The future of the forest management industry: Highly mechanized plantations and reserves or a knowledge-intensive integrated approach?[1]

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Intensive forest management has commonly become associated with forest plantations that have high initial investment costs in stand establishment. These intensive plantations will probably not produce high quality wood because they will be physically and economically unstable if grown to long rotations, and so will probably need to be harvested when quite young. An alternative to intensive plantations is integrated management, where more understanding of many ways to grow forests is substituted for the high initial costs of uniform, mechanized treatments used in plantations.

This paper is intended to generate a discussion of the economic, social, and environmental desirability of these, and alternative, management approaches.

Forest policy is presently moving in several directions, with some policies encouraging intensive plantations and other policies encouraging integrated management. All policy directions require government intervention to some degree to deal with the apparent surplus of low quality wood. Either governments will prohibit harvest of most of the world's forests and promote intensive plantations on the remaining area, or they will actively promote integrated management through various incentives and/or restrictions. Unless a consistent policy emerges, there will continue to be confusion in forest management that could last for decades. This confusion will be to the economic, social, and environmental detriment of most of the public and most forest landowners.

Key words: intensive forest management, plantations, integrated management, forest policy

L'aménagement forestier intensif est communément associé aux plantations forestières qui comportent des coûts d'investissement initial élevés lors de la création du peuplement. Ces plantations intensives ne produiront probablement pas de bois de haute qualité parce qu'il sera physiquement et économiquement instable, si les rotations sont trop longues, et devra probablement être récolté à un très jeune âge. L'aménagement forestier intensif constitue une alternative aux plantations intensives, lorsque la compréhension des différentes façons de faire pousser des forêts prend la place des coûts initiaux élevés des traitements uniformes et mécanisés utilisés dans les plantations.

Cet article vise à provoquer une discussion sur l'avantage économique, sociale et environnementale de ces traitements et de leur alternative, les approches d'aménagement.

Les politiques forestières se déplacent actuellement dans plusieurs directions, certaines politiques encourageant les plantations intensives et d'autres, l'aménagement intégré. Toutes les orientations politiques nécessitent une intervention gouvernementale jusqu'à un certain point pour affronter les surplus apparents de bois de faible qualité. Soit que les gouvernements interdisent la récolte dans la plupart des forêts du monde et fassent la promotion des plantations intensives sur les terres disponibles, soit qu'ils fassent la promotion active de l'aménagement intégré au moyen de diverses incitations ou restrictions. À moins qu'une politique constante n'en ressorte, la confusion continuera d'être présente en matière d'aménagement forestier pour au moins plusieurs décennies. Cette confusion s'opérera au détriment économique, social et environnemental de la majeure partie du public et des propriétaires de boisés.

Mots-clés: aménagement forestier intensif, plantations, aménagement intégré, politique forestière

Introduction

Intensive forest management has become associated with forest plantations, which are becoming increasingly expensive to establish because of their high costs of tree improvement, site preparation, planting, and early tending. The increasing establishment costs are based on the agricultural model of paying for the increasing investments by higher and more uniform crop yields per hectare. Justifying investment in these plantations has developed into a circular argument: the high establishment costs need high yields to be economically viable, and the high yields can only be provided by high establishment costs. To be economically feasible, the high costs and yields also necessitate relatively short rotations; however, these short rotations produce innately weak wood, which must be further overcome with investments in manufacturing and marketing.

Less effort has been invested in developing other ways to manage forests. This paper suggests an alternative management approach which may be more economically, socially, and environmentally desirable than intensive plantations in many cases. This approach entails investing less in stand establishment and obtaining less volume per hectare, but applying more diverse silvicultural activities and investing more in information systems to provide, keep track of, and market a more diverse array of timber and fiber products. Many of the silvicultural treatments needed to manage forests in this alternative way have been developed; however, they have infrequently been combined and applied to forest management in an organized manner.

Forests can also be managed by harvesting the wood, abandoning the forest while it regrows naturally, and harvesting

[1]Paper presented at the Forest Industry Lecture Series, College of Renewable Resources, University of Alberta, Edmonton, Alberta, Canada. October 15, 1998.

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it again when it has regrown. Furthermore, forests can be managed by avoiding all wood harvest from them. Which approach, or mixture of approaches, is most desirable depends on many factors; and this paper is intended to generate a discussion of the economic, social, and environmental consequences of managing forests in different ways.

The time lag between establishment of forests and their harvest presents further challenges to changing management approaches. There are many intensive plantations presently growing in the world which will be ready to harvest within the next few decades. Even if these plantations prove not to be economically profitable, many will be harvested to recover some investment; and the wood flowing from them may make it difficult to apply an otherwise desirable management approach during this period.

This paper will explore the effects of investing in alternative management approaches both in the United States and in the world as a whole. It will first describe the alternative management approaches. It will then describe the current and future wood supply and consumption in the United States and the world, followed by a comparison of the economic, environmental, and social effects of each approach. It will briefly discuss the various roles which different approaches can feasibly play in forest management. Then it will discuss the compatibility of the different management approaches and the current dilemma of forest landowners. Finally, it will describe the policy trends supporting the various approaches.

This paper compares the feasibility of alternative management approaches from a conceptual, global perspective. It assumes raw timber and fiber and manufactured products can be shipped throughout the world, and/or manufacturing facilities will relocate to be near raw timber and fiber supplies. It also assumes that forests are expected to make a profit for the landowner by selling timber and fiber. When discussing the roles different management approaches can play, it will briefly discuss conditions where forest management is not expected to make a profit.

Forest Management Approaches

There is a gradient of forest management approaches from very capital-intensive plantations to unmanaged and unharvested forests. For this paper, four management approaches will be described along the gradient:

- intensive plantations;
- integrated management;
- incidental harvest;
- reserves.

Each of these will be described in detail below. Zoning can allocate some land to any of these; and a common proposal is to zone areas among intensive plantations, integrated management, and reserves (Hunter 1990, Oliver *et al.* 1997).

Intensive Plantations

Intensive plantations are managed with the objectives of obtaining a high volume per hectare of one or a few uniform wood products, generally using mechanization and mass production.

The objectives are generally accomplished through high plantation establishment costs to ensure uniform species and spacings and similar subsequent treatments over large areas. The plantations are commonly, but not always, grown at narrow initial spacings to ensure high early volume growth; however, these narrow and uniform spacings make the plantations highly susceptible to stem breakage if the trees are allowed to grow tall (Wilson 1998). To avoid risk of stem breakage and mounting investment costs (described later), the plantations are commonly harvested when quite young—often when the trees are small in diameter. Wood grown on young trees is known as "juvenile wood" and is weaker and commonly warps more than wood added to the tree after the first two decades (Oliver 1994b). Because they are harvested when young, timber and fiber from plantations often contain very large amounts of this "juvenile wood."

Intensive plantations can commonly grow very large amounts of wood – between 10 and 40 m^3/ha/year on productive sites or when irrigated. The high volumes, uniform tree sizes, and uniform timber and fiber quality, combined with the efficiency of uniform stand establishment treatments, are expected to minimize harvesting and processing costs and thus offset the high stand establishment costs. Money is invested in expertise in designing stand establishment machinery, genetically improved seedlings, and wood processing equipment; but the silvicultural operations are relatively routine and uniform over large areas. Presently, many products are being designed to strengthen, stabilize, and otherwise compensate for the low quality timber and fiber produced from intensive plantations. It is unclear how physically durable these products will be – and how competitive they will be with substitute products made of steel, cement, aluminum, brick, plastic, or higher quality wood.

If silviculturally thinned before they become physically unstable, these plantations could be allowed to grow to longer rotations and so provide higher quality wood and habitat (described later); however, the high initial costs of plantation establishment make such thinnings and longer rotations difficult to justify financially.

Integrated Management

To avoid the economic, structural, and other problems of intensively managed plantations, an alternative approach can be developed which specifically avoids the two major problems of intensive plantations – high early investment costs and low quality, short-rotation wood. This alternative could be done by allowing stands to develop in a variety of natural patterns, but using a diversity of silvicultural treatments to modify the growth so a targeted diversity of wood products would be provided. Silvicultural treatments could include enrichment planting, natural regeneration, thinnings, selective harvesting, clearcutting, pruning, and others as needed in mixed and pure species stands to achieve moderate volumes of merchantable wood at minimal costs. These and other silvicultural treatments have been studied extensively; however, they are usually assumed to be additions to high stand establishment costs. Less effort has been spent on developing and applying management approaches that would use these treatments in place of high stand establishment costs.

