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The potential of high-yield plantation forestry for meeting timber needs

Recent performance, future potentials, and environmental implications

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Abstract. This study examines the performance and potential of intensively managed plantation forests as a source of industrial wood, and their environmental implications. The perspective of the study is global. Although it includes the United States and parts of Europe, much of the focus is on what are called the "emerging" plantation regions – countries largely in the semitropical areas of the southern hemisphere – which have not historically been important wood producers, but are growing in importance as a result of the productivity of their planted forests. The first section of this paper documents the growing importance of plantations as a source of industrial wood since the late 1970s. The study finds that plantations from nontraditional (new) regions have been growing rapidly in size and economic importance, and, thus, have been playing an increasing role as a source of the world industrial wood. Furthermore, experience seems to suggest that plantations are playing an environmentally beneficial role in (1) reducing pressure on greater areas of natural forests and (2) generating positive environmental effects as they replace degraded marginal agricultural lands. The second section of the paper examines the likely role of plantation forests in the future, and includes an assessment of financial, political and environmental considerations. This section pays particular attention to the concerns frequently expressed by environmentalists regarding plantations. Many of the objections directed at forest plantations on environmental grounds appear to ignore the substantial beneficial role of plantations on the environment. Plantations, which are financially very attractive in many locations, offer the potential of meeting large portions of the world industrial wood needs even while reducing substantially the disturbances on large areas of natural forests. This is possible because the very high productivity of plantation forests requires less area to produce industrial wood.

Introduction

Over a decade ago I wrote a book entitled the *Comparative economics of plantation forestry* (Sedjo 1983). In that book, I examined the potential financial returns to plantation forests in a number of promising regions around the globe. The economics of intensively managed forest plantations were examined in Australia, Brazil, Chile, Indonesia, New Zealand, South Africa,

Figure 1. Major regions of actual or potential premise for industrial forest plantations (Sedjo 1983).

and west Africa, as well as in Nordic Europe, the Pacific Northwest, and the U.S. South. In this paper I revisit the question of the potential of plantation forestry. I provide an assessment of plantation forestry's performance over the past 15–20 years, and reexamine its prospects and likely problems over the next couple of decades. Specifically, in the first section of this paper I (1) review the performance of plantation forestry in meeting the world's timber demand requirements over the past 15 years, and (2) examine the potential of high-yield plantation forestry to meet an increasing proportion of the world's industrial wood demand in the future. In the second section I examine the political and environmental issues and risks that are associated with plantation projects in various locations, especially in the context of large-scale plantation projects which involve nonindigenous species.

Plantation performance

Background

A decade ago I examined eleven major regions that had actual or potential promise for industrial forest plantations. These regions were (see Figure 1): North America (the Pacific Northwest, the U.S. South), South America (Brazil: Amazonia, Southern Brazil, Chile), Oceania (Australia, New Zealand), Africa (South Africa, Gambia-Senegal), Europe (Nordic – Sweden, Finland), and Asia (Borneo, Indonesia).

In the early work I examined the economics of plantation forestry for these regions with a representative prototype plantation for each region. Further,

I examined the economic returns given conditions circa 1980 from both a pulpwood operation and an integrated sawtimber/pulpwood operation. For the Nordic region and the United States, the plantations involved domestic native species that were established by reforestation activities after the initial forest was cleared and often after an intervening period during which the land was used for other purposes, e.g., cotton and tobacco in the South.[1] For the nontemperate northern hemisphere regions, however, industrial plantations almost always involved the introduction of a non-native "exotic" species. Commonly, these were either from North America, as with a southern pine species, Caribbean or radiata (Monterey), *Pinus radiata* D. Don, or from Australia, as with one of the *Eucalyptus* species. These regions have been called the "emerging" forest plantation regions.

The financial returns to all the operations, including those of the temperate region, were "acceptable." However, in general the financial returns to the plantations in the semitropics appeared to be potentially the most favorable. The returns to plantations in New Zealand, Chile, and Brazil appeared very promising.

I should note that plantation activity today is important in all of these areas, with the possible exception of Gambia-Senegal in west Africa. One area that was neglected in the earlier study is Iberia (Spain and Portugal), where *Eucalyptus* plantations have become of significant importance. In addition, some other countries, e.g., Uruguay, have shown promise of becoming important sources of industrial wood from exotic plantations.

Recent performance: 1977–1992

Table 1 brings us to the present and provides the official Food and Agriculture Organization of the United Nations estimates of industrial wood product for 1977 and 1992, a 15-year period during which industrial forest plantation wood production would have been expected to experience growth. Regions given in boldface type have relied extensively on industrial forest plantations for their industrial wood production. These regions have all experienced rapid growth in their industrial wood production, growth largely provided by exotic plantation forests, and much more rapid than the world average. An analysis of the data reported in Table 1 reveals that, in 1977, timber production from the plantation regions accounted for 6.11 percent of the world's total. Fifteen years later, in 1992, exotic industrial plantations accounted for 9.80 percent of the world's total. It should be noted that plantations in the U.S. South, Europe, and elsewhere are not included in this figure.

