wise, active management are making this possible.

DESCRIPTION OF THE SOUTHERN FOREST

Before discussing the **third** and **fourth** forests, we need an overview of trends in southern forestland ownership and in the real composition by tree species groups. The dynamics of the southern forest estate beginning in 1952 and projected to 2030 are presented in Table X. Part of the dynamic is the transition from **second** to **third** to **fourth** forests. The South -- the twelve-state region extending from Virginia to east Texas -- was about 60 percent forested in 1952, including 78 million forest hectares. Forest area peaked at 81 million hectares in 1963 (SFRAC, 1969), has declined to about 73 million hectares in 1990, with a continuing decline projected to 70 million hectares in 2030 (USDA, 1988).

Urban expansion and agricultural development are the primary causes of forest land loss. The United States population of 152 million people in 1950 increased to about 250 million by 1990 and is projected to be 319 million by 2030. The South, especially on the coast, is a high population growth area. This places increasing demands on the forest for not only more timber and recreational use, but also for the conversion of 10 million forested hectares to housing, agriculture, highways, etc., between 1963 and 2030. The forest ownership trend is one of gradual, proportional increase for public ownership from 9 percent in 1952 to 11 percent in 2030; gradual increase for forest industry from 17 percent in 1952 to 25 percent in 2030; and steady decline in other private ownership from 74 percent in 1952 to 64 percent in 2030. The greatest proportional shift in ownership is to forest industry as companies try to guarantee a wood supply to mills and to increase the efficiency of timber production.

The percent of area occupied by each tree species group remains surprisingly constant from 1952 to 1985 and on through the projection period to 2030. During that interval hardwood forest types range from 47 to 51 percent of the forest land base, with upland hardwoods from 28 to 35 percent, and bottomland hardwoods from 15 to 19 percent. The mixed pine-hardwood type ranges from 12 to 15 percent and pure pine types (natural and planted) from 38 to 41 percent. The greatest proportional loss is for bottomland hardwoods (19 percent in 1952 to 15 percent in 2030). The greatest proportional gain is for pine (38 percent in 1952 to 41 percent in 2030).

TABLE X. Area of Timberland, by Ownership, Species Groups, and Pine Plantation Details for the South[1], 1952-1985, with Projections.

	Million Hectares						
	Year				Projections		
	1952	1962	1970	1985	1990	2010	2030
Total, all ownerships	78.2	79.8	77.4	73.8	72.9	71.3	70.2
Ownerships							
National Forest	4.2	4.3	4.3	4.4	4.4	4.5	4.5
% all ownerships	5.4 %	5.4 %	5.6 %	5.9 %	6.0 %	6.2 %	6.4 %
Other Public	2.7	2.7	2.8	2.9	3.0	3.0	3.1
% all ownerships	3.4 %	3.4 %	3.6 %	4.0 %	4.1 %	4.3 %	4.4 %
Forest Industry	13.5	14.5	15.5	17.1	17.2	17.4	17.6
% all ownerships	17.3 %	18.2 %	20.1 %	23.2 %	23.6 %	24.4 %	25.0 %
Other Private	57.8	58.3	54.8	49.4	48.3	46.4	45.1
% all ownerships	73.9 %	73.0 %	70.7 %	66.9 %	66.2 %	65.1 %	64.2 %
Species Groups							
Total Hardwoods	37.3	39.3	37.8	37.8	36.8	34.2	32.8
% total forest	47.7 %	49.3 %	48.8 %	51.3 %	50.5 %	48.0 %	46.7 %
Upland	22.4	24.7	24.9	25.6	24.7	23.0	22.2
% total forest	28.7 %	31.0 %	32.2 %	34.7 %	33.9 %	32.3 %	31.6 %
Bottomland	14.9	14.6	12.8	12.2	12.1	11.2	10.6
% total forest	19.0 %	18.2 %	16.6 %	16.6 %	16.6 %	15.7 %	15.1 %
Mixed pine-hardwoods	11.0	11.1	11.8	10.9	10.0	8.9	8.5
% total forest	14.0 %	14.0 %	15.3 %	14.8 %	13.8 %	12.4 %	12.0 %
Pine (natural and planted)	29.9	29.4	27.9	25.1	26.1	28.3	29.0
% total forest	38.2 %	36.8 %	36.0 %	34.0 %	35.8 %	39.6 %	41.3 %
Pine Plantation Details							
Pine Plantation	0.7	3.1	4.9	8.5	10.6	17.9	19.6
% Total forest	1.0 %	3.9 %	6.3 %	11.5 %	14.6 %	25.1 %	27.9 %
% Pine forest	2.5 %	10.5 %	17.6 %	33.8 %	40.9 %	63.3 %	67.6 %
Pine Plantation owners							
% Public ownership	18.2 %	9.5 %	6.7 %	5.6 %	5.5 %	5.6 %	6.1 %
% Other-private ownership	46.0 %	49.3 %	46.2 %	31.4 %	33.6 %	37.8 %	38.3 %
% Industrial ownership	35.8 %	41.2 %	47.1 %	63.0 %	61.0 %	56.6 %	55.7 %

[1] Virginia, North and South Carolina, Tennessee, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, and the eastern forested counties of Texas and Oklahoma.

[2] Data for 1952 and 1962 are as of December 31. Data for 1970, 1985, and the projections years are as of January 1

THE THIRD FOREST

In a broad sense, the **third forest** is the one that follows the harvest of the **second forest**. In too many cases the **third forest** is the inadequate natural regeneration that follows high-grade logging, primarily on private, non-industrial lands. This lack of natural regeneration, especially of higher value pine, may or may not be compatible with individual landowner objectives (Alig, et al., 1990). We will say more about this later in the paper. The narrow definition for **third forest** is the pine plantation resource, the so-called **"man-made" forests** that are now emerging as a wood supply. This is the definition that we will use, unless we specify the broader one. Pine plantation area details are given at the bottom of Table X. A very minor area was planted to pines as early as the 1920s, with an accumulation to 729,000 hectares by 1952, about 2.5 percent of the pine area and 1 percent of the total forest area that year. Forest industry, other private owners and public owners have planted steadily since then.

The resource expanded to 8.5 million hectares in 1985, with projections to 10.6 million hectares in 1990. Thus, by 1990, pine plantations would occupy about 15 percent of the total forest area and about 41 percent of the pine area. Forest industry dominates with 61 percent of all plantations on the 24 percent of the southern forest that it owns. These are predominantly on the flat coastal plain where most industrial land is located. Other private owners have nearly 34 percent of the planted area, with public ownership at about 6 percent. Plantation ownerships range in size from a few hectares that are individually owned to several hundred thousand hectares by a single corporate owner. For example, Weyerhaeuser now has more than 607,000 planted hectares in the South, occupying about two-thirds of its southern lands. Other major companies each have several hundred thousand planted hectares.

What is the relative scale of this plantation estate? In simple terms, forest plantations in the United States are dominated by loblolly pine *(Pinus taeda)* tree farms in the South. Consider the following statistics presented by Boyer and South (1984):

• 1.6 billion bare-root forest tree seedlings were produced in the United States in 1980; 80 percent (1.3 billion) were produced by southern nurseries;

• 1.1 billion of this total were loblolly and slash pine;

• 0.97 billion were loblolly pine;

• loblolly pine accounts for 60 percent of all bare-root seedlings planted in the United States;

• the southern pines account for nearly three--fourths of forest planting in this country;

• southern hardwoods were only about one percent of the southern bare-root tree nursery crop.

More recent data for the 1986 to 1989 seedling production years imply even higher reforestation rates in the South. The annual southern tree nursery crop ranged from 1.6 to 1.8 billion seedlings for those years. A projected crop of 1.3 billion seedlings for the next few years implies surplus nursery capacity of perhaps 400 million seedlings per year (Stanley, 1990). Southern-pine tree improvement statistics for 1987 indicate that 33 private companies and 12 public agencies produced 1.33 billion improved seedlings to reforest 753,000 hectares that year. This area was approximately 85 percent of all southern reforestation (White, 1990). By 1985, pine plantations in the South were 9 percent of the reported world total of 92 million planted hectares. Only the USSR, China and Japan claim to have more planted forests (Postel and Heise 1988). The total area planted in the South is more than 25 percent greater than the combined totals for Australia, Brazil, Chile and New Zealand.

Why do we plant pines? Pines are the principal species used for lumber, plywood, pulp and paper. Pine is used, especially locally, at rates that approach or exceed the rate at which it is being grown in natural stands (Robertson, 1989). To complicate matters, second forest pine stands do not usually regenerate to pine by natural seeding after harvest. The conditions for successful pine regeneration -- a source of mature seed, exposed mineral soil, and minimal brush competition -- are seldom present. Thus, hardwood or pine/hardwood mixtures become the naturally regenerated third forest. Total volume yield and certainly pine yield from the naturally regenerated third forest is often less than for the second forest. Pine plantations are established by forest industry as the low-risk way to guarantee the future pine supply. Planting also permits use of the best genetic material and is compatible with intensive site preparation and silviculture.

Loblolly pine may not be the perfect tree, but in the South it is far ahead of the rest, accounting for nearly 90 percent of all pine planting (Boyer and South, 1984). Slash and longleaf pines have superior properties for most lumber and pulp products. Both are planted on a limited scale. So, why is loblolly number one? Loblolly pine is an aggressive species that practically blanketed the South through natural regeneration with the advent of wildfire control. Frequent fires, which favored longleaf as perhaps the dominant pine in the **first** forest, are no longer desirable or permitted on a broad scale. Loblolly pine, more than any other species, became the **second** forest, is the **third** forest, and is the strong favorite for the **fourth**.

Loblolly has adequate wood properties for most products and is the superior pine in most other respects. Genetically, it is the most diverse of all southern pines. Broad genetic diversity is a necessary attribute for a tree that is planted from Maryland to Florida to Oklahoma, and on the spectrum of sites from dry, rocky hills to wet peat swamps. No other species native to the South, either pine or hardwood, grows as well under such a wide range of conditions. Hardwoods such as sweet gum and green ash have been planted on about 32,000 hectares across the South, equal to only 0.30 percent of the area planted to pine (Lea, 1990). Hardwoods are more difficult and more expensive to plant than pines. Natural hardwood stands occupy about 50 percent of the total forest area and continue to supply adequate volumes to satisfy demand (USDA, 1988). Hardwood plantations will be more important in the future, but in no way will planted hardwood approach the dominance of loblolly pine. Exotic species such as eucalyptus, with potentially high growth rates in the South, do not survive the wide swings in winter temperatures. Many have been tried. None are extensively planted.

Droughts of the 1980s and root feeding by grubs on old field sites are the recent causes of plantation failures. These are confined to the upper coastal plain, the piedmont, and to the deep south. Loblolly plantation failures are practically non-existent when the latest technology of intensive management is applied. Mortality due to drought, to girdling by rodents or to root feeding by grubs (on grassy, old-field sites) can be overcome by the proper planting of genetically improved seedlings, on well prepared bedded and fertilized or ripped sites, and with follow-up treatments for insect and weed control where needed. The most intensive treatments are normally not required to get good survival, but these nearly always result in improved tree growth. Most failures occur when the landowner tries to get by with a cheap, poor-quality regeneration effort. Loblolly is so forgiving that cheap regeneration usually has adequate survival, but tree growth is well below potential.

The **second** and **third** forests are subjected to wildfire, insect, disease, and weather-related problems. Wildfire has been reduced to tolerable levels by the state forestry agencies, in cooperation with forest industry and with rural fire departments. Southern pine beetle attacks have increased in recent years due to droughts in the 1980s, in combination with stress in overstocked, maturing **second** forest pine stands. Thinning to maintain maximum basal area below 30 m^2/ha will minimize the susceptibility to beetle attack and subsequent tree mortality. Fusiform rust losses are reduced by planting the most resistant loblolly pine sources. Loblolly is to some extent replacing the more susceptible slash pine in the natural slash range as a result of this effort.

Ozone pollution, as well as normal decreases due to age, may be factors in declining growth rates in older pine stands in the mountains and the piedmont (USDA, 1988). Similar declines have not been documented for plantations in the coastal plain. Tornados are very destructive on a local basis, but in total are not very important. On September 21, 1989, Hurricane Hugo set a new national standard for catastrophic forest destruction. Timber loss to Hugo was more than five times the previous standard set by Hurricane Camille in the late 1960s. Hugo claimed 15.8 million cubic meters of sawtimber and 51 million cubic meters of pulpwood. Hugo did three times the timber damage of the Mt. St. Helens eruption (Davis, 1989). If the equivalent of Hugo was widely and frequently repeated across the South, forest industry would be doomed. We must assume that such will not happen.

TABLE XI Softwood Timber Removals[1], Net Annual Growth, Inventory of Growing Stock in the South[2] by Forest Mgmt. Type, Selected Years 1952-1984, with Projections[3].

	Million cubic meters									
	Year					Projections[3]				
	1952	1962	1970	1976	1984	1990	2000	2010	2020	2030
Pine plantations										
Timber removals[1]		4	3.4	15.4	20.4	39.6	73.4	103.8	120.4	123.9
Net annual growth	2.2	10.3	18.9	29.2	37.0	65.4	105.4	125.4	136.0	142.6
Inventory[4]	18.6	105.8	199.0	278.2	384.2	488.5	812.5	1,141.6	1,347.8	1,518.5
Natural pine										
Timber removals[1]	78.1	69.3	84.6	92.0	95.5	90.8	63.5	47.5	42.6	38.7
Net annual growth	79.9	90.5	99.5	100.2	84.2	55.5	44.8	41.0	38.4	37.4
Inventory[4]	1,249.5	1,404.6	1,522.7	1,648.5	1,653.8	1,279.6	877.4	689.2	617.2	575.3
Mixed pine--hardwoods										
Timber removals[1]	8.3	8.2	9.8	17.5	22.0	21.8	24.8	16.1	14.1	14.3
Net annual growth	12.7	18.6	24.9	26.1	23.7	15.4	13.4	16.7	16.3	14.5
Inventory[4]	194.3	288.9	397.7	467.5	458.3	461.3	377.0	296.4	311.7	331.8
Upland hardwoods										
Timber removals[1]	2.7	2.6	2.6	5.5	8.9	4.1	4.3	5.6	6.3	6.1
Net annual growth	4.0	5.9	8.0	9.6	10.0	5.4	3.5	4.1	4.8	5.2
Inventory[4]	73.8	106.0	143.2	173.3	181.3	237.7	243.1	231.0	214.7	200.6
Bottomland hardwoods										
Timber removals[1]	2.5	2.6	3.9	3.3	5.1	4.9	6.1	7.0	7.5	7.3
Net annual growth	5.0	7.3	6.8	6.6	6.9	7.1	5.4	5.3	5.6	6.0
Inventory[4]	113.4	159.5	181.3	207.4	226.5	272.0	281.6	270.3	251.3	232.3
All management types										
Timber removals[1]	91.6	83.0	104.4	133.6	151.9	161.2	172.0	180.0	190.8	190.3
Net annual growth	103.9	132.0	150.2	171.7	162.0	140.9	172.5	192.6	201.2	205.4
Inventory[4]	1,649.6	2,064.7	2,443.9	2,774.8	2,884.0	2,739.0	2,591.6	2,628.4	2,742.7	2,858.5

[1] Includes removals in the form of roundwood products, logging residues, the volumes of timber removed in cultural operations such as noncommercial thinning, and inventory losses resulting from the diversion of timberland to other uses such as *cropland, pastureland, parks, and urban uses*

[2] Virginia, North and South Carolina, Tennessee, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas and the *eastern forested* counties of Texas and Oklahoma.

[3] All projections at equilibrium prices, i.e., the stumpage prices at which projected timber demands and supplies are equal. Data are averages for 5 years centered on the projection year

[4] Data for 1952 and 1962 are as of December 31 Data for 1970 and all projection years are as of January 1. Data for 1976 and 1984 are as of January 1, 1977, and January 1, 1985

Note Data may not add to totals because of rounding

The South's **third forest** is young. The human analogy is that of a teenager or perhaps a young adult. In south Georgia, south Alabama and north Florida, the region with the greatest number of pulp and paper companies and with the oldest plantations, many mature planted stands have been harvested and replanted within the last 10 years. Some are managed for relatively short pulpwood rotations of about 25 years. The resource in the rest of the South is younger and also more likely to be managed on longer sawlog rotations of 30 to 40 years. For many owners, highly mechanized first and second thinnings have produced an increasing wood flow during the last 10 years, but few hectares have been clearcut. Table XI illustrates the transition to plantations as a wood supply. Comparisons are made for pine timber removals from the two major pine sources -- planted and natural pine stands. A small amount of pine also comes from mixed pine-hardwood stands; this is excluded because I had no method for identifying the pine component. In 1970, plantations accounted for only four percent of the pine supply from both planted and natural pine stands. By 1984, the pine plantation harvest of 20.4 million cubic meters was 18 percent of the combined harvest of 115.9 million cubic meters from pine plantations and pine natural stands.

Consider again our example of New Bern and Craven County. Craven County is now the first or second county in pulp roundwood production in North Carolina each year. With about 612,000 cubic meters harvested per year it usually ranks in the top dozen counties across the South (Hutchins, 1989). Thinnings from Weyerhaeuser's well-managed plantations are a significant and increasing percentage of the Craven County and coastal North Carolina wood supply. The proportion will increase dramatically over the next 20 years as plantations mature and are clearcut. Some of this will supply Weyerhaeuser's new high technology lumber facility which began operating in 1989 in nearby Greenville. Rated at 320,000 cubic meters per year, it is the largest sawmill in North Carolina. The consistently top wood-producing counties across the South are those with intensively managed industrial plantations. Across the South, the projection for 1990 is for plantations to provide about 30 percent of pine harvest, rising to nearly 54 percent by the year

2000 (USDA, 1988). This is an incredible rate of rise and brings us to a consideration of the **fourth forest**.

THE FOURTH FOREST

Southern pine plantations are a must -- no other option will produce the projected demand for wood (USDA, 1988). The **fourth forest**, our wood supply in the future, will more than ever depend upon the wise management of pine plantations. The pine volume to be required in 2030 is 25 percent greater than in 1990. The projection for 2030 is that pine plantations must supply 76 percent of the pine volume to be harvested from natural and planted pine stands. At this rate, pine plantations should produce 65 percent of total wood requirements in the South for all wood uses for all species (USDA, 1988).

Can we get there from here? The history of forest utilization and management in the South actually makes it more difficult to supply the projected demand in 2030. **First forest** exploitation established a pattern of "high-grading" that continues with all too many private, nonindustrial owners. No provisions are made for either natural or artificial regeneration when forest tracts are harvested. And the South has been spoiled by the success of the **second forest**. For nearly 50 years, from perhaps 1940 until the late 1980s, excess timber volumes relative to demand were grown at no cost or low cost to both industrial and other private land owners. Industry mill expansions and increasing wood demand have exceeded the expanding wood supply in only a few areas. Excess supply kept a lid on wood prices and was a disincentive to investment in plantation establishment. Most plantations have not been intensively managed. Plantation growth rates per unit area in the South are modest because of this. Plantation growth rates per unit area in Australia, New Zealand, Chile, Brazil and South Africa exceed those in the American South by a factor of two or three only partly because of milder climates and faster growing tree species. On average, the limited plantation resources in these countries are very intensively managed. Site preparation, weed control, and fertilization are much better than we practice, on average, in the South.

Federal and state governments have recognized the need to increase reforestation in the South. Most industrial companies have landowner assistance programs (Smith, 1989). More sources of financial and technical assistance are available to non-industrial, private timberland owners for reforestation and timber stand improvement practices than ever before (Gunter and Ogden, 1989). Federal programs include the Agricultural Conservation Program begun in the 1930s, the Forest Incentives Program of 1974, the Conservation Reserve Program of 1985 and the Tree Assistance Program of 1988. Seven southern states have reforestation incentive programs begun in the 1970s and 1980s. Virginia and Mississippi have mandatory regeneration "seedtree" laws.

Federal and state incentive programs typically have limits on minimum land area to be treated, maximum annual payment and permissible treatments. The proportion of timber harvest sites that are replanted has increased because of these programs. The ratio of replant-to-harvest, which was perhaps only one in ten in the early 1970s, has increased to better than one in two in many areas. The programs do not, however, tend to encourage the most intensive forestry, but they are getting more land area planted.

The Conservation Reserve Program (CRP), authorized by the Food Security Act of 1985 and the Conservation Reserve Soil-bank Program of the 1950s and 1960s are good examples of the incentives required to put large areas of private, nonindustrial lands into forest production. The CRP program, which was designed to retire highly erodible land from row crop production, has been a real success. About

810,000 hectares of farm land in the South have been planted to pine since the program began in 1986 (Canavan, 1990). A similar area -- about 810,000 hectares of farm land -- was planted to pines by the Soil Bank program 30 years ago (SFRAC, 1969). CRP program financial incentives are two-fold: a cost-share payment of up to 50 percent of plantation establishment cost *and* ten annual rental payments for keeping the land as a tree plantation. The cost of establishment and the lack of quick income are disincentives to forestry for most private landowners, even if the ultimate financial returns in 25 to 40 years are very high. The CRP program has successfully overcome these barriers. Any large-scale reforestation program that involves private landowners will need a similar package of incentives.

The South is capable of growing twice as much timber volume as it does today (Robertson, 1989). Some of the increase can result from timber stand improvement (TSI) of existing forests. The biggest opportunity, however, is for new planting. More pine plantations need to be established, using the most intensive treatments available. Forest industry has proved that higher yields are possible. The fourth forest wood supply projections apply a 50 percent higher growth rate for a 30-year crop cycle to industry plantations than to private non-industrial ones (USDA, 1988). Forest industry growth rate for medium sites is 7 m^3/ha/yr, compared to 4.6 m^3/ha/yr for private, nonindustrial plantations. By comparison, natural stands of either pine or hardwoods typically grow at only half these rates -- at 2 to 3.5 m^3/ha/yr. Companies committed to the most intensive management have average growth that is much better than this -- in the range of 10 to 14 m^3/ha/yr. With repeat fertilizer applications, growth can easily exceed 14 m^3/ha/yr on large areas of intensively managed lower coastal plain. Figure 13 compares growth rates and total volume yields that we would expect from three levels of management in coastal North Carolina. If all were established as one-hectare demonstration plots in 1990, the most intensive plantation would potentially store four times as much carbon as a typical natural stand by age 40, in the year 2030. Well managed, long-rotation pine plantations are the way to store carbon in the South. This is in contrast to the Pacific Northwest where the ancient forest already stores very high volumes. Westvaco and Weyerhaeuser are just two of several companies that have committed to research, to high technology and to intensive management to improve forest productivity (Martin, 1990).

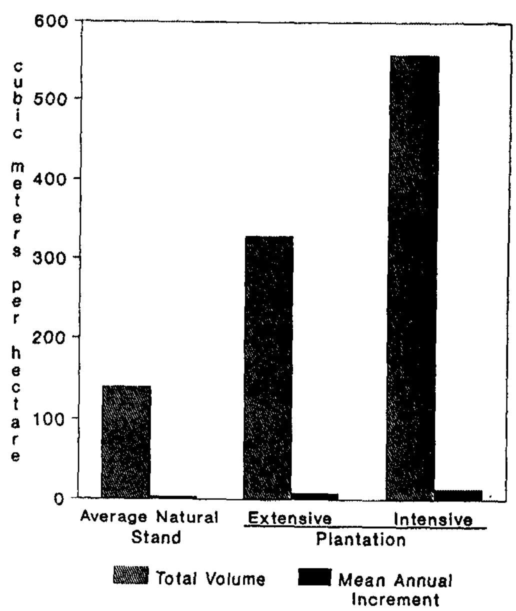

Figure 13. Comparison of Mean Annual Increment and Total Volume Yields That are Typical for 3 Levels of Forest Management.

The university-forest industry cooperative research programs are key in the effort to increase yields through genetics, nutrition, nursery practices, pesticides, yield modeling and development of environmentally sound best management practices (BMP's). Nearly every major company and state forestry agency is a member of one or more of the cooperatives.

FOREST MANAGEMENT FOR CARBON STORAGE

If forestry is to be a significant solution to the atmospheric problem of excess CO_2, what are the requirements?

• a large-scale effort -- The CO_2 problem is massive and global. Estimates for the incremental carbon sink range from 200 to 500 million hectares of new, fast-growing forests ($\geq$ 14 m^3/ha/yr) (Woodwell, 1987; Sedjo, 1989; Sedjo and Solomon, 1989).

• fast startup -- Forest growth rates need to be high, very quickly -- the atmospheric CO_2 level has risen 25 percent since the early 1800s and is increasing at an increasing rate relative to human population growth, which is projected to double to 10 billion by 2040. Carbon storage is directly proportional to forest growth rate expressed as dry weight accumulation. Every kilogram of tree growth removes half a kilogram of carbon (i.e., 1.8 kilograms of CO_2) from the atmosphere.

• long-term carbon storage -- Carbon should be stored in growing trees and/or non-oxidizing products for at least 30 to 50 years until other technologies are developed to reduce the excessive production of CO_2 and other greenhouse gases (Sedjo and Solomon, 1989).

As a forester, how do I think that these requirements can be met?

• A large-scale effort -- The magnitude of the problem is so large that it cannot be solved by plantations in just one region of the world. In the near term, resources should be applied to several or all areas that have:

1) an infrastructure for plantation forestry and forest utilization;
2) cost-efficient plantation systems, expressed as cost per unit of carbon stored;
3) a large land area that can be reforested;
4) potentially high growth rates.

• fast startup -- Establishing plantations that rapidly achieve maximum growth rates per tree, per unit area and per region can be met by:

1) an infrastructure for plantation establishment;
2) a large land area that can be reforested;
3) potentially high-site land;
4) intensive management;
5) tree species with high growth rates;
6) relatively high stocking levels.

• long-term carbon storage - Long-term carbon storage may be the most difficult part, especially if you achieve the first two -- a large scale and a fast startup. Strategies that quickly produce high growth rates over large areas will have high rates of tree mortality due to intraspecific competition unless steps are taken to prevent this. Dead trees rot and release CO_2 very quickly in most tropical and subtropical regions; thus do not provide carbon storage comparable to temperate regions. Short rotations (5 to 25 years) for energy fiber or pulp production are one solution to the excessive tree mortality problem. Short rotation crops can help solve the excess CO_2 problem if used to recycle CO_2 in lieu of new CO_2 production from fossil fuels. Short rotations, however, put the chance of long-term carbon storage at risk and for a variety of reasons will be harder to sell to the public. Some variation of Weyerhaeuser's High Yield Forestry (HYF) program can meet all three requirements -- large area, high growth rates and relatively long crop cycles. The objective of HYF is not only to double the growth rate per unit area relative to natural stands, but also to provide multiple thinnings and a final harvest which yields a high percentage of veneer bolts and sawlogs (i.e. long-term carbon storage in products). Applied technology and mechanization have made commercial thinning economically feasible and routine across the flatlands of the South. The economic result in the South justifies relatively long rotations of 30 to 50 years for HYF loblolly pine. High Yield Forestry requires:

1) commitment, cash and competence (McCarthy, 1974);

2) an infrastructure for plantation establishment, management, and utilization;

3) land ownership on a moderately large scale;

4) potentially high-site land;

5) intensive management to achieve site potential;

6) tree species that have high growth rates;

7) ability to thin, but to also maintain relatively high stocking levels throughout the rotation;

8) enlightened political, social and environmental treatment.

One of the best examples in the world where such a regimen has been made to work for nearly two crop cycles (100 years) is in the "Down under" South -- in South Australia (Boardman, 1988). Radiata pine *(Pinus radiata)* is intensively grown at the edge of the desert by the Woods and Forests Department at the remarkable rate of nearly 21 m^3/ha/yr on a 50-year crop cycle. Seventy (70) percent of the total volume is harvested as sawlogs which go into long-term carbon storage as particle board, plywood and lumber. Sixty (60) percent of the total volume is removed by five thinnings that are made between age 12 (primarily as pulpwood) and age 42 (primarily as sawlogs). South Australia provides the best example of "speedand-power-at-the-same-time" carbon storage that I have seen. Some owners, including Weyer- haeuser, are beginning to manage loblolly in similar fashion.

PINE PLANTATIONS FOR CARBON STORAGE IN THE SOUTH?

Yes, the U.S. Environmental Protection Agency should strongly consider an incentive program for privately owned, large-scale pine plantations for carbon storage *and* for wood production in the American South. These are a few of the reasons:

• The United States is the leading producer of CO_2 (Marland, 1988). We should take the leadership in reducing the problem by increasing the area of forests that provide carbon storage where it is being produced as well as encouraging reforestation in other countries.

• The South is the most logical region in the United States in which to do this:

1) The South is a vast timber growing region of 73 million forest hectares -- the forest area can be expanded.

2) The South provides an impressive example of increasing carbon storage as a result of forest management. The bottom line from Table XI (page 59) is that timber inventory increased from 1,650 million cubic meters in 1952 to 2,884 million cubic meters in 1984. The inventory will decline, however, due to increased wood demand and to conversion of forest area to other land uses unless forest management is intensified and expanded to more land area (Robertson, 1989; USDA, 1988).

3) The South has a timber growing and utilization infrastructure second to none in the United States and on par with the best in the world. Such a structure is imperative to successfully grow and store carbon on a long term basis.

4) With the best intensive management, loblolly pine plantations have high growth rates ($\geq$ 14 m^3/ha/yr).

5) The South is 90 percent privately owned and all sites have previously been harvested at least once. The forces of private enterprise can most easily be harnessed to do the job in the South. With proper incentives, forest produc-

tion in the South can more than double current growth and growth rates. Further, the South has 9.3 million hectares of marginal and/or highly erodible agricultural lands better suited for forestry (USDA, 1988). Also, in my opinion, an additional 10 to 20 million hectares of cut-over forest, and poorly stocked, slow-growing natural pine, pine-hardwood mixtures and hardwood uplands can be replaced with intensively managed pine plantations.

6) The South can provide 5 to 10 percent of the global need for incremental carbon storage, based upon my most optimistic estimates.

7) The South is going to need the wood. Without a greatly expanded pine plantation resource, the South is projected to have a serious timber shortage within 20 years -- with the potential loss of 297,000 jobs -- 85,000 directly in forestry and 212,000 in service industries (USDA, 1988). New plantations are a win-win solution. If projected wood demand occurs, new plantations can fill the gap. If it does not or if new technology or recycling offset demand, well-managed plantations with extended crop cycles provide even greater incremental carbon storage.