For this paper, the approach will be referred to as "integrated management." This approach would provide less wood volume per hectare than intensive plantations – especially at younger ages; and there may be occasional times when an unmerchantable vegetation structure develops. Forests developing through integrated management would provide predictable wood supplies because growth of the varied stand structures for the sev-

REGION	FOREST AREA (millions of hectares)	PERCENT CHANGE	WOOD PRODUCTION (millions of cubic meters)	WOOD CONSUMPTION: PRODUCTION RATIO	WOOD PRODUCTION PER HECTARE (cubic meters)	FUELWOOD USE (millions of m3)	FUELWOOD AS PERCENT OF REGIONAL WOOD CONSUMPTION
TROPICAL AFRICA	505	-3.6%	529	1.0	1.0	484	92%
NON-TROPICAL AFRICA	15	-2.0%	38	1.0	2.6	18	50%
TROPICAL ASIA	280	-5.4%	766	1.0	2.7	647	85%
TEMPERATE ASIA	194	-0.7%	374	1.2	1.9	231	53%
TROPICAL OCEANA	42	-1.9%	9	0.6	0.2	6	?
TEMPERATE OCEANA	49	0.6%	38	0.7	0.8	3	12%
NORTH EUROPE	53	0.1%	113	1.1	2.1	9	7%
WEST EUROPE	59	3.1%	155	1.1	2.6	32	19%
EAST EUROPE	34	5.6%	62	0.9	1.8	11	19%
FORMER USSR	816	0.3%	143	0.9	0.2	31 0	25%
NORTH AMERICA	457	0.8%	680	1.0	1.5	99	15%
CENTRAL AMERICA	79	-6.6%	72	1.0	0.9	62	86%
TROPICAL SOUTH AMERICA	828	-2.8%	330	1.0	0.4	239	73%
TEMPERATE SOUTH AMERICA	43	-1.4%	47	0.8	1.1	19	47%
TOTAL	3,454	-1.6%	3,358	13	1.0	1,890	56%

Fig. 1. Forest area change (1990–1995) and annual wood production and use by regions of the world. Current wood demands are met by an average annual production of only one cubic meter per hectare of forest. Forest area is increasing in developed regions, while forest area is declining in less developed regions. The decline is closely related to use of wood for fuel. (data from FAO 1997).

eral decades until harvest is predictable beginning soon after stand initiation. Some of the timber and fiber produced from these trees would be high quality, produced from the "mature wood" on the outside and lower part of the trees; however, a proportion of the wood would still be low quality "juvenile wood" produced from the tree centers and tops and from early thinnings. A more diverse mixture of wood qualities and species would be provided, and the forest would be much more flexible about the timing of harvest than plantations. Consequently, the forest could be managed as a "portfolio" to minimize risk of managing for a single product or objective and to maximize profits by harvesting different stands containing different species and products as these products' prices reach cyclical peaks (Oliver 1994a). Integrated management would also provide more diverse habitats to support biodiversity, recreation , and other values (Boyce 1985, 1995; Oliver 1992a,b; Boyce and McNab 1994; Oliver *et al.* 1997).

There is enough knowledge of how forests grow and can be manipulated to support this "integrated management." Instead of investing money (and research and development) into intensive plantation establishment, the investment could be made in on-the-ground managers with high levels of silvicultural expertise who know how to manipulate stands in a variety of ways for a variety of products and other values. Similarly, instead of investing money into reconstituting low quality, uniform wood into high quality products, money could be invested in sorting and manufacturing a diversity of products of both high and low quality.

Incidental Management and Harvest

Many forests have historically been harvested and allowed to regrow until economic conditions make it worthwhile to harvest them again, with no intervening tending or management. Such forests generally produce relatively low volumes per hectare and a variety of wood species with some high quality wood, but mostly low quality wood. The lack of uniformity of spacing, species and tree ages allows these stands to differentiate, creating a mixture of high and low quality wood of a variety of species – large and small trees and knotty and knot-free stems. The time of stand harvest can be moderately flexible because of the lack of uniformity and the low investment costs in each stand (Wilson 1998).

These stands often do not produce the variety of habitats or the large amounts of high quality wood of stands managed using integrated management. Incidental harvest requires no silvicultural expertise and little labor, except in the harvesting and sorting of wood.

Incidental management is often associated with a migratory wood industry, where the wood industry harvests the forest in a region and then moves its mills elsewhere in the world, returning decades later to harvest it again when the forest has regrown. Such "migrations" have occurred in southern New England (United States) when the white pine forests were harvested in the late 1800s and early 1900s and the regrown hardwood forests are now being harvested. Similarly, the southeastern United States pine forests were harvested periodically as the harvested forests regrew or abandoned agricultural fields regrew to forests. Companies that began in the 1800s in one part of the United States have periodically moved to other regions as the forests there regrew and became profitable to harvest. These companies are now moving to overseas forests as well.

Reserves

Reserves are currently considered areas where commodity extraction is excluded. They can be actively managed without the income of wood harvest to help offset the

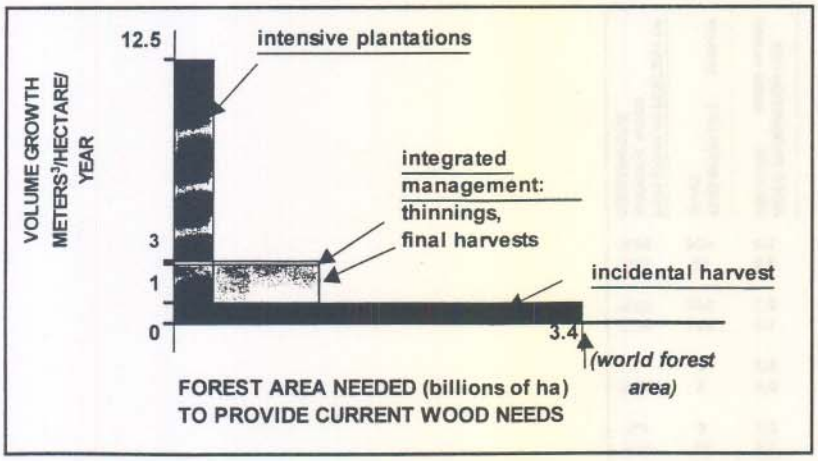

Fig. 2. Example of area of world's forest needed to provide wood using different management intensities and approaches. If "incidental harvest," where forests were not managed but harvested as they naturally regrew, grew wood at one cubic meter per hectare per year, all 3.4 billion hectares of the world's forests would be needed. If "integrated management" provided currently consumed low quality wood at three cubic meters/hectare/year (and another three cubic meters of high quality wood), about one third of the forest area would need to be managed this way. If intensive plantations provided 12.5 cubic meters per hectare per year, only eight percent of the world's current forests would be needed as intensive plantations.

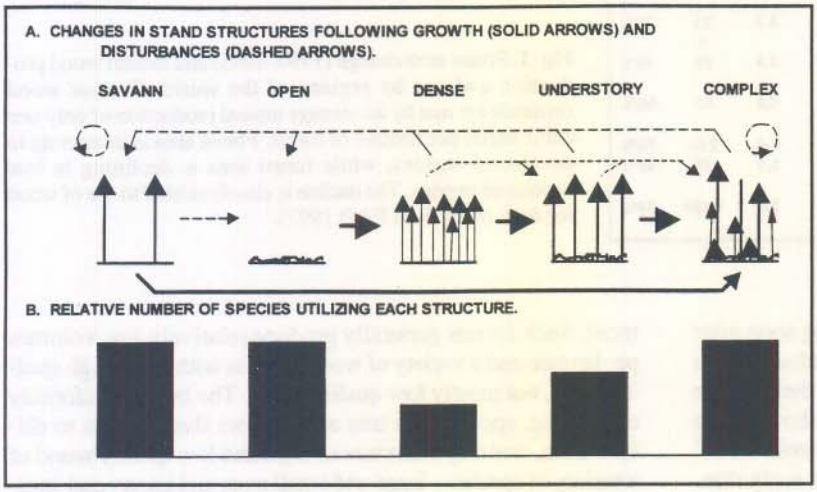

Fig. 3. Forests have naturally contained a variety of stand structures as disturbances and regrowth changed each area. Some species depend on each structure (habitat). There is an excess of small diameter, overly crowded stands in the "dense" structure in the United States resulting from agriculture and grazing abandonment, fire suppression, and forest management regeneration. There is also a shortage of "savanna," "open," and "complex" structures and consequently there are threatened, endangered, or extinct species which depend on these structures in each region, except Alaska (Oliver and Larson 1996, Oliver *et al.* 1997).

management costs, or management can be excluded. Active management of reserves can cost, for example, $30/hectare per year (Oliver and Lippke 1995) to provide the diversity of habitats, fire protection, and access. Alternatively, excluding management will limit access to the area but may not provide environmental and social values discussed later.

Current and Future Wood Availability with Different Management Approaches

Intensive plantation management has largely been based on averting a perceived "impending wood shortage" (Olson 1971, Oliver 1986). Such shortages have historically occurred locally, primarily because of an inability to transport wood to areas needing it. As countries develop, agricultural production increases on the more productive lands because technology allows greater production and farther, cheaper transport of the crops. The increased production and improved transportation make less productive lands economically unfeasible to farm. Because the more productive lands often produce over ten times as much commodities per area, very large areas of less productive land are abandoned as relatively little productive land is cleared for agriculture. The abandoned farm and grazing land often grows to forests and the displaced people move to cities (Oliver *et al.* 1993, 1997). The effects in the United States have been to create a stable, economically viable food supply; to increase the total area and volume of forests; and to create a primarily urban population.

The abandoned agricultural land in the United States has provided more forest land and wood volume than was present 50 years ago. In addition, forest management and fire protection, increased utilization, and use of substitute products made of plastic, steel, aluminum, concrete, brick, and other substances have created an abundance of low quality wood. The increase in forest land and low quality wood is occurring in other regions of the world as well. As countries become developed, similar declines of subsistence agrarian populations are occurring (Fig. 1). Many of the less developed regions of the world use much of the harvested wood for fuel (FAO 1997), creating two inefficiencies: the fuelwood is usually harvested before the trees grow fast, and so the potentially fast growth rate of trees is not captured; and using wood for fuel is not as energy (or pollution) efficient as using fossil fuels for fuel and using the wood to replace steel, aluminum, concrete, brick, and plastic for construction and other commodities. If less developed regions improve their economies and allow marginal agricultural land to grow to forests and replace wood with other sources of energy, much more wood will be available.