Table 1 also provides data that show total world industrial wood production increasing only 16 percent over the past one and a half decades, an annual compounded growth of less than 1 percent. The South America plantation

Table 1. Industrial wood production, 1977–1992 (*Source:* FAO Forest Products Yearbook, 1983 and 1993).

Region	Production (1,000 m^3)		Proportional change
	1977	1992	
World	1,381,203	1,603,376	1.16
South America	56,894	116,669	2.05
Brazil[a]	*37,319*	*77,714*	*2.08*
Chile	*6,022*	*17,774*	*2.95*
Uruguay	*347*	*1,043*	*3.01*
Argentina	*4,029*	*7,577*	*1.88*
Europe	262,973	278,451	1.06
Sweden	44,260	49,150	1.11
Finland	28,900	35,745	1.24
Spain	*10,596*	*15,112*	*1.43*
Portugal	*7,420*	*10,309*	*1.39*
Oceania			
New Zealand	*9,492*	*14,992*	*1.58*
Africa			
South Africa	*9,181*	*12,601*	*1.37*
North America	476,002	592,900	1.25
United States	320,441	402,500	1.26
Canada	143,365	179,215	1.25

[a] Italic type denotes regions that have relied extensively on industrial forest plantations with exotic species.

countries of Brazil, Chile, Uruguay, and Argentina all have approximately doubled industrial wood production in the past one and a half decades, whereas Chile and Uruguay have tripled production in this period. Spain, Portugal, South Africa, and New Zealand have all substantially increased production, primarily because of the role of industrial plantation forests.

By contrast to the emerging plantation countries, European production has hardly increased. Of course, many of the forests of Europe represent conscious tree planting and reforestation. However, for the most part, their production has increased only modestly. For example, Sweden and Finland, countries that rely on extensive reforestation and intensive management, show only modest production increases.

On the other hand, North America has increased production well above the world average, with both the United States and Canada increasing about 25 percent. In Canada, much of the increased harvest has come from essen-

Table 2. Pulp exports: Selected countries (*Source:* FAO Forest Products Yearbook, 1983 and 1993).

Region	Export (1,000 t)		Proportional change
	1977	1992	
World	17,072	24,520	1.43
South America	433	2,665	6.15
Brazil[a]	*95*	*1,630*	*17.16*
Chile	*339*	*939*	*2.77*
Europe	6,130	7,752	1.26
Sweden	3,220	2,756	0.86
Finland	1,181	1,287	1.09
Spain	*83*	*569*	*6.86*
Portugal	*318*	*1,041*	*3.27*
Oceania			
New Zealand	*477*	*592*	*1.24*
North America	8,509	15,416	1.81
United States	2,415	6,552	2.71
Canada	6,094	886	41.45

Note: Emerging plantation sources represented 7.69% and 19.46% of total world export in 1977 and 1992, respectively.

[a] Italic type denotes regions that have relied extensively on industrial forest plantations with exotic species.

tially wild "old-growth" forests that have been opened to logging by new access, e.g., roads. However, this increase is unlikely to be repeated over the next decade because of limitations in sustainable harvests and environmental concerns. Recently, the British Columbia (B.C.) government has committed itself to reducing harvests on public (Crown) lands in that province. Some of the reductions in B.C. harvests are likely to be offset by increased harvests in Alberta and perhaps other provinces. In 1994 and 1995, partly in response to favorable prices, Canadian exports to the United States have increased. Nevertheless, the steady increases of the past are not likely to continue indefinitely.

Woodpulp exports

Many of the industrial plantations that have been established have been oriented toward the production of woodpulp, often for the international "market pulp" market. Table 2 compares world pulp exports in 1992 with the level in 1977. A number of points should be noted. First, total world pulp

Table 3. Pulp and paper trade balance – Brazil (*Source:* Suchek 1991; preliminary data for 1994 from the Government of Brazil).

Year	Paper (million U.S.$)			Pulp (million U.S.$)			Total
	Imports	Exports	Balance	Imports	Exports	Balance	
1970	6	5	–1	48	1	–47	–48
1975	32	30	–2	116	9	–107	–109
1980	35	364	329	165	156	–9	320
1985	15	279	264	98	263	174	438
1990	42	598	556	244	603	359	915
1994	326	934	608	61	819	758	1,366

exports increased by 43 percent, and most major producers experienced some increases. However, the really large increases in pulp exports were experienced by a handful of countries that have been actively establishing industrial forest plantations; these countries I have titled the "newly emerging plantation region." For example, in addition to Brazil, countries like Spain, Portugal, New Zealand, and Chile have all increased pulp exports by multiple factors. The portion of pulp production exported from the newly emerging plantation region increased from 7.69 percent in 1977 to just under 20 percent in 1992.