ENVIRONMENTAL, POLITICAL AND SOCIAL ISSUES

Large-sale reforestation to slow increases in atmospheric CO_2 and thus to slow global warming will encounter the same issues that similar efforts for commercial wood production have encountered. In fact, forest plantations for carbon storage in the South should be intensively managed on long rotations for commercial timber production. In recent years, environmental issues very quickly become social and political issues. The following are a few of the issues that confront forest managers in the South:

Clearcutting. The most efficient harvesting and regeneration method for loblolly pine and most other rapidly growing pioneer species is by clearcutting mature natural stands or plantations, intensively preparing the site and planting genetically improved seedlings. Many people equate clearcutting with tropical rainforest destruction and are against it, anywhere, anytime.

Monoculture/reduced genetic base. Loblolly pine grows best in pure stands and better still if from a reduced genetic base selected for disease resistance and high growth rates. The most efficient management is for trees planted in uniformly spaced rows. The negative term for this is "cornfield" forestry.

Natural is better than managed. For aesthetic and perceived biological reasons, the virgin forest and the natural second growth forest are assumed to be better than an intensively managed plantation. Part of this issue is related to arguments concerning a reduction in biological diversity. Words such as plantation, tree farm, high yield forestry, intensive management and managed forest have a negative to very negative connotation for some people.

Competition from alternative land uses. Urban expansion, agriculture, wilderness, highway rights-of-way, impoundments, etc., continue to reduce the land available for production forestry. Intensive forest management is required to offset this trend. Intensive management does this in two ways: 1) an increased wood growth rate on a reduced land base can offset the loss of area, and 2) intensive management gives economic returns that are high enough to prevent some lands from being converted to agriculture. Nevertheless, the returns from intensive forestry are probably never high enough to compete with urban development.

Water use. Rapidly growing tree plantations cycle proportionally large amounts of water. Some people have suggested that droughts and water shortages in the South in recent years may have been magnified by the increasing area of intensively managed pine plantations. Conversely, others have suggested, as in the case of the Åmazon rainforest, that forests are an integral part of the hydrologic cycle and contribute to rainfall and water supply.

Tax base. Timberland is at or near the low end of the spectrum for land values. Farmland that is planted to forest trees normally will lose both market value and appraised value for tax purposes. Large-scale reforestation of such lands has serious consequences for local governments that depend upon property taxes as a primary source of income.

Wetlands. The most productive loblolly pine plantations in the South are intensively managed wetlands. Section 404 of the Clean Water Act provides permit exemptions for normal silvicultural activities in forested wetlands. The National Wetlands Forum strongly endorsed and encouraged continuing commercial forest management in wetlands (Conservation Foundation, 1988). Several activists groups do not agree with this, however, and have threatened lawsuits to greatly limit the intensity of management of forested wetlands.

Second rotation (2R) problems. Long-term soil/site productivity is a concern for lands that are intensively managed for successive harvests of high yielding timber or agricultural crops. South Australia provides the best example of second rotation decline and how to avoid it in forest plantations (Boardman, 1988).

Pesticides. Herbicides and, to a lesser extent, insecticides and fungicides are necessary for successful intensive forest management. Pesticides can improve seedling quality and increase survival and growth rates, thus making the difference between plantation success and failure. Pesticides pose minimal environmental hazards when used by professionals according to label directions. Nevertheless, some activist groups are opposed to the use of all pesticides and advocate extensive rather than intensive silviculture.

Habitat loss/endangered species/minor species. Intensive management on a large scale will encounter the issues of endangered species and habitat. Some problems are a matter of perception, others are a matter of content; both type problems must be confronted and solved.

Successful large-scale reforestation for wood production and for carbon storage will require that the above issues are resolved. A national and international consensus must be reached, because these issues concern all regions in the world that are suitable for large-scale reforestation. I believe that a designed landscape-scale mosaic of intensively and extensively managed forests, farmlands, residential areas and other land uses will be part of the ultimate solution. Forest industry, other land owners, state and federal agencies and environmental groups must reach an agreement on how to fit it all together. Elements of this solution are already being used. Most states are developing forestry best management practice (BMP) guidelines that address sedimentation, water quality and other issues. Scott Paper Company has won several awards for involving the public in an effort to utilize and regenerate natural hardwoods in the Mobile River Swamp. Champion International Corporation has recently developed management guidelines for the company's Escambia River bottomlands in Florida (Champion, 1990). These guidelines were developed jointly not only by company foresters and loggers, but also with input from state and federal agency and university professionals. Maintenance of wetland hydrology, wildlife habitat, and timber production functions are equally provided for in the guidelines.

I am a member of two environmental groups that are also beginning to say and do things that support the need for managed plantations, not just passively managed, natural timber resources. An element in the Sierra Club's Global Warming Action Campaign is for each member to "plant a tree, or two" (Sierra Club, 1990). This is good public relations. And, if planted in the right locations, trees will not only store carbon, but will also shade your home to reduce the need for air conditioning powered by electricity that is produced by burning fossil fuels. The Sierra Club should be very happy with at least part of what the forestry community did in 1989 -- we planted 2.7 billion trees in the United States (Polsky, 1990). That is more than one-half tree for each person on planet Earth. Audubon magazine editor Les Line made a very strong statement in support of both the need to preserve the ancient forest and the need for southern pine management in the March 1990 issue "Etcetera" column (Line, 1990). "As for trees, we're not chainsawing old-growth hemlocks to print *Audubon*. An average issue requires the cutting of three acres (1.2 ha) of managed Mississippi pinelands, a total of 900 trees 14 inches (36 cm) in diameter. One could argue that we're helping to keep trees growing. Indeed, the United States Forest Service is worried because too much private timberland in the South, acreage that should be growing trees for future harvest, is being converted to crops or pasture, simply not replanted, or lost to urbanization." Mr. Line said it better than I have in writing this paper. He has begun the description of a landscape-use mosaic upon which we all need to reach an agreement. Perhaps the universal need for both forest products and increased carbon storage will force us to resolve our differences.

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AFFORESTATION IN BRITAIN
--A COMMENTARY

Douglas C. Malcolm

Abstract

Ecological conditions in Britain allow a wide range of productive species to be used in afforestation. Progressive destruction of the species-poor natural forest and a national crisis stimulated the initiation of a 70-year program of planting, by state and private owners, of 2,000,000 hectares by the year 2000 that achieved its initial objectives. Techniques to afforest difficult sites emerged from applied research while concentration on financial criteria led to uniform plantations of a few species that did not gain public approval. The replacement of fiscal incentives by grant aid has caused a loss of confidence and further expansion of the forest estate is in doubt, despite the need to transfer agricultural land and a permanent timber deficit.

INTRODUCTION AND HISTORICAL BACKGROUND

The British Isles lie off the western seaboard of Europe between latitudes 50-58° N. This account will refer briefly to Britain and will concentrate on Scottish conditions, where the bulk of forests now occur and where the potential for further expansion of the forest area is greater than in England and Wales, despite their greater land area.

At the end of the last main glaciation (11,000 BP), which covered most of Britain except the southernmost parts, there followed a short reversion to colder temperatures for 1,000 years resulting in a recurrence of glacial and periglacial conditions. This had marked effects on the development of topographic features and the deposition of morainic and fluvioglacial deposits. Release of the land from ice-cover led to isostatic rebound of the surface with complementary fluctuation in mean sea level, leading ultimately (about 5,500 BP) to the separation of Britain from mainland Europe.

From 10,000 BP onwards, the development of forest vegetation was rapid, reaching its greatest extent by 5,500 BP when further colonization from Europe ceased. The composition of this forest was of mixed deciduous species with the only conifer, Scots pine (*Pinus sylvestris* L.), being confined essentially to the Scottish Highlands. Some species (e.g. *Fagus sylvatica, Tilia cordata*) never penetrated north of Cumbria in northern England. The so-called 'climatic-optimum' (ca 6,000 BP) allowed forest vegetation to reach 880m in elevation when mean summer temperatures are thought to have been about 2° C warmer than present.

From 5,000 BP onwards man had an increasing effect on vegetation which, together with persistent oceanic climatic conditions, led to the decline in forest cover and expansion of peat- or heath-covered landscapes. Although between the period of greatest extent and 2,000 BP it is difficult to distinguish climatic and anthropogenic effects, the decline of forest vegetation thereafter is due to agricultural and industrial developments. Sheep pasturage and arable production removed most forest in South Scotland, England and Wales by the 16th century. In the highlands of Scotland the introduction of extensive sheep farming together with charcoal production for iron smelting during the 18th century led to massive clearances which culminated in the 19th century.

It is interesting that the development of forest management in the 18th century in western Europe to restore its war-devastated forests was not paralleled in Britain despite the attempts of a few farsighted individuals to create interest in existing woodlands and the first attempts to introduce exotic species. Relatively small areas of broadleaved species, of course, had been managed on a coppice-with-standards system throughout the Middle Ages. The basic reasons for exploitation of native forest were the reliance on imports of high quality timber from an expanding colonial empire and abundant sources of cheap energy from fossil fuel. After 1850 there was increasing pressure for forestry development from the larger landowners, particularly in Scotland, who recognized the strategic weakness of relying on overseas sources and the irony of introducing forest management in tropical forests in India whilst neglecting those at home. Government took no action.

The potential for afforesting bare land was recognized in the latter part of the 18th century when initial plantations of European larch (*Larix decidua* Mill.) was established over about 4,000 hectares on the Duke of Atholl's estate in Perthshire. This species became popular throughout Britain because of its general usefulness for estate purposes. At the same time the upsurge of interest in amenity plantings led to botanical exploration throughout the temperate regions and collection of a long catalogue of exotic species that were more or less successful when planted on good sites around landed properties. The outstanding introductions were those originating from the coastal regions of western North America, brought back by Menzies, Douglas and Jeffrey. The potential for productive forestry was immeasurably increased by these introductions, beyond the limited scope in the British climate for the earlier introductions of larch, Norway spruce (*Picea abies* (L.) Karst.), silver fir (*Abies alba* Mill.) and sycamore (*Acer pseudoplatanus* L.).

The importance of this period in the late 19th century in the empirical assessment of species potential for British conditions cannot be overemphasized. Much of the subsequent expansion of forest area depended on this 'sifting' period which began to concentrate foresters' minds on the West Coast species.

In summary, by the start of the present century indigenous forest had been reduced to a few much-altered remnants and total forest cover was reduced to about 3 percent of the land surface (ca. 700 k ha). There was no national policy, although forestry education had begun and there were some small-scale initial attempts to establish plantations of exotic species.

DEVELOPMENT OF GOVERNMENT POLICY -- OBJECTIVES AND MEANS

The first World War demonstrated very clearly the need to have a forest resource independent of imports. The small areas of utilizable timber were exploited heavily, generally with little regard to regeneration or restoration. The national crisis led directly to the formation in 1919 of a forest service -- the Forestry Commission (FC). Interestingly, this organization was from the start independent of the agricultural departments. The FC was charged with developing a forest estate to provide three years' supply of timber as a strategic reserve. This was thought to require the afforestation of about 710,000 hectares in the 80 years following the war to add to the restoration of the 800,000 hectares estimated as existing woodland. These figures also included what is now the Republic of Ireland. Planting targets were 60,000 and 20,000 hectares for FC and private woodlands (PW) respectively in the first decade, for which £3.5 M was budgeted in the new Forestry Fund.

Subsequent budgetary constraints altered the program but not the objectives of expanding the forest area, until the Second World War once again led to intensive felling in those areas which had been too young twenty years earlier. Forestry Commission plantings were still too immature to contribute to the war effort. In 1943, however, the FC published a White Paper on Post War Forest Policy, later enacted in 1945 and 1946, which enhanced public support for PW and expansion of the state sector. The planting targets set for ten years were in line with the aim of 2,000,000 hectares by the end of the century, although this aim was not formally adopted. The requirement for felling licenses was introduced.

Forestry policy in Britain has evolved progressively by periodic review and ministerial pronouncement. It became clear by the mid-1950's that creation of a strategic reserve of timber was no longer appropriate and this was replaced by commercial and social objectives. Private woodland owners' organizations were then reorganized and support schemes were strengthened.

Starting in the 1950s and increasing rapidly thereafter, management companies were able to attract investment from the city for the afforestation of bare land. This development took advantage of the existing fiscal measures whereby those who paid high marginal rates of tax could offset new investment. It also attracted those who wished to pass on their woodland estates to heirs with minimal reductions in capital value through the estate duty provisions.

With the increase in PW planting (Figure 14) afforestation began to impinge on the public's perception of the countryside and more particularly the treeless uplands. Equally the application of economic criteria, notably net discounted revenue techniques, to the forests in the lowlands was leading to a change from predominantly broadleaves to conifer plantings. As the affluence and mobility of urban populations grew they increasingly resented changes in the landscape. Public opinion led to the passing of the Countryside Acts of 1967-68 which

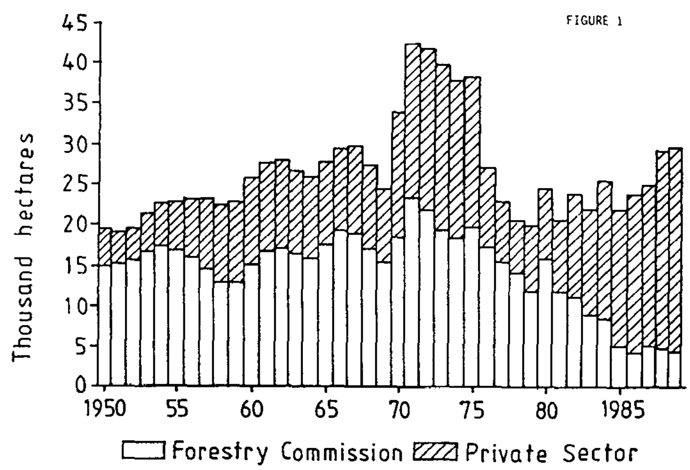

Figure 14. New Planting Since 1950.

set up the Countryside Commissions in England/Wales and Scotland. These Acts also empowered the FC to develop recreational sites and to plant and manage trees for amenity purposes.

A major review of policy took place in 1972 as a result of a cost-benefit analysis conducted by the Treasury and was published as a Consultative Document. This laid down the principal objective of new FC planting as the creation and maintenance of rural employment which was to be achieved by a planting/replanting target of up to 22,250 ha y^{-1}. The FC was allowed to pursue amenity objectives with profit foregone and recreation was to be emphasized.

The accounting system was reconstructed to set FC a target rate of return of 3 percent in real terms. The difference between this rate and the amounts normally charged to government departments is considered a forestry subsidy. This rate of return and subsidy have been reviewed quinquennially after a revaluation of the estate. The private sector support was also altered. In return for grant aid, not only sound forestry practice was demanded but also good land use, including effective integration with agriculture, environmental benefits and provision of recreation and access. In 1977, rates of grant aid were further increased.

Support for private sector forestry does not work in a vacuum but is influenced by general economic conditions and the fiscal approach of governments of different political persuasions. The introduction of Capital Transfer Tax in 1975 was softened for woodland owners as they could opt to defer payment, after the death of the previous owner, until the trees were harvested. Tax is then due on timber values at the time of transfer. Further, the investor in new planting could not only obtain relief by offsetting current tax liabilities but could, with a change of ownership, revert to another tax schedule that taxed land values rather than timber sales. In addition, commercial woodlands were not subject to capital gains tax.

These benefits led to an increasing rate of land transfer to forestry, particularly where farmers were having difficulty financially. Whole farms were purchased and large blocks of forest were established. Each transfer was subject, of course, to approval of the agriculture departments, but as they had to handle each case separately there was no overall land use planning mechanism that ensured a reasonable balance between competing land uses. In general, clearance for planting could be obtained (i.e., qualification for grant-aid) only for land of poor quality at higher elevations unless the better, lower land could no longer be considered as economically viable in agriculture. The market for land became distorted and in effect the vendor's sale price included the grant-aid for planting; that is, land prices were enhanced, as the investor sought the fiscal inducements rather than the grants.

The silvicultural developments, described later, made it possible to effectively afforest almost any quality of land profitability. Forestry thus expanded onto areas of extensive peatland and remote upland because of technical possibility, low prices of land and the government policy of retaining a reasonable amount of land in agriculture.

RECENT DEVELOPMENTS AND CHANGES OF DIRECTION

Since 1980 there have been a number of important changes in forestry policy and its support. These have arisen from the development of agricultural surpluses in the European Economic Community (EEC), the increase in environmental concern amongst the public at large, a disposal policy for state forests and, crucially, the alteration of fiscal arrangements.

The efficiency of agriculture, which has increased steadily since 1945 in Europe, began to generate huge surpluses within the EEC in the 1970s and became intolerable burdens for taxpayers in the 1980s. The imposition of dairying quotas was a first response, although beef, sheep and cereal support have all attracted attention. In the UK there are estimates of more than 1,000,000 hectares surplus arable land which might be removed from production. Government response has been to loosen planning restrictions on land transfer from agriculture, adopt 'set-aside' schemes and encourage diversification. As part of the latter approach, the planting target for forestry was increased to 33,000 ha/y in 1987. Similarly a trial farm woodland scheme aims for 12,000 ha/y of new planting by farmers between 1988-1991. The EEC proposals for forestry indicate the desirability of large scale transfer from agriculture to forestry.

Public concern with environmental matters has been evinced in a number of directions. One has been the effects of atmospheric deposition and associated fears of 'forest decline.' Although quite high atmospheric inputs are measured, particularly in the uplands, no clear evidence of general pollution damage to trees and forests has been discovered so far. There is, however, good evidence that forests are effective in trapping pollutants that are subsequently transferred to water courses, where they can be detrimental to fish and other aquatic life. This problem is of greatest concern on acidic igneous rock types where aluminum concentrations in forest streams can be quite high.

A second concern has been the change in habitat type from open moorland consequent on afforestation. Although new forests soon develop a wide range of wildlife, including the expansion of residual forest-dwelling creatures that were endangered, this is not considered by many conservationists sufficient compensation for the "loss" of open range species, particularly birds. This aspect of conservation has received the greatest publicity and resentment against afforestation in the media. The conservation organizations, particularly the Royal Society for the Protection of Birds and the Government's own department, the Nature Conservancy Council, have attacked forestry policy, with much attendant publicity, adducing evidence that does not always withstand scientific scrutiny.

The third and related concern has to do with landscape, originally in the lowlands but increasingly in the uplands. Complaints here have to do with ease of access for hillwalkers, but more particularly the visual aspect of the countryside. The industrial approach to agriculture and the formation of large, uniform, plantation forests has led to a perceived loss of visual diversity. This feeling has been growing in strength, particularly in more densely populated England, for the last twenty years.

These expressions of public opinion have separately and together had some impact on politicians so that there has been a number of reviews, such as the House of Lords Select Committee's investigation of the *Scientific Aspects of Forestry* in 1980 and, this year (1990), the publication of the House of Commons Agriculture Committee's two years of deliberation on *Land Use and Forestry.*

The effect of public concern has been to modify the possibilities of large-scale afforestation by the government's adoption of a series of constraints since the 1950s. These include:

- National Parks (England and Wales)
- National Scenic Areas (Scotland)
- National Nature Reserves
- Sites of Special Scientific Interest
- Environmentally Sensitive Areas

Not all of these prevent afforestation but they influence its location, extent and type. Finally in 1988 the Minister of the Environment announced that approval would not normally be given to proposals to plant conifers above 240 meters elevation in England.

A further response to public pressure was the adoption by The Forestry Commission of a Broadleaves Policy in 1985. This encourages broadleaved species by enhanced grant payments loaded heavily towards small woodlands and by insisting that all planting, even in the most extreme conditions, should comprise five percent broadleaves. This has been put into practice in all FC forests at the regeneration stage.

The present administration is well known for its emphasis on the supposed benefits of free market forces and the undesirability of national enterprises. Shortly after taking office (1981) it passed an act empowering the FC to dispose of forestland and then instituted a program of disposal to reduce the dependence of the FC on the public purse. A target of £82 M sales was set for six years and this year has been extended to a further 100,000 hectares in the next ten years. This rationalization has allowed the FC to get rid of some small and uneconomic areas and is supposed to improve the efficiency and commercial effectiveness of the forestry enterprise. The funding of the FC has been positive to the Exchequer (excluding interest on earlier payments) since 1982-83.

The whole basis of support for private forestry changed abruptly in the March, 1988, budget. As part of general policy, the marginal rate for income tax payments was reduced to 40 per-

Table XII WOODLAND GRANT SCHEME, 1988

WOODLAND GRANT SCHEME OBJECTIVES

* To encourage timber production.
* To provide jobs in and increase the economic potential of rural areas with declining agricultural employment and few alternative sources of economic activity.
* To provide an alternative to agricultural production and thereby assist in the reduction of agricultural surpluses.
* To enhance the landscape, to create new wildlife habitats and to provide for recreation and sporting uses in the longer term.
* To encourage the conservation and regeneration of existing forests and woodlands.

The rates of grant will be increased to levels set out in the following table:

AREA APPROVED FOR PLANTING OR REGEN. (HA)		RATES OF GRANT Conifers £ per ha	Broadleaves £ per ha
Area band	0.25-0 9	1,005	1,575
	1.0-2.9	800	1,375
	3.0-9.9	795	1,175
10 and over		615	975

Both new planting and replanting areas qualify for grant aid.

cent. This would have markedly affected city investment in afforestation in any case, but the Chancellor went further and removed forestry from all tax arrangements except inheritance tax. At a stroke, this stopped investment of the type that had driven private afforestation. It also removed management incentives from existing woodland owners, who could no longer offset expenditure on desirable silvicultural operations. These drastic changes in fiscal support were rapidly followed by a new grant scheme that unified previous schemes and increased materially the payable amounts (Table XII). Nevertheless, much confidence was lost, millions of plants in commercial nurseries were burnt and few investors who do not already own land are presently forthcoming. This is not altogether surprising, as present interest rates provide ample alternative opportunities to invest and the anticipated drop in agricultural land prices, because of uncertainties in future support, have not materialized. Existing landowners have shown some interest in the new scheme, but in its first year the new grant-aid planting reached only 318 hectares. There was, of course, a carryover from earlier approved schemes so that the total private woodland new planting for 1988-89 was a record 25,000 hectares. For the current year, forecasts range from 8,000 to 16,000 hectares, depending on one's degree of optimism.

THE PRESENT SITUATION AND TRENDS

In summary, the development of afforestation in Britain is a story of government reluctance to initiate a national program until forced by circumstances in a world war. Once begun, successive administrations have pursued a policy of expansion, reinforced by a second war, although they have never officially set other than periodic planting targets for the succeeding few years. Ironically, when the present government deliberately slowed down FC expansion and initiated a disposal program to emphasize private planting, public opinion was being swung against afforestation in the uplands. While the government began to tackle agricultural surplus land by increasing annual targets to 33,000 hectares and initiating a farm-woodland scheme of 12,000 hectares, the Chancellor, apparently in response to conservationist and media clamor, removed the means by which land transfer could take place. The switch to entirely grant-aid incentives might broaden the base of ownership of forest but the level of grant set does not take account of the inflated price of agricultural land. It is clear that either the planting targets or the incentives will have to change.

A number of verities continue to exist. Despite the increase in forest area to 10 percent, Britain still is dependent for 88 percent of its wood consumption on imports (Figure 15).

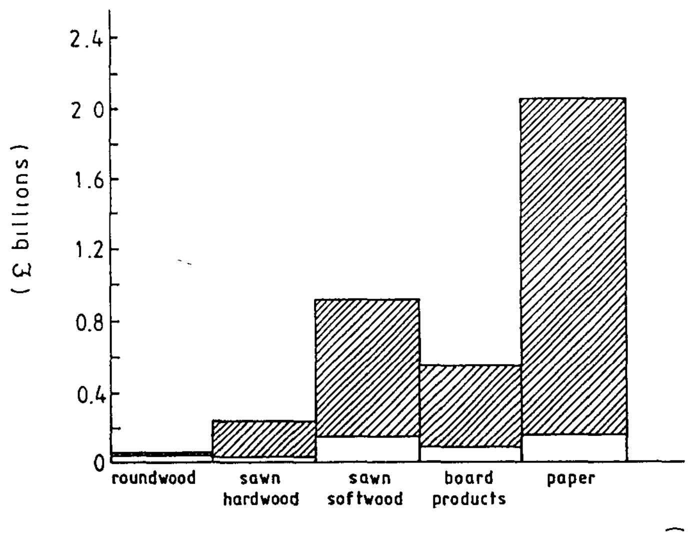

Figure 15. Value of U.K. Consumption, Showing Contribution of U.K. Production.

These imports of about 50 million m^3 per year cost about £6 billion, which is approximately equal to one month's total exports. The 6 million m^3 currently cut annually in Britain is predicted to rise to about 10 million m^3 annually by 2005 (Figure 16). On the strength of the existing wood resource, the timber industry has installed more than £650 millions-worth of processing capacity in recent years. Needless to say, processors are concerned at the present hiatus in afforestation, fearing supply shortages next century (Figure 17).

The steadily increasing felling program over the next decades will cut into the post-1945 plantings progressively so that, without continued rapid expansion, total production will fall. Assuming a 50-year rotation for conifers and 120 years for broadleaves, the current forest estate might be expected ultimately to balance out, in very crude terms, at an annual cut of 30,500 hectares and 4,750 hectares respectively. A very approximate sustained yield might then be 18.3 million m^3 conifer and 2.3 million m^3 broadleaves, which is still rather less than half present consumption levels.

The distribution of the current forest estate by ownership and type is shown in Table XIII, page 77. Some 57 percent is private woodland, including the vast bulk of broadleaved areas, predominantly in England. By contrast, 63 percent of conifers are found in Scotland and that is where further expansion of productive forests will occur.

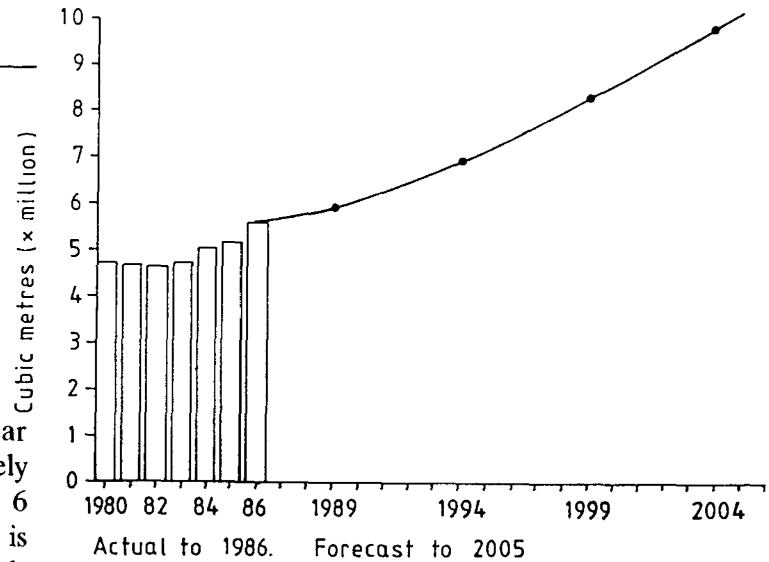

Figure 16. Timber Production in Britain -- Total of FC and Private Sector.

Present trends in public thinking are interesting. The aversion to large-scale upland afforestation does not extend to trees in general. For example several organizations have been formed recently to specifically promote tree developments with an emphasis on amenity planting. These include the National Hardwoods Program, The Woodland Trust, and the Small Woods Association, all of which pursue amenity and nature conservation through the use mainly of native species. The Countryside Commission in England propose a large, dispersed forest in the English Midlands and a similar scheme has been set up in the Central Lowlands of Scotland. These have been met with general approval and, although the initiatives will alter the social environment, they will add little to timber production.

To overcome the outright conflict between conservation and afforestation interests and to take account of local interests, as expressed by local government, there has been evolving in Scotland so-called Indicative Strategies for Forestry. These identify areas where afforestation is or is not appropriate and have been supported by land capability maps that take account of major site factors. Local authorities recognize the employment potential forestry brings to rural areas and have not been overawed by conservation claims. Whether indicative strategies are worthwhile remains to be seen in the light of any return to large-scale investment in afforestation.

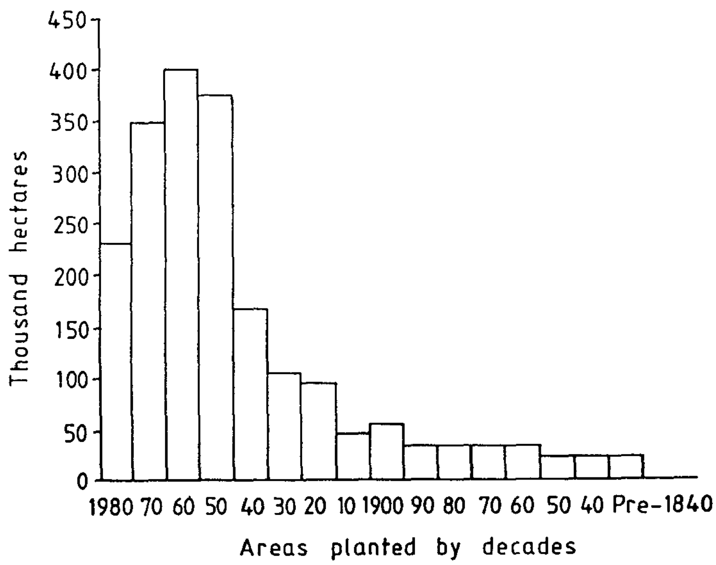

Figure 17. Age Profile of Forests in Britain Updated from Census of Woodlands, 1980.

SILVICULTURAL CONSIDERATIONS

The complex geology and topography, dominated on the smaller scale by the effects of the last glaciation, has given rise to a wide range of site types, particularly in the Scottish Highlands. Site types vary from quite extensive areas of apparently uniform organic soils to small-scale (< 0.5 ha) mosaics in fluvioglacial deposit areas. These variations have marked effects on species performance and demand varied cultural treatments. The condition of the sites (bare land) also owes a great deal to the man-induced effects of long-continued pastoralism, with its attendant regime of burning to remove unpalatable old or dead herbage. As indicated earlier, such practices began in Mesolithic times and were intensified in recent centuries. Dominating all other site factors is the climate, which is oceanic and very similar in general characteristics to that prevailing at similar latitudes on the Pacific seaboard of North America. The main and important difference is the windiness experienced in Britain. Wind has both physiological and mechanical effects on tree growth and ultimately tree stability. It is the single most limiting factor in British silviculture. Windiness is greatest in the north and west but is related to distance from any coast. It increases rapidly with elevation so that, with the concomitant decline in heat sum, it is possible to linearly relate the productivity of tree species with elevation.