At present and in the future, there seems to be an excess of small diameter, low quality trees. For example, the United States is only consuming about two thirds of the wood it is growing

	INTENSIVE PLANTATION	INTEGRATED	INCIDENTAL
Site Preparation, Planting, Weeding, & Stocking Control ($/ha)	$1,900	$350	$1
Commercial Thinning			
Volumes Removed in Thinnings (m3/ha)			
1st thinning; age 45 yrs (all low quality)	0	37	0
Second thinning; age 75 yrs			
Low quality	0	57	0
High quality	0	57	0
Logging & Hauling Costs ($/m3)			
1st thinning (all low quality)	0	$21	0
Second thinning			
Low quality	0	$5	0
High quality	0	$18	0
Delivered value ($/m3)			
1st thinning (all low quality)	0	$18	0
Second thinning			
Low quality	0	$18	0
High quality	0	$70	0
Final Harvest			
Logging & Hauling Costs ($/m3)	$11	$ 14 (high quality) $ 5 (low quality)	$20
Delivered value ($/ha)	$26	$ 70 (high quality) $ 18 (low quality)	$26
Volume Growth Rates (M3/ha/yr, MAI @ 100 Years)	12.5	3 (high quality) 3 (low quality)	1

Fig. 4. Assumptions of the investment analyses examples for different management approaches described in the text. (Assumptions are based on conservative, general estimates.)

(Oliver *et al.* 1997). Globally, people are consuming about one cubic meter of wood/hectare of forests/year (Fig. 1). The realization that there is not an "impending wood shortage" is part of a larger paradigm shift away from the concept that an increasing global population will soon lead to a critical shortage of resources (Meadows 1972). Although resources and the population changes are of concern, there is increasing evidence that the world may not be on the verge of simultaneously running out of resources and overpopulating itself (Simon 1996). Intensively managed plantations can provide 10 to 40 m^3/ha/year of wood volume – ten to forty times the world's annual consumption per hectare. Even more moderate increases in growth of some forests through management could dramatically exceed the world's current wood consumption. For example (Fig. 2), intensive plantations providing 12.5 m^3/ha/year could provide the world's current wood consumption by growing low quality wood on eight percent of the world's forest land. These intensively managed forests would be in highly productive, accessible areas such as the tropics, the southeastern United States, and southeastern Asia.

Alternatively, forests could be managed through integrated management. If this management grew 6 m^3/ha/year of total wood (about half as low quality wood and half as high quality wood), the world's current wood consumption in low quality wood and an equal amount of high quality wood – a product in short supply – could be provided by managing 33% of the current forest area through a combination of thinnings and final harvest.

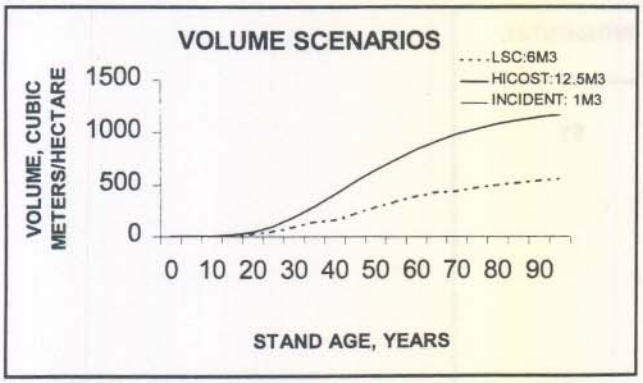

Fig. 5. Standing volume projections used in example analyses of integrated (a.k.a. landscape: LSC: 6M3), intensive plantation (HICOST:12.5M3), and incidental (INCIDENT: 1M3) management approaches. Half of the volume in the integrated approach would be high quality volume, which would not compete in the same markets with wood from the other management approaches. Removal of thinned volume creates fluctuating line shape using integrated management.

Incidental management and harvest would grow even less wood volume per year. If such management and harvest grew one cubic meter per hectare per year of wood, today's world needs could be met on the present forest area; however, any increase in wood consumption would lead to forest harvest exceeding growth – and a global shortage of wood if the trend continued.

Economic Profitability of different Management Approaches

High site preparation and planting costs have often been assumed to be necessary to ensure a new forest grows after harvest. Without such investments, no forest, an understocked forest, or a forest of undesirable species was expected. With more knowledge of stand dynamics and greater ability to utilize diverse tree species, it is becoming increasingly possible to grow a new forest with less early investment – the "integrated" approach. It may also be possible that much of the world's wood will be supplied through the "incidental harvest and management" approach, as it was in the past.

It is uncertain if the diversity of wood products, their higher quality, and lower stand establishment costs using the integrated approach or the higher harvest cost of the incidental harvest and management approach will offset the lower volumes of wood produced per hectare compared to intensive plantations. Although each situation will be different, a simple comparison of the profitability of the different management approaches can show the advantages and disadvantages of each. The example is limited by its assumptions of costs, returns, and interest rates; however, it can be used both to illustrate the effects of multiple sources of wood and to compare with more specific data to determine the sensitivity of the results. Reserves are not included in this economic comparison since they generate no wood revenue.

As described earlier, this section assumes the investor is trying to maximize return from wood, not subsidize wood growth for some other objective. It also assumes that consumers of low and high quality wood will purchase the cheapest source of each material. When there is a surplus of wood, the material of highest extraction costs will be left in the forest to grow and/or die.

Assumptions of the Example

Assumptions of the economic example are shown in Fig. 4. A 7% compound interest rate is assumed. For simplicity, stands grown using each management approach are assumed to be even-aged, although the integrated and incidental approaches could also entail both uneven-aged and even-aged harvesting.

This example assumes the world demand for low quality wood will remain at the present rate of consumption of total wood. Anything less than a very large increase or decrease in wood demand will probably not change the trends shown here because moderate changes in demand could be offset by moderate changes in forest area using different management approaches or by moderate changes in volume production per hectare. The example also simplistically assumes that, as prices change, non-wood materials (e.g., steel, aluminum, brick, concrete, and/or plastic) will not be substituted for the wood products. If such substitution occurred, the results of this example are even more negative for the high cost or low profitability management approaches.
The assumptions are as follows:

Early stand establishment includes site preparation, planting, early weeding and stocking control, and similar activities during the first 15 years. Plantation management incurs large costs for site preparation and careful planting; integrated management relies on less costly manipulation of the regeneration, and incidental management entails no efforts toward regeneration.

First commercial thinning is only done using integrated management. It entails a high harvest and hauling cost because of the difficulty of working within standing trees. The low price of the low quality wood removed makes the first thinning a net negative cash flow; it is referred to as a "commercial thinning" because a utilizable product is removed from the forest. All of the wood removed in this first thinning is low quality.

Later thinnings, final harvest, and hauling costs Final harvest and hauling costs are lowest in the intensive plantations because of the high volume concentration per hectare and the uniformity of wood.

Later thinnings are only done with integrated management. They are assumed to cost $\$18/m^3$; and final harvest using integrated management is $\$14/m^3$. The moderate costs are because of the large piece sizes removed and the moderately high volume concentrations per hectare (Fight and Briggs 1986). Low quality wood, assumed to be 50% of the volume during the later thinnings and final harvest using integrated management, is considered a residual. The major cost of harvest is borne by the high quality logs, and the transfer cost of sending the low quality residual to processing facilities is considered minimal (Jackson 1995).

Logging and hauling costs are considered highest with incidental harvests because the lack of management means access is difficult, and the low volume per hectare means the harvest and hauling equipment must travel long distances to obtain the material.

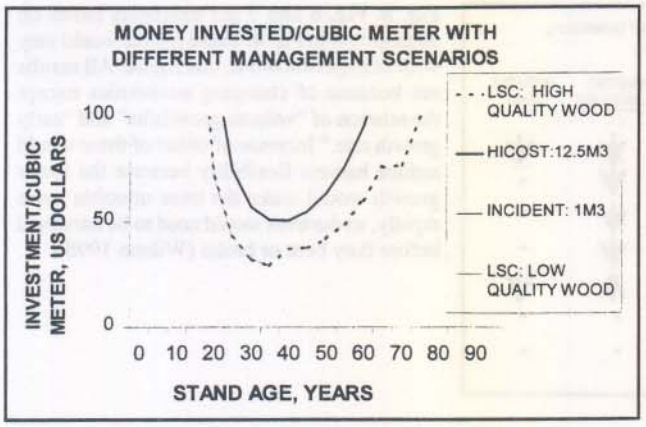

Fig. 6. Money invested per cubic meter of wood for each year after stand establishment using each management regime. This is the selling price (excluding harvest and hauling costs) needed to recover management costs at a seven percent interest rate. Using integrated management (LSC), low quality wood has no cost after the first thinning because it is a residual (in tree tops, chips, etc.) provided free by harvesting high quality wood. Note intensive plantations (HICOST) wood has a short harvest "window" before its investment costs become extremely high.