It is instructive to examine the growth of pulp exports for selected countries. In the decade and a half from 1977 to 1992, Brazilian pulp exports increased from 95,000 t in 1977 to 1,630,000 t, an increase of over seventeen times the one-and-a-half-decade period to 1992, the last year for which I have worldwide data (FAO Yearbook 1993). Moreover, Brazil's experience is not an isolated phenomenon within South America. The 1977 total pulp exports from South America, which were 433,000 t in 1977, had increased to 2,665,000 t by 1992. Brazil and Chile were the leading exporters.

Additionally, much of the increased pulp from other regions has come from countries where forest plantations are playing an increasing role in supplying wood. The United States, for example, almost tripled pulp exports. Much of this increase is related to plantation production, especially in the South. In addition, pulpwood exports from forest plantations are widely found in the Nordic countries and elsewhere in Europe.

Case study: Brazil

A slightly different perspective can be gained by examining the experience of a specific country, Brazil, with respect to its pulp and paper trade balance

Table 4. Countries providing a large portion of their industrial wood from plantation sources (*Source*: Pandey 1992).

Country	Forest area (1,000 ha)		Share of plantations (%)	
	Natural	Plantation	Total area	Total production
New Zealand	6,270	1,240	19.0	93
Brazil	396,000	6,500	2.0	60
Chile	6,300	1,400	22.0	95
Argentina	36,000	800	2.0	60
Zimbabwe	28,800	117	0.4	50
Zambia	12,900	60	0.4	50

timber trade of recent years. Table 3 shows Brazil's pulp and paper trading experience over the 1970–1994 period. The trade balance fell from –$48 million in 1970 to –$109 million in 1975. However, as a result of the plantation policy it initiated in the 1960s, by 1980 Brazil began to be a major net exporter of paper and pulp, and by 1994 Brazil showed a positive trade balance of $1,366 million in paper and pulp.

Plantations as a cause of deforestation of natural forests?

These data do not allow us to differentiate readily between harvests of plantation wood and that of native forests in these countries. However, a separate study has shown (Table 4) that most of the industrial harvest from the emerging forest plantation countries comes from their plantation forests.

For all of the countries for which data are presented, a disproportionate high fraction of industrial wood is from plantation resources. This finding reflects some inherent advantages of plantations in terms of location, accessibility, wood type, and wood quality.

Additionally, Table 4 suggests that plantations are likely to deflect harvests away from natural forests, thus contributing to their protection. Also, it should be noted that, although a common view is that plantations displace native forests, most forest plantations are actually established on former agricultural lands.[2] Thus, plantations are rarely an important cause of the deforestation of natural forests. Furthermore, in some countries, e.g., Brazil, almost 100 percent of the wood fiber for pulp and paper comes from industrial plantations.

The ability of the fairly modest, fast-growing, industrial plantation forests to make such a significant impact on the world's wood supply, to say nothing of their own domestic wood requirements, is surprising until it is recognized

Table 5. Worldwide timber yields (*Source:* adapted from Clapp 1993).

Site	Yield (m^3/ha/yr)	Rotation (yr)
Temperate and boreal softwood forests		
Canada average 1	—	
British Columbia	1.5–5.3	—
Sweden average	3.3	—
Finland	2.5	60–100
Russia	1–2.9	—
Siberia	1–1.4	70–200
Softwood plantations		
Britain (Sitka spruce)	14	40
South Africa (*Pinus* spp.)	10–25	20–35
New Zealand (Monterey pine)	18–30	20–40
East Africa (*Pinus* spp.)	25–45	20–30
Brazil (*Pinus* spp.)	15–35	15–35
Chile (Monterey pine)	20–30	15–35
Eucalyptus plantations		
Portugal and Spain	10–15	8–12
South Africa	15–20	10
Congo	30–40	7–20
Brazil	30–70	5–20
Chile	20–30	8–20

how rapidly plantation forests can grow. Worldwide timber yields, presented in Table 5, provide an idea of the rapid growth rates possible from these forests.

Trends in industrial forest plantation establishment

Historically, the source of industrial wood has been natural forests. Increasingly, however, the source is tree-growing plantations. Table 6 provides a recent estimate of the area of industrial forest plantations worldwide. The large number of plantations in Asia is attributable in large part to China, which has experienced fairly high seedling mortality; thus, this figure may be a bit high. Nevertheless, plantation forestry is active elsewhere in Asia, including Japan, Korea, Indonesia, and so forth. Furthermore, many of the

Table 6. Industrial plantations worldwide (*Source:* drawn from Bazett 1993).

Region	Plantation area (million ha)		Total
	Coniferous	Nonconiferous	
North America	12.0	0.5	12.5
Latin America	3.5	2.9	6.4
Asia	31.6	8.2	39.8
Africa	1.3	1.2	2.5
Europe	15.7	3.3	19.0
CIS	16.9	—	16.9
Oceania	2.1	0.1	2.2
Total	*83.1*	*16.2*	*99.3*

temperate plantations grow slowly, as, for example, in the Commonwealth of Independent States (CIS).

