

Reducing pressure on natural forests through high-yield forestry

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ABSTRACT

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High-yield forestry can make a valuable contribution to the conservation and sustained use of forest ecosystems. Despite the pressing reasons for conserving forest resources, population growth creates pressures for exploiting them. Unless needs for forest products, export credits, and local employment can be met by new devices, such as high-yield forestry, these pressures will be irresistible. Concentrating wood production on high-yield plantations increases flexibility in the use of forests and forest lands, making it possible to allocate native forest to parks and reserves. High-yield plantation management implies the following: (1) choosing the appropriate species; (2) improving the composite genotype of the plantation trees; (3) optimizing the morphological and physiological condition of the trees prior to and at planting time; (4) improving the physical environment of the crop at all stages of development; (5) protecting the plantation from pests and catastrophic events; and (6) modifying the shapes, dimensions, and qualities of crop trees to enhance the utility and value of harvested timber.

In addition to the advantages that plantations have demonstrated in the temperate zones, tropical plantations capture the benefits of a benign physiological environment, namely near-constant year-round temperature, and the absence of frost. Relative to the productivity of undisturbed or partially logged humid tropical forests, plantation growth rates represent 4–10-fold increases in volume production. Displacement of some proportion of shifting agriculture and natural forest management (or mismanagement) systems by high-yield forest plantations is desirable and biologically feasible. The ultimate key to both conservation and successful tropical-forest management is population stability, a condition toward which integrated wood-processing facilities, supplied by a reliable plantation system, can make a major contribution.

INTRODUCTION

High-yield, plantation forestry can contribute to forest conservation by reducing demands on native forests and slowing the rate of deforestation. Deforestation is a major global concern, in part because it contributes to the loss of biological diversity, and in part because of its potential to disrupt present climatic patterns. The rate of deforestation is highest in the tropics; e.g., de-

forestation has been only about 1.2% over a recent 25-year period in California (Bolsinger, 1980), one of the most rapidly growing states in the United States, but is 1.3% *annually* in tropical Latin America and as high as 4.7% in Paraguay (Anonymous, 1987). These figures reflect forest conversion to urban development, agriculture, or grazing land, not sustained timber harvest.

Clearing and burning of tropical forest contributed 20% to the recent global increase in atmospheric CO₂ (Schneider, 1989). Because of the increase in CO₂ from the burning of fossil fuels and tropical forests, and the release of other greenhouse gases, global temperature is projected to increase about 2.5°C by the year 2050 (Harrington, 1987). An increase of this magnitude will disrupt agriculture, forestry, and regional economies. In addition to its contribution to atmospheric CO₂, the destruction of forests eliminates a major sink for CO₂ because forests effectively remove it from the atmosphere and bind the carbon in wood.

Less than 60% of the world's tropical forest still remains, and, if present demands for forest products and trends in conversion of forestlands continue, native tropical forests will all have been cut by the year 2000 (Wadsworth, 1983). Both foresters and environmentalists have recognized that high-yield plantation forestry can reduce pressure on native forests (Wadsworth, 1983; Myers, 1984; Ledec and Goodland, 1988). Native forest produces only 3 m³ of wood per ha annually, not enough to meet demands (Wadsworth, 1983). Plantations managed for high yield are at least 4–10 times more productive.

Ideally, a developing country's principal forested lands should progress toward a balance of reserved natural forest, managed second-growth forest, forest plantations, and appropriate agroforestry systems. Such a balanced system can take advantage of the high levels of productivity and homogeneity offered by intensive plantation management, while at the same time ensuring the ecological and environmental stability conferred by proper management of both reserved and managed indigenous forests. Effective conservation and use of genetic materials are fundamental to long-term success in producing wood and, concomitantly, in reducing demand on native forest ecosystems.

THE PLANTATION APPROACH

It is difficult to identify a raw-material resource that is more versatile and inherently useful than wood. And if we further stipulate that this resource be renewable, then no comparable material exists. Building materials, furniture, paper, textile fibers, fuel and industrial chemicals are all examples from a broad spectrum of wood-based products, most of which compete with or substitute for materials that are derived from irreplaceable mineral resources. Renewability is the key, and it is essential that we capitalize on that unique feature of the forest resource, represented by the sustainable production capacity of commercial forest land and forest trees. However, much of the wood

cut during the clearing of tropical forests is wasted, partly because the great number of tropical woods do not fill traditional needs. Tropical forests are incredibly diverse. Over 300 species of trees per ha are found in some forests of South America (Gentry, 1986), and the technology to convert these species to products such as paper, lumber, or plywood is not yet available (Wadsworth, 1987).