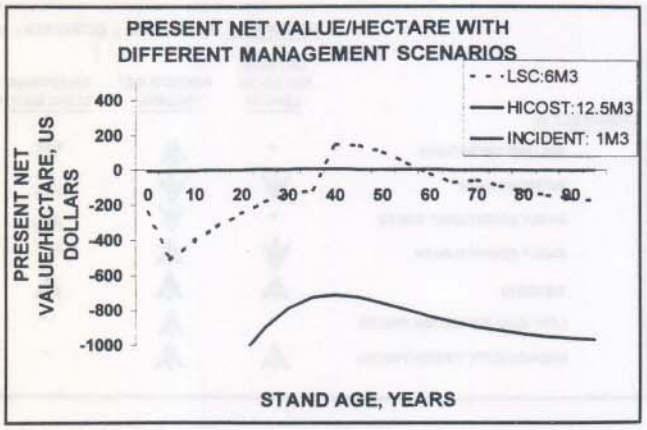

Fig. 7. Investment expectations (net present value) at different harvest times and different management approaches discounted at a 7 percent interest rate, based on assumptions in Fig. 4. Plantation management (HICOST) would not be profitable, but integrated (LSC) and incidental (INCIDENT) would if harvested at appropriate times. Higher prices for the high quality wood would make later harvest ages more profitable than shown here for integrated management.

Delivered price of wood from intensive plantations is higher than the delivered price of wood from the first thinning using integrated management because the plantation-grown wood is more uniform. Higher quality wood from integrated stands is assumed to have the highest delivered price; and the delivered price from incidentally harvested stands would be higher than from thinnings because some wood in these stands would be of relatively high quality.

Volume growths (minus volume removed in thinning for integrated management) are shown in Fig. 5 for each management approach. Volumes for all approaches are conservative, but within the ranges for their respective management approaches. As described earlier, only half of the wood removed from integrated management stands is used for low quality products.

Investment Analyses

Investment in the various management approaches is analyzed in two ways: money invested per cubic meter of wood at the time of harvest (Fig. 6), and net present value of the investment per hectare (Fig. 7).

Money invested per cubic meter compounded until time of harvest shows the minimum selling price (stumpage value, not including harvesting costs) needed for the management approach to have been economically worthwhile at the 7% compound interest rate (i.e., the future value of the investment). For example, for intensive plantations to have been economically worthwhile when the wood is sold at age 40, the stumpage selling price (which excludes harvesting and hauling costs) would have to be at least $\$53/m^3$ – or $\$64/m^3$ including harvest and hauling costs (Fig. 4). The investment in the first thinning with integrated management was calculated as proportional to the percent of volume removed. Investments in low quality wood removed in later thinnings and final harvest were considered to be negligible (treated here as zero), since this wood is simply the residual of harvesting, hauling, and processing high quality wood.

Figure 7 shows the net present value per hectare of the investment using the cost and price assumptions described earlier (Fig. 4). For example, maximum net present value for integrated management would be obtained if the stand were harvested at age 40 years using these assumptions; however, the relatively slow decline in present net value after this age indicates the stands could be harvested later to wait for a possible price increase. Higher delivered prices for high quality wood would make longer rotations more desirable.

The effects of variations in the assumptions are shown in Fig. 8. All effects are based on the economic analyses except the effects of "volume growth/ha" and "early growth increase" on "harvest flexibility." Harvest flexibility describes the ability to delay thinning or harvesting the stand (e.g., to avoid harvesting during times of low delivered prices) without dramatically losing money through accelerating costs or accelerating risk of the stand being destroyed by wind, fire, insects, or other biological mechanisms (Wilson 1998). Fast growth rates cause the trees to grow tall rapidly, increasing the risk of missing the thinning or harvesting "window," after which the trees are too tall, thin, and unstable to be thinned or left standing safely in uniformly spaced plantations.

Results

Assuming that some of the world's forests were managed by each of the three approaches described above, management can be viewed from two perspectives: cash flow and profitability of management. The best "cash flow" perspective allows the manager to sell his wood more cheaply than anyone else, while (hopefully) making some small profit so at least some monetary return can be obtained when there is a wood surplus.

The best "profitability" perspective allows the landowner to profit most by the investment in growing wood – and so he is willing to reinvest in this approach.

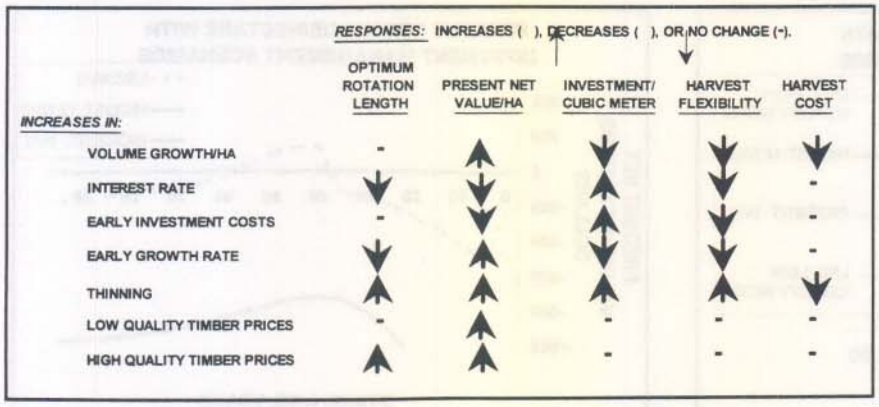

Fig. 8. Fig. 6 and 7 are examples based on assumptions in Fig. 4. These figures would vary with changes shown in this figure. All results are because of changing economics except the relation of "volume growth/ha" and "early growth rate." Increase of either of these would reduce harvest flexibility because the faster growth would make the trees unstable more rapidly, so the trees would need to be harvested before they bent or broke (Wilson 1998).

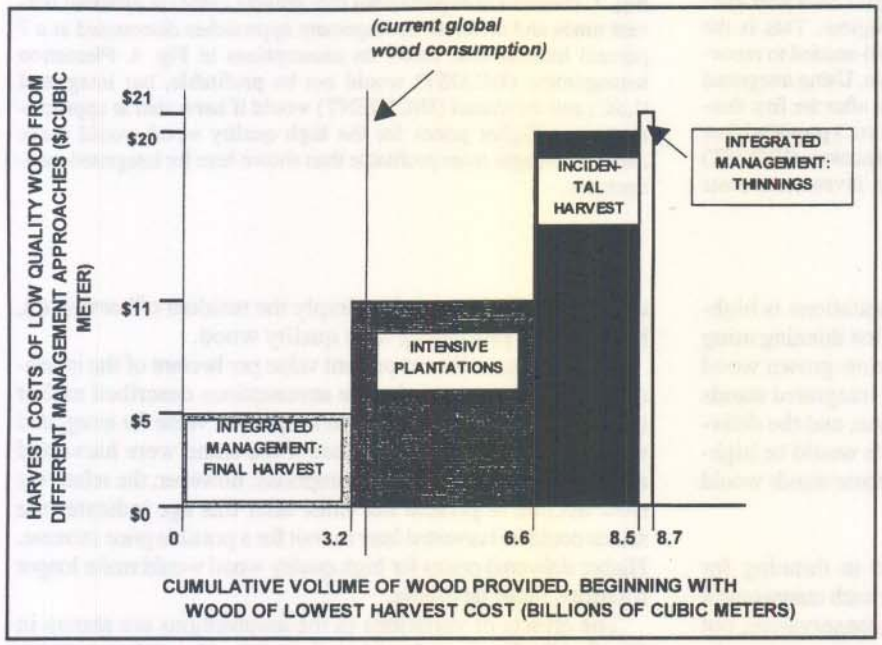

Fig. 9. Schematic example of harvest preferences assuming slightly less areas are managed using intensive and integrated approaches than are shown in Fig. 2. With a surplus of wood, owners may try to harvest their stands simply to obtain some "cash flow," even at a loss of profit. Those stands that could be harvested most cheaply would be sold, and other stands would not. Consequently, the cheap costs of low quality wood upon final harvest (and late thinnings) of integrated management would cause these stands to be harvested first. (The high quality wood would cover most investment costs, so low quality wood would be cheap.) Only enough of the wood with the next higher harvest cost – the "intensive plantation" wood – would be harvested to fill the world's wood consumption needs. The remaining intensive plantations would not be harvested, nor would non-managed stands, and the young stands intended for integrated management would not be thinned (first thinning) because the wood was not needed and other wood could be obtained more cheaply.

Cash Flow: Ability to Sell Wood from Different Sources The "cash flow" advantage – ability to sell wood most cheaply when there is a surplus – would be based on the harvest costs of the wood. The least expensive low quality wood is from the later thinnings and final harvest of stands managed through integrated management (Fig. 9), since the low quality wood is the residual from the harvest and manufacture of high quality wood and does not have to "pay its way out of the woods" (Jackson 1995).

Next most advantageous would be intensive plantations, since their uniform conditions enable harvesting costs to be low. Third most advantageous is the periodic, incidental harvest of non-managed stands. Least advantageous from a "cash flow" perspective is the first thinning of stands when doing integrated management. In fact, the cost of thinning is often higher than the return (Fig. 4); however, without this thinning, integrated management is not possible and the unthinned stands would behave like stands managed through incidental management instead of integrated management.

Figure 9 shows the effect of having large areas of the world's forests in each management approach if managed from a "cash flow" perspective. All of the "integrated management" stands would be harvested and some of the intensive plantations would be harvested to supply the world's present wood consumption at the lowest harvest cost. After this, the world's wood needs would be met and many intensive plantations would not be harvested, nor would any of the unmanaged stands be harvested, nor the integrated management stands thinned.