Table 7 presents data on what are called fast-growing plantations. These are found largely in the tropics and semitropics, and include the U.S. South. Fast-growing industrial plantations constituted about 25 percent of total industrial plantation area, or about 25 million ha, in the late 1980s. Although commercial harvests are commonly viewed as a major source of deforestation, most knowledgeable observers now recognize that commercial timber harvests generally do not involve the permanent conversion of land to another use. Rather, forest lands involved in commercial harvests typically remain as forest lands. Reforestation occurs either through tree planting, or, less commonly today, through natural regeneration.

Recent experience

A quick reconnaissance of some of the experiences of plantation countries might be of interest. Worldwide, we estimate that something over 4 million ha of forest plantations are being established annually,[3] with a significant portion for commercial purposes.[4]

The United States in recent years has planted between 1.0 and 1.2 million ha (about 2.5–3.0 million ac) annually. This amounts to the planting of 4–6 million seedlings *each day* over a 365-day year. In 1992, 70 percent of the total planting was in the South, and 84 percent of the total was on private lands (Moulton et al. 1993).

Table 7. Fast-growing industrial plantations, circa the late 1980s (*Source:* drawn from Bazett 1993).

Region / Country	Plantation area (1,000 ha) Coniferous	Nonconiferous	Total
North America			
U.S. South	12,000[a]	500	12,500
Latin America			
Brazil	1,600	2,300	3,900
Chile	1,140	60	1,200
Argentina	460	180	640
Venezuela	180	20	200
Mexico	60	20	80
Other	80	350	430
Total	3,520	2,930	6,450
Europe-Iberia			
Spain	—[b]	450	450
Portugal	—[b]	400	400
Total	3,520	2,930	6,450
Africa			
Republic of South Africa	500	800	1,300
Angola	20	50	70
Congo	—	40	40
Kenya	160	10	170
Zimbabwe	70	10	80
Other	550	330	880
Total	1,300	1,240	2,540
Oceania			
New Zealand	1,180	20	1,200
Australia	900	60	960
Other	50	30	80
Total	2,130	110	2,240
Asia			
Indonesia	—[c]	100	100
China	—	400	400
Other		170	170
Total		670	670
World total	18,950	6,300	25,250

[a] The conifer plantations of the southern United States are “borderline” fast-growing.
[b] Iberia also has up to 4 million ha of slow-growing conifers.
[c] Indonesia has about 700,000 ha of slow-growing conifers.

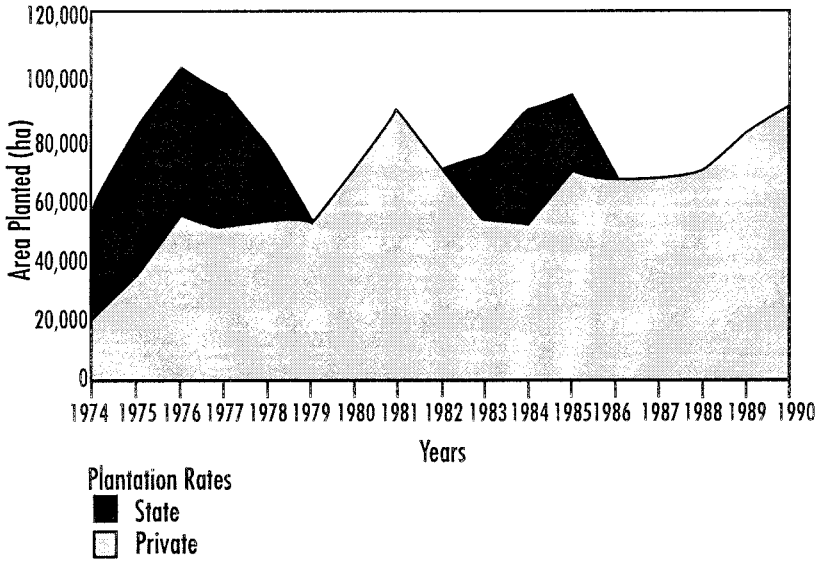

Figure 2. Plantation establishment rates in Chile.

New Zealand has about 1.3 million ha of industrial plantation forests. Although the establishment of new forests was reduced to 10–20 thousand ha in the early 1990s, planting for 1994 is estimated at a record 130,000 ha, the result, in part, of very strong international prices in 1993 and 1994. It is also estimated that another 3–4 million ha of land are potentially available for industrial plantations. Most of this land is from sheep pasture, which has been in decline for decades because of weak market prices.

Essentially all of New Zealand's industrial wood production is from plantations. Production is expected to increase from current production levels of about 15.5 million m^3 annually to more than 25 million m^3 after 2000, as trees already planted reach rotation age.

Chile has become a major focus of plantation establishment and production. In the past one-and-a-half decades, plantation establishment has fluctuated between 50,000 and 100,000 ha annually, and reached 107,500 ha in 1991 (Figure 2). Associated with this has been the development of both a pulping and a solid wood industry.