Table XIII. DISTRIBUTION OF FOREST AREA (K HA).

	High Forests		Coppice	Total	FC	PW
	Conifer	Broadleaved				
England	395	430	38	863	233	630
Wales	175	60	2	237	130	107
Scotland	956	79	0	1035	525	510
Total	1526	569	40	2135	888	1247

Unproductive woodland amounts to 172 kha and comprises amenity, pastorage and scrub areas

FC - Forestry Commission, PW - Private Woodlands

The initial attempts at afforestation relied heavily on the native Scots pine and sometimes the then-economic native oaks (*Quercus robur* L. and *Q. petraea* (Matt.) Lieblein). The latter species generally failed when tried on other than the best sites, readily identifiable as recently forested, while Scots pine is a tree of well-drained sites and relatively low elevations. It proved highly successful when transferred to heathlands in Southern England. There was therefore great interest in the successful use of European larch in early plantings on freely drained soils up to quite high elevations (450 m) because it was useful for a wide range of products. It was planted pure and as a nurse species with broadleaves. During the 19th century many stands were planted as mixtures of larch, pine and Norway spruce, any of which could become dominant on different site types. The range of species available was limited, however.

When serious afforestation began it was quickly realized that there were extensive areas of land of very low agricultural productivity in the uplands. The problem lay in knowing what cultural treatments would be required to establish productive forest. There were examples of failed plantings of well-tried species indicating that site amelioration was required. At the same time, a range of newer exotics were selecting themselves in arboreta and trial plantations. The most promising were Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), Sitka spruce (*Picea sitchensis* (Bong.) Carr) and several others from northwest America.

Pioneer work on exposed low fertility land at higher elevations (350-450 m) in the Sottish Highlands had indicated the value of, first, an aerated planting site and, second, the need for phosphatic fertilizer. The former made use of upturned turves on peaty land, an idea obtained from spruce planting in the High Ardennes in Belgium. The latter was discovered empirically using basic slag, a waste material from steel mills. The value of these two techniques applied manually on organic or organo-mineral soils was known by the mid-1920s but they were slow to become standard practice. One reason for this was the cautious approach engendered by a lack of knowledge of the characteristics of the newer species. It was not until the 1940s that it was fully realized that, in Sitka spruce, British forestry had found a most responsive species, clearly well-adapted to extreme exposure and productive on a wide range of site types from fertile brown earths to acid peats up to elevations not previously thought plantable (550 m).

Table XIV. CHANGES IN USES OF CONIFER SPECIES SINCE 1920.

	Percentage composition of planting decades							
Species	**81-90**	**71-80**	**61-70**	**51-60**	**41-50**	**31-40**	**21-30**	**All Ages**
Scots pine	3	5	13	22	24	26	46	18
Corsican pine	6	3	4	3	3	6	6	4
Lodgepole pine	10	15	14	8	1	1	1	10
Sitka spruce	68	63	42	29	37	26	11	39
Norway spruce	1	3	8	10	16	19	11	9
European larch	-	1	2	2	4	8	8	3
Japanese larch	5	6	7	13	10	8	6	8
Douglas fir	4	2	4	5	2	3	7	4
Other conifers	1	1	4	3	1	1	1	2

NB 81-90 refers to FC only, all others include PW

Since 1945 the expansion of forest, forced on to poorer land by agricultural policies, has involved the development and mechanization of these two basic cultural techniques, drainage and fertilization on the wetter uplands, with corresponding treatments for the drier heathland soils. Sitka spruce has proved the most productive species on all but the more sheltered fertile sites, where its performance is equalled by Douglas-fir, grand fir (*Abies grandis* Lindl.), noble fir (*Abies procera* Rehd.) and western hemlock (*Tsuga heterophylla* (Raf.) Sarg.). On the poorest of peats and the drier infertile heaths, Sitka spruce suffers nitrogen stress and there it is replaced or mixed with either Scots pine or lodgepole pine (*Pinus contorta* Dougl.). As Sitka spruce provides a versatile wood equally suitable for saw timber or pulping, it is easy to understand why its use has expanded so much (Table XIV). Additional aspects of its popularity have been the ease of raising it in nurseries, its robust nature in plant handling and its ability to withstand and recover from browsing or other damage.

Until 1960, species selection was usually determined on the basis of a site classification which made use of existing ground vegetation. The extensive use of mechanical site preparation and aerial application of fertilizer -- mainly ground rock phosphate -- became standard at this time and allowed afforestation to extend to the poorest sites. It became important then to identify soil factors that might limit root growth and wind stability of the trees, so that a site classification based on major soil types evolved along with cultivation machinery to appropriately remove these limitations. Thus the site could be altered for the species, rather than the species selected for the site.

The increasing emphasis on poor quality sites in new planting is evident from Table XIV as the proportions of Scots pine and Norway spruce steadily decline. Another factor, of course, was the demand that forestry should be economic, which has been interpreted in volume production terms. Sites which are unlikely to achieve a yield class of 8 (maximum mean annual increment, m^3/ha/yr) are generally not acceptable for planting. In effect, this limitation applies to climate, as the soil factors can be ameliorated readily with positive economic results. The steady use of a low proportion of Douglas-fir and Corsican pine again reflects site availability. The former is restricted to freely draining soils at lower (< 280 m) elevations and Corsican pine is adapted mainly to lowland heaths in south and east England.

FAILURES AND PROBLEMS

Failures in afforestation usually arise from incorrect species to site matching. Failures to establish a viable stand disappear quickly, while later failures may materialize in pole stage or semi-mature stands. Perhaps success should be assessed in the second rotation. So far, failures in British afforestation have been few because species choice has tended to be conservative and species trials in the uplands have almost all indicated the superiority of Sitka spruce. Most of the failures that have occurred have been related to inadequate appreciation of provenance differences within species. Important examples include European larch and lodgepole pine. The 18th century introduction of larch proved highly adapted to the British climate, but in the rapid expansion after 1920, a series of alpine sources were introduced that were ill-adapted to an oceanic climate and became subject to a variety of pests and diseases. Early introductions of lodgepole pine were of ssp. *murrayana* and ssp. *latifolia,* but the species was not used initially to replace the native Scots pine as the more productive Corsican pine was available on appropriate sites. When afforestation moved on to peaty soils, the inexacting nature of lodgepole pine was recognized as a virtue and its use increased. Seduced by the early rapid growth of ssp. *contorta* (shore pine), of Oregon and Washington origin, however, these south coastal origins were favored, but proved to be of poor form and very liable to snow damage in the thicket or pole stages. Further problems have arisen with this species when used in large-scale afforestation of infertile peat in North Scotland. An innocuous and endemic moth, the Pine Beauty *(Panolis flammea)*, normally on Scots pine, switched to lodgepole and rapidly reached epidemic proportions, defoliating and killing several hundred hectares at a time.

All the provenance trials with Sitka spruce, many of which followed expansion in its use, demonstrate that the original selection of the Queen Charlotte Island origin was among the best. In areas of low frost incidence, origins from Washington perform as well or slightly better. In real exposure in North Scotland, Alaskan origins are better, but over most of the country Queen Charlotte spruces are preferred. This selection, which was fortuitous initially, has been a real success. Despite its widespread use, only *Elatobium* aphid has caused reductions in growth and, although the much-feared bark beetle (*Dendroctonus micans*) has appeared in Britain, its spread has been slow and capable of containment so far.

The critical silvicultural problem mentioned earlier is wind-throw. Catastrophic gales (wind speed of about 40 m/s sustained over several hours) periodically devastate forests over whole regions. The most recent in 1987 blew down about 6 million/m^3 in southeast England. Clearance and replanting is the only remedy. On the other hand, most upland areas are subject to 'endemic' windblow from about 12 gales per year (> 15 m/s) which partially damage stands that have reached pole stage. Initiation of damage can now be predicted from a knowledge of the region, elevation, geomorphic shelter and rooting depth. Silvicultural regimes can thus be adjusted to potential time of windblow or attainment of 'critical stand height,' which ranges from 13-20+m depending on site. Early windblow obviously affects the economic return and thus provides another criterion for determining afforestation limits.

The other major problem influencing afforestation practice is the occurrence of browsing animals. More than 300,000 red deer (*Cervus elaphus*) are an expanding wild population in the Scottish uplands that necessitate expensive exclusion fencing at the afforestation stage. This is a temporary measure, as inevitably they invade the plantations by the polestage, where they are difficult to see and control. In forests the deer are more fecund and suffer less mortality than on the open hill. Within the forest they, together with roe, Sika and fallow deer, damage young plants by browsing and in older stands sometimes by bark stripping. Tree species show differential palatability to deer browsing, with broadleaves and the possible alternative species to Sitka spruce highly sought after. Thus, potential deer damage is a major factor preventing the increase of species diversity in second rotation stands. Sitka spruce is the least palatable of all commonly used species.

CONCLUSIONS

It has been possible here to highlight only some of the many ecological, silvicultural, social and economic factors that have influenced the development of large-scale afforestation in Britain.

Located on the seaboard of Eurasia, Britain enjoys an equable climate, much warmer than its latitude might suggest. The adequacy of precipitation over most of the country, together with the topographic and geological conditions, provides an environment ideally suited to the growth of a wide range of exotic species drawn from very disparate parts of the world. The paucity of the post-glacial tree flora and the careless destruction or wastage of the native forest was a stimulus to the introduction of exotics, initially for aesthetic reasons.

The availability of large areas of low-quality land, suitable species and a program of vigorous empirical research allowed afforestation techniques to be developed for almost any site. Mistakes, of course, were made but were few in relation to the successes. A national crisis was required to motivate government to begin a serious afforestation program. This was doubly successful because suitable incentives were given to attract private investment to match public endeavors. The initial objective of 2,000,000 hectares productive forest in 80 years was achieved in 65 years.

Changing political circumstances removed the concept of a strategic reserve of timber even though the UK remains the second largest importer of timber products in the world. Most economists do not support arguments in favor of import substitution by home-grown products, but simple prudence would seem to suggest otherwise.

The application of somewhat simplistic economic criteria to forest management operations led to attempts to maximize financial return with insufficient attention being paid to other benefits. An increasingly affluent and environmentally aware public perceived land-use changes as being adverse to nature conservation and aesthetic values. Despite the man-made nature of the landscape and the long-term national economic and resource realities, public opinion forced a government dedicated to free market forces to withdraw the main fiscal incentives of the afforestation program.

Undoubtedly the trend toward diversity of the existing forest in structure and species composition will continue. Similarly, small-scale planting of broadleaved woodland for urban recreation and landscape purposes will gather momentum. Without a radical rethink of policy and incentives, however, the present hiatus in developing productive forest in the uplands will not be temporary, far less will the transfer of excess agricultural land be achieved. Afforestation programs depend on a sustained effort towards defined objectives and the political will to achieve them.

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THE NEED FOR REFORESTATION

Renato Moraes de Jesus

Abstract

This work emphasizes the necessity of breaking inertia and aggressively initiating programs for environmental recuperation. The reforestation activities in Brazil are summarized, where reforestation is characterized by and has historically been accomplished through fiscal incentives. The supply-and-demand of wood in Brazil is presented, demonstrating that 69 percent of the wood supply originates from natural forests under an alternative use. Pros and cons of fiscal incentives are discussed. For third world countries, reforestation must help to solve imminent problems, and in this manner will have greater motivation for implementation. For tropical conditions, the potential of reforestation through natural regeneration cannot be ignored. In conclusion, reforestation on a large scale will be successful only if the planting units are on the scale of small farms, where the problem becomes a question of forest extension and environmental education.

INTRODUCTION

As in many countries around the world, the devastation of Brazilian forests is reaching intolerable levels. Despite increasing denunciation of deforestation through the media, the process is still accelerating. According to the World Bank, the Amazon forest lost 12 percent of its original area in the last 20 years, and the Atlantic forest is today restricted to little more than 6 percent of its original area, mostly in small fragments.

The principal objective of this paper is to bring attention to the status of reforestation in Brazil today and to offer some alternatives for overcoming the problems of large-scale projects. There has been and is currently a great deal of energy spent in speaking, writing and promoting the cause of ecology and of saving the remaining Brazilian forests. Unfortunately, the implementation of reforestation as part of the restoration and sustainability of forest resources is rare, occurring in the cyclic rhythm of cataclysmic events. For example, in the states of Espirito Santo and Rio Grande do Sul, a great deal has been said about deforestation over the last three decades, but what has happened? In Espirito Santo, only 1.5 percent remains of the primary forest, much of it removed during this time period of 30 years. Rio Grande do Sul has the largest area of desert in the country today. There *was* an increase in the awareness of ecology in general, yet what good did this do for those forests which no longer exist?

The first step is to halt the process of destruction, and in any part of the world the methods are available to do so. It is not necessary to spend more money diagnosing the issues, as they are known to be cultural and economic. With the restoration of the environment, genetic resources for the future are assured. Ideally, recuperation should be implemented at least as swiftly as the destruction.

Certainly there are difficulties involved in reforestation, but they can be addressed only after the process begins in the field. The obvious and urgent need is to get the trees in the ground, to begin the process. Reforestation on a large scale is needed and, though the *total* area should be large, in reality for Brazil it must consist of many small areas at the local farm level. Paradoxically, the destruction was at the same level. Deforestation began with axes and manual saws, progressing to chainsaws, chemical defoliants and modern skidders.

THE REFORESTATION OF BRAZIL

Data from the last century was recorded in the first forestry register of reforestation in Brazil. Around 1860, in the city of Rio de Janeiro, about 120 thousand seedlings of native and exotic tree species were planted on the hills of Morro da Tijuca with the objective of recuperation of the watershed.

The first reforestation for economic objectives was made at the beginning of this century through the introduction of *Eucalyptus* species. The wood was utilized principally for fuel and railroad ties for the Companhia Paulista de Estradas de Ferro (Paulista Railroad Company), located in Jundai, in the state of Sao Paulo. By the end of the 1940s and beginning of the 1950s, the coniferous species were introduced, principally the genus *Pinus*. The introduction of conifers was largely motivated by the severe reduction of natural populations of *Araucaria angustifolia* (Parana pine).

It was in the decade of the 1960s that reforestation attained truly operational levels. In 1965, the federal government instituted the Brazilian Forestry Code, establishing rules for permanent preservation of forests, conservation of water and soil, and forest harvesting. The Brazilian Institute of Forest Development (IBDF) was created as the controlling institution (Cherkassky, 1990).

From 1966 on, with the implementation of fiscal incentives by the government, reforestation in Brazil increased significantly. The incentives given were trade-offs as a function of taxes. A company could write off a certain portion of taxes by implementing a reforestation project. As shown in Table XV, reforestation projects reached about 6.2 million hectares, and were composed of 52 percent *Eucalyptus*, 30 percent *Pinus*, and 18 percent other species.

Table XVI shows the supply and demand of wood in Brazil for the period 1987-1988. Of the total wood supply, 69 percent originates from natural forests.

The Negative Side

The fiscal incentives for reforestation were abolished in December, 1987, and after 20 years resulted in a reported planting of 6.3 million hectares. In practice, however, this area was not planted. Many projects, despite the protocol, were never planted at all; others were planted with inappropriate species in areas unsuited to reforestation. In little less than two years after planting, many plantations were lost completely. Evidently this political mechanism contributed to the public deficit and generates judicial problems even now.

TABLE XV. REFORESTATION WITH FISCAL INCENTIVES IN BRAZIL 1967-1986 (1000 ha)

YR.	PINUS	EUC.	OTHER	ALL
1967	18	14	3	35
1968	61	30	12	103
1969	96	54	12	162
1970	120	84	18	222
1971	99	129	21	249
1972	101	172	31	304
1973	86	161	47	294
1974	83	188	53	324
1975	94	223	81	398
1976	87	262	100	449
1977	99	194	53	346
1978	141	228	43	412
1980	89	272	75	436
1981	117	230	71	418
1982	158	187	86	431
1983	74	91	50	215
1984	71	124	91	286
1985	65	131	89	285
1986	85	174	150	409
TOTAL	1,862	3,231	1,159	6,252

Source: IBDF, 1988

To some extent the political incentives stimulated the creation of graduate courses in forestry which were unfortunately based principally on the silviculture of *Pinus* and *Eucalyptus*. In a country where 60 percent of the territory is covered by natural forests and less than one percent is reforested, the education of students should not be allowed to be based solely on exotic species. If this continues, we will not use the potential of our tropical conditions, natural regeneration, and vast resources. More than this, we have already bypassed many alternative uses and have not fully utilized the forests up until now.

Companies which chose reforestation projects for fiscal incentives were obligated to plant one percent of their area in so-called native species, or to leave ten percent of the natural vegetation intact. In most cases, the preference was to plant the one percent, yet the lack of silvicultural data for those species led to the loss of nearly the whole area. Nevertheless, there has been impressive progress in Brazil in developing silvicultural technology by industry-led research programs as a necessity to increase the productivity and decrease costs for these native species used in planting projects.

TABLE XVI. SUPPLY AND DEMAND OF WOOD IN BRAZIL, 1987-1988

SOLID WOOD TEM EQUIVALENT	% ($100m^3$)	
A) WOOD DEMAND		
Cellulose (10 t)	14,740	6
Charcoal (vegetal)	68,700	26
Sawn wood	33,500	13
Veneer	7,550	2
Fuelwood	139,000	53
TOTAL DEMAND	263,490	100
B) WOOD SUPPLY		
From reforestation	82,300	31
C) WOOD SUPPLY		
From native forests	181,190	69
TOTAL SUPPLY	263,490	100

Source: IPT/SBS

In contrast, research with native Brazilian species did not receive the same attention. The immediacy of capitalism in developing countries inhibits private initiative to do research involving species with longer rotation cycles. As a result, the sector left responsible for native species has been governmental institutions, which suffer from a lack of continuity. Invariably, each government came forth with their plan of research and, since forest species do not have the short cycles of agricultural crops, programs ended without conclusions.

The Positive Side

Despite many problems, the fiscal incentives promoted excellent development of the silviculture of *Eucalyptus* and *Pinus* in Brazil. Initially, there was not much concern for the selection of species, much less provenance. The actual goal for improvement is to develop a local race. According to Ikemori (1990), the criteria for selection should be as inclusive as possible. Considering phenotypic traits as well as genotype, the following characteristics should be included:

- volume of tree in relation to age
- disease resistance
- insect damage resistance
- branching habit
- branch size
- bark proportion
- sprouting ability
- root formation ability
- wood properties for pulp, charcoal, etc.
- properties of leaves, extractives, etc.
- metabolic efficiency.

Productivity has been significantly increased through the perfection of silvicultural techniques and success in the area of forest biotechnology. According to Cherkassky (1990), yields up to 100 cubic meters per hectare in *Eucalyptus* and 45 cubic meters per hectare in *Pinus* have been attained. The specific consumption of wood (m^3/t90 cel.), or the amount of wood used to produce 1 ton of cellulose with 90 percent dryness, on a commercial scale in Brazil is 4.87, and at Aracruz Florestal has reached 3.71 in the second stage of work (Ikemori, 1990).

The cost of production of *Eucalyptus* seedlings has been gradually reduced and now does not carry excessive costs in reforestation projects. To give an idea of the planting costs of this species using the dibble tube, Jesus and

Junior (1984) reported a cost of US$ 0.02/seedling. In addition to this reduction, the dibble-tube system allows the following advantages:
- diminishes problems with fungi;
- uninterrupted production, (nightfall, precipitation, etc.);
- better working conditions not only due to the nature of materials but also operationally;
- significantly more economical transport of materials to the field;
- decrease of man-hours/ha from the conventional 25 hours/man/ha to 8 hours/man/ha.

IMPROVEMENTS NEEDED

According to present knowledge, reforestation programs on a large scale with *Pinus* and *Eucalyptus* in Brazil do not have problems which would prevent implementation. Nevertheless, more conservation practices need to be incorporated such as:
- no more destruction of natural forests to implement reforestation programs;
- breakup of monocultures with associations of leguminous species;
- integral protection and recuperation of watershed forests occurring throughout the projects;
- limitations on the annual cut of contiguous areas;
- elimination of clear-cut by leaving a minimum of 50-60 trees/ha;
- in those projects involving cellulose, debarking will be made on site;
- limitations on type of burning used for site preparation;
- implementation of biological control programs for insect and disease control.

Operationally, it is necessary to improve the efficiency of protection against leaf-cutting ants. With the homogenization of tropical resources, there is a loss of the natural enemies and leaf-cutters become a formidable enemy. The cost for protection is US$35/ha/year. At the same time, it is necessary to reduce the cost of site preparation as this constitutes a significant proportion of the project costs.

Another concern involving costs will be the allocation of projects to more productive sites, which may diminish the total area available for reforestation. According to a specialist in the region of Sao Mateus, north of the state of Espirito Santo, there are sites which could reduce the area needed for reforestation by 20 percent. Additionally, the areas which are not reforested could enter into the natural regeneration process and contribute to reducing the impacts of monoculture.

REFORESTATION TO DIMINISH CO_2 LEVELS

The problems caused by increasing levels of CO_2 are of global order and logically no one country alone can solve the situation. Every day it becomes more urgent to adopt methods to reduce these trends. Reforestation on a large scale is one of them, notwithstanding that it requires large investments and a lot of motivation.

We must consider that in countries of the Third World, including in this case Brazil, the destruction of forests has caused infinite serious damage and reforestation has had objectives which do not necessarily include diminishing of CO_2 levels. It is much more urgent to control erosion, reduce the siltation of rivers, maintain or restore site productivity, regulate the water tables and rivers, and to produce wood for energy.

For whatever reasons reforestation is implemented, the planting of trees in areas where there were none is contributing to the reduction of CO_2 levels. It could be a case of marketing, but should be considered when making decisions about the promoting of reforestation on a large scale. It is still difficult to convince the small landowner to include trees in the management plans for his property. It is even more difficult for him to understand the implications of increasing levels of CO_2 in the atmosphere.

In addition to reforestation through planting, natural regeneration management in tropical regions should be encouraged. In Amazona, for example, significant areas of pasture are abandoned annually. Since the occurrence of fires is not a threat, naturally regenerated secondary forests are often formed. Active management to maintain these fast-growing forested areas should be prompted along with standard planting methods. In the same way, degraded forests must be managed in such a way as to stimulate growth and production, thus increasing the capacity for CO_2 absorption.

Due to the magnitude of conflicting needs to both utilize and preserve forest resources in Brazil, large areas must be reforested to both assure a supply of wood and to restrict the use of natural forests. It is not easy to make large-scale reforestation operational, especially when costs of establishment of species other than *Eucalyptus* and *Pinus* are used.

Ab'Saber et al. (1989) present a plan for mega-reforestation for potential areas of about 20 million hectares, where corrective forestry, mixed reforestation and industrial reforestation attain percentages respectively of 14.3, 13.8 and 71.8 of the total area respectively. The projected rotation cycle is 30 years and costs presented in the televised press are on the order of US$1,500/ha, financed primarily by fiscal incentives.

The intention is very good; however, once more the beneficiaries are large industries and the plan leaves behind the small landowner. If 6 million hectares have already brought serious social problems, imagine 15 million! It would be difficult to find a way out of these problems; this approach will not be the way to implement large-scale reforestation.

Since the paternalistic system of fiscal incentives has immobilized us and there are many well-known cases of corruption, we want to emphasize systems of reforestation which address the reality of the small landowner. It is the obligation of the government to make known the available technology and to orient the landowner as to how, where and why to plant trees.

In an effort to create many smaller planting units instead of a few large units, the problem becomes more one of forestry extension and environmental education. It is essential that each municipality has its own program in order to solve problems in a consistent and effective manner. It must have favorable backing of technology, inputs, training and practical examples in order to be successful (Jesus, 1989).

This author affirms that this type of structure, called Horto Florestal (Forest Garden), provides not only the conventional structure for seedling production, but also is a community unit where essentially all of the benefits are assimilated and reproduced in the local region.

The government of the state of Espirito Santo, through its Development Bank, is implementing the Horto Florestal Project (Jesus, 1989) in various municipalities. The expectation of the state is that each of its 80 thousand farmers plant annually at least 1 hectare of forest in Espirito Santo. In this way, the Horto Florestal will become a place where farmers can exchange ideas and see examples of conservation, utilization and recuperation of the ecosystem.

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INDUSTRIAL EUCALYPTUS PLANTATIONS IN THE PEOPLE'S REPUBLIC OF THE CONGO TECHNICAL, SOCIOLOGICAL AND ECOLOGICAL ASPECTS

Francis Cailliez

ABSTRACT

In the Congo, near Pointe Noire, the proximity of a deep-water port and a city providing a large labor pool, a favorable political climate, and a vast area of unoccupied savannah with little relief allowed the realization of a large-scale forestry project.

From the example of these Congolese plantations, we intend to show how an important afforestation project that addresses the financial and social requirements imposed by economists can also contribute to the maintenance of a satisfactory global environment, even if it involves plantings of Eucalyptus and conifers, which often have a poor reputation, primarily among misinformed people.

INTRODUCTION

Recent evolution in scientific and public thought, which should include political leaders and funding organizations, has occurred requiring that a greater awareness of global environmental constraints be brought to bear in development projects, no matter what the field.

Two important themes within the concept of "global environment" are closely linked with protection and improvement of tropical forests: They are the conservation of biodiversity and the atmospheric changes related to the "greenhouse effect".

During the last 50 years in temperate countries the land tenure system, political stability and the accessibility of lumber mills have all played an important role in allowing large-scale forestry projects to be both economically profitable and socially acceptable. These projects involve either improving existing stands or creating new plantations (France, Portugal, Chili, New Zealand).

In tropical countries, which are generally developing countries, however, reforestation and conservation projects are neither economically secure nor profitable enough to warrant the amount of investment necessary for largescale projects. In general, other more immediate problems tend to be given higher priority over forestry projects in investment decisions.

It was in this vein that the European Development Fund (EDF) decided in 1969 to fund only projects which would pay for themselves within five years. It was therefore no longer possible to count on financing for forestry projects from the EDF for tropical countries. Fortunately, however, this philosophy of the EDF is changing.

In francophone Africa, there are some exceptions to this rule: the Congo is one (described below in detail); in Madagascar, 265,000 hectares of plantations on savannah soils supply raw materials to local paper industries and sawmills and furnish fuelwood and polewood to nearby towns; in Burundi, high population density puts a large demand on forest products, making reforestation and protection of remaining indigenous forests easily justifiable.

In the Ivory Coast, the government supports the planting of around 1,000 hectares per year with a dozen commercial species of medium rotation rates using mechanized planting techniques. This is carried out in areas where the existing forest is judged to be too poor and is consequently suppressed and replaced. These projects have had various levels of success, having encountered difficulties associated primarily with questions of land tenure, a lack of secure long-term financing, a lack of a viable market for by-products from thinning, and appropriate means of marketing the products.

THE CONGOLESE CASE

The country of the Congo is not heavily populated. It has approximately 1.9 million inhabitants, of which 600,000 live in Brazzaville and 300,000 in Pointe Noire. The rest of the country is practically empty with only three people/km^2.

Natural forests of the Congo are not really threatened, except in the Mayombe (South) and in the vicinity of the main cities, in particular around Brazzaville, where the influx of population has lead to the disappearance of natural forests, sometimes accompanied by severe erosion.

Natural forests have supplied the Congo with large resources contributing significantly to national revenue: log exports were 600,000 m^3 in 1985 and 715,000 m^3 in 1986, and are expected to reach 1,000,000 m^3 in 1990.

Since the end of World War II, large areas of forest have been exploited in order to retrieve only a relatively few commercially valuable species. As larger tracts of land are explored, the exploitable timber is found farther and farther from the sole practicable shipping port, Pointe Noire. As a consequence, foresters have responded by concentrating their efforts on high productivity plantations.

It was as part of this response that the 6,500 hectares industrial plantation of Limba (*Terminalia superba*) was established in the Mayombe district between 1949 and 1961.

This project concentrating on Limba was not as large as that carried out in the neighboring Gabon for okoumé (*Aucoumea klaineana*). There, plantings of 2,000 hectares (with anticipated increase to 300 hectares) annually from 1960 to 1965 were almost adequate to compensate for the annual export volume, at that time 1,250,000 m^3. A total of 26,000 hectares of okoumé were planted in Gabon.

Like many other governments in newly independent African countries, the Congolese authorities emphasized plantations of fast-growing species rather than management of natural forests to solve forestry problems linked to fuel wood needs or papermill projects.

Two initial objectives were ascribed to the experimental Eucalyptus plantations:

- to supply the city of Pointe Noire with fuel wood,
- to provide raw materials to a papermill planned in the Niari valley (Loudima experimental farm) in parallel with other activities related to a power dam project on the river Kouilou Niari (which, ultimately, was never completed).

Eventually, the needs of the papermill became the primary force behind the reforestation projects around Pointe Noire, as fuel wood was obtained as a by-product of these industrial plantations.

Since 1958, this forestry research has been supported by the Centre Technique Forestier Tropical (CTFT), of France, which set up a local experimental branch, now included in the Congolese Research Department[1]. Research on industrial plantations is growing and is now in the process of reorganization in order to integrate public research carried out by the CTFT and the research carried out by the United Afforestation Industrial of the Congo (UAIC), an organization which will be described in more detail below.

BACKGROUND OF THE PROJECT

Climate

Pointe Noire is situated near the equator at 4°45' south latitude. The southern tropical climate is characterized by consistently high temperatures (mean annual temperature = 24.5° C), average rainfall of 1250 mm/year, and two contrasting seasons: one is humid, hot and sunny from November to May; the other is rather cool, dry and cloudy with high relative humidity (80 to 85%) and heavy dew.

Topography

Pointe Noire lies on a low coastal plain extending about 30 kilometers inland from the coast. The soils date back to the quaternary period and are generally fine, sandy soils, increasing in clay content with depth. These soils cover an area of about 100,000 hectares.

The tableland vegetation is a grassy savannah with scattered shrubs, burned every dry season. It becomes more wooded and more broken as one goes farther from Pointe Noire.

The soils are deep, homogeneous and easily tilled, but they are nutritionally very poor and therefore neither cultivated nor grazed, so there is no objection to devoting them to wood production. In contrast, experiments have shown that wood can be produced on these soils using fast-growing species and appropriate symbionts (e.g. *mycorrhizae*).

The valleys are wooded, but these stands are threatened by shifting cultivation and, until recently, by cutting for fuel wood.