Using the assumptions of this analysis, most intensive plantations would not be harvested and future integrated management would not occur since the stands could not be thinned unless there were a dramatic increase in wood demand, an exclusion of wood harvest from most of the world's forests, or a cessation of integrated management.

Profitability: Ability to Profit by Managing Using the Different Approaches The most "profitable" management approach would provide the greatest net present value to the landowner (Fig. 7). Alternatively, this profitably could also be calculated as the greatest difference between the selling price and the sum of the money invested in the wood and the harvesting cost. Fig. 10 shows the relative profitability of growing low quality wood using different management approaches when large areas are managed using each approach.

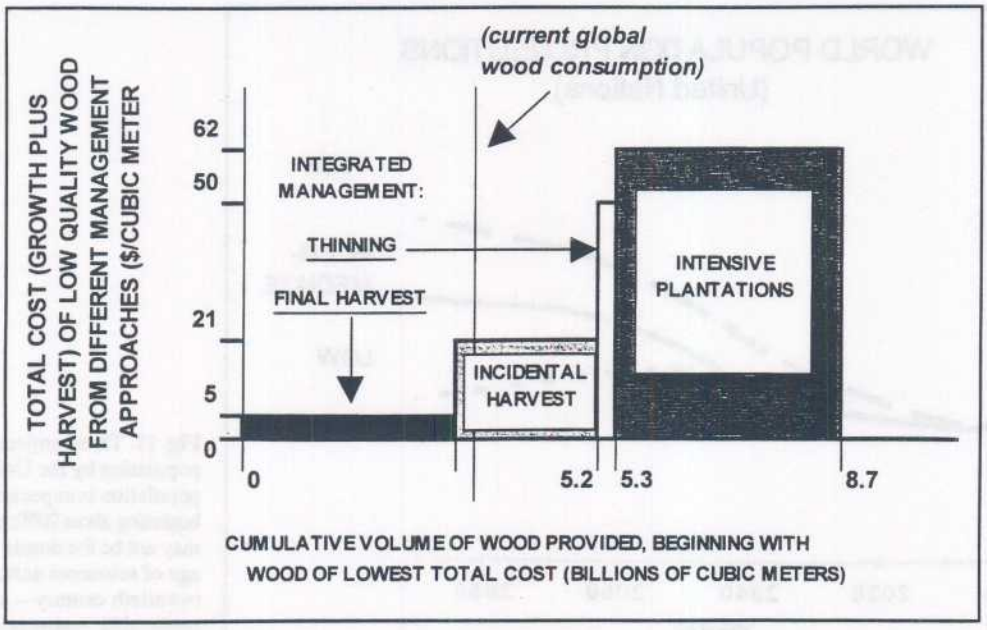

Fig. 10. Schematic example of investment advantages assuming slightly less areas are managed using intensive and integrated approaches than are shown in Fig. 2. In the long term, management approaches that provided the wood at the least investment and harvest cost would remain in business. Late thinnings and final harvest of integrated management would provide low quality wood with least investment cost, since this low quality wood is a residual from harvesting higher quality (and price) wood which pays the harvest cost. Enough incidental harvest, the next cheapest wood source, would be done if there were not enough wood provided from integrated management until the world's consumption needs were met. Thinnings needed to continue integrated management as well as intensive plantations would be costly investments and so only done (unless subsidized) if no other wood were available.

Using the assumptions of this analysis, later thinnings and final harvest using integrated management would provide the greatest profit, since the investment costs are borne by the high quality wood. Incidentally harvested wood would provide the next greatest profit, since there was little investment in the wood. The first thinning during integrated management would be the next most profitable, because much of the investment cost is provided by the high quality wood harvested later. Least profitable would be the intensive plantations.

Unless there were a dramatic increase in demand for low quality wood, an exclusion of wood harvest from most of the world's forests, or a cessation of managing forests through integrated management, forests managed using integrated management could be managed profitably and no intensive plantations would be profitable. As long as thinnings were expected to compete for profitability with other sources of wood, integrated management would not be done in the future since the stands could not be thinned when the remaining integrated management stands disappeared. Without thinning, incidental management and harvest would be most profitable.

Discussion

The results described above are intended to show global trends; there may be local conditions where intensive plantations are a profitable investment or thinning is a "cash flow" advantage because of certain species needs, different prices than those described above, or other considerations. This discussion is based on the assumptions and analyses shown above.

For large scale investments in a global wood economy, however, the trends described above are important. Forest owners using the most profitable ways to manage wood – incidental harvests and integrated management in this example (Fig. 10) – may not be able to sell their wood because other owners with intensive plantations may sell their wood much more cheaply, and at an investment loss (in this example), simply to recover some money. In the long term, intensive plantations could be unprofitable and could prevent other forest management approaches from being profitable. The first thinnings are costly (or show a low return), but are necessary for integrated management. As long as these thinnings are only done if they are profitable or yield a positive cash flow independent of their contribution to future stand value, integrated management may not be widely practiced.

Consequently, forest landowners may be caught in a position where they may not be able to manage profitably in any fashion – except possibly through incidental harvest of their forests.

Integrated management, including early thinnings, would be feasible in the long term. Recognizing that the first thinning is an investment, rather than a profit, could make integrated management more easily practiced, as would increasing the price of high quality wood. The flexible harvest time of stands managed by integrated management could allow owners of these stands to endure times of low wood prices caused by extensive harvest of plantations or by general economic cycles.

Social Consequences of the different Management Approaches

Many of the industrial wood corporations and the environmental groups are separately promoting national and international forest policies leading to zoning of forests in the United States

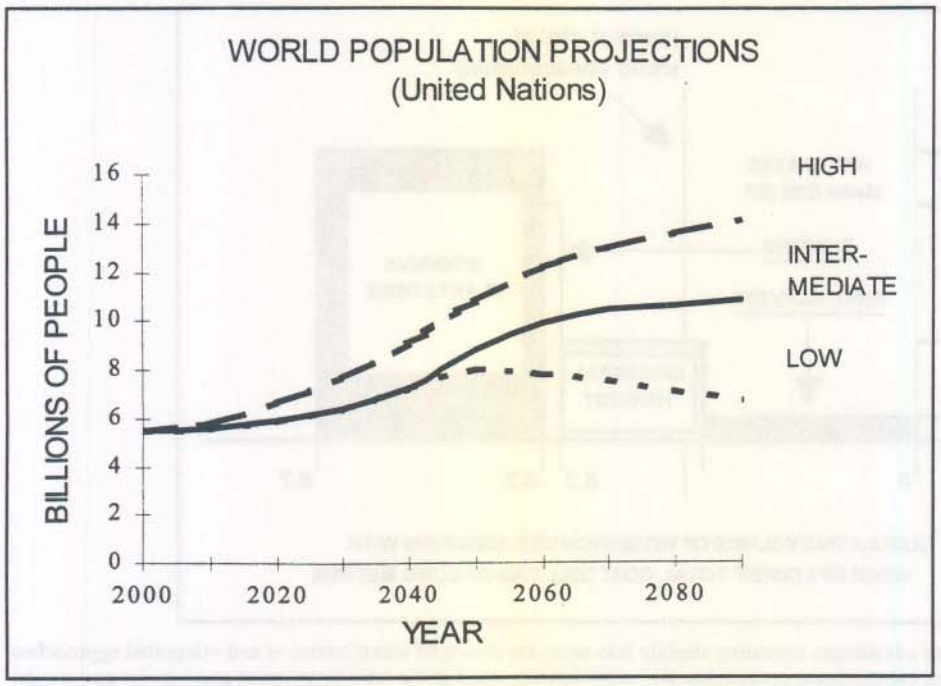

Fig. 11. Three projections of the world population by the United Nations. The population is expected to slow or level beginning about 2050; consequently, there may not be the drastic impending shortage of resources anticipated in the late twentieth century – especially not for renewable resources such as wood. (from Sedjo 1997).

and elsewhere (Birchfield and Grant 1993, Sedjo and Botkin 1997). This zoning commonly divides the forest between areas of no forest commodity production and areas of very intensive, agriculture-like forest plantations. Others (e.g., Hunter 1990) have suggested dividing the forests into three zones: reserves, intensive plantations, and integrated management areas.

A scientific report to the United States Congress cursorily examined the effects of managing different public and private lands by various management approaches (Oliver *et al.* 1997); however, it did not examine in detail the effects of the combination of management approaches on the profitability to the landowners. That report and other analytical comparisons of the preservation, intensive plantation, and integrated approaches show that the integrated approach provides more of nearly all values than either, or a combination of, the intensive plantations and reserves approaches (Oliver and Lippke 1995, Lippke *et al.* 1996).

With a doubling of the world's population (Fig. 11) and an increase in the average standard of living during the next 50 years, the relation of forests and people will become more critical. A reduction in subsistence agriculture as countries become more economically developed will provide more forest area and volume; however, it will cause more people to move to already crowded cities.

This section will compare two ways to allocate management to the different approaches:

- Zoning the forest between intensive plantations and reserves
- Managing the forest by integrated management

Adding integrated management to the zoning mixture creates conflicts that will be discussed later.