Indonesia has yet to become a major producer of industrial wood from plantations. However, the country has made very ambitious plans centered around the establishment of plantations and pulpmills. Planning documents call for the establishment of as many as thirty-two pulpmills over the next three decades. Although this may be overly ambitious, Indonesia recently put three new world class mills into operation to supplement the two that already

exist. Furthermore, two more mills are expected during the decade of the 1990s, and three additional mills by 2005. Initially, much of the feedstock for the pulpmills is to come from mixed tropical hardwood sources. However, this source will gradually be replaced by plantation wood.

Argentina has about 800,000 ha of industrial forest plantations, and is adding about 25,000 ha/yr of new plantation forests. It has long-term plans for the planting of about 400,000 additional ha. Argentina's growing conditions are quite good and large amounts of low cost land are potentially available for industrial forest plantations. A major drawback with some of the sites in Argentina is their distance from major markets and a weak transportation infrastructure.

Australia has been establishing plantations at a modest rate throughout the post-World War II period. Since the late 1960s that annual rate of establishment has been in excess of 20,000 ha, and reached as high as 35,000 ha in 1978. The vast majority of the early plantings were softwood species, mainly radiata pine. Beginning in the late 1980s there has been a shift to hardwood species, predominantly indigenous. Nevertheless, softwoods still constitute well over half of the new plantings (NAFI News 1995).

In Brazil large areas of mostly degraded agricultural lands have been converted to plantation forests over the past several decades, and especially since the late 1960s. During the 1970s, annual plantings often exceeded 500,000 ha; Brazil has an estimated 6.5 million ha in plantation forest currently. The potential for additional plantations is great, both in terms of land area available and also given the high growth experienced in many Brazilian forests. Although the Jari project in the Amazon has received much notoriety, the great potential for plantations lays largely outside of the Amazon region in the tropical and semitropical region in the south of the country. In recent years, a number of new pulpmills have come into production with much of the output being exported.

Plantations into the future

The past 15 years have demonstrated that forest plantations can be viable financial investments in many parts of the world. Although it was not that long ago that many foresters argued for special criteria for forestry investments (e.g., see Leslie 1977), in recent years the financial returns to plantation forestry in many regions are adequate to promote forestry as an investment capable of competing with alternative uses of capital.

Forest plantations have provided the base for the development of new and vital industries, especially pulp and paper. They have allowed countries to utilize lands that have become largely degraded for agricultural purposes,

and to redirect those lands into productive activities that also generate environmental benefits.

Financial returns

These results are consistent with the study results of over a decade ago that found that the financial returns to investments in forest plantations are likely to be favorable in many regions (Sedjo 1983). Signals from the market suggest that the financial returns to plantations have been more than adequate to generate continued and increased investments in planting in many regions. In addition to large and continuing investments in tree-growing and intensive management by many major multinational forest products firms, we now observe a variety of investment instruments being utilized to collect capital for tree growing. The instruments include various types of partnerships, limited partnerships, investments designed for pension programs and the like. These are not confined to the United States, but are also active in places like New Zealand and Argentina.

Additionally, plantation forestry began largely as a government activity in many countries, among them the United States, Brazil, Chile, and New Zealand. Recently, the trend in tree planting has been away from public sector direct planting and subsidies to private sector planting, with diminishing or no subsidies.

For example, in the early post-World War II period, most of the plantings in the United States were by public authorities, usually on public lands. Today, over 80 percent of the area planted is done by the private sector on private lands. Similarly, in New Zealand there has been a dramatic shift in tree planting away from the public sector to the private sector. Much of this has been driven by the broad privatization program of the New Zealand government, which privatized most of the plantation forests and largely eliminated planting and forest management subsidies. Although these actions were initially followed by a sharp decline in planting, recent plantings in New Zealand have been at record levels (MacLaren 1993). Furthermore, most of these plantings are reported as being undertaken by small landowners. In Brazil the initial plantings were propelled by very generous government tax write-offs, and were available almost exclusively to large companies that could use the write-offs. In recent years, however, these write-offs are reported to have been discontinued. Nevertheless, plantings are reported to be high despite the reduction in official government support. Similarly, in Chile the subsidy that once covered about 70 percent of the establishment costs has essentially been eliminated; nevertheless, tree planting is at record levels. Also, in Argentina much of the subsidy on tree planting has recently been reduced.

This is not to suggest that the world no longer contains tree planting subsidies. Rather, the point is that these subsidies are declining and, generally, are less critical to continued activity.

Political and environmental considerations

Plantations require long-term investments, and long-term investments require a degree of political stability. Even the fastest growing plantations require at least 7 years for a harvest rotation. Furthermore, if pulpmills are viewed as part of the investment package, investments can be well in excess of $1 billion and have production lives of perhaps 30 years.