GENETIC IMPROVEMENT OF EUCALYPUS

More than 60 *Eucalyptus* species have been introduced in trials since 1956. A number of species have been selected for use as pure species, e.g. *E. tereticornis* and *E. urophylla*.

Outstanding individuals were first observed in 1963 among progeny collected in trial plots composed of several different species. These progeny resulted from interspecific hybridizations that would not occur in the natural range of the species because of natural barriers (geographic distance, physiology).

Bi-specific seed orchards were established in 1970 with potentially interesting hybrid parent species in order to favor desirable combinations. However, seed production (by natural pollination) in these seed orchards is heterogeneous and uneven and cannot be depended on for large-scale plantations.

Efforts then were concentrated on vegetative propagation. This led to the development of reliable rooting techniques for Eucalyptus hybrids in 1974, paving the way for the development of clonal forestry based on vegetative propagation of high-performance hybrids. First clonal tests were established in 1975. Nearly 1,000 clones have been selected since, in a two-phase selection scheme.

This intensive clonal selection has two main objectives:

- To improve productivity
- To enhance the genetic diversity of the plant material in use in large scale plantations, in order to minimize the effects of climatic or health hazards.

Hybrids occurring naturally in the trial plots are of two types only, however, and interesting clones are from a limited number of parent trees. In order to more systematically explore all the possibilities (different hybrid types and different combinations within each type), controlled pollination techniques have been used since 1978.

During the first phase, an extensive testing of possible interspecific combinations was done to find out which are the most interesting. Since 1983, proper crossing plans have been applied for the more interesting interspecific combinations. This quite recent development of the breeding program significantly enhanced the genetic diversity of the plant material in use, while maintaining its productivity. More improvement is expected as more artificial hybrids come through the clonal selection scheme.

STARTING FULL-SIZE PLANTATIONS

Following improvements in these rooting techniques in 1976 to make them more practicable, it was decided to undertake the "Kissoko Pilot Project" in 1978 to test the techniques on a relatively large scale by planting 3,000 hectares. This successful project led to the creation of a Congolese state-owned forest plantation company, the United Afforestation Industrial of the Congo (UAIC), with broad ambitions. Its goal was to establish industrial plantations to supply enough raw materials to run a pulp mill.

The researchers then began to propagate trees from natural hybrids in the stands, producing several clones whose performance has been evaluated in clonal tests since 1975. Several advancements were made: mastery of techniques of propagation from buds; successful multiclonal plantations on several dozen hectares; confirmation of the ability to massively reproduce genetic copies of the best clones. These all set the stage for the proposal of a 3,000-hectare project whose goal was to show the feasibility and advantage of such an enterprise on an industrial scale.

THE UAIC: REALIZATION AND PROSPECTS

Today, UAIC manages a 25,000-hectare area and has the technical experience necessary to manage these types of modern and highly productive clonal plantations. The company currently produces 400,000 m^3 of paper pulpwood per year, which is exported to the European market and as such, the UAIC has become a prime supplier of pulp wood. Given the relatively modest cost of the investment (1,400 $/ha), the high production per unit area (up to 30 m^3/ha/yr pulp wood) and the very strong world demand for this type of industrial wood (homogeneous *Eucalyptus*), the project is today mainly geared towards satisfying external investors which will bring the firm to 50,000 hectares and eventually 100,000 hectares capacity. This capacity could even be doubled within 10 years. Due to this breathtaking growth rate, foreign partnerships will likely become the rule. Already, a 25,000-hectare cooperative project with the Shell Company is establishing plantations at the rate of 4,000 hectares per year. The planting methods are described in Appendix II and as shown on the location map in Appendix I.

Table XVII. ADVANTAGES OF CLONAL EUCALYPTUS PLANTATIONS, COMPARED WITH OTHER TYPES OF FORESTS (source: UAIC)

Type of Forest	Coniferous Temperate Climate	Traditional Eucalyptus Plantations Congo (1971) Niari Valley	Clonal Plantations of Hybrid Eucalyptus (1985) Niari Valley
Total Pole Production	5 m^3/ha/yr	20 m^3/ha/yr	40 m^3/ha/yr
Rotation Age	60 yrs	7 yrs	7 yrs
Area Required to Produce 1,500,000 m^3/year	300,000 ha.	75,000 ha.	37,500 ha.
Planting Cost per Hectare	15,000 FF*	10,000 FF	8,000 FF
Total Investment	4 5 billion FF	750 million FF	300 million FF

*French Francs, 1990 value $1 US = 5 6 FF

The UAIC is proposing to extend the plantations in the Niari valley where the soil is more fertile and tree growth better than on the coastal plains of Pointe Noire. The UAIC presents Table XVII, comparing the advantages of clonal Eucalyptus plantations to other types of forests.

Logging and export began at the end of 1986 from the earliest planted stands. At this time, a series of contracts had already been signed with European industries for the long-term supply of high quality pulpwood.

In the heart of the plantation, a mill was set up to treat posts and poles for use as electric and telephone lines. Moreover, UAIC negotiated with foreign partners to create small- and mid-sized wood processing units for charcoal, glued laminated products, prefabricated wood materials, etc.

In the future, with increasing production, the construction of a local pulp mill is a realistic priority for the Republic of the Congo.

SOCIAL CONSEQUENCES

The development of such a large forestry project creates considerable employment, particularly since the philosophy of the UAIC is not to mechanize at any cost but to maintain a balance by providing jobs to suburban or unskilled rural workers. On-the-job training of team-monitors is given by French and Congolese technicians.

The creation of suburban and rural employment opportunities provides resources to help revitalize the villages which were in recession a short time ago. The employment of women in the nurseries allows a more even distribution of family revenues. The network of forest roads reduces the isolation of villages, helps make life a little easier and opens the villagers to the outside world.

The UAIC employs both permanent and temporary workers, with peak employment at the height of the planting season. Table XVIII describes the labor needs in 1985 to **plant** at a rate of about 5,000 hectares per year in three sites.

Table XVIII. UAIC PERSONPOWER REQUIREMENTS TO PLANT 5,000 HA/YR (EXCLUDING HARVEST AND EXPORT)

	Permanent Personpower (August)	Supplementary Personpower (February)	Total Personpower
Industrial cutting unit	43	52 *nursery* workmen 25 nursery workwomen	120
3 planting units	60 X 3	50 X 3	330
Mechanized field work	30	20	50
Central garage	30	5	35
Surveyor Office	6	2	8
Maintenance Unit	15	30	45
Financial and Administrative Office	25		25
TOTAL*	329		613

*for harvesting, bark removal and logging operations in June 1987, the UAIC employed 1900 people, including some small, private contractors. The total amount of money distributed monthly was 80 m. francs CFA, with an average amount per worker/mo. of 40,000 francs CFA (equivalent to 800 French francs, or approx. $140 U.S.). In total, an average of one job was created for every ten hectares planted.

ENVIRONMENTAL CONSEQUENCES

The primary goals of protection of the health of these plantations consist of a dynamic and evolving process aimed at providing the UAIC with plant material of constantly improving genetic diversity and of providing intense protection against fire.

Multiclonal Stands of Hybrid Eucalyptus

A monoclonal plantation of a highly productive hybrid offers an advantage only in terms of production. This criterion is applied to poplar plantations, for example, or fruit orchards. But one cannot ignore the risks inherent in plantations of only a single or a few clones.

There is no doubt that one must research and conserve enough genetic diversity to assure resistance to eventual disease or insect attacks. Therefore, strong efforts are made to increase the number of clones planted. At the beginning of the project, the choice of the clones was limited by the small number present in the existing clonal test plots, but now UAIC can widen its choice every year. Since its initiation, the goal has been to establish about 40 different clones each year, a number which seems sufficient to assure adequate protection against parasitic attacks.

The question of how many clonal types to use remains open: numerous related clones may represent a very poor genetic diversity compared to relatively few clones (five or six) from unrelated hybrid stock.

New clones are now created by man-made pollination. New introductions of planting stock from natural ranges of the selected species are going to be included in future hybrid combinations in order to again improve the requisite genetic diversity.

This dynamic strategy adopted by the UAIC, which involves the continuous production of new and more efficient clones coupled with a patchwork spatial distribution of small (25 hectares) monoclonal blocks, serves to assure the protection of these plantations against pests or diseases.

Controlled Mycorrhizal Inoculation

The study of mycorrhizal associations on planted Eucalyptus and of more efficient partners *(ectomycorrhizae)* and the use of antagonist interactions with parasitic fungi are of interest not only to control the parasites but also to improve the yield. Research work is on-going in these areas.

Protection Against Fire

Great importance is given to good maintenance of the stands in regard to fire protection: mechanical and manual weeding are carefully performed.

A strict observance of the timing of the silvicultural operations allows an early canopy closure and better protection of the stands. Look-out towers have been set up on two high points on the edge of the plantation with immediate radio communication with a fire-fighting team.

Biodiversity

The natural biodiversity -- as opposed to the manmade biodiversity of the different clones -- is preserved by this *Eucalyptus* afforestation. This assertion may appear to be paradoxical. Nevertheless, the natural, more diverse, woody vegetation in the valleys is respected by the project and left undisturbed. Harvesting of fuelwood in these areas is actually decreased, since the woody debris in the *Eucalyptus* stands is available to the workers' families to gather for fuelwood. In addition, in spite of the young age of the plantation, we have already noted the reappearance of some of the original flora (this has also been observed in other plantations, e.g. in Cameroon). One notes, then, an actual enrichment of the flora compared to the pre-existing savannah which was regularly burned.

Also, big game and other wildlife can be seen here again, due probably more to better tree cover than to significant enhancement of the vegetation. After over a dozen years, this is an encouraging sign.

A Contribution Against
"The Greenhouse Effect"

A more favorable carbon balance can be expected for three reasons:

• fixation of carbon dioxide by photosynthesis in a 25,000-hectare plantation producing at least 20 m^3/ha biomass (much more than the amount of dry matter found on an equal area of savannah) corresponds to a gross reduction in atmospheric CO_2. About 8 tons of carbon are fixed yearly per hectare.

• *Eucalyptus* is a very efficient producer of dry matter (a 7-year-old *Eucalyptus* plantation will produce 350 kg dry matter for every 1 kg nitrogen in the leaves, compared with spruce, which will produce only 20 kg.).

• The emission of gases due to the yearly burning of savannah since time immemorial is halted, except perhaps from accidental fires which up to now have been quite rare.

• Plantations improve the soil structure by significantly increasing organic matter, through leaf litter, logging residues and the removed bark.

Sustainability

Management of these populations after the first harvest at seven years is now completely defined: only a single coppice shoot is allowed to develop until the next harvest. But management guidelines have not yet been established following the second harvest at 14 years. Based on observations of other, older plantations, one should be able to expect a third harvest at 21 years. At this point it will undoubtedly be necessary to remove the stumps and replant.

A precise study of nutrient contents in the leaves, branches, bole, bark, etc., of trees from a seven-year-old clone has provided an estimate of nutrient export per hectare from barked trees (e.g., bark and fine branches are left on the ground):

Calcium	5.99 kg/ha/yr
Phosphorus	3.83 kg/ha/yr
Nitrogen	15.57 kg/ha/yr
Magnesium	2.36 kg/ha/yr
Potassium	7.66 kg/ha/yr

It is difficult to compare these figures with those of available nutrients in the soil in order to estimate the time during which such production can be maintained under these conditions. It is very likely that fertilizer applications will be required, since the littoral Atlantic soils of Pointe Noire are very nutrient-poor, with the exception of phosphorus. A 48-month study of the effects of mineral fertilizer (N-P-K in one or two applications) on wood production gave the following results:

100 g in one dose:	+18%
200 g in one dose:	+38%
200 g in first dose, 150 g in second dose:	+47%

TOWARDS A VAST REGIONAL PROJECT

A look at the map of Central Africa reveals a large area of grassy plateaus surrounded by dense forest stretching from Gabon to Zaïre and covering, in particular, the Batéké plateau of the Congo. These plateaus, at an altitude of 700 meters, offer a favorable climate to *Eucalyptus* trees and a soil richer than that of the more washed-out coast savannah.

The development of a large interstate project covering 3 million hectares could be of global importance. For an investment of 1,200 billion F CFA (24 billion French francs) -- i.e., the equivalent of the Congolese debt -- it could be possible within seven years of planting to provide 60 million tons of wood, enough to produce 20 million tons of first class pulp. This represents the equivalent of the anticipated increase in world demand for paper over the next 20 years.

Such an investment would provide jobs to 300,000 workers (the number of heads-of-households in the current Congolese population). The parallel development of an intensive agricultural system would be necessary to ensure the harmonious development of this population. At the end of the seven-year period, the gross income generated by such a project would be approximately 1,000 billion F CFA (20 billion FF) per year.

The economic pressure on natural forests would be decreased. Further, the standard of living of the population on the plateau would be significantly improved, reducing the excessive demand on the dense forests of the region. By such production, CO_2 fixation would be approximately 30 million tons per year, or one percent of the total carbon dioxide poured into the atmosphere every year as a consequence of human activities.

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NOTE

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ACKNOWLEDGMENT

This communication makes use of published documents or recent experimental results presented in internal technical papers by agents of the Center Technique Forester Tropical and the United Afforestation Industrial of the Congo. The particular publications are listed in the citations.

Further information on this project may be obtained by contacting the project director directly at the address given below:

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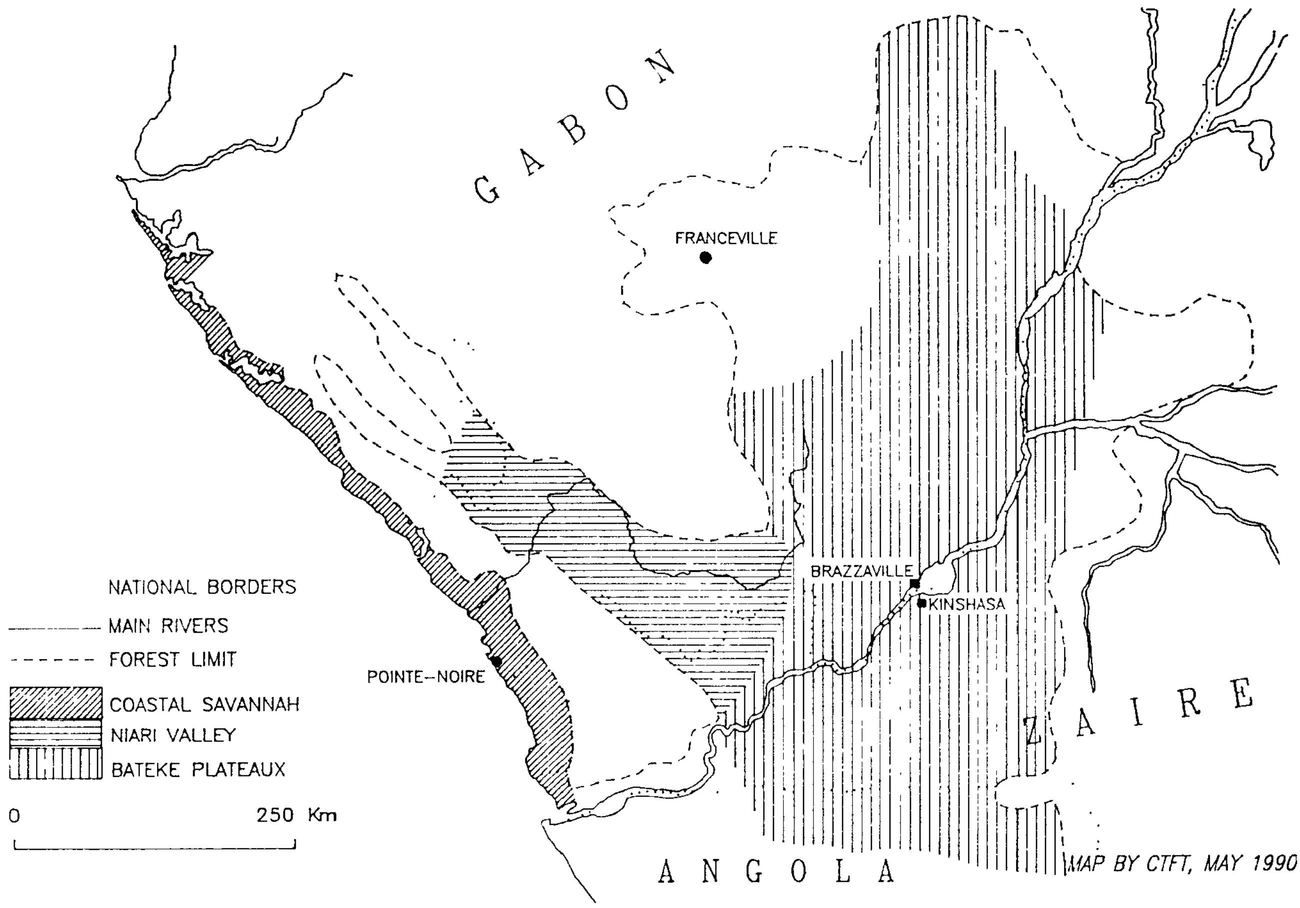
APPENDIX I

UAIC INDUSTRIAL EUCALYPTUS PLANTATIONS IN THE PEOPLE'S REPUBLIC OF THE CONGO

UAIC INDUSTRIAL EUCALYPTUS PLANTATIONS IN THE PEOPLE'S REPUBLIC OF THE CONGO

LOCATION MAP



APPENDIX II

FIELD WORK SCHEDULE

Trees in the mass production parks are coppiced and the shoots are cut one month after the beginning of the rainy season. Irrigation allows the timetable to be forced somewhat. Forty thousand cuttings are produced per hectare.

Shoots are collected 6 to 8 weeks after coppicing during the most physiologically suitable time, which lasts only 2 or 3 days. They are brought immediately into the nursery, then pruned, processed and finally cut and rolled in a man-made "Melfert" ball. This ball consists of a non-woven envelope containing vermiculite and fertilizer. The volume of each ball is 200 cm3, containing one two-leafed cutting. Balls are placed under fog sprinklers for 20 to 25 days and fertilized. The rooting rate is up to 80 percent. Plants are plantable 60 days after cutting.

They are transported in boxes containing 60 balls. One truck carries 180 boxes, that is 10,800 plants, enough to plant 15 hectares. The management schedule begins with stump removal (of *Annona aenaria*), most often manually, followed by burning and plowing with a heavy harrow. Tilling, fertilizer application and marking the place where the plants are to be set is done by a single machine which beeps each time it covers a pre-set planting distance. At this point, two workers, one for each line, hearing the sound, drop the amount of fertilizer and marking powder required into each of two bins. This mixture is released, marking the planting spot. Holes are dug by hand at each mark and the seedlings are planted. Each is then watered and given a single application of a termaticide.

The interplant spacing has been optimized to provide the maximum volume of pulpwood after a 7-year rotation. In the beginning, a 5m x 5m spacing was used. It later became 4.5m x 6m (370 plants/hectares), and then changed to 3m x 3m and 3m x 4.70m (709 plants/hectares). Weeding with a disk harrow is carried out four times between the initial planting and the next rainy season.

AGROFORESTRY IN GUATEMALA: MITIGATING GLOBAL WARMING THROUGH SOCIAL FORESTRY

Mark C. Trexler

ABSTRACT

Scientific debate on the likelihood and magnitude of human-induced global warming has been underway for almost a century, but calls for national and international action to respond to the threat have proliferated only in recent years. The 1988 decision by a United States power generation company, Applied Energy Services (AES), to offset the carbon emissions of a newly constructed coal powerplant was one of the first actions taken by the U.S. business community to counter the threat of global warming. To achieve the carbon offset, AES is now funding a sustainable development forestry project in Guatemala. It is the first forestry project ever funded specifically for carbon offset purposes.

This paper introduces and describes the AES-funded and CARE-administered forestry project now underway in Guatemala. Although the project is projected to offset more than the 15.5 million tons of carbon that will be emitted from the coal-fired power plant over the next 40 years, the paper also highlights the many uncertainties involved in making such projections. In addition, the paper sets out to assess the advantages and disadvantages of this project, an example of a sustainable development forestry project, as compared to the type of plantation forestry more conventionally suggested to counter global warming.

INTRODUCTION

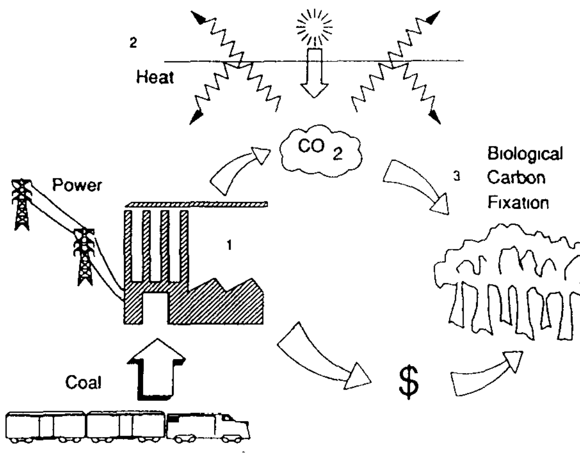
The literature addressing forestry's potential role in mitigating global warming is growing rapidly and is generally enthusiastic about the prospects for large-scale arresting of deforestation and replanting of degraded lands.[1] Domestically, the President's recent "America the Beautiful" initiative involving the planting of an additional one billion trees per year in the United States remains the only global warming policy initiative that has received broad-based political support.[2]

Forestry-based options appear to be among the most politically, technically and economically attractive of potential global warming policy responses. Politicians see few of the economic and political impediments that face efforts to modify energy consumption patterns and foresters see the opportunity to capitalize upon their own expertise to intensify forest management and to plant huge areas of degraded and apparently abandoned lands in developing nations. Although the economic analysis of forestry options has been markedly simplistic thus far, such options are often characterized as the cheapest way of significantly slowing the build-up of carbon dioxide in the atmosphere.

When forestry projects are actually proposed as global warming mitigation mechanisms, however, it becomes difficult to assess their likely effectiveness in offsetting fossil fuel emissions. This can be readily seen from the analysis surrounding the only such project yet undertaken.

PROJECT HISTORY

During 1988, Applied Energy Services (AES) finalized plans to construct a new coal-fired power plant in Thames, Connecticut.[3] During its 40-year life, the plant is expected to emit some 15.5 million tons of carbon as carbon dioxide(CO_2), a primary contributor to whatever global warming occurs in future years.[4] For all practical purposes, stripping CO_2 from the



The power plant (1) burns coal to produce electrical power, unavoidably emitting carbon dioxide (CO2) as a by-product. The carbon dioxide acts to trap heat from the sun, warming the Earth's atmosphere (2). An efficient way to remove carbon dioxide from the atmosphere is to grow trees (3), biologically "fixing" the carbon in the form of wood. In an effort to mitigate the warming impacts of its power production, the power company is sponsoring a tree-growing project in Guatemala. (Paul Faeth, World Resources Institute)

Figure 18. Conceptual Functioning of a Carbon-Offset Project

plant's flue gas is not feasible. This led AES to request the International Institute for Development and Environment-North America (now the Center for Development and Environment within the World Resources Institute [WRI]) to suggest means by which the plant's emissions of CO_2 could be offset and its role in aggravating global warming negated. Based on a review of several alternatives, WRI concluded that a forestry project located in the tropics was likely to prove the most cost-effective carbon offset opportunity (Figure 18). WRI's conclusion to focus on the tropics grew primarily out of three variables:

- Higher potential biomass growth rates;
- Lower costs and much greater grant leveraging opportunities;
- Greater social need for forestry-based services.

Once AES decided to pursue a project, WRI developed and circulated a Request for Proposals (RFP). Four criteria formed the basis for the RFP:

- *Carbon offset*: The RFP required proposed projects to provide for an average carbon offset rate of 387,000 short tons per year for 40 years, totaling 15.5 million tons over the life of the powerplant.
- *Local participation*: The RFP noted the desirability of projects that would promote social goals beyond the mitigation of global warming. Any proposed forestry project had to further the general aims of sustainable development, and proposals involving planting or management of trees that would be harvested required a plan for sustained yield management. The RFP encouraged local participation, particularly by women. It emphasized sensitivity to and consistency with the needs and goals of the host country. The RFP discouraged proposals for the establishment of large-scale plantations.
- *Grant leveraging*: AES was willing to provide a grant of $2 million. Since a project capable of offsetting the emission of 15.5 million tons of carbon would cost much more than $2-million, it was crucial that grant recipients be able to leverage additional funding.
- *Organizational experience*: WRI recognized that no organization responding to the RFP would have past experience with the concept of carbon-offset forestry. Sustainable development projects of the sort envisioned by WRI, however, are generally difficult to implement and WRI viewed a proven track record in this field as important.

The eight proposals submitted to WRI in response to the RFP ranged widely in approach. One proposed sealing off and protecting standing forest, counting the carbon benefit as deforestation foregone. Another proposed a restoration ecology program as the means to store the required carbon. Several involved variations on agroforestry and woodlot development programs. Based on the recommendations of an RFP review panel, WRI ultimately recommended to AES that it fund the international relief organization CARE's agriculture and natural resources activities in Guatemala. AES' decision to undertake this funding reflects the first time a U.S. corporation has accepted responsibility for offsetting its CO_2 emissions in the same manner that current law often requires for other pollutants.

PROJECT ENVIRONMENT AND CONTEXT

Guatemala, which is in Central America, is roughly the size of Tennessee. Its topography is highly variable, ranging from a fertile coastal zone to highlands of 1,800 to 12,000 feet, making the region the highest in Central America. Twenty-one volcanoes, some of them still active, formed a large portion of the highland soils. The broad diversity of Guatemala's climatic and soil conditions, as well as the variable topography, have resulted in the most diverse vegetation in the region. The country's forests contain at least 16 species of conifers and 450 species of broadleaf trees.

Guatemala's natural endowments contrast sharply with severe imbalances in income and land distribution. Of a population of approximately 8 million people, 6.5 million are considered poor. With a three percent population growth rate, the country's resource base is coming under intense pressure. Biomass, primarily firewood, supplies an estimated 80 percent of the country's energy needs. Deforestation has been extensive.[5]

CARE has actively promoted agricultural productivity, reforestation, and soil conservation in Guatemala since 1974 (Figure 19). In partnership with the former Guatemalan forestry department (INAFOR) and the Peace Corps, and with funding provided by the U.S. Agency for International Development (USAID), CARE undertook to improve the livelihoods of farmers in the highlands by improving the management of the natural resource base. Specifics of the program have evolved over time and vary from region to region within Guatemala. The program incorporates several major forestry elements:

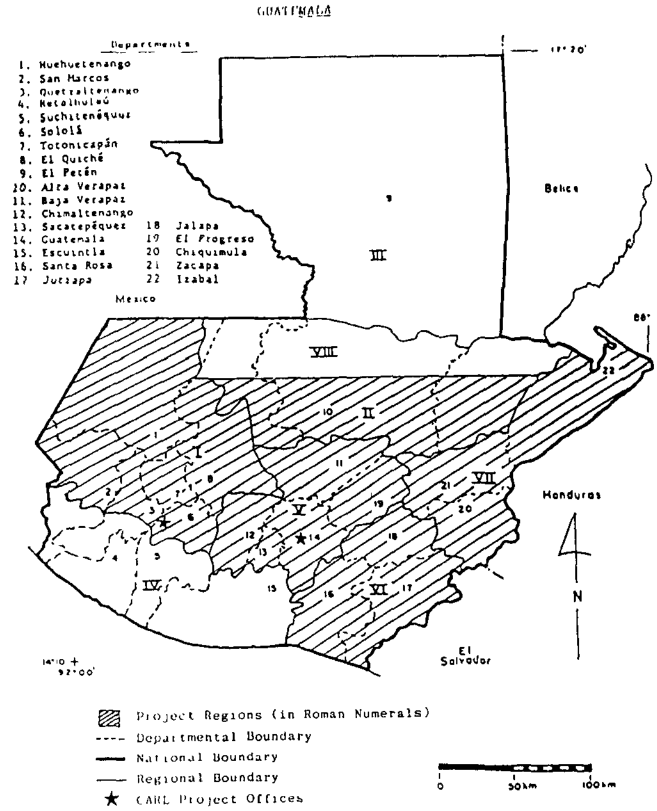


Figure 19. Map of CARE Project Areas

- Emphasizing seedling production in dispersed community nurseries, with subsequent planting of the trees in woodlot and agroforestry applications.
- Sustainably increasing biomass yields and land productivity through soil conservation techniques; e.g., live and dead barriers.
- Conservation of biomass through techniques such as the establishment and training of community forest fire brigades.
- Providing technical forestry extension services to farmers.
- Promoting long-term sustainability of project initiatives through empowerment of local and national organizations, ranging from farmer

cooperatives to the national forestry department.

- Involving women in project activities.

CARE's forestry record in Guatemala is impressive. Since 1979, its activities have resulted in the planting of 25 million tree seedlings. These seedlings are providing fuel, food and building materials for 360,000 people in 400 communities. During 1988, CARE's activities were responsible for at least 50 percent of all organized tree planting in the country. Aggregate nursery capacity now exceeds four million seedlings per year and is increasing.

THE PROJECT IN PRACTICE

CARE's response to WRI's RFP did not suggest a sudden interest in expanding the scope of CARE's work to include global warming mitigation. In CARE's eyes, offsetting carbon emissions through its activities is an ancillary benefit to its primary goal of benefiting poor farmers. AES' decision to finance the CARE proposal will make it possible for CARE to continue to expand its outreach and training programs to new communities around the country over the next 10 years (Table XIX).[6] During these 10 years, some 40,000 farm families will be involved in growing over 50 million trees in community nurseries. With the expansion of CARE operations from about 80 to 100 sites in the next few years, annual seedling production should reach over 7 million seedlings. Many more trees will be planted during the subsequent 30 years if nursery production becomes self-sustaining after the end of CARE's involvement.[7] These trees will be planted on private as well as community lands for pole, lumber and firewood production, as part of agroforestry plantings yielding fuelwood, fodder and soil nitrogen-fixation, and for fruit and nut production. A wide variety of species will be used in the project, many of them indigenous.

Table XIX. CARE GOALS OVER THE NEXT 10 YEARS

- To involve 40,000 farm families in project activities
- To produce more than 25 million woodlot trees
- To produce more than 25 million agroforestry trees
- To plant trees for:
  - fuelwood and fodder
  - nitrogen fixing
  - fruit and nut production
  - live barriers
  - living fences
- To see more than 12,000-ha woodlots established
- To see more than 60,000 ha of agricultural land converted to agroforestry
- To establish more than 3,000 km of live fencing
- To undertake soil conservation and rehabillitation activities on more than 2,000 ha.