Zoning the forest between intensive plantations and reserves

Zoning the forest between intensive plantations and reserves would need to be strictly enforced; otherwise, the large amount of wood in the reserves could be harvested and the intensive plantations would prove uneconomical to continue (Fig. 10). If enforced zoning of the forest between intensive plantations and reserves were somehow implemented, the intensive plantations would probably be in the world's very productive, accessible, and operable places such as Chile, Argentina, Brazil, Indonesia, southeastern Asia, and the southeastern United States. Forests in other regions such as Canada, the Scandinavian countries, and the western United States would be zoned as reserves, even if they traditionally had a wood growing economic sector.

It would be socially and politically difficult, if not impossible, to displace traditionally wood economic sectors from parts of the world to be zoned as reserves. The monetary costs of removing these lands from commodity production could be very high. For example, intensive plantations in the United States could provide its wood needs on about 15% of the currently managed forest area – about 30 million hectares; however, to purchase the 110 million hectares of excess forests currently owned by small, private landowners would probably cost nearly one trillion dollars. Globally, the cost would be much higher – if it were possible to purchase the forests.

Zoning the forest between intensive plantations and reserves would cause even more people to live in urban areas. Neither the reserves nor the intensive plantations would have the road and fire protection infrastructure, jobs, and other amenities suitable for living. In addition, the automated nature of intensive plantations would produce few jobs in wood growth and processing.

The physical locations of intensive plantations and reserve areas would be awkward. Presumably, the intensive plantations would be somewhat isolated from urban areas (to avoid social protests, vandalism, and the dangers of mechanized operations around people). If the reserve areas were interspersed with cities, there would be problems of fires and wild animals

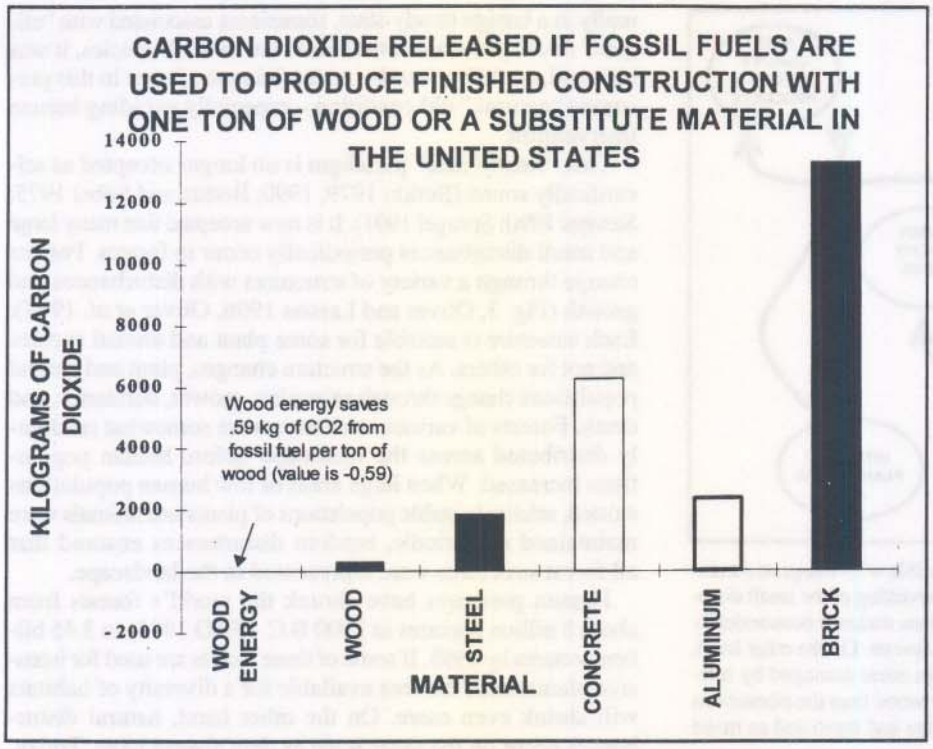

Fig. 12. Carbon dioxide released if one ton of wood or equivalent use of substitute products is used for construction, and carbon dioxide saved (by not burning fossil fuels) if one ton of wood is burned as fuel instead of an equivalent energy use of fossil fuel. As can be seen, wood fuel does not keep as much carbon dioxide out of the atmosphere as wood substituted for more polluting products in construction. (data from Koch 1991, Kershaw et al. 1993)

hurting people, and people annoying rare and sensitive animals. If the reserve areas were far from cities, they would provide limited amenity value; people would continue to crowd into urban areas, and the urban problems of the last half of the 20th century would continue or increase.

Road maintenance, control of fires, and similar activities in the reserve areas would either be very expensive or not done without the production of wood to help support these costs. If they were done, they could cost an estimated $30/ha/year (Oliver and Lippke 1995). If all forests in the United States not in intensive plantations were managed as reserves without wood extraction, there would be 175 million hectares of such reserves with an annual maintenance cost of at least five billion dollars.

Without such management in reserves, there would be outbreaks of native and introduced pests such as the Asian Gypsy Moth (Pacific Northwestern United States) and the balsam woolly adelgid (United States' Great Smokey Mountains National Park) as well as fires in the overly crowded stands or following windstorms. The windstorms occur in all regions and commonly create tens or hundreds of thousands of hectares of overturned trees highly likely to burn without proactive management (Oliver and Larson 1996). And, the presently abundant, crowded stands would be difficult to thin either to prevent fires or to create understory or complex habitat (Fig. 3). With a lack of roads or logging infrastructure, these outbreaks would not be easily prevented, stopped, or recovered from.

The isolation and inaccessibility of these areas would mean that only those people with the leisure time to hike long distances and the money to pay for helicopters and similar means of travel could make use of them. These areas would become playgrounds for the rich while the poor remain isolated in cities. In regions and countries with high rural populations, resentment against the imposed reserve areas (with little value to these rural people) would lead to illegal burning of the forests, vandalism, poaching, and wood theft. To prevent these activities, law enforcement would be increased and/or people would be forcibly moved to cities. The result would be counterproductive to a present trend of trying to shift people away from urban poverty and welfare and into productive environments and employment.

Managing the Forest by Integrated Management

Alternatively, integrated management would allow much larger areas of the world to have wood economies because larger areas would be managed. To be successful, integrated management would not require zoning of other areas as reserves (Fig. 10), because the most economical land would be managed through integrated management and the other forests would be left idle, to become *de facto* reserves. Integrated management would provide more high quality wood, which provides more employment in secondary manufacturing facilities.

In addition, integrated management has the social benefits of providing employment, fire protection, and access to rural areas for people (Lippke and Oliver 1993, Oliver and Lippke 1995, Lippke *et al.* 1996). Integrated management could be applied both near urban centers and in distant, rural locations since the forest would be accessible, safe in places where necessary, and aesthetically pleasing. The diverse landscape, and the modern technologies, would allow people presently congested in cities to live in rural areas and have a safe and accessible environment as well as the infrastructure and technological amenities once confined only to urban areas.

Integrated management is sometimes assumed to involve immediate harvesting of all "old growth" (the complex struc-

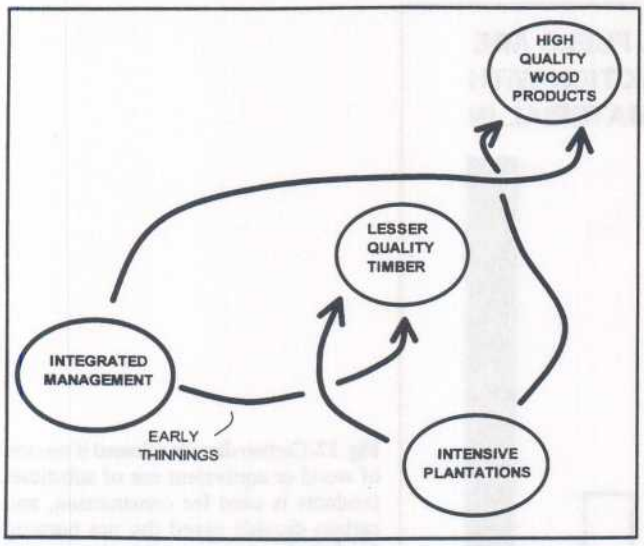

Fig. 13. Intensive plantations are incompatible with integrated management, since the less expensive clearcut harvesting of the small diameter, relatively low quality wood in plantations makes it economically difficult to thin the integrated management forests. On the other hand, the later harvest of high quality wood from areas managed by integrated management provide higher quality wood than the plantations (and cheaper low quality wood in the scraps and tops) and so make the plantations economically unattractive.

ture, Fig. 3) and replacing it with young, selectively harvested stands. This assumption is not necessarily correct. Since an objective could be to maintain the best quality of all structures across the landscape, existing "old growth" could be left, but supplemented with selectively harvested stands until sufficient amounts of "old growth" were provided. The other extreme – no harvest of "old growth" ever – could also be avoided, since there could eventually be cases where so much "complex" structure were provided that it could be appropriate to convert some to another structure which was in short supply. In that case, the "complex" structure that was less effective in providing the "old growth" functions could be converted to another structure through appropriate operations, including harvest and salvage.

Environmental Consequences of the Different Management Approaches

Each forest management approach would affect both the local and global environment in many ways. Since many of the effects are related, "biodiversity" will be used to describe the effects on the local environment and "carbon dioxide sequestration" will describe the effects on the global environment.

Biodiversity

Biodiversity (biological diversity) describes the variation in life forms, genetic makeup, biological processes and ecological niches (Wilson and Peters 1988). Too many species exist to try to protect each one individually. Alternatively, biodiversity can be promoted by maintaining the full range of habitats in which species are found.