The experience of the 1980s suggests that these types of investments are unlikely to be forthcoming in the absence of a degree of stability. However, in some cases, the political situation may be viewed differently by foreign investors than by locals. Thus, one of the lessons of the past 15 years is that domestic investments may be forthcoming even if international investments are not. After all, Jari in the Amazon continues production, although foreign investors have long since liquidated their interests.

Perhaps the most delicate current issue related to forest plantations is the environmental effects. This may also be one of the most troublesome for the future. Although plantation forests are not likely to ever be viewed as environmentally preferable to native forests, they are widely viewed as superior to most other land uses. Nevertheless, the difficulties associated with the acceptance of forest plantations can be substantial.

The environmental movement appears to have a high degree of ambivalence toward plantation forestry. On the one hand, some individuals with incontestable environmental credentials have agreed that plantation forests offer a viable alternative to management and logging natural forests in the tropics. In essence, plantation forests can serve to deflect logging away from native forests to renewable forest plantations. As shown in Table 6, countries with active industrial plantations tend to rely heavily on their plantation forests for industrial wood.

On the other hand, many environmentalists are suspicious of plantations. Forest plantations are often viewed as displacing either native forests or local agriculture and native peoples. Where the plantations are large, the discussion is often couched in terms of the huge multinational firms displacing workers' livelihoods in the pursuit of export dollars. Furthermore, plantation forests are often viewed as creating a sterile landscape, even when they are established on lands that have long been in marginal agriculture.[5] A related issue involves whether the species planted are native or exotics. Native species, perhaps not surprisingly, appear to face much less opposition than do imported exotics. However, in many parts of the world the timber exotics have a clear advan-

tage in growth and overall financial viability, just as do many introduced species in agriculture (e.g., wheat has been introduced to the Americas, and potatoes to regions outside of the Americas). Especially despised is the *Eucalyptus* genus, which has been accused of all types of foul behavior, including absorbing excessive water, maintaining a sterile understory, and even political crimes.[6]

It is clear that if the plantations are viewed as leading to the destruction of native forests, they will face stiff opposition from environmentalists. On the other hand, if they are viewed as an alternative land use to marginal cropping or pasture, they are likely to be perceived more sympathetically. Finally, if plantations are viewed as an alternative source of industrial wood, which reduces the pressures on native forests, they are likely to have appeal both to environmentalists and to society more broadly.

Aracruz: A Brazilian case study

The political acceptability of plantations appears to be closely related to the degree of environmental hostility that they may create, and also to the extent that they do, or do not, disrupt the existing social order. Aracruz in Brazil provides an interesting case study of the demands and pressures that a plantation enterprise may face[7] (see Campinhos, this volume).

Aracruz Celulose S. A. is a holding company of a group that includes 5 subsidiaries. The operation, located along the coast north of Rio in Espirito Santo, began in the 1960s and includes a plantation area of 132,000 ha, as well as a pulpmill and other facilities. It employs about 3,300 people in its various forestry and processing activities. The mill has a capacity to produce 1,025,000 t/yr of bleached *Eucalyptus* pulp. It exports roughly 90 percent of its pulp, most to Europe and the United States, with the rest remaining in Brazilian markets. The company has roughly $2.5 billion in assets and its shares are traded on the New York stock exchange. Aracruz is famous for its work on improving its *Eucalyptus* genetic stock, and has produced some of the most rapid tree growth ever recorded. Commonly, trees in the Aracruz plantations reach 35 m in height and are ready for harvest in 7 years. The company also produces hybrid seeds, both for its own use and for export. Aracruz has received numerous awards, from the Brazilian government and internationally, for its accomplishments in forestry and exceptional work in developing cloning techniques. Aracruz has also been involved in social and environmental projects in its region, as well as in a program that provides local farmers with seedlings, assistance, and a market for their timber production.

Despite its accomplishments, Aracruz has been under heavy attack from some environmental organizations, including Greenpeace. The opposition to

Aracruz appears to have a number of bases. First, there is a general distrust of forest products companies based upon perceived "past harmful environmental activities." For example, Greenpeace claims that Aracruz destroyed much of the native forest and productive farmland in the process of establishing the forest plantation. Aracruz claims that the tree plantations were established on degraded agricultural lands.

Second, environmentalists express concern over the impact of forest plantations upon the land. Plantation forests are often referred to by environmentalists as "green deserts", which inhibit other vegetation from inhabiting the area. Although Lugo et al. (1993) have published scientific research results that seriously challenge this view of green deserts, this perception continues to be common. Environmentalists often view the *Eucalyptus* genus as particularly negative.

Third, concern is expressed over the effects of pulp production wastes on local water, fishery resources, and human health. Clearly, pulpmill discharges can be environmentally harmful if not treated properly.

Fourth, criticisms of claimed environmental damages are supplemented by criticisms of the impacts for plantations on local peoples. These include charges that agricultural land displaced by the forest plantations was reasonably productive, and conversion to plantations involved the expulsion of local peoples.