The more than 50 million trees grown in project nurseries over the next 10 years will allow some 12,000 hectares of new woodlots to be created, while agroforestry practices will be extended to some 65,000 additional hectares of agricultural land.[8] The fast-growing nature of these trees will allow farmers to begin reaping the benefit of their labors within just three to five years. Several other practices intended to improve productivity and conserve the resource base will accompany these two aspects of the project. Some 3,000 kilometers of live fencing will be planted, terraces will be built to protect 2,000 hectares of vulnerable slopes, and forest fire brigades will be formed to protect the newly planted trees and existing forest.[9] Training and technical extension services will support the tree-planting efforts. Hundreds of forestry committees will be established to define local needs, develop forestry plans, plan activities, assign responsibilities, and share benefits. The groups will coordinate in the management of community woodlots, community nurseries, and forest fire brigades. These educational and technical support activities are viewed as crucial to long-term project sustainability.

The CARE project operates through a

carefully developed infrastructure reliant upon both indigenous and external resources. Each of the approximately 80 Guatemalan municipalities containing project sites is served by a local "promoter," a farmer employed by the current Guatemalan forestry department, DIGEBOS. The promoter organizes farmer cooperatives in the municipality within which he works. An average of five actual project sites are located within each municipality. Approximately 20 DIGEBOS "coordinators" are responsible for line supervision of the promoters. Some 35 Peace Corps volunteers are distributed among the municipalities served by the project, providing technical instruction in agricultural and forestry techniques, including the establishment of tree nurseries. Finally, about a dozen CARE employees provide training for promoters and Peace Corps volunteers, technical backstopping for all forestry and agriculture activities, and general administration of the project. As such, CARE's role is much more than an administrative one. CARE financial support, for example, allows the purchase and maintenance of DIGEBOS vehicles. CARE's organizational support allows DIGEBOS to play a partnership role in an important domestic project it would otherwise be powerless to implement.[10]

THE CARE PROJECT AND CARBON STORAGE

WRI's analysis of the carbon off-set potential of the several proposals received in response to its RFP immediately suggested how complex such analysis could become. WRI's review of project proposals demonstrated that the reliability and predictability with which forestry projects can serve as carbon sinks depends significantly on whether existing trees are being protected or new ones are being grown, on their location and type, on the rotation times of the trees being planted, on the ultimate disposition of the wood being grown, and on the indirect implications of this disposition for the utilization of other biomass and fossil fuel resources. Unless trees are planted for the long term on currently denuded land, the quantity of carbon storage cannot be measured simply by quantifying total biomass growth.

In the case of this project, however, trees are not being planted for the long term. Instead, it is assumed that they will be harvested for poles, fuelwood or fodder within several years of their being planted. Much of the carbon withdrawn from the atmosphere through project tree planting will therefore be released to the atmosphere in a relatively short time period. As a result the carbon storage benefit of the project does not result primarily from the tree planting itself.[11]

Instead, the tree planting provides services for which project participants would otherwise have had to turn to the natural forest. Since the protection of standing forest is being assumed, carbon offset assumptions have to be predicated on estimates of the degree to which incursions into standing forest are actually prevented, the carbon content of the saved forest, and how much of the currently standing forest would actually have been lost in the absence of the new tree planting. These assumptions are in turn dependent on local sources of deforestation, possible shortages of fuelwood or other wood products, and the impacts of the project on land use as well as population migration patterns.

Given these and many other related variables, a complex model of the carbon flows associated with a sustainable development project can easily be envisioned. Unfortunately, the information needed for construction of such a model was simply unavailable. Indeed, such information is just now becoming available even for more conventional forestry projects in temperate zones, and the information required for this case would be considerably more complex. In addition, organizations such as CARE have historically had little reason to even identify, much less collect, the information necessary for modeling project-related carbon flows.

WRI's conclusion that the project would more than offset the 15.5 million tons of carbon emitted by the powerplant, therefore, had to be based on highly simplified assumptions. Using empirical data regarding seedling production and mortality, as well as limited data on representative growth rates, the following primary assumptions were used to calculate the size of the carbon offset:[12]

1) The planting of 25 million trees in woodlot applications, with an assumed stocking rate of 2,000 trees/ha, an assumed stemwood growth rate of 20 m^3/ha/yr, and a biomass multiplier of 2.0.[13]

2) The planting of 27 million trees in agroforestry applications, with an assumed stocking rate of 400 trees/ha, an assumed stemwood growth rate of 13 m^3/ha/yr, and a biomass multiplier of 2.0.

3) Ten percent of the biomass growth over 40 years is assumed to represent a net addition to standing biomass.

4) Ninety percent of total stemwood growth is assumed to be harvested.

5) Each cubic meter of harvested wood is assumed to displace the harvesting of a cubic meter of wood from standing forest as well as the oxidation of the equivalent of an additional half a cubic meter of biomass in the form of forest roots and other vegetation.

These assumptions, among others, make it possible to conclude that 40 years from today some 18 million tons of carbon that would otherwise have been emitted to or remained in the atmosphere will instead be tied up in biomass or soils as a result of this project (Table XX). This estimate exceeds the 15.5 million tons the AES powerplant is projected to release during that same period, and thus supports the conclusion that the project will offset the plant's emissions.

Inevitably, however, the robustness of this or any other estimate of carbon offset resulting from a sustainable development project is suspect when the project is located in a developing country facing rapid population growth and serious economic problems. Guatemala's rural poverty and political instability as well as its three percent population growth rate raise serious questions about the ability of forestry projects to achieve long-term carbon storage, even those well-integrated into the self-interest of individual farmers such as this one. Even if the project is successful in planting and growing the trees, for example, it may simply allow more people to remain on the land rather than be forced into the cities. Rural populations might consume not only the trees being planted, but the original standing forest as well, in effect simply delaying a crash of the resource base.

Unfortunately, it will probably prove impossible to accurately determine the degree to which these and other uncertainties will undercut the long-term carbon-offset success of this

Table XX. FINAL ESTIMATE OF CARBON FIXATION VS. SEQUESTRATION

CARBON FIXATION	
Total carbon fixed in project biomass	17.2 x 10^6 tons
CARBON SEQUESTRATION	
Net addition to standing inventory of biomass carbon	2.6 x 10^6 tons
Usable harvested carbon	9.7 x 10^6 tons
Standing forest carbon retained as result of demand displacement	14.4 x 10^6 tons
Carbon added to project soils	.4 x 10^6 tons
Standing forest carbon protected through fire brigades	.7 x 10^6 tons
TOTAL LONG-TERM CARBON SEQUESTRATION:	**18.1 x 10^6 tons**
40-YR. EMISSIONS OF AES POWERPLANT	15.5 X 10^6 tons
PROJECTED NET PROJECT BENEFIT	2.6 x 10^6 tons

project. Although CARE will track the more measurable of the project's milestones, many uncertainties that might affect its long-term success are likely to prove impossible to evaluate. This is partially a function of the large geographic coverage represented by CARE activities in Guatemala. Nevertheless, this is likely to be a common problem facing evaluation of almost any sustainable development forestry project.

THE GUATEMALA PROJECT AND ITS LESSONS FOR GLOBAL WARMING MITIGATION

There is little doubt that extrapolation of biomass growth rates across huge land areas in order to arrive at estimates of forestry's global potential to mitigate global warming is of quite limited usefulness, regardless of the forestry strategy envisioned.[14] Nevertheless, if pursued on a large enough scale, a wide array of forestry approaches could, in principle, contribute significantly to the mitigation of global warming. These include forestry policies aimed at protecting or managing existing forests, restoring degraded or secondary forests to their natural state, pursuing industrial plantation forestry for timber or energy, as well as sustainable development forestry utilizing such techniques as agroforestry and woodlot development.

The uncertainties surrounding estimation of the carbon storage benefits achieved through sustainable development forestry projects such as the one being funded by AES might appear to argue for an emphasis on other forestry-based options. CARE's activities in Guatemala, for example, might appear sadly insufficient when viewed against the context of Guatemala's natural resource crisis or against the threat of global warming. Given rural energy shortages in Guatemala, it could be argued that large-scale fuelwood plantations would be a more productive vehicle for storing carbon. Indeed, most discussion of forestry as a global warming mitigation strategy assumes the planting of fast-growing plantations rather than the implementation of alternative options such as sustainable development forestry.

In Guatemala and many other developing countries, however, it is not at all clear that large, fast-growing plantations are superior to other options such as sustainable development forestry in mitigating global warming, either substantively or as a matter of public perception. While large-scale plantations will certainly be appropriate under some circumstances in developing countries, large-scale plantations are inimical to the forestry goals being pursued by many interest groups around the world, particularly in the non-governmental sector.[15] Different forestry options will often differ widely in terms of their practicality, ethics, sustainability, and public acceptability. There are, in fact, a number of important issues raised by the concept of carbon offset forestry that are highlighted by the differences between this project and the more conventional plantation approach. Using the situation in Guatemala as a point of reference, one can identify several problems with a course of action premised on large-scale plantation forestry.

The Practicality of Plantation Forestry in Developing Countries

Where would the projects be sited? As already noted, Guatemala has high population densities, particularly in those areas possessing the best climates and soils for agriculture and forestry. Most private landholdings in these regions are very small and barely able to support the existing residents. Tree planting on communal and municipal lands has proven problematic in CARE's experience due to uncertainty regarding future ownership and utilization rights. The large private landholdings that do exist are often located in arid parts of the country, and there is no guarantee that these lands will not be subject to future land tenure reform. Even today, however, these private holdings are far from unused. Sharecroppers may have established themselves, and owners routinely graze cattle on these lands.

What would be the immediate purpose of the project? Because global warming mitigation *per se* is unlikely to be a convincing rationale for tree planting in many developing countries, it will usually prove important to link forestry activities to more pressing national concerns. In Guatemala, current deforestation is caused by needs for additional agricultural land and for energy. Unlike agroforestry and other sustainable development techniques, however, conventional plantations would be unlikely to improve agricultural productivity. Depending on the location of the plantations and on the price ultimately charged for wood products, conventional plantations might or might not decrease energy-related pressures on natural forest.

Who would have an interest in project success? The strength of successful sustainable development forestry efforts is their linkage to the self-interest of the individuals working on them. Farmers' cooperatives, for example, can see agroforestry on their lands as a source of future revenue, as a source of greater agricultural productivity and as a labor-saving device. Whose self-interest is served by plantation forestry as a tool to mitigate global warming is much more difficult to ascertain. If pursued primarily through subsidies to wealthy landowners to plant trees on their own holdings, the tree-planting effort might even be reacted to with hostility by the economically less fortunate. And if land-reform were to occur eventually, who would provide for the protection of the already established plantations?

Who would administer the projects? Numerous organizations support forestry activities in Guatemala. With the exception of DIGEBOS, however, these organizations are almost exclusively relief- and development-oriented and would have little interest in or experience with large-scale reforestation. DIGEBOS, however, is a weak organization that has its capabilities already stretched to its limit. CARE, for example, sees little opportunity for expanding even its own activities significantly within Guatemala given the institutional weakness of its government partner. Short of a willingness to simply supplant the government's role in forestry policy, any large-scale reforestation effort would have to look elsewhere for expertise and institutional support.

Thus, small-scale social forestry may be more appropriate than first impressions might have suggested. This is not to suggest that plantation forestry has no role in the country. Indeed, some successful reforestation has occurred on large private landholdings. For example, the country's largest cement manufacturer has reportedly reforested enough area in the neighborhood of the plant to supply its future fuel needs. Nevertheless, the opportunities for large-scale forestry are probably quite constrained in comparison to alternative approaches.

The Ethics and Public Acceptability of Plantation Forestry

Many tropical countries face crises in their forest sectors, and there is a clear need for increased efforts in providing and maintaining forest-related services. Demand for forest products is increasing while forest stocks are decreasing, watersheds are being denuded and topsoil is being lost. Indigenous peoples in many tropical forest regions face severe threats. When forestry is discussed as a global warming response option, however, it is already common to hear the argument that such forestry would represent just another instance of the rich, developed nations solving their problems -- in this case excessive fossil fuel use -- at the expense of the poor masses in developing nations. Indeed, issues of ethics and public perception may be the most obvious point of difference among alternative forestry approaches to mitigating global warming, particularly in tropical countries. CARE's agriculture and natural resources project in Guatemala, for example, is oriented primarily towards addressing the survival and development needs of the people of Guatemala. A large-scale plantation achieving the same amount of carbon storage, however, might involve the displacement of residents from their land and might benefit only those who are already wealthy. So, while there is little reason to suggest that AES funding for CARE's activities constitutes an attempt to dump the pollution of the United States onto the backs of the people of Guatemala, other forestry approaches are likely to prove far more susceptible to this argument.

The degree to which global warming forestry is welcomed around the world will depend partially on the degree to which forestry projects can be matched to the perceived needs of the country. If future global warming forestry projects can meet the same test as this project does, the ethics of forestry response strategies should not be excessively suspect. Many forestry projects, however, will probably not meet this test. Projects could reduce the funding available for critically needed economic development. Projects could displace large numbers of people from their lands, and indeed buttress inequitable systems of land tenure. Projects could result in the loss of critically needed agricultural land. Projects could be constraining to the development opportunities of developing country populations. These are all key issues in considering the circumstances under which different types of forestry can help respond to the threat of global warming.

In considering these issues, it is helpful to remember experience with international forestry assistance in the past. Development assistance in the forestry sector, for example, has been criticized historically for its emphasis on large-scale projects with few benefits for local residents. Indeed, large numbers of farmers have on occasion been displaced by such projects.[16]

In response to these problems, the originators of the Tropical Forestry Action Plan (TFAP), established in 1985 to slow global deforestation, intended to foster an integrated forestry sector planning process through which the social, environmental and economic needs of a country would be addressed through development assistance targeted to the forestry sector.[17] Most tropical forest countries are now involved in the TFAP planning process.[18]

The TFAP has come under attack, however, for failing to live up to its goals. Deforestation is increasing rather than decreasing, and forestry assistance continues to emphasize industrial forestry projects at the expense of sustainable development for the millions of individuals already living off of the forests. As a result, it is commonly alleged that the national TFAP planning processes have failed to account adequately for the voices and interests of those countries' non-governmental communities and indigenous peoples. Several groups are now calling for a complete moratorium on funding for TFAP projects pending a restructuring of the program.[19]

Discussion of large-scale plantation forestry for the mitigation of global warming could be perceived as yet another attempt to ignore the interests of the rural poor in developing countries. Severe damage will be done to the credibility of global warming forestry if it is perceived by the non-governmental community to simply reflect an extension of the TFAP. Avoiding this perception, however, is likely to prove difficult for the initiatives currently being discussed in the global warming literature. It is commonly argued, for example, that some one billion hectares of degraded lands are available for reforestation in tropical countries.[20] As non-governmental organizations in many of these countries might point out, however, these lands are rarely, if ever, abandoned regardless of the degree of degradation, and the people on them face far more important concerns than sacrificing their meager livelihoods to offset pollution emitted in developing countries.

Sustainability of Plantation Forestry as a Global Warming Response Option

The long-term viability of any forestry initiative intended to mitigate global warming is of paramount importance. At the same time, it is by its very nature difficult to predict the success of such initiatives. The approach taken by CARE in Guatemala is to give local farmers good reasons to protect and nourish the planted trees, in the hope that the many benefits accruing from their planting will persist over time. Even then the long-term viability of the project is uncertain. What if population growth continues unabated? What if future political instability deprives many small farmers of the lands they currently farm, but to which their claim is questionable?

These questions are hardly unique to CARE's approach to sustainable development forestry. Indeed, questions of long-term project viability are almost certainly more severe for projects that do not correspond as closely as this one to individual perceptions of self-interest. If tax incentives are established to encourage large-scale reforestation of private holdings, what would be the effect of their discontinuance by a future government? What would be the fate of subsidized plantations if further land-tenure reforms are enacted?[21] If large amounts of money become available to foster tree planting, corruption is obviously an additional threat. And local opposition to unpopular projects can take quite tangible forms including the sabotaging of plantations. Even more broadly, what are the implications of the mounting debt crisis for developing countries' ability to manage and fund greatly enlarged forestry sectors? All of these variables will significantly affect the viability of a large-scale forestry response to global warming in developing countries.

CONCLUSIONS

It is often assumed that a ton of carbon stored in new biomass is the mitigation equivalent of a ton of carbon not emitted in the first place through fossil fuel combustion. The numerous uncertainties surrounding characterization of forestry's potential role in mitigating global warming, however, suggest caution about carrying the presumed equivalence too far. First, under most circumstances one must wait for years for trees to grow large enough to further significantly carbon sequestration goals. Many energy sector initiatives, on the other hand, begin preventing carbon emissions immediately. Second, it is impossible to predict with complete reliability the extent to which the projected carbon storage goals of forestry-based projects will actually come to pass, particularly when tropical forestry is considered. Although forest protection, reforestation and afforestation can further global warming as well as many other policy objectives, forestry-based options should not be seen as substituting for far reaching emissions-reductions efforts.

The agroforestry and woodlot approach being taken in Guatemala to offset the emissions of Applied Energy Services' U.S. powerplant is just one of many forestry options that are available. Other approaches could be based upon large-scale plantations for timber, electricity or biofuels, the regeneration or physical protection of existing natural forest, or even urban forestry. Proposals for future carbon offset projects will have to take a case-by-case look at the different options and decide which to pursue. The desirability and viability of these different options will differ markedly from country to country, leading different projects to rely upon different approaches for achieving carbon offsets.

Most analysis, however, unjustifiedly assumes that commercial plantations are the mechanism of choice for global warming forestry. This conclusion is generally arrived at by overlooking several important social and economic variables relating to the suitability and acceptability of alternative project types under different circumstances. For forestry to be viable as a significant global warming response option, policy analysts and planners will need to pay attention not only to physical and economic variables, but to social and human variables as well. If these variables are not adequately considered, there is good reason to fear that the concept of large-scale carbon offset forestry will be discredited among both governmental and non-governmental communities in many developing countries. Moreover, large sums of money could be spent with little or no long-term global warming mitigation benefit.

NOTES

[1]Houghton, R. A., 1990. "The Future Role of Tropical Forests in Affecting the Carbon Dioxide Concentration of the Atmosphere." *Ambio* 19 (4):204-209; Sedjo, R. A., 1989. "Forests: A Tool to Moderate Global Warming?" *Environment* 31 (1):14-20.

[2]Trexler, M. C., in press. *Reforesting the United States to Combat Global Warming?* Washington, D. C.: World Resources Institute.

[3]AES is a nation-wide independent power producer that relies on advanced coal combustion technologies to control the conventional range of air pollutants.

[4]The validity of concern over the prospect of global warming is assumed for the purposes of this paper.

[5]A 1987 survey of the country's forest resources classified only 38 percent of the country as forested -- just half of the proportion found 35 years earlier. Only the forests in the northern Department of El Peten remain relatively intact, and migration into this region threatens them as well. University of Georgia, Institute of Ecology, 1981. *An Environmental Profile of Guatemala: Assessment of Environmental Problems and Short- and Long-Term Strategies for Problem Solution*. Athens, GA; Leonard, H. J., 1987. *Natural Resources and Economic Development in Central America*. International Institute for Environment and Development, Washington, D. C.

[6]AES funding is therefore making possible the continuation and expansion of an existing forestry project, rather than the undertaking of a completely new one. One advantage of this approach was the opportunity to avoid the lead time of several years that would have been required to get a new project of any comparable size off the ground. Under most circumstances, however, future proposed projects will have to overcome this problem.

[7]CARE does not intend to provide assistance to rural communities on a permanent basis. Instead, it attempts to provide infrastructural assistance as well as training and extension services in the expectation that project participants will eventually become self-sufficient in all aspects of the forestry program.

[8]Although CARE expects to continue its work in the project area for only 10 more years, the expected lifetime of AES's coal-fired powerplant is 40 years. For purposes of analyzing the carbon offset benefits of CARE's forestry operations, it was decided to assume that the areas planted during the first 10 years will be sustainably managed and replanted for another 30 years after CARE's involvement ends. The possibility that planted areas will continue to expand as a result of the successful functioning of the infrastructures put into place by CARE was not accounted for in calculating the carbon offset benefits.

[9]Forest fires, often intentionally set for brush clearing, currently consume millions of trees each year.

[10]Although DIGEBOS pays the salaries of its promoters and coordinators, for example, CARE staff play a major role in hiring and training them.

[11]This is similar to planting trees for energy. Since the trees themselves will eventually be oxidized to produce energy,

NOTES, cont'd.

the real global warming benefit is in keeping an equivalent quantity of fossil fuels in the ground. Since the trees cannot release more CO_2 than they originally absorbed via photosynthesis, they contribute no net CO_2 to the atmosphere.

[12]These assumptions are more extensively documented in Trexler, M. C., Faeth, P. F., and Dramer, J. M., 1989. *Forestry as a Response to Global Warming: An Analysis of the Guatemala Agroforestry and Carbon Sequestration Project.* Washington, D. C.: World Resources Institute.

[13]WRI did not have growth rates for specific species at particular sites available for its analysis. Representative growth rates for tropical softwood species under reasonably good conditions were therefore used.

[14]Unfortunately, this is about as far as such analysis has gone. The author is currently involved in research aimed at integrating country-specific physical and social variables into estimates of forestry's global warming mitigation potential in the tropics.

[15]For an introduction to the social forestry literature, see: Cernea, M. M., ed., 1985. *Putting People First: Sociological Dimensions of Rural Development.* New York: Oxford University Press; Chambers, R., 1983. *Rural Development: Putting the Last First.* Longman Press; Gregersen, H., et al., eds., 1989. *People and Trees: The Role of Social Forestry in Sustainable Development.* EDI Seminar Series. Washington, D. C.: World Bank; Foley, G. and Barnard, G., 1984. *Farm and Community Forestry.* London: Earthscan.

[16]Lohmann, L., 1990. "Commercial Tree Plantations in Thailand: Deforestation By Any Other Name." *The Ecologist* 20 (1): 9-17.

[17]World Resources Institute, World Bank, and United Nations Development Programme, 1985. *Tropical Forests: A Call to Action.* Washington, D. C.: World Resources Institute.

[18]Winterbottom, R., 1990. *Taking Stock: The Tropical Forestry Action Plan After Five Years.* Washington, D. C., World Resources Institute.

[19]Sierra Club, 1990. *Stop the Tropical Forestry Action Plan.*

[20]Grainger, A., 1988. "Estimating Areas of Degraded Tropical Lands Requiring Replenishment of Forest Cover." *International Tree Crops Journal* 5(1-2).

[21]The issue of land tenure reform is a vexing one in the context of global warming forestry. Land reform is often characterized as a prerequisite to the long-term economic development of many countries. But if large-scale afforestation is pursued on large private holdings, will the industrialized countries that will likely have footed the bill be in the position of having to oppose such reform in the future?

REFORESTATION IN INDIA

A. N. Chaturvedi

ABSTRACT

The legal meaning of forest includes areas with good overwood cover, scrub, grass lands and wastelands devoid of tree growth. According to 1989 assessment the forest cover is only 19.52 percent of the total geographical area of the country, dense forest being only 10.99 percent. The population density varies from 21 per km^2 in eastern Himalayas to 418 km^2 in the Gangetic plain. While the population of livestock has increased by 42 percent between 1951 and 1982, that of goats alone increased by over 100 percent during the period. The fodder production is only about 700 million tonnes against the requirement of about 2000 million tonnes. All forest areas are open to grazing. Excessive grazing is resulting in ecological degradation and gradual loss in productivity. Plantation forestry is more than 150 years old and about 12 million hectares have been reforested. The bulk of reforestation was started in 1951 with changing emphasis on objectives. The present emphasis is on meeting the increasing demand of fuel and fodder. Wood prices have shown increasing trend since 1980 and this increase has encouraged tree farming, but it is still confined to only a few states in India. Large number of tree species and bamboos have been raised under afforestation projects to suit the edapho-climatic conditions. Aerial seeding tried over a large area has been a total failure. The technology for afforestation is available, but the resources commensurate with needs are lacking. The political and social environment fosters a lack of will to control the agencies responsible for deforestation and land degradation. Wood-based industries have not been involved in any forest plantation projects. The forestry program lacks clear thinking and patience. The present rate of deforestation exceeds that of afforestation. Far too many social benefits are expected from afforestation in too short a period.

INDIA'S FORESTS

The legal meaning of "forest" includes not only tree growth of varying density and quality but also scrub and grasslands, wasteland more or less bare of vegetation and hilltops above the altitudes at which tree growth is possible. The forests of India include a greater range of composition and appearance than can be found over a similar area in any other part of the globe. Their silviculture is accordingly more complex by far than that of the relatively narrower range of types and conditions met with in Europe and temperate North America. The number of tree species of importance runs at least into several hundred. Some of the forests of the country, notably the tropical evergreen forests of the wetter portions, are undoubtedly still in their original state just as they have developed in accordance with natural conditions of climate, topography and soil. The greater part of them, however, have been much influenced directly or indirectly by human activities. Although sometimes, owing to the different hardiness of some tree species under ill-treatment, the impact of a human population has favored a more valuable tree species against less valuable ones, the results of human activities have mostly been destructive to the forest.

In the earlier stages of the occupation of the land, the forest has everywhere been looked upon as the enemy of mankind and its destruction an indication of progress. This hostile attitude still persists. Where local conditions promote luxuriant growth and the pressure of population is not too great, but where the larger part of the forest has already been destroyed and the last remnants are seen to be doomed to early disappearance unless something is done to protect them, the realization of the great benefits conferred by the forest is gradually dawning on those who are at the same time both the destroyers and among the victims. The climatic conditions of India, and in many parts soil conditions also, are such that the adverse consequences of forest destruction are quicker to appear than in most countries of the temperate region. The heavy monsoon rainfall is largely responsible for this difference (Champion and Seth, 1968; World Bank, 1978).

FOREST COVER AND POPULATION

The 1989 assessment of the forest cover of India carried out by the Forest Survey of India based on maps of 1:250,000 scale resulted in the figures given in Table XXI.

Table XXI FOREST COVER IN INDIA, 1989.

Category	Area in Km^2	% of Total Geographical Area of Country
Forest:		
Dense forest (crown density 40% and over)	361,412	11.0
Open forest	276,583	8.4
Mangrove forest	4,046	0.1
TOTAL	642,041	19.5
Scrub Area: (tree lands w/less than 10% crown density)	76,796	2.3
Uninterpreted Area: (under clouds, shadows, etc.)	11,524	0.3
Non-forest (incl. tea gardens)	2,557,436	77.8
GRAND TOTAL	3,287,797	100

This study estimates the actual forest cover in the country at 64.20 million ha (19.52%) against the official recorded area of 75.1 million hectares (22.8%). Of the actual forest cover of 64.20 million hectares, only 36.14 million hectares is of more than 40 percent crown density. Thus only 10.99 percent of the country's geographical area has adequate forest cover against 33.33 percent required for ecological stability as enunciated in national forest policy.

FOREST AND POPULATION

The forest cover situation by ecofloristic zones and population density is shown under Table XXII.

Eco-floristic Zone 4, which comprises Goa, coastal areas of Karnataka, Kerala, and the Andamans and Nicobar Islands, has a good forest cover in spite of a high population density because of its unique climate conditions. In the rest of the country, population density is inversely related to forest cover (Anon.1989).

Table XXII. FOREST COVER BY ECOFLORISTIC ZONES AND POPULATION DENSITY, IN INDIA.

Sl. No.	Eco-Floristic Zone	Total Geog. area (sq km)	Actual Forest cover (sq km)	% of 4 to 3	Population/ density
1	2	3	4	5	6
1.	Western Himalayas	283035	56754	20.0	53
2.	Eastern Himalayas	94029	73565	78.2	21
3.	North East	171470	97592	56.9	152
4.	Western Coast and Andaman & Nicobar Islands	69738	30793	44.1	433
5.	Deccan	581358	133145	23.0	174
6.	Central India	750600	177249	23.6	153
7	Gangetic Plain	548867	44542	8.1	418
8	Indus Plain	632770	26360	4.2	155

Anonymous, 1989 Table 6

FOREST AND LIVESTOCK

Besides a high human population, the forests of India have to support a very large bovine population. While the forest areas have shrunk, the livestock population has increased by 42 percent over a period of 31 years between 1951 and 1982. Goat population recorded over 100 percent increase. The position with respect to different categories of livestock given in Table XXIII.

The estimated fodder requirements of the

Table XXIII LIVESTOCK POPULATION OF INDIA (GIVEN IN MILLIONS)

Unit: Nos. in Millions

Category of Livestock	Livestock Population in Different Years						
	1951	1956	1961	1966	1972	1977	1982
1	2	3	4	5	6	7	8
Cattle	155.3	158.7	175.6	174.1	173	180.1	190.8
Buffalo	43.5	44.9	51.2	53.0	57.4	62.0	69.0
Sheep	38.4	39.3	40.0	42.0	40.0	41.0	48.0
Goats	47.1	55.4	60.9	64.6	67.5	75.6	94.7
Horses/ Ponies	1.5	1.5	1.3	1.2	.9	.9	.9
Pigs	4.4	4.9	5.2	5.0	6.9	7.7	9.6
Camels	.6	.8	.9	1.0	1.1	1.1	1.0
Others	1.3	1.1	1.2	1.2	1.1	1.3	1.8

Anonymous, 1987 (Table 12.2)

livestock population has been worked out as under Table XXIV.

The estimated fodder production at present (1985) is shown in Table XXV. The demand for fodder for the livestock is not fully met by the estimated production. All forest areas are, therefore, open to grazing except in the national parks, covering an area of 3.39 million hectares (Anonymous, 1989; Table 9.2). The grazing pressure, however, varies with the local conditions. The intensity of grazing is higher in the hilly parts and the semi-dry and dry tracts of the country. The livestock migrate from one area to another during periods of stress. This is one of the main reasons for the decreasing density of the forest cover. The grazing is also responsible for frequent fires in forest areas. The forest floor is deliberately burnt year after year. The burning induces a new flush of grass which is eaten up by the hungry livestock. The fire, however, causes heavy damage by killing the regenerating forest plants. It destroys whatever little humus was built up along with the accompanying microflora. The species composition of grasses also changes and coarse grasses replace the softer grasses. In the Dudhwa National Park, lying between 28°18' - 28°42' N and 80°28' - 80°37' E, the study over some years has shown the ingress of fire tolerant *Themeda anathera* grass into the areas previously occupied by reeds *Arundo donax* and *Phragmitis karka* (Chaturvedi, A.N and Misra, C.M. 1985). The overall biomass production goes down and the exposed soils gradually erode.