Until recently, forest communities were thought to exist naturally in a benign steady-state, sometimes associated with "climax" or old growth forests. Preservation of all species, it was believed, could be done by maintaining the forest in this presumed "natural," old condition – especially avoiding human intervention.

This "steady state" paradigm is no longer accepted as scientifically sound (Botkin 1979, 1990; Botkin and Sobel 1975; Stevens 1990; Sprugel 1991). It is now accepted that many large and small disturbances periodically occur to forests. Forests change through a variety of structures with disturbances and growth (Fig. 3, Oliver and Larson 1996, Oliver *et al.* 1997). Each structure is suitable for some plant and animal species and not for others. As the structure changes, plant and animal populations change through migration, growth, dormancy, and death. Forests of various structures were somewhat randomly distributed across the landscape before human populations increased. When large areas of low human populations existed, relatively stable populations of plants and animals were maintained as periodic, random disturbances ensured that all forest structures were represented in the landscape.

Human pressures have shrunk the world's forests from about 8 billion hectares in 2000 B.C. (FAO 1993) to 3.45 billion hectares by 1995. If some of these forests are used for intensive plantations, the area available for a diversity of habitats will shrink even more. On the other hand, natural disturbances occur on the same scale as they always have. Today, a natural disturbance can impact a greater proportion of the remaining forest and upset the balance of habitats more easily than when the forest area was larger. The remaining forest is also more fragmented than it prehistorically was. Consequently, a large natural disturbance can also isolate species from suitable habitats more easily than when forests were not interspersed with highways, farms, and cities.

Given the smaller, fragmented forest area, the full range of species will be best protected by ensuring that the full range of structures always exists in the forests by proactive management – through integrated management.

Many forests in the United States and elsewhere exist in the species-poor "dense" structure of Fig. 3 because they grew after agriculture and grazing abandonment (Oliver and Larson 1996, Oliver *et al.* 1997). Zoning these forests as reserves would probably be less effective in providing habitats for endangered species needing the savanna, open, understory, and complex habitats than appropriate pro-active (integrated) management intended to provide these structures. Many United States national parks and other reserves are infested with exotic plants and animals (Campbell and Schlarbaum 1994). Some of these are threatening extinction of native species which can best be saved by proactive management, including selective weeding, pest control, and genetic breeding and replanting of native species.

All habitats can be provided with more certainty through integrated management than through the reserves approach. The access, inventory, and management infrastructure maintained in integrated forests can ensure that exotic pests and other unwanted plants and animals are detected and dealt with before they reach catastrophic population levels. In addition, the economic value of these forests to local people for employment, products, and values would ensure local people protect them rather than treat them as a nuisance to be burned, poached, or otherwise molested.

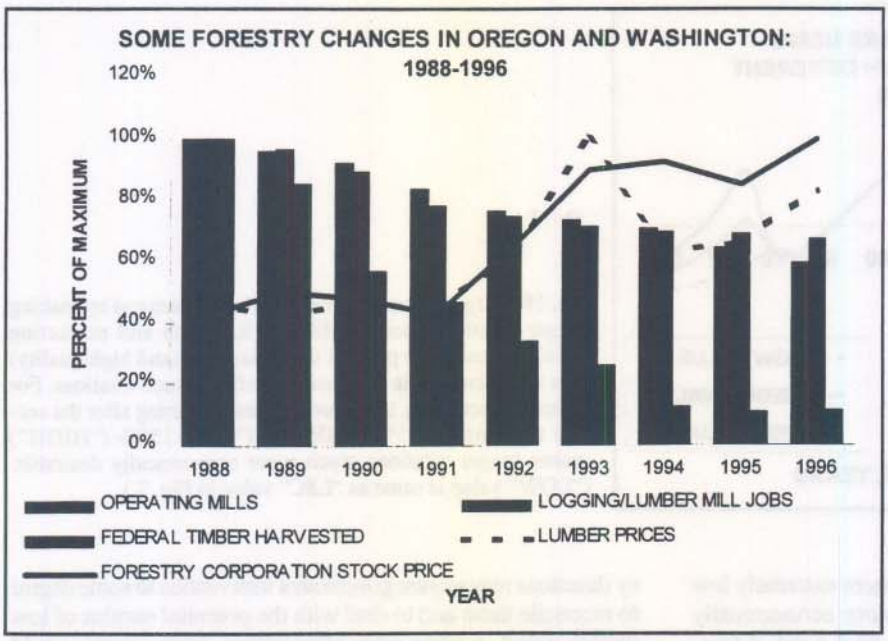

Fig. 14. Changes in forestry characteristics in Washington and Oregon, U.S.A., as National Forest and other federal wood quit being available because of ecological concerns. Many mills (primarily small, independent companies) went out of business and thousands of jobs were lost, while lumber prices increased as did the profits of private forest landowners and forest industry not dependent on federal wood. It is uncertain if these high lumber prices and profits will continue as surplus wood and substitute products from elsewhere in the world fill the demand (data from Paul F. Ehinger & Associates, Eugene, Oregon, U.S.A.); "jobs" in logging, sawmills, & softwood plywood/veneer; lumber based on Douglas-fir "2X4"; corporate stock price is from a large forest owner in Washington and Oregon taken from *http://.yahoo.com.*

Carbon Dioxide Sequestration

There is concern that the increase of carbon dioxide in the atmosphere is causing global climatic changes and other possibly deleterious effects. Forests can help reduce carbon dioxide emissions to the atmosphere in several possible ways. The greatest gain in reducing carbon dioxide is to use wood instead of substitute products made of steel, aluminum, concrete, or brick (Koch 1991, Kershaw *et al.* 1993). These substitute products consume more fossil fuels and add more carbon dioxide to the atmosphere than corresponding wood products (Fig. 12). A little carbon dioxide savings can be obtained by protecting old growth forests, and some carbon dioxide and fossil fuel savings can be gained by using wood instead of fossil fuel for energy. However, these gains are much less than the carbon dioxide savings gained by using wood instead of substitutes as construction products.

Setting aside reserves where wood harvest is avoided will do little to reduce carbon dioxide emissions into the atmosphere. Intensive plantations can provide wood to help avoid carbon dioxide emissions, but at a tradeoff of establishing reserve areas to make the plantations economically feasible. In addition, the relatively low quality of plantation-growth wood may not make strong products to substitute well for steel, aluminum, concrete, and brick.

Globally, integrated management would provide large amounts of high quality wood that could be used as an environmentally sound substitute for steel, aluminum, brick, concrete, and similar non-wood building materials. In this way, less fossil fuel would be consumed and less carbon dioxide would be added to the atmosphere.

The Conflict Between Intensive Plantations and Integrated Management

A further consideration in deciding upon forest management approaches is that the integrated and intensive plantation approaches are relatively incompatible, because each makes the other economically unfeasible (Fig. 13). Attempts to manage forests by the integrated approach could be blocked by intensive plantations because the integrated approach requires thinning of dense stands to provide the understory and complex structures. These thinnings are costly, and the availability of similar, cheaper wood by clearcutting plantations could make such thinnings economically unfeasible. On the other hand, harvest of high quality wood from forests managed by the integrated approach could make the intensive plantations economically unfeasible. The high quality wood would outcompete the plantation wood for high quality uses; and the residual ends, slabs, and cores from the high quality wood would be cheaper for low quality products than the wood harvested from plantations – since the cost of harvest of this low quality product would be borne by the high value portions of the log.

Future Roles of the Different Management Approaches

Each management approach could be applied to large or small areas in the future, depending on future conditions. An exhaustive discussion of this subject is beyond the scope of this paper; however, the subject could be examined from two perspectives:

- if forest management were subsidized for some other objective;
- if the forest were expected to make a profit for the landowner by growing and selling timber and fiber.

Forest management could be subsidized for such objectives as providing a secure supply of wood for a mill, providing a strategic resource for a country, or providing enough wood for a mill owner to manipulate the price of other wood it purchases on the open market. In these cases, the management decision would be only partly based on the discussion above.

If forest management were based on making a profit by growing and selling wood, then different future global wood supplies and demands could lead to different approaches having the advantage. For example, if future supplies and demands led to a moderate surplus of low quality wood but a shortage of high quality wood and their substitutes, integrated management

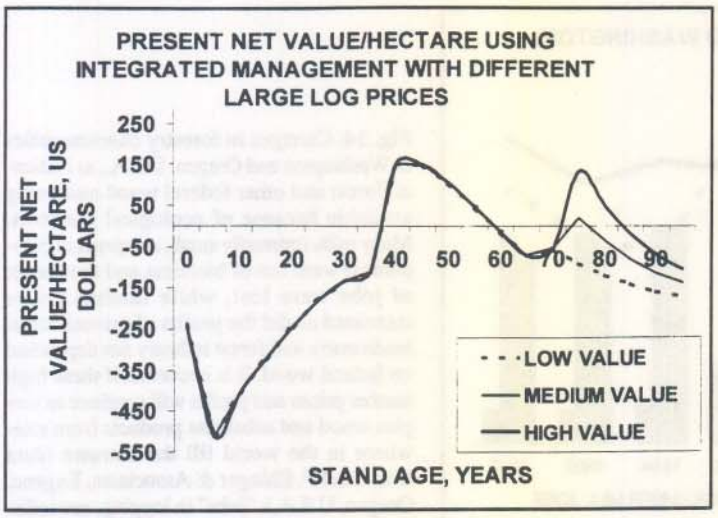

Fig. 15. Integrated management can be encouraged by making longer rotations more profitable. Research and marketing which increases the price of large diameter (and high quality) logs will increase the economic benefits of such rotations. For example, increasing the value of trees remaining after the second thinning by 75% ("MEDIUM") and 150% ("HIGH") makes longer rotations much more economically desirable. ("LOW" value is same as "LSC" value in Fig. 7.)

would be relatively advantageous except where extremely low costs of plantations made them much more economically feasible than the example shown. On the other hand, if fluctuating markets (e.g., Fig. 14) created temporary shortages of low quality wood, plantations may be economically feasible if they were strategically placed. Other future conditions could make each management approach more or less economically feasible.