Plantation forestry provides several benefits. Because production of usable wood and fiber is 4–10-fold greater than that in unmanaged tropical forests, plantations can make a greater contribution to domestic needs than native forest and also help the balance of foreign trade. Forest growing, harvest, and manufacture of forest products provide greater economic returns to the land and more employment than other land uses – especially grazing which is the fate of most cleared tropical forest land (Leonard, 1987). And while much wood from native forests is burned during land-clearing in tropical countries, the very same countries are net importers of forest products, contributing to their trade deficits (Anonymous, 1986). Plantation forestry need not displace large areas of tropical forest; cleared lands could be managed as high-yield plantations, blunting the drive to harvest more natural forest. In fact, national planners can only justify reserves of natural forest if demand for forest products and employment can be met from plantations.

HIGH-YIELD FORESTRY

High-yield forestry in the context of this discussion means sustaining timber production and use within biological and economic constraints (i.e., without degrading the site). Achieving this objective will require even-aged plantation management, which in turn implies:

- (1) choice of appropriate, fast-growing species, often exotic pines or eucalypts;
- (2) improving the composite genotype of intensively managed plantations;
- (3) optimizing the deployment of improved genotypes in the plantation environment;
- (4) improving the environment for plantation trees at all stages of development; and
- (5) utilizing all of the wood and fiber available from managed forests, commensurate with any biological constraints that may be detected as rotations progress.

In the next section we describe high-yield forestry in temperate regions, using Weyerhaeuser's experience in the southeastern United States as examples; finally, we extend the argument to tropical forests.

Improving the genotype

Conventional clonal seed orchards currently supply seeds for all Weyerhaeuser planting stock. These grafted orchards consist of parent trees which have undergone intensive selection in natural stands (first-generation orchards) or in genetic tests (second-generation orchards). A broad genetic base is maintained, inbreeding is minimized, and the performance of orchard offspring is closely monitored. Volume-growth gains of 12% in the first generation have been demonstrated by thorough progeny testing, and the ability to shift improved material among our geographic regions, sometimes beyond a species' natural range, provides additional and substantial growth increments.

Useful traits that have demonstrated, or promise to demonstrate, significant responses to genetic manipulation include stem form, branch size and distribution, disease and insect resistance/tolerance, tolerance to drought or excessive moisture, nursery influences, wood density, and many others. Hybridization among provenances promises to produce additional variants that are rare in nature but which can fill intermediate habitats, combining genetic gains with improved adaptation.

Pumping it up

Given genetically improved seeds, every practical effort is expended to optimize the production and quality of the seedlings produced and their transfer into the plantation environment. Up-to-date nursery, greenhouse and field-planting practices thus set the stage for capturing the superior genetic potential of the seedlings by enhancing their morphological and physiological condition prior to and at planting time. Irrigation, mulching, undercutting, wrenching, mycorrhizal inoculation, fertilization, weed, disease and insect control, and management of seedling density are among the tools which our nursery managers use to produce ideal planting stock. Precision sowing, and segregation by family, improve the uniformity of nursery output and insure that only high-quality seedlings get to the field. Planting practices, both manual and mechanical, are greatly enhanced by thorough site preparation, though the primary objective of this procedure is to improve the growth environment of the young plantation.

Nursing it

The myriad of post-establishment cultural options that are available to and used by high-yield-forest managers can be categorized as those that improve the physiological environment of the plantation tree, those that protect the tree, and those that modify the form of the tree and thus the plantation prod-

uct. Collectively, all of these treatments improve the general plantation environment for specific harvest objectives.

Site preparation precedes planting and, as mentioned above, contributes largely to the improvement of the plantation's physiological environment. Shearing, chopping and broadcast-burning, for example, greatly reduce the consumption of moisture, mineral, and spatial resources by noncrop vegetation. Bedding and ripping, where appropriate, provide additional vegetation control, improve the physical properties of some soils, are effective moisture-management tools, and establish excellent row integrity, an important contribution to the efficiencies of subsequent cultural and harvesting practices. Drainage-ditching, post-planting vegetation control, and fertilization, both corrective and promotive, are further examples of very intensive efforts being directed at improving the physiological status of the plantation tree.

To realize the benefits of improved genotypes and physiological environments, the encroachments of destructive diseases, insects, animals and fire must be minimized. In concert with genetic manipulation, mechanical, chemical and biological treatments, and fire itself are used where justified to protect plantations and the substantial investments they represent.

Finally, spacing and thinning are used to modify the shapes, dimensions and qualities of individual trees; when properly applied, these treatments can enhance the utility and the value of harvested timber. These treatments too can be viewed as modifiers of the plantation environment in that all crop-tree individuals are competing for the resources of the site.

Responses to cultural treatments are seldom independent of other treatments or stand conditions generated by other practices. For example, the interdependence of thinning and spacing, of spacing and weed control, and of weed control and fertilization are illustrative of the complexity of high-yield forest-management systems and emphasize the need for a sustained and determined commitment once a plantation program is undertaken.