Table XXIV. LIVESTOCK FODDER REQUIREMENTS (IN MILLION TONS)

Year	Fodder Requirement (million tons) Dry fodder	Green fodder
1	2	3
1985	780	932
1990	832	992
1995	890	1064
2000	949	1136

Anonymous, 1987 (Table 12.4)

Table XXV. ESTIMATED PRESENT FODDER PRODUCTION IN INDIA

Type of Fodder	Fodder Production (million tons) Dry fodder	Green fodder
1. Agric.residues	236	--
2. Grasses	205	--
3. Green fodders:		
a) cultivated green fodder	--	208
b) top feed, incl. sugarcane tops	--	4
c) weeds	--	14
4. Fodder from trees	--	24
TOTAL	441	250

Anonymous, 1987 (Table 12.5)

HISTORY OF FOREST PLANTATIONS

Plantation forestry has been known in India since the middle of the last century and the oldest plantation dates back to 1842 when teak was artificially raised in Nilambur (Kerala). In northwest Bengal, teak was raised in 1868 in Bamanpokhri (west Bengal) and planting continued till 1888 in the first phase. *Eucalyptus globulus* was introduced in Ootacamund (Tamil Nadu) in 1843 and was later extended by both government and private agencies for meeting the fuelwood demand and local oil distillation plants. Wattles were planted at about the same time for leather tanning and for fuelwood. In the Western Himalayas planting of conifers was taken up little later and *Cedrus deodara* was the principal species while in the eastern regions *Cryptomeria japonica* marked its advent in 1868 with an admixture of indigenous oaks, maples, laurels and magnolias. Plantations of *Dalbergia sissoo* have been raised in the dry Punjab plains with and without irrigation since 1866.

FIVE-YEAR DEVELOPMENT PLANS

Afforestation was taken up on a bigger scale with the launching of five-year development plans. The objective in the first few plans was to raise plantations for meeting the demand of the wood-based industries, especially paper, matches, plywood, sporting goods, etc. Some plantations for afforestation and soil conservation were also started during this period. The progress of afforestation through successive development plans has been as shown under Table XVII. In the plantations by forest departments, the targets and achievements were in the land area proposed and reforested.

SOCIAL FORESTRY

The concept of social forestry evolved through different stages over a period of 100 years but the Fifth Plan changed the emphasis of forestry plantations. Under its social forestry program, the plan indicated that plantations be raised on both wastelands and community lands. For areas deficient in forests, a program of plantations along the roads, canals and railway tracts was proposed. Raising of trees on the edges of fields of private land holders was also included. In the subsequent plans, the major object of plantations shifted to afforestation to meet the growing local demand for fuel, fodder and small timber. These were also considered as rural employment programs. As area measurements were difficult in such programs, the targets were fixed on the basis of number of trees. Areas were computed by assuming the rate at a density of 2000 trees per hectare. During 1987-88 and 1988-89, 3800 million and 4500 million seedlings were planted. These were computed to afforest 1.9 million and 2.3 million hectares of the area respectively.

Table XXVI AFFORESTATION IN INDIA SHOWN UNDER SUCCESSIVE DEVELOPMENT PLANS

Sl. No.	Five-Yr. Plan	Period	Area Affor. (m. ha.)	Affor. Exp.(m.INR)
1.	First	1951-56	0.1	12.8
2.	Second	1956-61	0.3	68.6
3.	Third	1961-66	0.6	211.3
4.	66-69		0.5	230.2
5.	Fourth	1969-74	0.7	443.4
6.	Fifth	1974-79	1.2	1072.8
7.	Interim	1979-80	0.2	371.0
8.	Sixth	1980-85	4.7	9260.1
9.	Seventh	a)1985-86	1.5	3785.8
10.		b)1986-87	1.8	4912.1
	TOTAL		11.6	20,368.0

(Note: 1 U.S.$ = 17.20 INR, Indian Rupees)
(Source: Anon., 1987, Table 5.1)

FARM FORESTRY

Due to increased demand and reduced supplies, the wood prices increased at a higher rate than the averages during the last decade.

Table XXVII. INCREASE OF WOOD PRICES OVER PAST DECADE IN INDIA

Year	All commodities	Logs/Timber
1970-71	100.0	100.0
1975-76	173.0	164.5
1980-81	257.3	407.1
1985-87	357.8	820.5
1987-88	405.4	871.8

(Source: Anon., 1987, Table 12.6)

The increase in prices of wood induced farmers to plant trees on their lands for profit. Farm forestry on private lands has developed in India as a business only recently. This is supported by financial institutions and by wood based industries. As profit is the chief motive, fast-growing species are preferred over slow-growing ones. Eucalypts, Poplars, Bamboos, *Acacia nilotica, Prosopis juliflora, Casuarina equisetifolia* are the main species planted.

AFFORESTATION

In the afforestation of degraded and barren lands a number of species are used, depending on existing conditions of the sites. Basically, the problem is of water budgeting and soil conservation. A large number of species are being raised which include *Acacia auriculiformis, Acacia nilotica, Acacia tortalis, Ailanthus excelsa, Albizzia lebbek, Anacardium occidentale, Azadirachta indica, Bambusa arundinacea, Cassia siamea, Casurina equisetifolia, Dalbergia sissoo, Dendrocalamus strictus, Eucalyptus hybrid, Pongamia pinnata, Prosopis juliflora, Syzygium cumini* etc.

In the hills, *Acacia mearnsii, Alnus nepalensis, Alnus nitida, Cedrus deodara, Cupressus torulosa, Eucalyptus globulus, Fraxinus floribunda, Juglans regia, Melia azedarach, Populus ciliata, Salix spp.* are generally planted. Vast tracts of barren lands of the country are affected by salinity and alkalinity. Equally large tracts are severely eroded and ravines have been formed in the catchment areas of several rivers, especially the Yamuna, Chambal, Sabarmati, etc., in the states of Uttar Pradesh, Madhya Pradesh and Gujarat. These call for special techniques of soil working, water conservation and afforestation (Chaturvedi, A.N. 1982; 1983; 1985; 1986 and 1989).

AERIAL SEEDING

Afforestation through aerial seeding was started in India in 1980 and has been carried out each year in different regions. Initially, only clean seeds were used. Later, seeing the poor success, the seeds were pelletized with insecticides and fertilizers. By 1989, about 0.20 million hectares had been covered without any success whatsoever. Aerial seeding failed due to lack of protection from domestic animals, compact soils and drought following germination.

RESULTS OF REFORESTATION

Reforestation activities in the area under the control of forest departments have been reasonably successful. Teak, *Shorea robusta, Eucalyptus globulus, E. grandis, E. hybrid, Acacia mearnsii, Acacia nilotica, Casurina equisetifolia, Anacardium occidentale* (Cashew), *Dendrocalamus strictus, Bambusa arundinacea, Prosopis juliflora, Acacia tortalis, Alnus nepalensis, Pinus roxburghii* have been successfully grown as plantation crops. During the last decade successful plantations of Eucalyptus, Poplars, Bamboos, and *Acacia nilotica* have been raised by farmers on their farmlands, especially in the states with low forest area cover such as Haryana, Punjab, Gujarat and Uttar Pradesh. Afforestation along roads and canals has also been very successful. The afforestation has largely been a failure on public lands where local pressures of grazing and firewood removal could not be controlled (Shingi et. al. 1986).

TECHNOLOGY

Technology for afforestation of lands with different edaphic and climatic conditions is available from few individuals and institutions. Because of constraints of funding and lack of support from the government, enough resources are not made available for setting up demonstration projects. Even where such successful demonstrations have been done, these are not maintained. The staff involved is changed frequently and long-term protection of such areas is lacking. The successful works do not receive adequate publicity as they do not generate news.

INVOLVEMENT OF INDUSTRIES

Because of land ceiling legislation due to government policy on land holding, the wood-based industries cannot buy lands. These industries are not, therefore, involved in any large-scale afforestation activities. There is a strong possibility of substantial afforestation taking place if there is a change in policy and industries are encouraged to plant trees by exempting such activities from land ceiling acts. This has been done for tea, coffee, rubber, etc., but not for wood production.

SOCIAL PRESSURES

Afforestation for social purposes has in recent years become a populist subject. Many social scientists advocate that all forests natural or artificially created are meant for local use. Any government control is undesirable. This is unduly publicized by the politicians and the press in the name of supporting the poor. This results in heavy damage to existing natural forests as well as young plantations. Using leaf fodder, which destroys the photosynthesis and soil amelioration mechanism of the trees, is one such practice encouraged under social forestry programs. These pressures discourage planting of non-fodder trees while fodder trees cannot be protected. This "functional" approach to forest management has fostered a narrow view of the role of forestry in the economic development process and, in turn, has resulted in inadequate government funding of forestry programs or, in extreme cases, the complete exclusion of forestry from rural or agricultural development schemes.

LIMITATIONS OF AFFORESTATION

Successful afforestation programs have several limitations:

1. Due to harsh edaphic and climatic conditions, the process of afforestation is necessarily slow. The social forestry programs, however, envisage meeting the social needs of fodder and fuel from such plantations at an early age. The expectations are not realistic.
2. Originally the program envisaged afforestation over 5 million hectares per year, but the areas available for afforestation were not identified. The program could not reach anywhere near the expected area of five million hectares. The average area afforested was only about 1.5 million hectares annually.
3. The money allocated for afforestation projects was not commensurate with the physical targets fixed.
4. The expectations of supply of goods and services from these afforestation projects are very high and have ignored the productive capacity of the sites.
5. The agencies responsible for deforestation were not correctly identified and no efforts are made to control them.
6. It is thought that people's participation can be realized by involving non-governmental agencies which are funded by government and international agencies. Most NGO's lack the technical know-how of afforesting difficult sites. The funding agencies expect quick results. Therefore, the data of achievements are produced to impress them.

7. The demand of firewood is estimated at about 155 million tonnes while the recorded production is only about 50 million tonnes. Thus, there is continuing process of deforestation. This rate exceeds the rate of afforestation. It is, however, possible to meet the firewood demand by afforesting about 40 million hectares of land. This can be done at dispersed locations to minimize cost of transport. Since the sites for firewood farming will be generally degraded lands, the harvest rotations will have to be such that land productivity is restored (1, above). Presently the annual afforestation rate is about 1.5 million hectares.

8. Success of afforestation is dependent on protection from grazing and fires. The livestock population is beyond the carrying capacity of land. Afforestation cannot succeed unless the bovine population is reduced.

SUMMARY

Successful large-scale afforestation is possible in India and technology is available. The program is not, however, supported correctly either by the government or the public at large. There is no clear mandate of what the nation wants. Lots of vested interests have joined in and are taking the afforestation program in wrong directions. Afforestation can provide large employment opportunities and restore ecological balance with connected benefits, but besides funds the program needs patience and restraint on local use in the early stages. The program should be linked to reduction of livestock population, especially goats. The wood-using industries should be actively involved in industrial plantations on presently degraded lands. Large areas under open-cast mining should be afforested by appropriate technology and linked to mining concessions.

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INTERNATIONAL WORKSHOP ON LARGE-SCALE REFORESTATION

GROUP DISCUSSION

PARTICIPANTS: Jack Winjum, moderator; Francis Cailliez, A. N. Chaturvedi, Chris Geron, Joe Hughes, Ian Hunter, Dean Jerstad, Lew Ladd, Denis Lavender, Leon Liegel, Douglas Malcolm, Renato Moraes de Jesus, Pete Owston, Charles Peterson, Paul Schroeder, David South, Ben Stout, Mark Trexler, Tom Turpin, Terralyn Vandetta, Steve Winnett, and Jamie Wyant.

Winjum (*after introductions of those in attendance*): For this discussion, we will take for our background and assumptions that there will be a climate change in the next four or five decades as a result of man's activity (Table XXVIII). Further, we will take the position that forests do sequester carbon and can therefore be a significant aid or help in reducing CO_2 buildup. There is a need to have some international consensus and coordinated effort on a world scale for reforestation. We will take the position that land is available but that there are questions of how much, where and what the productivity is of those lands. Also, we feel the technology, experience, and available know-how exist to get started.

Table XXVIII. BOARD NOTES #1.

PERSPECTIVES/ASSUMPTIONS

* Climate change *natural* vs. *induced*
* World forests: boreal, temperate, tropical
* Carbon sequestering by forests a significant aid
* International consensus for reforestation
* Land *is* available, but:
  where?
  what kinds?
  how much?
* Technology and know-how:
  - start-up period: adequate/CRP?
  - long-term: will improve through research, experience, species vs. site?
* Costs: modest (?) vs. energy efficiency — *economic equity?*
* Benefits: many compatible
* Objectors: few; supply/demand shift: esthetics, cattlemen
* Educational and extension needs: especially in tropics, over time.

In the longer term, we can even improve on the knowledge base with experience and research on a global scale. We take the position that compared to other mitigating possibilities, such as alternative fuels and energy conservation to reduce greenhouse gases, that reforestation is moderate in cost -- even though we have heard some pretty big numbers on cost per hectare mentioned. There are many compatible benefits such as reducing erosion, providing jobs and a better standard of living, and all of the positive factors that forestry can provide to serve humans everywhere.

There is what the textbooks call economic equity. Large blocks of people are penalized when we impose a tax on CO_2 emissions or prohibit the burning of high-sulfur coal or any coal at all. How would large-scale reforestation affect the supply and demand of some wood resources and therefore the economic equity of people in forested regions?

And there's another matter that we've frequently heard in the workshop papers: that of human displacement. There are many people currently living at subsistence levels in non-forested areas, or in areas that don't carry a heavy forest cover but could be reforested. It isn't a matter of just going in and moving people aside to establish plantations, however.

So there are some down sides; but there are, by and large, mostly positive ways of looking at global reforestation. We've heard that there are objections to large-scale reforestation that would certainly affect the supply and demand of some wood resources. Some people just don't like the whole idea of a man-made forest because they aren't "natural." We should expand that category to include agricultural lands; in our country we are going to compete for land availability, especially with the cattle people, who look askance at this notion.

Trexler: If you assume that forests are a significant aid, it seems like you've stacked the decks before you've gotten into the discussion, since that's going to depend a lot on the land availability. And if you assume that the costs are going to be modest, there are people who will argue that energy efficiency is much, much cheaper than forestry, so I'm not sure about the basis of that assumption as well. It is going to vary dramatically over the extent of a billion hectares. And I think we want to be careful -- some types of forestry activities will have beneficial characteristics and some won't. I don't think you can make a blanket statement that "forestry is good." Sometimes we achieve economic equity and sometimes we don't. We must be careful about assuming that we have that problem solved. Some people argue that energy efficiency is a negative cost. They're probably wrong as well, but different things will fit into different places in the curve. What I'm saying is, if you assume it's a panacea going into the discussion, it's not going to be surprising to come out falsely with forestry as a panacea.

Jerstad: In the South, where we plant one-and-a-half billion seedlings a year, you'd think we'd know how to plant trees and keep them alive. The recent Conservation Reserve Program (CRP) is a good example to show that in all cases we don't have the know-how. They are planting old agricultural fields. In some of those old "ag" fields, there were problems that were hard to identify. The trees did not survive. It seems that in a massive program like this there should be some start-up research dollars provided so that these problems can be solved.

Lavender: Another thing, Jack, is that if we are doing this with reference to a possible warming, that warming could take place before these plantations are sequestering very much carbon. This is certainly true in the temperate zone and as we go toward the boreal forests it will be more true, so we'd better know what we're doing. Otherwise the plantations will disappear because of the climate change itself. That would be true on the west coast in Oregon and Washington. If we were to start planting Douglas-fir, then have it warm up to where the Douglas-fir is no longer a viable species, we'd have nothing but dead plantations.

Winjum: We need to take a longer term view. A rotation or two in the tropics wouldn't show significant change, but if we are going to be thinking about rotations in the more northern climates, the considerations Denis mentions need to be taken into account.

Turpin: It seems to me, as we sit around the table here, we know how to regenerate our land and plant trees in general, but there's got to be a massive education program, both public and private, to make global reforestation both feasible and acceptable.

Winnett: That's especially the case when we're dealing with people in the tropics who are not familiar with good forestry methods. You're trying to change their life practices in agricultural methods. It will have to be even more massive an educational push, and it's going to have to be continuous.

Moraes: Jack, this "push" must include both extension *and* education.

Stout: Jack, during the course of the presentations, we saw wide expanses of land in the Congo where there appeared to be blanket planting. Also, what I understood in Brazil, there is blanket planting of *Eucalyptus* and conifers over wide areas. I kept wondering as I watched how it was done. I can remember when I was working in New York state and seeing plantations that were put in in the 1930s that were dying in the 1950s. These were species that were put in off-site. Do we have an understanding, do we know how to fit species to site? Is that important, or isn't it? I don't know.

Lavender: Well, that was my point. Even if we do know for the present day, the changes that occur in the future may adversely affect what we plant today.

Malcolm: The trouble is, we don't know exactly what the climatic changes are going to be.

Winjum: Yes, in that regard I was surprised. We recently had Stephen Schneider here in Corvallis to present a seminar on global climate change. He's the author of *Global Warming: Are We Entering the Greenhouse Century?* Someone asked him about the current climate change scenarios and the probability of getting improvements on those. His answer was, "Don't hold your breath." He felt it would be ten to twenty years before there are reliable global circulation models which would give us more definitive answers -- even with the advanced computer and modelling technology that we have today. And he's a person who would come down on the side of "It's here today, it's going to happen."

Schroeder: And then he went on to tell us that in particular circumstances, we don't even know the signs of the change.

Winjum: Yes. Schneider said we have a feel for the confidence limits (wide), but we don't know whether the signs are pluses or minuses. His comment was a bit tongue-in-cheek, but it punctuates the idea of uncertainty.

Winnett: What we have to do is try to incorporate the idea that climate change will take place. In the Pacific Northwest, for example, we might plant ponderosa pine mixed with Douglas-fir. Then with climate warming, the ponderosa pine would take over. If it didn't take place, the Douglas-fir would predominate.

Winjum: Yes, hedging our bets, taking some precautions, may not be an unwise thing to do.

Ladd: Does anyone know today anywhere in the world where trees have been planted in anticipation of global climate change?

Stout: Yes, I did, and I hadn't thought about this in years. Irving Bailey, who was a world-reknown plant anatomist, came to me when I was working on the Black Rock Forest in the 1950s. He had been talking to Paul Mengelthorpe, who was one of the developers of hybrid corn, and he said, "Ben, the people who are growing hybrid corn in Illinois are substituting genotypes and moving them north constantly. You are going to have to do the same thing with trees. Therefore, go into the valleys on the Black Rock Forest and collect red oak seeds, take them up to the tops of the mountains and plant them." So I did, and the mice followed me around and ate the seed, and I went off to another job.

Peterson: So you were tipped off 30 years ago. You should have come here with a lot of answers!

Hughes: I can think of a situation where we are thinking the opposite: we've moved loblolly pines of North Carolina to Oklahoma, and so far we have not had a serious problem. Oklahoma is a more interior climate, lower rainfall and a little harsher environment for loblolly pine. We're defying gravity, you might say, or by doing that, defying predictions. But so far we're doing it with good success -- higher growth rates for loblolly from North Carolina than from the local sources.

Winjum: Bill Carlson told me a couple of years ago that one thing Weyerhaeuser Company was doing was trying to identify some of the droughty sites in the Oklahoma-Arkansas region. Knowing that if it's dry now and global warming takes place it may get drier, they are planting plots of each of the loblolly pine families that they are using at these droughty locations. Then the last several summers they've observed growth, pre-dawn water stress measurements, etc., on these plots. In this manner they will identify which families are more drought-resistant to plant more widely if climate change causes drier conditions on their southern forest lands.

At the same time they applied vegetation management treatments to some of the plots for moisture conservation. Their philosophy was that if an increasing number of droughts occurred the plantations would have to be predisposed to withstand drier conditions -- waiting until droughts occurred would be too late.

Hughes: There are other cultural practices to offset droughts also; for instance, lower stocking levels.

Winjum: I don't know if Weyerhaeuser has gone operational on this, but at least from a research standpoint it is being tested.

Chaturvedi: One point related to climate change in India is that we have found that where we have planted eucalyptus on typically dry sites, they have died in years of unusually high rainfall. So, even when you plant for a particular condition, you may get an unexpected temporary change that will cause a problem.

Lavender: There are people who say that these exceptional weather events correlate with the increasing greenhouse effect.

Chaturvedi: Yes, that adds to my point.

Winjum: It also emphasizes the need for better climate scenarios on a more regional basis. Until we get that, we are going to have to expect that atypical weather events are probably going to occur more frequently.

Liegel: One more question, Steve: is the Intergovernmental Panel on Climate Change (IPCC), and their group on forestry looking at reforestation strictly from a carbon sequestration standpoint, or are they looking at it also from the standpoint of improved standards of living or increased GNP? The answer affects where we come from on large-scale reforestation.

Winnett: Part of the analysis has to do with what the effects of increased planting would be on local economies, the timber supply, the price of timber and agriculture, and the supply of agricultural land for increasing populations, but the main purpose of the analysis is for the sequestration of carbon. So they are looking at it for that reason but they are also looking at all the additional effects that would result.

Trexler: But remember, the level of analysis being done by the agricultural and forestry group is extremely low. It's really been an educational exercise for all these countries which have never encouraged the concept of forest management for sustainability. So there is not much advanced analysis in this work yet.

Winnett: But the economic models they use are becoming more refined; as we get more data we can look at more and and more offshoot effects.

Winjum: The answer to Leon's question seems to be, then, that the IPCC is definitely interested in carbon sequestration but also is trying to be mindful of all the ripple effects of social and political considerations. (See Table XXIX)

Geron: They also are taking into consideration other options in developing countries in a bit more thorough manner than what we've heard discussed the last few days. That is, they've done a more thorough job of integrating the policy and agricultural people into their deliberations.

Table XXIX. BOARD NOTE #2

PERSPECTIVES/ASSUMPTIONS

* Climate change: natural vs. induced (temperate and boreal)
* World forests: boreal, temperate, tropical
* Carbon sequestering by forests significant aid
* International consensus for reforestation
* Land *is* available, but--where? what kinds? how much?
* Technology and know-how
  -start-up period: adequate/CRP?
  -long-term: will improve through research experience
  species vs. site?
* Costs -- modest (?)
  vs. energy efficiency
  economic equity?
* Benefits -- many compatible
* Objectors -- few: supply/demand shift; aesthetics; cattlemen
* Educational and extension need, esp. in tropics, over time

Trexler: The primary conclusion out of the agricultural and forestry group is, of course, that they are saying, "Look, maybe we can do some good on the forestry side, but it is absolutely up to the energy side to make it possible for us to do anything."

Winnett: Yes, and in fact, if you will look at the second page of the handout on the IPCC, the workshop that took place in Brazil in January, 1990, recommended the development of a world forest conservation protocol (see Appendix to Group Discussion). But on the energy supply and use question, the convention made very clear that most developing nations -- especially the tropical countries -- were not interested in doing anything until the energy question was addressed by the developed countries -- and quickly.

Lavender: I think we are going about this whole thing backwards. I think the first priority as far as forestry is concerned is a greatly beefed-up, much more efficient fire-fighting establishment. For instance, in Canada last year we burned over 7 million hectares of forests. It will take a tremendous amount of planting and a good number of years before we put back the carbon that went up in flames in a brief period last summer. I don't see that these forest fires are necessary. The point is, we have never really put the resources into controlling the forest fires that we should have. It is far cheaper to control forest fires than it is to reforest the area that's been burned over -- particularly in the temperate and boreal zones.

When you get a fire in the boreal zone, there's a tremendous amount of carbon that's stored in the soil, and when you get a forest fire there the soil starts to warm up. Then you lose not only what was in the trees, but tremendous quantities of carbon that become oxidized in the soil as well.

Winnett: You could also include methane and nitrous oxide. We are increasingly trying to address now questions of soil emissions following biomass burning or forest burning. Emissions include nitrous oxide that has a heat absorbing factor of 170 times that of CO_2 and methane, which has seven or eight times that of CO_2. So these emissions are very important.

Geron: I think that some of the other Canadian forestry people might question the cost effectiveness of excluding fire from the Canadian systems, given that it is a natural part of the ecology there.

Lavender: Yes, but if we're interested in the cost of maintaining carbon where it is so it doesn't get into the atmosphere, this is a different economic question than has ever been addressed by Canadian foresters.

Table XXX BOARD NOTE #3, a and b.

APPROACH

Fire Protection -- a top need, particularly in temporal and
boreal forests;
vs. reforestation
-- and from N_2O and NH_4 new

Questions --
Fuel Buildup and eventual fire preservation
vs. planting relative to CO_2 and C storage;
Depending upon condition of existing forest;
Timber stand improvement.

Geron: A couple of points that were made by Canadian fire ecologists should be mentioned. Fire suppression has been successful in keeping the fire size down, but this increases fuel loads. Then when a fire does eventually comes through, the intensity is increased. In this way, organic build-up in the soil is less than what might have occurred if fire were allowed to evolve on its natural cycle.

Wyant: That is one of the Yellowstone issues, but the jury is still pretty much out on that conclusion. Yellowstone is a good example of the attempts to increase fire fighting efficiency not working very well. When there is a horizontal roll of fire vortices sweeping across landscapes, there's nothing you can do to stop this type of wildfire.

Stout: What we're saying, then, is that all carbon in forests is going to recycle sometime.

Winnett: The objective of sequestering carbon with forests is to buy ourselves a little time; in other words, to delay global warming 50 or 60 years. Not only do we need to talk about fire protection in forests, we have to protect standing forests in general -- especially the tropical forests. Given that for every hectare of tropical forest lost for whatever reason, even if we could replant them we are not going to get the same carbon sequestration as is sitting there in the existing forest. This depends, however, on the extent of durable products that are made out of whatever is removed -- and to be effective, that should be for one hundred or more years. So one of the points in the IPCC discussion has been that it is more economic to preserve standing forests than it is to replant.

Malcolm: That's the negative approach, is it not? You're saying that this carbon is stored in this climax forest, where it is in fact neutral in terms of CO_2. It's stopped, but it doesn't relate to younger stands which are sequestering CO_2.

Hughes: It depends on the kinds of stands you are preserving, too. In the ones we saw yesterday, obviously there are great quantities of carbon there. A lot of forests in the South and other parts of the world, however, will store a lot more carbon in the next forty years if they are cleared now and replaced by managed plantations.

Winnett: It should be noted that there are at least three analyses on the question of whether harvesting the Northwest old-growth trees and replacing them with young, vigorously growing stands for the sake of sequestering. In those three cases, the results came down in favor of keeping old-growth stands.

Hughes: I think I would agree.

Winnett: It was clear from your presentation that the intensively managed loblolly stands would be very well suited to contributing carbon sequestering.

Lavender: No one has addressed the question of internal rot. Many years ago I was investigating internal rot in old-growth Douglas fir, and we looked at stands from 200-500 years old. We were unable to find many that were over 400 years because once they get beyond that age the internal rot becomes progressively greater, until by the time they are 500 years, over half of what appears to be standing biomass is totally rotted out. The same thing is true to an even greater extent in the old-growth boreal forests of Canada: lots of those forests are shells of wood around nothing.

Winjum: Another chart put together some time ago can be used as an entry point to the next question: If we were called upon to address people at the top levels of federal agencies, what recommendations we would make with respect to the whole issue of global reforestation? Let's discuss what we would say, with all the appropriate caveats about ecological issues, the socio-political concerns, and the technical management considerations. Using this as a guide, how might we summarize the workshop? This is our objective for this day.

The first one is the land availability question.

Table XXXI. BOARD NOTES #4

WHAT RECOMMENDATIONS
SHOULD WE MAKE ABOUT:

- Ecological/Biological Considerations
  - Lands
  - Species
  - Hazards
- Social/Political Concerns
  - Present policies
  - Economic development
  - Social acceptibility
- Technical/Management Requirements
  - Planning
  - Infrastructure
  - Follow-up tending
  - Research needs

As a first approximation based upon the literature and preliminary discussions, Paul and I estimated that an upper limit was 1 billion hectares in 25 years. This says nothing about suitability, only availability. The estimate consists of 750 million in the tropics and possibly 250 million in the temperate and boreal zones.

The remark came back to us, "Okay, that sounds great, but does it pass the laugh test?" That's the question I'd like to ask you now. Does it pass the laugh test?

Trexler: Could you explain where you got these numbers?

Schroeder: The 750 million comes directly from Alan Grainger, in a paper in the *International Journal of Tree Crops*, 1988. All are very rough numbers, mostly guesses.

Ladd: He got them, as I did, from the United Nations F.A.O.

Winjum: And how much of that did he say was degraded or abandoned land?

Liegel: Did he specify whether it is dry or more moist and humid?

LARGE-SCALE REFORESTATION

Table XXXII BOARD NOTES #5

LAND: TECHNICAL SUITABILITY
Upper limit 1 billion hectares over 25 years
750 b. in tropics (Brazil, approx. 200 m.) -not arid lands
250 b. in temporal and boreal 1/10 m. in s.e. United States Also, New Zealand, Australia
Population effects Shifting agriculture will continue Food needs will continue to call for agricultural lands
Much uncertainty and need
GIS analysis
More research

Schroeder: This leaves out the most arid part. We actually came up with a grand total of about 2 billion hectares in the tropics, of which 1.25 billion are unsuitable for trees because of aridity. The lands run from being quite moist to semi-arid.

Winnett: Jack, did the 250 million include more than North America? Does that include the Soviet Union and degraded eastern Europe?

Winjum: Only in very rough terms. For the temperate regions, we took the number out of the *Trees for U.S. Report*. It was about 15 million hectares for the U.S. alone. We said, "If there's that much for the U.S., surely in the circumpolar, temperate region there ought to be 250 million hectares available.

Winnett: What do people think? I haven't heard anyone's reaction to this, what do people think about the feasibility?

Schroeder: This says nothing about feasibility. Nobody is standing here proposing to plant a billion hectares of forest.

Winnett: What you're saying is a billion will be available over the next 25 years?

Winjum: That was our estimate. We confess that we're pretty naive about this, which is why we want to get the reaction of this group.

Caillez: I think part of the issue is whether agriculture will be able to feed the coming generation of people in every type of climate. In the subtropic areas the numbers of people will increase and it will be possible to feed them. But in the humid zones we do not have a good agricultural model for feeding people, and the shifting population will be increasing more and more. We will have strong immigration problems in Africa. For instance, the population from Sudan will go south to countries where agricultural development is not advanced. So I think deforestation in the tropics will increasingly go up. This number seems to me very much optimistic.