The Dilemma of Forest Management

Many forest landowners are in a dilemma. On the one hand, managing intensive plantations may be economically unfeasible unless much of the world's forests are reserved from wood harvest — a political improbability. On the other hand, these landowners are prohibited from integrated management for several reasons:

- Publicly traded wood corporations have difficulty practicing integrated management, because the high value of the standing forest using integrated management makes them subject to hostile takeovers, followed by rapid harvest of the wood to repay the cost of the takeover.
- In the United States, non-industrial private landowners have difficulty practicing integrated management because they must pay estate taxes upon death of the owner. These payments commonly entail harvest of the forest to generate cash to pay the taxes.
- In most areas, the first thinning needed to practice integrated management is not independently profitable from both cash flow and investment perspectives; therefore, these thinnings are often not done.
- Since many forest landowners in the categories above can not manage by integrated management, it is not in their best interest to encourage other forests to be managed by integrated management — at greater profitability — and so undercut their own profitability.

Trends in Forest Policy to Resolve the Dilemma

Forest policy is presently moving in several directions, with some policies encouraging intensive plantations and other policies encouraging integrated management. The various policy directions may require government intervention to some degree to reconcile them and to deal with the potential surplus of low quality wood. Among other alternatives, governments could prohibit harvest of most of the world's forests and promote intensive plantations on the remaining area, or they could actively promote integrated management through various incentives and/or restrictions. Unless a consistent policy emerges, there will probably be confusion in forest management that could last for decades. This confusion would be to the economic, social, and environmental detriment of most of the public and most forest landowners.

Several of the directions of forest policy are described below:

Zoning between Reserves & Intensive Plantations

Many presently growing plantations will be harvested during the next two or more decades. Some of the younger ones can be thinned to provide more harvest flexibility and diverse products, and so can be treated more like forests managed by integrated management. It is too late to thin others, and they will be harvested before they physically die and all investment is lost. Whether or not the plantations are economically successful, owners will harvest them to recover at least some investment. While these plantations are being harvested at an economic loss, it will be difficult to manage forests by the integrated approach.

To recover as much investment in these plantations as possible, it will be within the best interest of plantation owners both to discourage other landowners from managing by the integrated approach and to promote an artificial wood shortage. The integrated management approach could be discouraged by providing barriers to the first thinning. Without wood from thinnings as competition, plantation wood would be worth more; and, the unthinned forest would grow like incidentally managed forests which provide lower quality wood than integrated management does. Without the high quality wood from later thinnings and final harvest, there would be less residual, inexpensive low quality wood from tops, slabs, etc. to further compete with the plantation growth wood.

An artificial wood shortage could be promoted by zoning certain forests as reserves, thus excluding commodity extraction. The consequences would at first seem similar to the con-

sequences of agriculture reform in the United States in the 1930s – 1950s: the limited wood supply would raise wood prices high enough to make intensively managed plantations economically viable. Limiting the supply has been very successful in agriculture and at first appears successful in forest management (Fig. 14). However, similar attempts to limit oil supplies (and hence keep prices high) have been less successful. Intensive wood plantations will probably have the same result as oil management. There probably is, and will be, so much low quality wood in the world that it will be virtually impossible to exclude harvest from enough forests to make intensive plantations economically feasible in the long term.

Private forest owners in the United States' Pacific Northwest realized high profits when the President's Northwest Forest Plan artificially created a local wood shortage (Fig. 14). These profits will probably decline as global wood resources, mills, and substitute products respond to the changed supply. The result may even be that a glut of products and very modern facilities elsewhere in the world will reduce the profitability of private forest owners and the remaining wood processing mills in the Pacific Northwestern United States. A similar pattern of temporary profits followed by reduced profitability occurred in the petroleum industry when an artificial shortage was instigated in the 1970s.

Such induced shortages can make nearby plantations temporarily profitable until the world wood supply and location of mills adjusts. It may be that a series of such induced shortages will occur in different places during the next few decades if interest groups successfully convince policy-makers that such reserves are desirable. In such a case, plantations can appear profitable if appropriately located during the times of shortages.

In the long run, it may prove ecologically, socially, and probably politically problematic to reserve enough of the world's forest land to make intensive plantations economically feasible, as described earlier.

Restricting Intensive Plantations

Another emerging trend is to restrict intensive plantation management. This restriction is already occurring and is taking the form of insisting that wood only be provided from forests which sustain biodiversity, e.g., forests that provide the full range of stand structures (Fig. 3). This range and balance is not provided by intensive plantations, but is provided by integrated management.

The insistence is being done in several ways. Some organizations are promoting certification, whereby wood grown in forests that sustain biodiversity and other values are labeled as "certified." Some governments are permitting use of only certified wood. In the United States, some landowners are developing "habitat conservation plans," which are agreements with the government that the landowner will maintain selected or all habitats in exchange for their assurance of harvest where endangered species might be found. In many parts of the United States, landowners may only be allowed to harvest wood from riparian zones if done in an integrated management approach. As countries become frustrated because their residents can not profitably thin or harvest their own forests – because of the large volume of imported, plantation-grown wood – they may increase support of these and other efforts to discourage intensive plantation management.

Unless phased in, the restrictions could be economically problematic for forest plantation owners – and ecologically harmful as well. If they could not sell the wood, the plantation owners would not harvest the stands and so would obtain no money from their efforts. Until global wood resources and mills responded to the changes, there would be economic shortages and increased use of more substitute products. The unharvested plantations would create fire and insect hazards – and would still not provide a diversity of habitats.

A gradual phasing in of restrictions on the proportion of ownership allowed in plantations, and mandates of the proportion of area that needs to be in each structure, may be successful. This phasing in would allow landowners to make the transition to "integrated management." Like the Clean Water Act in the United States, such restrictions and promotions can not be adopted by an individual without putting him at an economic disadvantage. They would need to be imposed on all landowners to ensure that those complying do not become economically bankrupt. Imposing such goals of morally acceptable behavior internationally would be consistent with previous child labor and human rights mandates; however, it would expand such mandates to environmental protection.

Such a mandate of forest biodiversity would cause a dramatic change in the way many landowners managed their forests. However, it would allow publicly held corporations to manage their forests for high quality wood without the fear of hostile takeovers. For small landowners in many countries, it would be an economic stimulus, rather than a regulation – especially if laws in each country were crafted which provided financial help for the first thinning.

Economic Incentives for Integrated Management

Many economic incentives have been proposed to encourage landowners to practice integrated management (Lippke and Oliver 1993, Bourland and Stroup 1996, Kennedy *et al.* 1996, Lippke and Fretwell 1997). The basis of these incentives is that the public should compensate landowners for providing such public values as biodiversity on their lands. Various environmental groups could "rent" a continuing amount of stand structures for targeted species from a landowner, even though the location of each structure could change with time. The landowner would thus receive money for managing stands to the "complex," or other structures.

In the United States, an incentive could be the changing of estate tax laws on forests (e.g., deferring estate taxes until time of wood harvest).

Similarly, integrated management would be encouraged by financial assistance which would make the first thinning profitable, or by a loan against the wood value which would give the landowner liquidity without harvesting the wood.

Any research, marketing, or other measures to increase the value of high quality wood would make integrated management more economically desirable (Fig. 15). The strong ability of high quality wood to keep carbon dioxide out of the atmosphere by using it instead of more polluting substitutes could make carbon credits a suitable way to encourage landowners to practice integrated management.

Acknowledgments

The Department of Renewable Resources acknowledges the following list of donors to the Forest Industry Lecture Series:

Alberta Forest Products Association, Alberta Department of Environmental Protection – Alberta Lands and Forest Service, Alberta Research Council – Forest Resource and Business Unit, Ainsworth Lumber Co. Ltd., Alberta Alumni Association, Alberta-Pacific Forest Industries Inc., Alberta Newsprint Company, Association of Registered Professional Foresters of Alberta, Beck Consulting, Canadian Forest Service – Northern Forestry Centre, Canadian Institute of Forestry / Rocky Mountain Section, Daishowa-Marubeni, Mr. Con Dermott Consulting, EZRA Consulting, The Forestry Corporation, Genstat Consulting, Hasselfield Forestry Consulting Services, KPMG Consulting, Millar Western Industries Ltd., Silvacom Ltd., Simons Reid Collins Ltd., Mr. Clifford B. Smith Consulting, Sundance Forest Industries Ltd., Sunpine Forest Industries Ltd., Tall Timber Forest Service Co. Ltd., Timberline Forest Inventory, Weldwood of Canada Ltd. – Hinton Division, Weyerhaeuser Canada Ltd.

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