Finally, there is recited a litany of grievances against Aracruz. These grievances include poor working conditions, promises not kept, and so forth.

Some lessons

The above criticisms appear to be representative of the types of grievances that are often directed against plantation forests. Without trying to determine the precise facts in this situation, the nature of the charges suggests that there are some lessons as to the types of issues that are likely to arise and that need to be addressed if a large-scale plantation is to be successful. A provisional list of such issues includes the following:

1. *There is a need to try to avoid destroying native forests in the process of establishing plantations.* This rule should hold, if for no other reason than that the destruction of native forests, and their replacement by industrial plantations made up of non-native species, is likely to generate opposition.
2. *Land tenure is important. Private land is generally recognized as the domain of the owner*. Where private land is converted to plantations, there is likely to be a greater acceptance of that prerogative of ownership. Where public lands are involved, interest groups are more likely to believe that they are justified in vying for alternative land uses. Addition-

ally, local peoples who have occupied lands for some period are likely to be viewed as having legitimate interests.

3. *External impacts, or externalities, on other regional resources need to be considered.* To the extent that negative external effects, such as water quality issues, are associated with plantations and/or processing facilities, these larger concerns can become a basis for opposition.
4. *Opposition to plantations is likely to be more modest if native species are used.* For example, there is relatively little opposition to plantations in the U.S. South or the Nordic countries, especially where species native to the region are used. However, the introduction of non-native species is often viewed with hostility and can become the rallying point of opposition. However, because non-native species often have far superior growing characteristics, this dilemma is not easily addressed.

To address briefly each of these points, first, it is almost universally true that investors in forest plantations in the tropics prefer to establish plantations on lands cleared earlier, rather than to clear existing native forests. Areas cleared earlier for agriculture generally provide for much greater ease of establishment; this is because of the absence of competing vegetation, flatness of terrain, location with roads and other infrastructure, and access to markets. However, these areas of cleared agricultural lands are often adjacent to patches of forested area that have never been cleared. This generates a conflict between maintaining pockets of native forest and the establishment of efficiently designed plantations.

Second, where lands are privately owned with clear title, the transfer from agriculture to forestry will usually involve the sale of land, and with it the associated expectation that local peoples relinquish rights to inhabit the area. However, where land is in public ownership and occupied, government transfer of use rights will not necessarily be communicated to or accepted by peoples occupying the land. Commonly, compensation will not be forthcoming (e.g., see Anderson and Huber 1988; Sedjo 1990), and, indeed, the results may highly disadvantage local groups.

Third, external environmental effects on other resources in the area, such as impacts on water availability and quality, wild and aquatic life, and so forth, are important and need to be considered. Furthermore, to the extent that industrial plantations are viewed as crops, and land in plantations is viewed as an alternative to agriculture, forest plantations in general and those utilizing non-native species may receive greater tolerance. This acceptance may be enhanced if local peoples also recognize that many other crops are non-native, and that even non-native tree plantations provide habitat for many native plants and animals.

Finally, hostility to plantations may be mitigated if it is widely understood that plantations take pressure off of native forests for timber harvesting. However, since most deforestation is generated by the desire for agricultural lands, not commercial logging, industrial plantation forests can provide only part of an answer to deforestation.

From where will the world's future industrial wood come?

The exploration of the question of the likely sources of the world's wood supply is not a moot exercise. In the United States, much of the harvest increase over the past 15 years has come from "old-growth" forests, largely in the Pacific Northwest. However, recent concerns about the spotted-owl, the Endangered Species Act, and ecosystem management of public lands have, in effect, taken much of the U.S. public land out of the nation's timber base. Also, in British Columbia, the source of about 40 percent of Canada's industrial wood, the provincial government has committed itself to reducing harvests on public (Crown) lands.

A recent study (Sedjo et al. 1994) uses the Timber Supply Model (Sedjo and Lyon 1990) to examine the impact of reduced timber harvests in the western United States and in British Columbia. This study's projections indicate that reductions in harvests from U.S. public lands are likely to be offset by increased harvests on private lands in the United States, as well as by increased harvesting outside the United States. In Canada, some of the declines in B.C.'s harvests can be offset by increased harvests in Alberta, and the projections show the potential for increased production in eastern Canada. Also, the projections indicate that increasing wood production can be expected from the Nordic countries of Europe. Finally, the study indicates a growing role for the emerging plantation region of the southern hemisphere and the semitropics.

Overall, the study suggests a decreased role for the western United States and British Columbia, because accessible timberland in these areas is declining as land is being withdrawn from the timber base. Although western North America has recently accounted for about 12 percent of the world's industrial wood, this fraction can be expected to decline.