Trexler: Since Grainger does a lot of sustainable agriculture work, is he assuming that we are bringing the latest technology in sustainable ag to bear on existing ag lands so all the other lands could be freed up? In principle, we could grow a lot more food on a lot less land if we're willing to make some heroic assumptions about those lands. But as you said, the FAO calculates that we're going to be using more than an additional 200 million hectares just to grow food.

Schroeder: He didn't say that, but that may be the case.

Owston: One of our project leaders went to an international meeting in Vienna about two months ago. I don't know whether it was a meeting about a monitoring system or whether it dealt with land inventory, but I think the latter. I will check on this and see if any useful data is available.

Hunter: Could we not accept the Grainger numbers as being indicative of the potential amount of land that's going to be available, and that there will be some conflict with agriculture, with the result that we may need to use some kind of global information system?

Trexler: That's an incredibly high number. To leave that number in as *the* number seems dangerous.

Hunter: What I didn't say in my paper was that Australia has got itself into a pickle with badly acidified land in the east of the country.

Winnett: Ian, if you had to give a best guess for Australia, what would you say?

Hunter: I just don't know. I'd have to get the figures and get back to you with them.

Ladd: The methodology isn't spelled out. I'm not so interested in getting specific numbers and estimates, but in getting ideas on how we could make better land availability estimates.

Moraes: Jack, the main issue in the tropics is to produce forests and food. So how to grow food with forests is highly important. Some of the land could be used for agro-forestry.

Winjum: That's a good thought, too. We didn't really consider the agro-forestry opportunity.

Liegel: Let me just make a comment. I heard Lanly of FAO speak a few years back. He admits there are a lot of unknowns in how the countries report the figures. Some use remote sensing; some use no remote sensing, but just the best estimates of the people on the ground. There are big discrepancies in the quality of the data and in some instances, it is just a paper exercise.

Table XXXIII. BOARD NOTES #6.

AGROFORESTRY

Factored in
Promising trend in India

* Grainger's estimate may be too high; others lower

Availability vs. Need

* Need: 5.6 Gt C -- optimal
--to offset deforestation in last 10 yrs.

Natural reforestation? -- Yes!
India gap planting -- Yes!
(special conditions; e.g., Diptocarps)
Extension of natural forests into savannah;
e.g., Gabon, okumé

Hunter: I'd like to ask Mark why he's unhappy with the figure of 1 billion hectares, because to me, maybe the land availability isn't a constraint. There are constraints we haven't really talked about, one being suitability.

Trexler: The thing is, there's so much degraded land out there, but as we heard yesterday, we aren't going to be able to put forests on that degraded land in any sort of large-scale manner. I think the degraded lands account for an awful lot of what Grainger summed up. Many more people rely on Houghton's numbers. He estimates that five to six million hectares are available for reforestation. And he admits even that may be too high, since all it consists of is adding up the brown spots on the GIS maps.

Ladd: How does one look at the brown spots, then assess the other criteria associated with that, and make it a reasonable estimate?

Trexler: I don't think we've done that yet. This is a first level of brown spots.

Schroeder: Personally I don't think there is *the* number. Whether it's a half-billion or three quarters of a billion, it doesn't make any difference one way or the other; it's such a huge number. The realm is so big, it's irrelevant whether it's one or the other.

Hughes: It's either big or small according to what you think you need. They are relative numbers. I was confused a little when I read something that you sent out (prior to the workshop). I saw your availability numbers and I read it to be need. The earliest article said 200-300 million hectares needed, I think. And Roger Sedjo's estimate was about twice that. But the availability numbers we're discussing here are the highest I've seen in respect to what you need.

Schroeder: But what do you need?

Malcolm: The objective is to sequester 5.6 gigatons of carbon per year. If you don't think it should be that, then how much do you need to sequester? How much land do you need to sequester how much carbon to meet that objective?

Winjum: Yes, one of the targets was to sequester 5.6 gigatons of carbon annually, but it could be less and still aid in delaying global warming.

Moraes: Natural forest management should be included in this as well.

Winjum: Yes, I would think so. What we have focused on are the new forests. I don't know what the opportunity is for managing the natural forest. We did look a little bit at timber stand improvement, for example, forest fertilization or weed control. That opportunity seemed quite small in terms of its carbon-sequestering potential versus reforestation. We didn't analyze natural reforestation through natural seeding.

Chaturvedi: There are parts of India where we have started planting by a method called gap planting. In the existing forest we depend on natural regeneration, but in most of the areas we have also been gap planting as a method for increasing stocking density. We find this to be working much better than other methods of planting. In many of our natural forests we have introduced teak in this fashion. We have found this method to be satisfactory provided you don't plant very large areas or too densely.

Hughes: That's going to depend on the species, isn't it? We would never think of doing that in the southern United States.

Chaturvedi: One problem is, if you open up the canopy then suddenly lots of weed species come in, which we must then spend a lot of money to eliminate. In India, shifting cultivation is on the decline, the primary reason being that the cycles of cultivation have been shortened and the productivity is much lower. Therefore, it is no longer effective. So it is possible to increase forest cover in these areas by combining tree growing with agricultural crops. This agro-forestry approach is a promising trend.

Cailliez: I think it is rather difficult to plant in small openings for a system of enrichment or artificial planting. In Gabon there was a lot of land occupied by agriculture when there was slave labor. Since the end of the slavery, with the population at a low level, The natural forest of okumé grows up, provided some simple and cheap working of the ground is done. Okoumé is in high demand and grows in almost pure stands. The cost of this practice is 1/6th that of a forest plantation establishment.

The area conserved can be as large as 2 million hectares. So I think it's a third type of possibility, which favors the natural expansion of natural forests in combination with some small, cheap mechanical work of the ground. This is possible in certain types of areas where populations are low. If I were the Minister of Forestry for Gabon, I would prefer to receive a certain amount of dollars to do this type of forestry, instead of the same amount to establish forest plantations..

Winjum: To conclude this land availability question, I'm still trying to decide what's the sensible thing to tell agency policy-makers? We can say we made an early estimate of this based upon library sources. Then we asked the opinions of people from the international scientific community at this workshop. They responded that one billion hectares of available land is on the high side. Over the next 25 years, they felt there may be only half that number.

But that's probably not the major limiting factor we must think about. There are more matters that will influence the decision to support large-scale reforestation than just the land availability, such as the socio-political considerations relating to needs and concerns of local people. But this original estimate does say that there are a good number of hectares available if we learn how to approach the whole issue in the right manner.

Hunter: Do you want to use the phrase "available land," or do you want to say "technically suitable?"

Trexler: You may have your terms reversed here. Suitable land is land that we can grow trees on, and no one can disagree with that. Available land is much, much more constrained. Available means available in a holistic sense and is not a scientific term.

Winjum: Do you agree with that, Ian?

Hunter: I think technically suitable is the right term.

Winjum: We want to keep the land estimate more realistic. There isn't a lot of background material, but your impressions are what we are after now, given the level of familiarity we all have.

Hunter: I think you need to stress the fact that more analysis needs to be done before a realistic estimate of the amount of available or technically suitable land can be made.

Malcolm: I think you need to emphasize what the objective is in terms of the quantities of carbon you are trying to sequester.

Trexler: But isn't that backwards? I mean, the amount of carbon you sequester depends on the land, it's not the amount of land that's dependent on the carbon.

Malcolm: The amount of land you're looking for also depends on the amount of carbon you want to sequester. Is the goal to mop up the entire fossil fuel input or is it not? If it isn't, then you're not looking for that much land.

Winnett: The Noordwijk Ministerial Declaration, in November, 1989, suggested the goal of reforesting 12 million hectares annually over the amount of hectares deforested annually. This would be another way of looking at it, rather than purely in terms of carbon sequestering. Could we replant 12 million more than is deforested annually in order to regain that which has been lost?

Wyant: What is the ultimate goal, a return to the extent of pre-Pleistocene forest cover?

Winnett: Well, I think this Nordwijk Ministerial Declaration was looking at the last 10 years of deforestation as the beginning, and then setting a goal of trying to gain back that which has been lost by planting 12 million hectares annually for 40 years over the level of deforestation.

Liegel: Even in that context one needs to get an estimation of how much has reverted naturally to forest, either from agriculture or from some other source. And those estimates are probably just as poor as the estimates on deforestation.

Winjum: We do need a better inventory system on a global scale.

Winjum: From the workshop papers, we have presented some examples on costs, incentives and social/political considerations of large-scale reforestation. Some of these numbers are on the board (Table XXXIV). Let's discuss them to get an idea of how much one-time development cost it takes to produce so many cubic meters. The point is that in different parts of the world and under different forest situations, it is going to take different levels of investment to establish new forests. Then, based on the growth rates, the cost in dollars of wood produced is going to vary. But such analyses will guide strategies on where dollars are best invested.

Table XXXIV. BOARD NOTES #7

Reforestation Data

COUNTRY	MAI (M^3/HA/YR)	COST $/HA	EST.COST $/$M^3$
New Zealand	25	300	12
S. U.S.	9	300	33
Brazil	35	600-1000	--
Congo	30	1400	47
U.K.	14	1100	78
India	9	800	88
West Coast US	14	1730	124
BC	6	1000	166

(Land costs are not included)

Lavender: I think the MAI (mean annual increment) numbers you have for British Columbia should be doubled from three to six, m^3/ha/yr. There's a lot of land that no one in their right mind would spend money to plant that is involved at 3 m^3/ha/yr.

Hughes: But that's fair. If you can increase the productivity on lands with poor productivity, you don't need as much area for new plantations..

Hunter: Has anybody included the capital cost of the land? That would greatly change the New Zealand figures.

Stout: No, and no maintenance costs are shown either. I think we should think about this, Jack, and go back to my New York experience. In the 1930s, during the depression, New York State planted 400,000 acres of pine plantation. In the 1950s all of the state budget for forest management was devoted to those 400,000 acres, which were degraded because the pine were planted so much off-site. Yet they had four million acres of good hardwood forest that was not being managed simply because of the money tied up in plantations. The money was spent and and New York foresters felt compelled to take care of the plantations with the funds available. I can see this happening worldwide.

Hughes: This points to the issue of incentives. Land availability is one thing, but there have to be incentive costs to get people to do reforestation.

South: On the incentives, I'd like to point out that in Scotland they have changed from tax breaks for growing forests to a grant system. A grant to a forest land owner now ranges from $1500 to $1700 per hectare, with an additional

$1500 to $1700 per hectare, with an additional $340 per hectare per year for 20 to 30 years, depending on what species is planted. Correct me if I'm mistaken, Douglas.

Malcolm: That's certainly applicable to the farmer who owns woodlands.

South: My point is, however, that even though you are spending that much money, or holding that much money out as a carrot, it often doesn't work as well as a tax break.

Lavender: In Oregon, landowners have the option to choose between a forest yield taxes or an *ad valorem* taxes. Under the forest yield tax system, the landowner pays a minimum tax until harvest; then he pays 12.5 percent stumpage value to the state in lieu of the taxes he would have paid before. Oregon pioneered forest practices regulations and has almost 100 percent compliance with its forestry regulations.

Malcolm: There's a psychological aspect to the tax break. It's doing the tax collector out of some money, and that's very attractive compared to receiving a hand-out.

Winnett: Is that necessarily the case in the developing countries?

Winjum: How about it, Renato, what kind of financial incentives would work in Brazil?

Moraes: In Brazil, there is no longer a monetary incentive to plant trees.

Winjum: But when an incentive existed, what was its form?

Moraes: Before, all people paid taxes and part of it was applied to reforestation; but this has been discontinued.

South: In Chile, plantation costs were put into the tax break category.

Hunter: Yes, they were. There was a tremendous effect in terms of increases.

Schroeder: How do the economics of things like agro-forestry or small farm woodlots compare with the more traditional type of reforestation practices?

Table XXXV. BOARD NOTES #8.

AGROFORESTRY COSTS VS. REFORESTATION

- Agroforestry costs usually much cheaper (i.e., few $/ha; but also consider $/m^3)

  --because local people are involved in helping themselves, this would greatly reduce all reforestation costs.

- Brazil: forests then not taxed
- China: 8 billion trees/yr. planted

Trexler: In my experience, agro-forestry is very inexpensive by comparison. If in fact you are providing extension services for doing what the local farmers want to do anyway, then to grow seedlings there's no labor cost -- they do it themselves; there's no land cost -- it's their own land; it's generally not fertilized, so there's virtually no cost except putting into place the infrastructure to manage the extension services and the training. That costs money, clearly, but it's dollars and not hundreds of thousands of dollars per hectare. (See Table XXXIII.)

Hunter: What you are saying, Mark, is exactly the same in philosophy as in housework.

Trexler: Well, I wouldn't take it that far. But the point is that these people are doing something in their own interest that has a payback in terms of their property rights; a payback in terms of not having to go and collect the lumber and pay for it, so overall it's an economic activity on their part that can legitimately be supported because local people are better off without large financial payments. A lot of people in these systems would argue that you shouldn't be paying people to undertake large planting programs. If you are paying local people to plant trees, you have no idea whether they are doing it for the pay or for the long-term interest in the tree. Survival rates and success is likely to decline pretty substantially if there is no long-term interest as found by experience of some past programs.

Table XXXVI BOARD NOTES #9.

INCENTIVES: EXAMPLES

*	Tax breaks vs. grants (or *ad valorem* yield tax)
Brazil:	None now for reforestation
Chile:	Tax breaks
India:	Low interest loans to private land owners -Land ceiling laws - exemptions for non-forest plantations (tea-coffee), but a need for cutting permits. -Need to eliminate -Money for forests competes with other land uses

Ladd: While we're on the subject of incentives, it seems that we should consider the disincentives or counter-incentives (Table XXXVI). For instance there might be an incentive to develop land for ranching that would be a disincentive to planting trees.

Winjum: What are some of the examples of where there are more financial incentives for other land uses which competes with forestry land use?

Chaturvedi: In India there would be two applications of this example. One is tree planting on private lands. These farmers do need money at a low rate of interest. Government-backed, low-interest loans as incentives work well for the private small farmer. Without such incentives, land is used for other purposes.

The second, which is equally important in India, is that we have what we call the land ceiling laws. You cannot own more than 16 acres. The government has exempted some plantations, those that grow coffee, tea, cocoa, etc., from these laws, but not forestry. There would be greater incentive if forestry plantations could be taken out of the land ceiling laws, or if the limit to land ownership was increased for forests. Also, there is a tree protection act. People plant trees in order to use them in a few years, not to protect them. They believe they should be able to cut them down.

Moraes: Formerly in Brazil, landowners paid taxes on productive forests. Now, owners with forested land are not taxed on that land.

Peterson: If there are no forests, then there are taxes, right?

Moraes: If you have forests on your land, then you pay no tax. There are taxes on other kinds of land, but not on forests.

Hunter: Jack, I think the point that Renato is trying to get across is that if governments can find a way to give incentives which harnesses their energy, then reforestation can be achieved at very much less cost. So there are quite a number of case studies which show that relatively minor changes in taxation laws can have enormous leverage in promoting forest activity. Chile and New Zealand are good examples. I'd guess that's the kind of incentive that needs to be achieved.

Lavender: The Chinese have planted eight billion trees a year. I wonder what kind of

Trexler: The biggest incentive in the world is land tenure.

South: The chart (Table XXXIV) shows that it's cheaper to plant in the U.K. than in the Congo. But from a broader perspective it would be cheaper to plant in the Congo. Just because reforestation is cheaper per hectare initially doesn't mean it is cheaper in the long run.

Peterson: You mean we need another column of figures which includes maintenance costs?

South: I am suggesting we need another column for the agroforestry numbers.

Table XXXVII. BOARD NOTES #10.

LAND TENURE

- Developed Countries
- Developing Countries
  - o people do not own land, so hard to motivate local population
  - o even in cases of small land owners, no annual incomes w/o some incentives (e.g., Puerto Rico)
  - o for mega-reforestation, where would agricultural people go? Cities!
  - o perhaps could use income from forests to buy feed; e.g., India

Winjum: Do we need to talk more about land tenure? I seem to hear that it can be both an incentive and a disincentive.

Trexler: Denis talked about Canada -- a developed country where land tenure is helping to prevent poor forest and land practices. In many, many developing countries where people don't own the land, it's very tough for them to get excited about reforestation for long-term purposes. It's a very big issue.

Ladd: Somebody owns the land. What incentives do they see or feel?

Trexler: In many cases, it's the government that owns the land and people are doing long-term squatting. They just don't know at what point they might be kicked off. In some cases, you can grow the trees on your land, but even then you don't have the right to cut them.

Hunter: In some cases, they may own their land and the taxation may be low, but if they sell the land to a forestry organization, for example, they have to go out and look for some kind of employment. They must change their lifestyle to that of an employed wage-earner.

Liegel: It's like a lot of small countries in the Caribbean; in Puerto Rico, for example, where a farmer might own an acre. In such cases, even if the program gave the trees free to the people, there is no incentive to growing them for ten years. Furthermore, though there's a law in that country which says that forest areas greater than five acres in size are forest reserves and no tax payments are required until the timber is harvested, basically nothing is planted.

Trexler: Why is that? Because they don't own the land?

Liegel: No, local people still own the land, but they can plant bananas or tomatoes or something which produces an income once or twice a year, even on steep slopes.

Winnett: What is needed is to create a situation where land tenure is granted to grow longer term crops, and also to provide the ability to produce in the short term yields until the long-rotation crops are ready and sustainable.

Liegel: In regard to the technical suitability of the land, there have been umpteen studies that show that out of .9 million hectares of land in Puerto Rico, 200,000 hectares are technically suitable for forests and forest-growing is the best use of the land. This was first reported in 1950 and they still know it in 1990. To get that land into trees for water protection and for forestry, and for other benefits, however, doesn't work.

Hunter: Renato made a point that should be followed up. The large corporations in Brazil had to put considerable pressure on the farmers to make them give up their land.

Winjum: And what happened to the farmers?

Moraes: They are finished, they have to move away. That is the result of mega-reforestation Brazil.

Winnett: A question here might also be: is it possible, in this conflict between agriculture and forestry, to substitute the income from forestry to provide food for the people who were growing agricultural food to support themselves?

Winjum: You mean as an incentive?

Winnett: Well, no; if the conflict is between people producing their own food and people producing forests, is the income from the forests sufficient to pay for the food which they would otherwise raise? Does that solve the problem?

Winjum: Is that an approach that has been used anywhere?

South: In India, when I was there last, the EEC was sponsoring such a project. They went into an area and on some communal land, instead of having the goats running loose there, the organization said, "We will lease the land from the community, fence the whole area, so there will be no more goat grazing, and pay the community a certain amount per hectare of land leased and fenced."

Table XXXVIII. BOARD NOTES #11.

UNITED STATES - C.R.P. LANDS

- 2 million acres, agriculture to forest
  $55/ac. initially,
  then
  $45/ac/yr. for 10 years
  --so some income to landowner in place of agricultural income

Top countries with average income also are forested, so forests *can* produce wealth.

Hughes: The C.R.P. program provides an example we ought to consider. It took 2 million acres (810,000 hectares) of land out of agriculture and converted it to forests. The cost to government was half down plus ten annual payments to the land owner, so there's some income. The program proceeded at about a half million acres a year from 1986 through 1989, to accomplish the 2-million-acre goal.

South: In some parts of the United States, I think the cost was $55 an acre initially, plus $45 per year for ten years ($135 and $110/hectare, respectively).

Hughes: That first $55 an acre was actually about half the cost of replanting.

South: That's half the cost; so the landowners finally have to pay $110 an acre to get plantations established, but the maximum reimbursement was $55.

Hughes: That's the sort of example of what

Hughes: That's the sort of example of what might be done in the third world, where landowners either work the land or lease it out.

Ladd: Is there any stick associated with that program; in other words, any penalties?

Hughes: The landowner has to reimburse government for the entire amount if he takes it out any time during the 10-year period. These were erodable lands. This year, apparently, the program was started for wetlands within farmlands. It's similar except that at the end of the 10-year period wet forest lands are created which can't be cleared again for agriculture. But landowners would probably leave it in forest anyway, because within five years they'd be able to harvest a thinning for income. In that way, the plantation is far enough into the rotation that there's quite an incentive to leave it in forest.

Lavender: Jack, I think we see a correlation, or a cause-and-effect situation. If you look at the countries with the highest average income in the world, a remarkable proportion of these are heavily forested countries, like Norway, Sweden, Finland, Canada, even the U.S. (although in the U.S. I wouldn't ascribe it to forestry). So apparently forest resources pays.

Malcolm: But the rate of return on most forest land is one-half of one percent.

Lavender: That may very well be, but forest incomes contribute to a country's balance of payments.

Hughes: These are the nations where people don't necessarily make a living on forest land that they own. The one reason we have extensive forests in the southern U.S., for example, is that people aren't really dependent on their own land. They may live out in the forested countryside, but they actually work in a mill somewhere.

Lavender: I'm just suggesting that forests are capable of producing wealth.

Hughes: Oh, no doubt. I'm saying that people in these situations are not dependent upon the forests for feeding themselves.

Table XXXIX. BOARD NOTES #12

SPECIES

- Native species not always the best
- What local people want may need to be tempered
- Seed availability needs to be considered
- Climate change will require some changes in species
- Need a column in Table XXXII for native species to compare with exotics
- Technology of large-scale limited to few species and provenances
- Wood use of harvest needs to be considered
- Biodiversity or protection factor should guide species question
- Need to consider public resistance
- What is temperature tolerance of key species? Precipitation?
- Maybe a diverse base is best

RESEARCH QUESTION:
Productivity problem, as caused by genetics vs. site: must consider this for spp. selection in certain sites

Winjum: We've talked about land availability, reforestation costs and land tenure. What about species and hazards? What we heard yesterday was that we have to learn to match species to sites if we are really going to be effective. It seems to be a fundamental, underlying concept for reforestation success. I thought the point that Mr. Chaturvedi made was interesting too: that since we're going to be looking at these varied lands where the soil facing climate change also, it makes sense to look at the use of exotics more widely. That is, we shouldn't be locked into native species, but maintain flexibility in the choice of species.

Chaturvedi: Yes. In many sites, exotic species do much better than natives.

Winjum: Even though in some of these sites, the local population is much more in favor of the native species.

Chaturvedi: Yes, local people generally give preference to trees because of their material use, not because they necessarily grow best on the site. For instance, in India, most people will plant oaks in the hills because they grew there historically, but it is not necessarily true that oaks should be planted on those sites. So here too much importance is given to what the site historically grew, but it may not be technically sound.

South: If we're talking plantation establishment of natural species by artificial regeneration -- like hardwoods in the southern United States - - you can triple the numbers in the second column (Table XXXIV), and most of the time it will reduce the numbers in the first column, i.e., yields.

Moraes: Another point, Jack. Without the tree seed, we cannot grow the most valuable species. It depends upon seed availability.

Malcolm: Also, we should consider what Denny said this morning regarding the matter of a likely interaction between climate change and the potentiality of the species.

Hunter: I wonder what people would really think if we used education to convince them of the necessity of using exotics. I wonder if they could be persuaded to plant potentially more valuable species.

Winjum: Comparing the numbers for exotics with those for native species might help persuade people that they ought to consider a change of species. It may be a bit naive, however, to think people will jump on the bandwagon just based upon a set of numbers. Demonstration trials will likely be needed also.

Table XL. BOARD NOTES #13

CARBON TAXES?

- Could help to educate or persuade people toward more forests.

- Rapid communications and technology can do a better job to evaluate where and what species are better in certain locations.
- Maintaining long-term productivity with successive crops
- Biomass for fuel might not be so efficient, especially for liquid fuels (in southern US)--
  --need the right accounting system

Malcolm: Taking up a point that Ian was making earlier, there's a school of economic thought developing in Britain that there should be a ban on exotic plantations. If they went through that route, however, and raised the money for the sequestration of carbon by taxing the use of fossil fuels, it might alter the perceptions about fast-growing exotic plantations quite quickly.

Liegel: One of the comments I'd like to make relative to species has to do with world communications and the knowledge base. That is, right now in this day and age, due to instantaneous communications, we have, via satellite link-ups and computers, computerized data bases and a wealth of information available for each individual country. For these reasons, I think we are in a much better position now to know what species are suitable under different climatic and soil conditions.

No one has started to assemble such a system for forestry, but assuming that climate goes up and it's warmer than it is now, it should be no mystery about what can be brought in from someplace else. The warmer conditions are probably similar to someplace else on the globe. Twenty -- even fifteen -- years ago people planting in the tropics had to invent the wheel, species trials were established over and over again, in part because the English didn't know German or French and couldn't use their information. That is, because of language barriers, they didn't know what was going on in other countries. I think that era is past now, but it's going to take a lot of money to synthesize all that information, to educate people about that knowledge and how to utilize it.

Moraes: Another consideration is the system of rotation. If plantations are harvested after seven years and replanted again and again, there is long-term concern regarding maintenance of the productivity of the land, particularly when growing fast-growing exotics.

Lavender: If we're going to have a significant carbon tax, Jack, then a lot of the areas we commonly think of as having low productivity could be managed for something like fast-growing poplar to fix much more carbon and then convert it to alcohol. That would conserve fossil fuel and conserve carbon at the same time.

Trexler: We were just talking about this yesterday. Some of the work that Chris Geron is involved with includes early studies accounting for the exchanged carbon. It hasn't changed that much from years ago, when it was estimated that to make synthetic natural gas it took about 1 Btu of fossil fuel for every 1.4 Btu's of gas you got out of the energy plantation. So a lot of carbon benefits seem to leak out on the way to the gas tank.

Hunter: Is that still true?

Geron: Yes, it's basically still the case. Just to get to the standing wood to generate energy, half the amount of energy produced is used to establish the plantation, whether it be from fossil fuels or other sources. It's more economical in the third world to use agricultural crops, such as sugar cane, to convert to methanol.

Stout: But doesn't that mean that you might have to put in more than you get out?

Geron: Yes, after you account for the chemicals that you need for the process.

Trexler: A lot depends on the accounting system. For ethanol production, if you don't count the value of the cattle or chicken as food, then you are losing energy by producing ethanol. If you do count those things and give them separate credit, then you gain energy. So the accounting is everything.

Ladd: There are people in New England making a living selling firewood. How are they doing that?

Geron: That could be different. I'm talking about synthetic fuel. I don't know what the regional numbers are for firewood.

Winjum: Any more broad generalities that you can think of here that need to be considered?

Hunter: We need to warn reforestation planners, and I'm reluctant to say this, that we have only limited species.

Winjum: You're saying that we have a rather narrow kit of tools right now.

Hughes: It's even narrower than species, too.

There's a very much reduced genetic base.

Caillez: We should consider the final product, too. We should put forward the idea to people who use wood, the architects and others, the idea that wood is wood. As long as a rich country demands of a poor country some defined species, we cannot make proper utilization of tropical forests. In France, for instance, if you want to build a house you see an architect. The architect demands just certain kinds of wood or specifies certain species. This has no importance at all; an equally good job can be done with a wider mix.

Winjum: That is related to another important point. While reforestation might buy us some time, we still have to know ultimately what to do with the wood produced. converting it into durable wood products, substituting it for fossil fuels, or other approaches to prevent release of carbon back to the atmosphere, must ultimately be factored in as well.

Caillez: Only a few of the total trees found on the list of principal species are used. The others could be used by glueing them together or covering them with something such as paint. In fact, you could mix a lot of kinds of wood, except for furniture, of natural wood. So I think we could transform many other forest and tree species into productive and working plantations.

Moraes: Another aspect to think about is the protection of forests. Biodiversity and the protection factors should guide the species selection also.

Licgel: It's a kind of two-edged thing, though. We are not only talking about maintaining the diversity of the native species, some of which we don't know because they haven't been categorized. What are we doing to those areas where exotic species would be widely planted? How is this practice going to affect local animal and plant diversity? Really, at this point no one has dealt with that.

Stout: On plantations the productivity shown up there (Table XXXIV) in cubic meters per hectare per year, how much of that is site controlled and how much is germ plasm controlled?

I guess what I am leading to, Jack, is the question of selection of species for the site. How are the best species fit to the site? In considering tree breeding, how much of that is going to have to be done? Maybe this applies to research needs, but it seems to me that we in forestry have said, "We have a species, this is what it is, and we will live with that." We've said it too long.

Winjum: This is a research issue that with more attention would contribute to more efficient carbon sequestering by forests.

Owston: Another point here. Maybe we need to reforest with a diverse genetic base to kind of hedge our bets against the probability of climate change.

Hunter: Do we need to know the temperature tolerance of a species?

Wyant: I think it's important to think in terms of more than just temperature. Precipitation regimes, for instance, must also be considered. It might not even be drier; it might be the temporal distribution of precipitation that may change -- the wet season, the dry season -- with relatively minor shift on an annual or area basis.

Owston: And planting a species that normally has a wide genetic variability, like a seed-lot of Douglas-fir, which has more variability than, say, lodgepole pine.

Hunter: The reason I raised the point of using

Hunter: The reason I raised the point of using too narrow an array of species is because we are already considering use of species that there's a lot of public resistance to. Think of the problems of trying to use more exotics.

Schroeder: That point came out in several of the papers yesterday. *(End of Morning Session.)*

(Afternoon Session)

Winjum: This afternoon we will begin with discussion on those points of particular interest to EPA's policy group (i.e., OPPE). What are some of those points now, Steve, that this group might discuss to be of help?

Winnett: I am anxious to focus some attention on the Noordwijk Declaration goal of attaining 12 million net hectares of reforestation per year for, say, ten years. I wasn't quite sure we'd answered that question this morning. Does this workshop group think it is feasible to attain 12 million net hectares of additional reforestation per year over the next ten years. That would be defined as 12 million hectares gained over and above what is being lost through deforestation. In other words, if 12 million hectares are being lost each year, that entails planting 24 million hectares per year, or stopping the deforestation completely for a given year and planting an additional 12 million hectares.

So the first question is, whether people feel that it is possible to do this, and if they aren't sure, how do we go about doing a global analysis of the deforestation and reforestation goal to determine the feasibility?

Table XLI BOARD NOTES #14.

CAN WE STOP DEFORESTATION?
• WHAT TO DO WITH PEOPLE?
• WHAT TO DO ABOUT EMPHASIS FOR QUICK DOLLARS

Caillez: Do you wish to differentiate between continents?