Using it

Just as silvicultural treatments are interdependent, so are the biological production system and the wood utilization system. Utilization standards substantially influence the costs and methodology of site preparation, for example, as they do also the frequency, the timing, and the intensity of thinning interventions. The use of forest and mill residuals for composites, fiber, and fuel is pushing forest industry relentlessly toward total stand utilization. When total stand utilization becomes a reality, and fossil fuel costs seem to insure that it will, then the per-ha recovery of above-ground biomass will increase to roughly 125% of recovery based on stemwood to a 10-cm top. That is not silviculture in the usual sense, but efficient and complete recovery of wood produced above-ground is an important element of high-yield forestry. How-

ever, appropriate research into the long-term effects of increased biomass removal on the nutritional and physical status of plantation soils will be necessary to ensure that the productive capacity of the site is not damaged.

The outcome

To put the productivity of plantations into perspective, consider that, under 1970 levels of management, average pine growth on all ownerships in the U.S. South was estimated to be $4 \text{ m}^3 \text{ ha}^{-1} \text{ year}^{-1}$ (Anonymous, 1973). Intensively managed plantations well stocked with trees derived from first-generation seed orchards are projected to average from 10 to $14 \text{ m}^3 \text{ ha}^{-1} \text{ year}^{-1}$, a 3-fold increase in growth rate over the older, low-intensity and 'no management' systems.

These projections of average performance are being verified in Weyerhaeuser high-yield forest plantations, and many high site plantings are substantially exceeding these average growth estimates. The prospects are bright for increasing even those excellent growth rates, given advanced-generation breeding, optimum matching of species, provenances, sites and utilization, and greatly refined application of cultural practices. All of this depends on applying practices that do not adversely affect the productive capacity of the site – physical structure of the soil, soil nutrients, or soil microorganisms – because that will negatively affect the sustainability of plantation forestry.

EXTENSION TO THE TROPICS

What else can be done to grow more wood on less area? One eminent option is to extend high-yield plantation forestry, much of which has been applied to temperate environments, to include the tropics, wet and dry, and thereby capture the advantage of the benign physiological environment, i.e., near-constant year-round temperature and the absence of frost. The average growth of commercial Caribbean pine (*Pinus caribaea*) plantings throughout the tropics is about $18 \text{ m}^3 \text{ ha}^{-1} \text{ year}^{-1}$, with the best reaching $34 \text{ m}^3 \text{ ha}^{-1} \text{ year}^{-1}$ (Johnson, 1976). The best plantations of tropical broad-leaved species such as white albizia (*Albizia falcataria*) and flooded gum (*Eucalyptus grandis*) can produce $60 \text{ m}^3 \text{ ha}^{-1} \text{ year}^{-1}$. Relative to the productivity of undisturbed and partially-logged, humid tropical forest, these growth rates represent 4–10-fold increases in volume production.

That the tropical forest will be utilized, and on a large scale, seems inevitable. More pervasively than in temperate regions, expanding human populations in tropical areas are seeking new sources of living space, food, water and, justifiably, an improved standard of living. The inhabitants of the developing countries wherein most of the commercial tropical forests lie are turning to these forests for relief from biological and social pressures, since

the forest can be a source of space, food and water, and immediate capital as well.

Tropical forests are disappearing at a rapid rate, but not for timber harvest. Little destruction is actually caused by forestry development; most is the result of/and conversion to agriculture. And most of the lands cleared and burned are converted to grazing (Ledec and Goodland, 1988). Grazing does not require extensive management, so settlers use cattle grazing to establish claims over large areas. However, grazing provides little employment and contributes little to the economy. Export receipts per km² grazed are less than 3% of that obtained by raising coffee, or 6% of that from sugar cane (Leonard, 1987), and grazing contributes less to employment in the local economy than high-yield forestry (Hornick et al., 1984; Brandao, 1989). Furthermore, many of the poor tropical soils decline in productivity under crops or grazing in only a few years.

There are many factors, however, that place short-and long-term constraints on the utility of the forests as effective pressure-relief valves. In the undisturbed commercial forest, there is limited space, food, and water. Unharvested stands are at or near growth equilibrium and hence are not producing growth dividends. In the stands which have been logged to silvicultural or merchantability standards, there is a tendency toward the depletion of useful species (Gentry and Vasquez, 1988) and regrowth is characteristically slow. High levels of species diversity result in major conversion inefficiencies. Soils are generally unsuitable for permanent agriculture and thus unable to support relatively concentrated and stable populations – yet the invasions continue.

Forest plantations, in a context of planned and integrated land-use, constitute a valuable tool in relieving many of the constraints listed above. By integrated land-use, we mean integration of agriculture, grazing, and wood production. Displacement of some proportion of shifting agriculture and natural forest by intensively managed plantations is logical and desirable. Plantation forestry can provide greater employment and relieve pressure on reserve areas by providing a better standard of living for local peoples, and eliminating the need for shifting agriculture.