These projections are generated by the base case of the Timber Supply Model, which assumes that there are only modest increases in the establishment of new high-yield plantations worldwide. The base case used for the projections assumed that new high-yield plantations would be established at a rate of about 200,000 ha/yr for 30 years, thereby adding an additional 6 million ha of plantation to the timber base over that period (Sedjo and Lyon 1990). However, the original study examined a high plantation scenario in which the rate of plantation establishment was raised to 600,000 ha annually

for 30 years, for a total new plantation area of 18 million ha. This scenario generated higher regional and total harvest levels and associated timber prices that were lower than they would have been in the absence of the greater plantings.

Evidence suggests that current levels of industrial plantation establishment are considerably above 200,000 ha annually. In fact, as noted, just two countries, New Zealand and Chile, are currently planting a total of well in excess of 200,000 ha of new plantation forests annually. Should these high rates of plantation establishment persist, one would expect plantations to play a greater role in providing future timber supplies than anticipated in the base case of the model.[8]

Another possible source of additional industrial wood is from the former Soviet Union and particularly Russia. It is well known that the forest resources in the region are vast, but that the infrastructure is weak. Currently, the industrial wood production of Russia has dropped considerably from levels of the late 1980s, apparently as a result of disruptions related to recent political changes. Nevertheless, despite the disruptions, log exports to Japan in recent years have risen in response to the financial incentives available in that market.[9] In the near term it appears unlikely that Russia could expand industrial production sufficiently to offset decreases elsewhere and increasing demand. In future decades, however, the potential for substantial increases in industrial wood harvest will exist.

Conclusions

This paper has shown how dramatically industrial wood from plantations has increased over the past 15 years and its likely rising role in the future. Based upon existing plantation inventories and planting rates, it appears likely that plantation source wood will grow even more rapidly in the next 15 years and beyond.

In recent years, there have been two impediments to plantations. The first relates to concerns over political stability and the unwillingness to make long-term financial commitments in an unstable political environment. This concern has generally been on the decline in much of an increasingly internationalized world, especially with the debt crises of developing countries largely behind us. However, the recent financial crisis in Mexico may have revived these concerns. The second impediment is found in the objections to plantations that are being made by some environmental groups. To overcome these objections it must be demonstrated that plantation forestry can serve a protective function for native forests, generate positive environmen-

tal benefits, and mitigate any associated environmental damages and social disruptions.

Despite impediments, substantial volumes of trees planted over the past 15 years will soon be ready for harvest in such countries as New Zealand and Chile. Also, the high wood prices of the last 2 years appear to have triggered an upsurge in planting, not only in the United States, but worldwide. Furthermore, mills are being constructed to utilize the wood that will be available. The rapid expansion of pulpmills associated with fast-growing plantations in the tropics and semitropics is likely to continue into the foreseeable future, and, indeed, it will likely become the major engine of worldwide pulp production expansion.

Notes

1. By some definitions these might be characterized as intensive forest management, rather than as plantations.
2. Despite some notable exceptions, e.g., the Jari plantations in the Amazon, there are distinct advantages to locating plantations on degraded agricultural lands. These advantages include availability of roads, modest slopes, favorable location *vis a vis* markets, and so forth.
3. Estimates of annual rates of plantation establishment vary. The WRI (1986) estimated that in 1980 there were 14.5 million ha of forest land is reforested or renewed annually. However, the area actually planted is probably substantially less. Mather (1990, p. 86) estimates plantings in the 1980s to be about 10 million ha annually. That estimate may also be too high as it assumes 4.8 million ha annual plantation establishment by China and 1.3 million ha annually by the former U.S.S.R. By the mid-1990s, given the political changes in both countries, these rates have probably decreased considerably. Hence, our estimate of about 4 million ha annually for the mid-1990s seems reasonable.
4. We estimate new exotic industrial plantation establishment in the tropics and semitropics to be about 600,000 ha annually. South America is establishing about 250,000 ha annually; New Zealand and Australia, 150,000 ha annually; and Southeast Asia-Pacific, about 200,000 ha annually. This does not include China.
5. This view has been challenged by the research of Lugo, Parrotta, and Brown (1993), which indicates that, contrary to the conventional wisdom, tree plantations located in the tropics provide habitat that allows for the flourishing of a large number of native plant species. Their work shows that number of native plant species increase in the understory of tree plantations in about the same numbers as in secondary native forests.
6. An FAO forester relays the experience of discussions with a Spanish environmentalist who was vehemently opposed to the establishment of *Eucalyptus* plantations. Frustrated that his objections were refuted with technical responses, the exasperated environmentalist finally blurred out, “But *Eucalyptus* is a fascist tree.”
7. This section draws heavily from “Aracruz Celulose S. A. A Brazilian Kraft Pulp Company Confronts Sustainable Development”, May 1994, a senior thesis by Meredith Mallis Persily submitted to the Center for Comparative Study of Development, Department of Portuguese and Brazilian Studies, Brown University.

8. The form that "foreign" wood might take is an open question. Although it is possible that it would be imported as logs or chips and processed in the United States, it is more likely that much or all of the processing would take place outside the United States.
9. The Japanese Wood Supply and Demand Information Service reported increases in Russian log exports to Japan beginning in 1993.

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