Winnett: We're speaking of a global goal, but partitioning by continents would be appropriate. Obviously some gearing up is going to be necessary. One of the questions is what is necessary to achieve this? There is a dispute over what the level of yearly deforestation is now. The estimation in 1980 was 11 million hectares per year. The most recent estimates, which I believe will be coming out this year, are expected to be in the range of 20 million hectares. The Dutch ministers picked 12 million.

Trexler: I don't think those deforestation rates include about a million hectares that are being degraded annually in one way or another.

Caillez: For me, it seems to be completely out of reach. With an increasing population, it is completely impossible. We speak of between 10 and 15 millions of people in Gabon alone in 100-150 years. Even if 10 percent of these people die of illnesses, there is a need for land to support an increasing amount of agriculture. To compete with this situation by establishing a large amount of more or less productive forests --- I don't think it is possible.

Stout: You see no change in rate of population increase, as the pressures build?

Caillez: I think it will begin to go down in a hundred years.

Hunter: Well, Steve, do you want something practical? I can start the ball rolling by estimating that a technically feasible plan for New Zealand might be to return to a 40,000-hectare-a-year rate. This wouldn't be beyond the bounds of possibility and could go up to 100,000 hectares a year net increase. The two problems confront this rate. First, we would need to find a mechanism to actually do it. There would have to be some kinds of incentives -- first, people wouldn't do it altruistically; and second, we also have to embark on a fairly large program of propagation if we intend to use radiata pine.

Hughes: We've got to convince the public that they are on the Titanic, it is sinking, and sequestration of carbon is the only way by forests or other means to keep it from sinking.

Winnett: Or, if you could convince the public that it was in their economic best interests to stop deforestation, the next question is, how do we stop deforestation? Or can we stop deforestation, and if so, how? And along with that is the question, is it possible to make the conservation of standing forests as economically attractive as harvesting them for wood products. And can someone get out there and demonstrate how it's possible to make more money through reforestation, than it is through land practices that destroy biomass.

Malcolm: You've got at least two other problems in relation to people. One is where will you put the people who are on the land that you're going to reforest? The second thing is, if you get involved, as I understand it, with trying to manage native forest in the tropics, you've got to deal with the problem of the need for more agricultural lands. That seems to be insuperable at the moment, unless you can convince everyone that they're on the Titanic.

Lavender: I would suggest that we would be extremely fortunate if Canada reforests as much land as it cuts over in the next years, and that does not take into account the forest lost by insects, disease and fire. So if you are looking at Canada as a possible contributor to the 12 million hectares, I would say no. Why? Because Canada has a budgetary crisis that's worse than that of the U.S. Canada depends almost entirely on forestry products for their balance of foreign payments and I just don't see Canadians putting up the amount of money necessary to do the reforestation.

The province that's the worst is Ontario, and most of the people in Ontario couldn't care less about forestry. They are concerned about what's going on in Toronto. I see the same thing in British Columbia -- they are concerned about what's going on in Vancouver. They're not interested in paying taxes for Ontario reforestation. So I think Canada will be lucky to hold its own in the foreseeable future.

Winnett: You can almost guarantee then that if the western countries are unwilling to foot the bill, in terms of reforestation, third world and developing countries are going to be as unwilling, if not more so, to do it, and probably justifiably so.

Lavender: On top of everything else, there's a very good possibility that Canada is going to split up and not remain a single country, anyway.

South: If you are talking about artificial reforestation, the ratio of hectares planted to hectares harvested in the South could be a 1:8 ratio for the private land owners.

Hughes: It's all successfully reforested eventually, however, because nature abhors a vacuum and something will come in on these deforested lands.

Winnett: What sort of incentives would increase artificial reforestation?

Hughes: I think incentives comparable to the CRP program, in which up to half the cost of regeneration is subsidized plus some annual payment for a period of years, like 10. We know that it works in getting the highly erodable lands put into something other than crops. It worked in the 1950s and '60s through the soil bank program and it worked again just recently. We know that it was a carrot that brought a significant number of acres into forest through reforestation practices.

Jerstad: I think it would take a lot more money now, though, because fewer available lands are old agricultural lands.

Hughes: Actually, there are two sets of acreages. One is the ag lands that could go into forestry if the incentives were there, other than erodable or wet lands. The second is the 23 million acres of highly erodable or marginal crop lands in the South. These would give a better return in forestry. So if you had an incentive program comparable to the CRP program for highly erodable, then the 2 million acres would be available.

Lavender: If you look at the trends for product values and regeneration costs, the regeneration costs have risen a lot faster than the product values, which is another disincentive.

Hughes: The larger driver would be stumpage values. What you'd really want for incentive would be a very competitive market. It's independent of the value you put on the property. To some extent we are already seeing that happen because there is more overlap between the wood baskets in the South and a tightening wood supply. Therefore, the prices have gone up rapidly. Locally, it's had a tremendous impact on prices and improved the ratio of reforested areas among the cut-over lands. For instance, in south Georgia, it's something like 80 to 90 percent of the lands that are either planted or have successful regeneration, so if you put a high value on stumpage, people will put their lands back in forests.

Wyant: But if we have a global objective of planting a billion hectares, it kind of wreaks havoc on the supply curve.

Hughes: In the longer run, that's for sure, but in the shorter run, the market anticipates.

Winnett: Renato, do you have any ideas on what kind of incentives would encourage reforestation and stop deforestation in Brazil?

Moraes: I think first, education. If you have money, the people will conserve the forests for one year, two years, three years, but after that they cut the forests. I think a good incentive is education.

Winnett: Do you think that standing forests can ever become as attractive financially as the products of deforestation?

Moraes: In the cut-over areas, where there are no more forests, the big problem is in the government. People do not receive money annually so they cut the forests to use the land for agriculture.

Winjum: So, some alternative is needed to compensate people who depend upon deforestation. And where that money is going to come from is an issue.

Liegel: Yes, and where do those people go? There's not just the matter of paying them for their food. There would be all these other costs, of where they are going to be housed, their water supply, sewers, and all the other supporting necessities. Deforestation basically doesn't get you a whole lot of wood to use on the market. If Jari, in Brazil, is an example, I think out of two hundred and some species they were harvesting, only 40 were being utilized for any type of wood products. The rest were basically being burned. Some near Jari were being utilized at the mill by being ground up and burned to supply the energy for the mill. Under ordinary circumstances, though, that doesn't happen; half of it is being burned so the person can use the lands to plant a food crop. It's a very inefficient way to do things.

Moraes: With the lack of enforcement, anybody can cut the trees.

Winjum: There's also a lack of infra-structure to provide enforcement.

Stout: What kinds of things are you thinking about when you ask if people could get as much from an uncut forest as from cutting, Steve?

Winnett: Deforestation leads, in most cases, to a temporary, several-year, ability to harvest agricultural products or graze livestock. These uses eventually run out when productivity falls. The alternatives people have suggested include such things as ranching iguana meat (and you can laugh), which in some cases can produce more meat in pounds per year, sustainably, than can be produced in pounds of beef for 7-9 years. Nuts, fruits, rubber, herbs, medicinal drugs, birds nests were even mentioned. You could even go so far as to say, "What about selectively cut trees that would preserve the character of the forests?" Those types of things have been suggested. The question is, whether on a yearly basis, people who manage the forests for those products can make as much money doing that as they can through deforestation. And of course they have to move after 7-9 years.

Hunter: It's not the money they make. It's the food they raise.

Winnett: Can they make the cash that would be required to buy the food they need?

Trexler: A large part of deforestation has been for the money realized from exports of meat and other products. In a lot of cases it has been strictly financial, allthough in some cases, most of the money came from subsidies.

Owston: Another point. If President Bush's program to plant a billion more trees gets going and is successful-- and I gather that's in a dispersed way in urban and rural areas, not in large-scale reforestation -- at 500 trees per acre, a billion trees comes out as being enough to plant 2 million acres if there were a hundred percent survival. He doesn't budget the money for that, but that's the goal. It's supposed to be a ten-year program.

Winnett: Some of the money will go to reforestation and some to community groups.

Winnett: They're assuming a standard cost share like the CRP, but no land rental costs?

Winjum: One question that interests me is how do we get better data on land availability or technically suitable land. Can we get this from the FAO or is it available from satellite or remote sensing imagery?

Owston: It's being planned. This Forest Service person I tried to call this morning is in Rome now on a two-month detail working with FAO to plan out a process for this.

Winjum: So there's someone working on it in the Forest Service, but apparently it is FAO-related. Is this the best source?

Trexler: The FAO started a 1990 tropical

Table XLII. BOARD NOTES #15.

LAND AVAILABILITY
Sept. Report

- FAO project
  Tropical forest assessment, 1980 and 1990
- ILCA vegetation monitoring
  $250,000 from UNEP
- NGO meeting in Central America
  (June, 1990)
- NASA - EOS: interested
- EPA-U.S. Forest Service
  Monitoring

Diffuse: need social/political input

forestry assessment, but they have fewer people working on forestry than we do at WRI, and to make a global assessment? --it's crazy. They're not going to make much progress. They are having to rely mostly on information the countries submit, with virtually no ground crew and very little satellite data in most cases. Our people who monitor these things don't think the 1990 assessment is going to be any more realistic than the 1980 assessment.

Wyant: But there are other agencies that are taking on such monitoring efforts. International Lifestock Center for Africa is beginning rudimentary efforts in both western and eastern Africa. They are concentrating largely on dry zones, as you might imagine, but they are looking at vegetation monitoring for the most part. The funding is limited -- a quarter million dollars from UNEP. They are looking for leadership in monitoring programs. NASA's EOS system -- Earth Observation System -- is a possible source of information. Lots of people are gearing up to use it but no one really knows what to do. The joint EPA and Forest Service forest health monitoring program is another possible source of data, though no one really knows what to do just yet. In the U.S., the Forest Service's FIA program does 10-year, or decadal, assessments, with 50-year projections. This is probably where you are getting the numbers about losses of lands to industrial and urban use. There there are economic modelers working on the problem as well. But the information is diffuse.

Winjum: Diffuse -- that's probably the concluding word right there.

Ladd: If the question is land availability, then introducing other needs of society for the landscape has to be considered.

Winjum: You are going back again to saying that technically suitable is one thing, but how much is economically, socially and politically available? How do we factor in all these land characteristics? I wonder about the IPCC. Are they trying to get themselves into a position to provide some leadership?

Winnett: I think the idea of IPCC is to reach some sort of consensus about what should be done and then get various companies to go off and do it.

Winjum: So that's probably a year or two away.

Winnett: The big IPCC report is supposed to be out in September of this year. It will describe what the situation is, the response strategies, and such.

Trexler: But it won't have this number? They are making no attempt to come up with the land availability number?

This workshop we are doing in a couple of weeks in Guatemala, which involves the Central American NGO's, should provide interesting information. For the first time, I think, we'll be asking the NGO's of tropical countries, and governmental representatives, what do you think will pass the laugh test in terms of reforestation in Central America? If they say, "Don't be ridiculous, there's no potential for that at all," then that's going to be a pretty unfortunate sign. But it will be the first time we will have gone in and talked with a broad spectrum of people in respect to this issue.

Winjum: Will there be a report or proceedings?

Trexler: Yes.

Hunter: Going back to what Renato just said, isn't the problem here the perception that the world's timber supply is just about okay, but that there may be a shortage sometime in the future? How do we move people away from that notion and ask them to plant large areas of trees or some kind of non-economic crop? I don't think we've addressed how we attain that behavior.

Wyant: Ian, I don't think it's a non-economic motive. It's just a non-timber economic motive. I think it still has to be driven by an economic stick or carrot.

Hughes: I think we see regional shortages looming. The South's Fourth Forest Report says that within 20 years we could lose 85,000 jobs in the forest industry in the South directly, and another 200,000 in service industries because the supply of wood won't be there. This is because we are currently cutting eight acres and only regenerating one. I assume somewhat the same figures can be used for Canada -- is that true?

Lavender: It's like everything else, the politicians are interested in the election next month and business is interested in the next quarter profits and very few if any are interested in the next 50 years of forest resources.

Another question, where are we going to get the labor to do all this reforestation? We're having trouble with this matter already in British Columbia.

Table XLIII. BOARD NOTES #16.

LABOR SUPPLY?

United States:
* Southeast - with machines, it seems to be no problem (could double the program in the next few years)

* Other U.S. regions and Canada - could be a problem

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* *Just affecting the 12-19 million ha would be remarkable!*

Hughes: In the South, I think we are a ways away from being saturated; I think there is some room to expand. If you look at the North America, the place that you could increase reforestation levels relatively easily is in fact in the South. There's a lot of land that is not doing what it could do. There's an infrastructure, the population, all you need is enough carrots and I believe you could reforest somewhere between 50 and 75 million acres. I don't know whether society would put up with all these pine trees in rows, though.

Wyant: But in the global picture, Joe, isn't that really just the tip of the picture of what needs to be done?

Hughes: Light one candle! A thousand points of shade! Who if not us? When if not now?

Trexler: Could I ask a variation on Steve's question? Given the feedback on the Noordwijk Declaration, I am sort of getting the impression that people would find it remarkable if we could offset the current forest loss through increased reforestation, without even considering starting to offset 5.6 billion tons of carbon from fossil fuel emissions. Would it be

Table XLIV. BOARD NOTES #17.

SOUTHEAST UNITED STATES

- Artificial reforestation to harvest is 1:8
  -Won't change without incentives-

  WHAT KIND OF INCENTIVES?
  CRP-type works, but would have to have more dollars now to get 23 million acres of marginal farm lands that could be in forests.

BRAZIL

- INCENTIVES

  -Money to compensate people who depend on natural forests
  -Where do the people go?
  -Where does the money come from?

UNITED STATES

- One billion trees would reforest 600,000 ha/yr., providing we keep up w/harvests

remarkable if we could just end biotic release of the carbon and forget about fossil fuel release?

Hunter: Yes.

Trexler: That would be remarkable.

Ladd: It strikes me that our possibilities for conservation, for not putting the CO_2 in the atmosphere, is much more feasible, much more achievable, than offsetting it later.

Lavender: That was my point about increased fire protection. That's one way to do that.

Winjum: We should spend a few more minutes scanning down our list (Table XXXI). We've talked about most of the items. We've heard a lot about the hazards; gone down through the socio-political sorts of things; the economic issues in terms of incentives; social acceptibility -- how people feel about exotic species and plantations that are in straight rows -- that sort of thing. It may, as somebody mentioned, take some public education, with some comparisons on the table like Dave put together (Table XXXIV), where there is another column for the natural forests as well. It seems that those kinds of numbers need to be developed.

Sequestering significant amounts of carbon through a higher level of global reforestation will take considerable international planning and good follow-up. Without local infrastructures, however, all the good intentions, plans and money wil not accomplish reforestation. These are tough problems. Some work is going on to try to approach that through the NGO's and some organizations such as CARE. I suspect that the IPCC must be considering some of these matters, too.

What else can you think of that we should bring out to heighten our awareness of the potential for large-scale reforestation? There are research needs also. We can pull ideas out from the workshop papers. Examples are matching species or genetic source to site conditions and expanding the use of more indigenous species.

Malcolm: One point I'd like to make is that these figures depend upon stands which are in a healthy condition. Also stands which are managed. If you allow the stand to reach its maximum basal area, it is difficult to maintain its health and increase its carbon fixing rate. It's not simply a case of going out in the forest and increasing growth for this purpose. Otherwise you would start out with less dense stocking. It ties in a bit with increasing the hazards from wildfire through accumulation of fuels, too.

Hunter: I have this awful feeling that we have a lack of knowledge as to how that's achievable. There's the question of *how to do* a global analysis of reforestation and forest management for carbon sequestering. When we have the information, then we can come out with a series of prioritized schemes.

Table XLV. BOARD NOTES #18.

MAINTAINING FOREST C-SEQUESTERING
• MAI's won't go on without follow-up treatments or tending
• also need to reduce hazards to maintain
What's really achievable?
• --but we have to start somewhere while we're improving knowledge
(5 million ha mentioned in Washington, D. C., at ministries meeting)
• Need to "quantify" the other forest benefits besides wood
• Add in other values

Trexler: I would point out that if we wait until we have priorities, we will be here for 20 years before we actually do any tree-planting. There are a lot of forestry projects that could be undertaken for a whole series of reasons besides global warming. Why not just go ahead and say let's try to push some of those along? We don't need to have the complete answer before we start doing something.

Hunter: I agree, but I think we have to be gradually improving on the choices.

Trexler: It would be nice.

Hunter: Steve, was it you who said that they figure 5 million hectares reforested as soon as possible?

Trexler: That was sort of a funny story that came out of Noordwijk. There was an conference in Washington two weeks ago where parliamentarians from all over the world were brought together. The number that they had given to them, based on some phone calls that his forestry staff made, was that conceivably it might be possible to reforest 5 million hectares per year, but as soon as they remembered what had been said at Noordwijk, that number went out the window in favor of 18 million hectares.

Ladd: There's an awful lot of money that's been invested in reforestation that you could argue was probably wasted. If these international meetings are serious about continuing on with reforestation for carbon sequestering, it's up to us to come up with investment dollar figures. We can say, yes, it's economical, it won't cost a trillion dollars, or it will cost whatever. It seems reasonable to push the analysis in that direction instead of turning our backs and saying wood prices will be depressed as the end of the argument.

Winnett: And it might be more valuable. At least in the Northeast, we don't know what the demand for products is going to be, say 30 or 40 years from now. We don't know what the technology will be or possibly what manufacturers are turning wood into. Thirty years ago the black cherry species in the Northeast was considered to be junk wood, and now it is the most valuable species, next to black walnut, on the entire continent.

Winjum: We've got the same story with red alder here on the West Coast. It was a weed 20 years ago, and now they are growing it in nurseries and in plantations.

Hughes: Jack, what are your next steps? Maybe I'm getting to that too soon, but if we knew what your next steps were we might be able to facilitate them.

Winjum: I think we're at the point now where we are going to have to go over the papers and glean from them a summary report. We say we went through this exercise, we brought some people together, we asked some questions, now we are going to say something about the feasibility of large-scale reforestation projects in the world, and what the main concerns and limitations are that we've heard about. Also the land, the lack of data, the lack of information about indigenous species -- there are a whole litany of uncertainties.

Hughes: To whom is the information from the workshop going and what choices will they have in terms of action?

Winjum: I can give you my view and others can elaborate. We've been given some resources to do an exercise on the problem of large-scale reforestation projects to sequester carbon. That is, what are the possibilities, what are sensible estimates about the feasibility. A summary proceedings will be prepared that is aimed at informing agency policy makers. A further aim is to give us some indications of where we might reasonably put some research dollars in the next five to ten years.

Schroeder: The audience is what you might call senior management.

Hughes: So essentially we're setting the stage for research that the EPA will do.

Winjum: That's part of it, yes. And gathering some information that may shed some light now on the realities of what we know about the applicability of large-scale reforestation in the world.

Hughes: Is it connected to President Bush's initiative? Does it feed into that?

Winjum: It could contribute to that, but really it's more independent. As acid rain research winds down, the next big issue on the horizon is this warming. How does the agency, which has a mission of air quality regulation, position itself to help this country provide some leadership, some guidance, to play a role, to make a contribution internationally to the global warming issue? I think we're all kind of fishing for those kinds of sensible directions, recognizing that it is going to have to be international in scope.

Lavender: One very positive contribution Canadian forestry can make to global warming overall, not just reforestation, is an example from the province of Quebec. They have developed an extremely sophisticated forest fire fighting system, by the use of triangulation by radar and extremely sophisticated weather records. In 1980, their average forest fire in Quebec was about 16 hectares in size. They lost a substantial acreage in wildfires. In 1985, they got their fire fighting system pretty well in place. Now the average fire in Quebec is .6 hectare, and the losses through forest fire in that province have been dramatically reduced. They were able to do it on an economic basis, apparently with provincial funds. As I say, they have a very sophisticated radar system that covers the province. In daylight hours they have planes in the air the entire daylight period. I think this is very significant and is an alternative to reforestation that should be pushed. We say we can't do anything about forest fires, but Quebec is an example of where they have done something about it very dramatically. The rest of Canada has burned off something like 7 million hectares. That's a lot of reforestation.

Winjum: That's a good point and we'll try to include that. Another matter where we need coordination is with the Forest Service. They are getting active in global warming too, and they are the major forest land management agency in the U.S.

Owston: Global climate change is the number one research priority item for the Forest Service for the FY 91 budget year. They just appointed a new national coordinator and four regional coordinators for the various regions. The one for the Pacific Northwest and California combined is Sam Sandberg, and he's going to be moving to Corvallis in a few months. One advantage to his move is that he'll be close to the EPA Corvallis laboratory so we can coordinate efforts.

Caillez: Last month there was a meeting in Gabon where the ministers of forestry from eight countries, the main countries of central Africa, met. They decided there to give much more attention to the management of natural forests instead of plantations. In collaboration with logging companies which want help to develop a type of silviculture to favor about 80 forest tree species. Right now this isn't possible. The logger harvests about 10 species and must be reimbursed for removing the other trees.

Trexler: In the natural rainforest, have they decided to protect biodiversity?

Caillez: As long as we have an upper story with more than a hundred species represented, it is considered impossible to manage these forests with realistic silviculture. There is no dominant species in this kind of forest, so with regard to biodiversity, this means it will not be protected in the forests put under new silvicultural management.

Chaturvedi: So far we considered the value of forests mostly for the wood and its carbon content. What about considering the soils, water, shade trees along the road, esthetics, recreation, and so forth? Some method of quantifying these values must be found. We have not given any value to the shade of a stand of trees, for instance.

Winjum: Yes, we need to add in other values. I know that it's been considered by forest economists, but often the issue is how to accurately quantify the value of other benefits, like water, esthetics, recreation. Those significant additional benefits are also gained with reforestation investments, and they should be part of the overall cost/benefit evaluation.

In conclusion, let me say we've appreciated having you all here. There are so many interesting people in this room. It would be nice to be able to spend a lot more time with each of you. It seems we just got the discussions started and now it's over. But I do want to thank all of you, especially those who presented papers. Thank you very much.

INDEX TO GROUP DISCUSSION

GENERAL APPENDIX A

Tree Species List

TREE SPECIES LIST

Abies
- *alba* - silver fir
- *grandis* - grand fir
- *procera* - noble fir

Acacia
- *auriculiformis*
- *meamsii* - black wattle
- *nilotica* - gum arabic
- *tortalis*

Acer
- *pseudoplatanus* - sycamore
- *saccharinum* - silver maple

Ailanthus excelsis

Albizia lebbel - Lebbek tree

Alnus
- *sp.* - alder
- *nepalensis*
- *nitida*
- *rubra* - red alder

Anacardium occidentale - cashew

Araucaria angustifolia - Parana pine

Aucoumea klaineana - okoumé

Azadirachta indica - neem

Bambusa arundinacea - bamboo

Cassia siamea - Kassod tree

Casuarina equisetifolia - Australian pine

Cedrus deodara - deodar cedar

Cryptomeria japonica - Japanese cedar

Cupressus torulosa - Bhutan tree

Dalbergia sissoo - sissoo

Dendrocalamus strictus - giant bamboo

Eucalyptus
- *globulus* - blue gum
- *grandis* - rose gum

(*Eucalyptus*)
- *tereticornis* - forest red gum
- *urophylla*

Fraxinus floribunda - ash

Gmelina sp.

Juglans regia - English walnut

Larix decidua - European larch

Laurus sp. - laurel

Limba terminalia superba

Magnolia sp. - magnolia

Melia azedarach (australis) - bead tree

Picea
- *abies* - Norway spruce
- *sitchensis* - Sitka spruce

Pinus
- *sp.* - Caribbean, Corsican pines
- *contorta* - lodgepole or shore pine
- *nigra* - black pine
- *roxburghii* - emodi pine
- *sylvestris* - Scots pine
- *taeda* - loblolly pine

Pongamia pinnata - Karum tree

Populus sp. - poplar

Prosopis juliflora - mesquite

Pseudotsuga menziesii - Douglas-fir

Quercus
- *robur* - English oak
- *petraea* - durmast oak

Salix sp. - willow

Shorea robusta

Syzygium cumini - Java plum

Tectona grandis - teak

Tsuga heterophylla - western hemlock

GENERAL APPENDIX B

Table of Equivalents

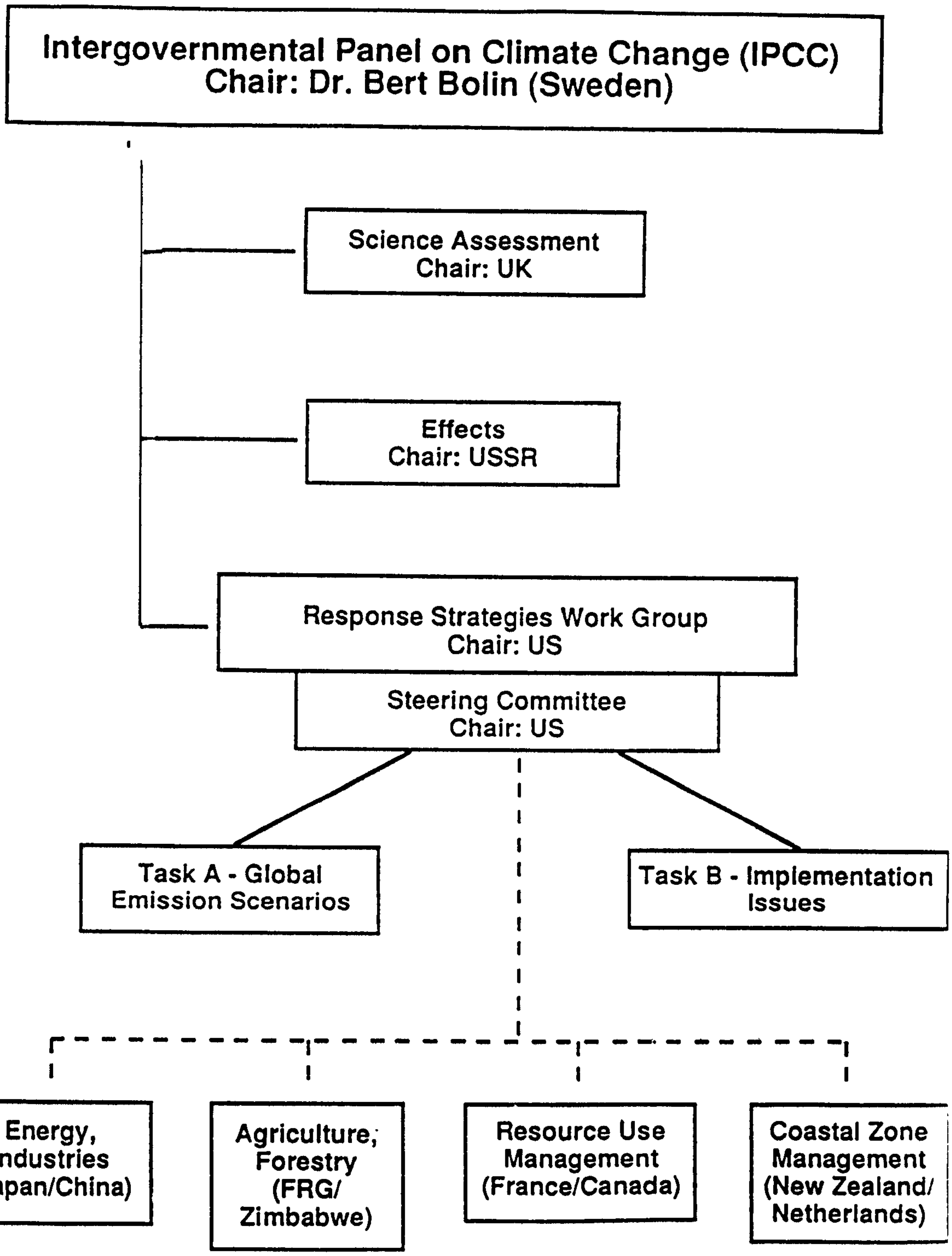
TABLE OF EQUIVALENTS: AREA

	FEET^2	MILE^2	ACRE	METER^2	HECTARE^2	KILOMETER^2
ACRE	43,560	.0016	1	4046.86	0.4047	0.004
MILE^2	27,878,400	1	640	2,490,929	258.999	2.59
HECTARE	107,600	0.004	2.47	10,000	1	0.01
KILOMETER^2	10,760,000	0.386	247.1	1,000,000	100	1

GENERAL APPENDIX C

IPCC Structure, Recommendations
Noordwijk Declaration

IPCC Structure



IPCC Brazil Conference on Tropical Forestry
Subgroup on Agriculture and Forestry

Sao Paulo, January 1990

Workshop recommended:

IPCC support the development of a World Forest Conservation Protocol in the context of a climate convention process that also addressed energy supply and use.

Possible elements include:

- Trade
- Labelling of tropically produced forest products
- No-net-loss policy
    - Reforestation
    - Conservation
- Biodiversity

Dutch Ministerial Meeting

Noordwijk Declaration

Examine Stated Goal:

Achieve a Net gain in forest area of 12 Million Hectares / Year, Globally, through conservation of existing forest and reforestation of degraded forest lands, and agricultural, pasture and savannah land.

<u>Identification of Noordwijk Goal Feasibility Issues</u>:

- **How to do a global analysis of reforestation goal feasibility**
- **How much reforestation can be done (local, national and global goals)**
- **Where can it be done (land availability)**
- **What kinds of changes in policies and new policies are needed to slow deforestation and increase reforestation**
- **How to launch national and global programs to design, coordinate and implement such goals**
- **How to stop deforestation, especially in the tropics, and reach goal of no-net-forest-loss**

Data Needs for Assessing Noordwijk Remand:

Forest Assessment Data:

- **Forest per capita**
- **Forest area, by type, by country**
- **Reforestation potential**
    * **Lands available**
    * **By land-use type**
    * **By condition, quality**
    * **Cost data, including management, and timber product revenues**
- **End-use of converted forest land, by country**
    * **Forest products**
    * **Fuel wood**
    * **Agriculture**
    * **Pasture**
    * **Development**

Land and Resource Use Data:

- Energy supply mix, by country
- Gross National Product, by country
- Demand for agricultural land from forest sector, by country
- Presence of timber export industry, by country

Greenhouse Gas Emissions and Sequestration Data:

- Emissions coefficients for natural forest ecosystems, disturbed systems, and other land uses
- CO_2, N_2O, and CH_4 from primary and secondary forests, fallow, pasture and agricultural systems
- Carbon sequestration rates (biomass growth rates)
- Standing biomass, by forest type
- Soil Carbon

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