Sustained management, at least for several rotations of forest plantations, on soils that are unsuitable for permanent agriculture under indigenous technologies, seems biologically and socially feasible. Wadsworth's (1983) analysis of nutrient requirements is encouraging, and suggests that repeated harvest usually would not result in serious deficiencies, with the possible exception of phosphorus. The risks associated with tropical plantations are undoubtedly higher than those with temperate-zone plantations because the increased tempo of biological activity generally exacerbates the effects of weed competition, insects, and fungi. By the same token, rotations are shortened, and much of the high-yield forest technology and experience suggests that it can

be successfully applied to the tropical situation. Tropical plantations must be carefully monitored and adverse effects mitigated, should they appear.

The removal of uncertainty through abundant, reliable and concentrated production of relatively homogeneous plantation wood, supplementing the production of associated logged forests, permits the establishment of a stable cash economy, often where none existed before. This can help to stabilize population, one key to successful tropical forest management, and to creation of forest reserves. To cite Leslie (1977):

“Plantations are therefore a rational move toward making the future wood supply in tropical areas much less uncertain. Plantations also have an added appeal in that management then becomes concerned with species and methods about which something is known, instead of groping with something about which, relatively speaking, nothing is known.”

However, inequitable and insecure land-tenure arrangements make long-term forest management efforts difficult, and in some cases impossible. These and other common property problems increase the risks associated with concessions or management units based upon lands held individually or collectively in private hands, upon lands held by governments with unnecessarily flexible or non-existent land-use policies, and upon lands that are subject to unauthorized but uncontrollable invasions of pioneering farmers and settlers as soon as access roads are constructed. Political problems were largely responsible for the sale of the Jari operation in Brazil (Hornick et al., 1984).

Nevertheless, high-yielding commercial forestry plantations have already begun to reduce pressure on tropical forests, as in Kenya (Ledec and Goodland, 1988) and Latin America. The introduction of the rapidly-growing Australian blue gum (*Eucalyptus globulus*) in the Peruvian Andes in 1973 slowed the clearing of native forest (Rocca Calienes, 1985). By 1984, over 182 000 ha had been planted with blue gum in Peru (Ruiz, 1987). The potential of high-yielding plantations is evidenced by statistics on wood production summarized by the Latin American Forestry Commission (Anonymous, 1986): in 1983, 40% of wood production in Latin America was harvested from exotic conifer plantations that occupied only 3% of the forest area.

If the area under plantation were increased, more native forest would be available for other uses such as nature reserves, parks, and watershed protection. If plantation area were doubled, tropical countries could supply 30% of their projected needs for wood by the year 2000 and free 2.5 times as much native forest for purposes other than timber harvest, according to Wadsworth's (1983) analysis. Total requirements for wood could be met by an 8-fold increase in plantation, from 0.21×10^6 km² to 1.71×10^6 km², which would simultaneously permit an increase in the area of conserved native forest by 10-fold, to 5.84×10^6 km² compared to 0.60×10^6 km² if plantations remain at their present level. Not incidentally, fast-growing plantations would

be a more effective sink for CO₂ than native forest, helping to offset the global increase in CO₂ from burning fossil fuels and, therefore, damping the projected global warming. The arguments for intensive plantation management have never been stronger.

In the face of diminishing tropical forest resources, the world needs a conviction that high-yield forestry is a useful tool in the resolution of tropical-forestry problems. Once held, local governments, international agencies and industry must act on that conviction by indentifying and minimizing the biological, economic, and political risks associated with plantation establishment. To complement plantations and to provide a continuing supply of natural forest timbers, multiple-use silvicultural systems for the natural forests must be established or refined. Research designed to optimize the distribution of land-use for agriculture, forestry, and natural reserves for the protection of biological diversity is mandatory. Finally, incentives are needed to promote the establishment and maintenance of industrial-scale plantations and agroforestry systems. Some indirect facets of such incentives are stability in business relationships, in the administration of tax laws, in import/export regulations, and in the dedication of land to various uses.

Observers of the tropical scene lament the loss of potential, as yet unidentified, sources of drugs, oils, foods, etc., that uncontrolled exploitation of the diverse tropical forest portends. They are equally concerned about preserving scientific, educational and aesthetic opportunities that complex tropical ecosystems provide. Considering the basis of forest exploitation, the surge in population and the 'human needs and desires' of tropical peoples, it is apparent that only *inviolate* reservation of appropriate tropical forest areas will provide long-term protection for endangered biological systems. Successful high-yield forestry can and must replace the wood production of such reserves and also can help to minimize encroachment on them by stabilizing local populations.

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