Journal of Tropical Forest Science 11(1):255–269 (1999)

THE SOCIAL AND ENVIRONMENTAL IMPORTANCE OF FOREST PLANTATIONS WITH EMPHASIS ON LATIN AMERICA

J. L. Whitmore

Vegetation Management and Protection Research, USDA Forest Service, Washington Office, 14th & Independence SW, P.O. Box 96090, Washington, DC 20090-6090, United States of America

Received May 1998

WHITMORE, J. L. 1999. The social and environmental importance of forest plantations with emphasis on Latin America. As long as the demand for wood products is not reduced, these will more and more have to be produced in forest plantations. In the next century, without silvicultural plantations, a great shortage of wood will likely result. Currently the world-wide harvest of wood is from three main sources: 1) primary forest, 2) secondary forest, and 3) plantations. Each of these sources produces about a third of the global harvest now, but the plantations portion is increasing. In Latin America there has been a strong tendency to use exotic species in forest plantations, largely with great success. Recently there has been progress in research to analyse the favourable and unfavourable conditions for successful introduction of an exotic species. Our ability to predict beforehand the probability of problems has improved greatly with models which distinguish whether a species offers low, medium or high risk of invading a site if we introduce it as an exotic. Without a doubt, a massive programme of intensively cultivated plantations, utilising unforested, marginal lands, can supply a major part of the wood society needs, and other benefits as well, including a diminished pressure on native forests. A combination of intensively cultivated plantations, native forests under extensive management, and protected areas set aside for biodiversity and similar non-wood benefits is the model most likely to succeed during the next century.

Key words: Forest plantations - intensive silviculture - wood harvest - fibre production - Latin American forestry

WHITMORE, J. L. 1999. Kepentingan sosial dan persekitaran di ladang hutan dengan penekanan kepada Amerika Latin. Selagi permintaan ke atas pengeluaran kayu tidak berkurangan, selagi itulah lebih banyak kayu perlu dihasilkan di ladang hutan. Di abad yang akan datang, ketiadaan ladang silvikultur akan menyebabkan kekurangan kayu dengan banyaknya. Pada masa ini pengusahasilan kayu secara meluas datangnya daripada tiga sumber utama: (1) hutan primer 2) hutan sekunder, dan 3) ladang. Setiap sumber menghasilkan lebih kurang satu pertiga daripada pengusahasilan dunia pada masa ini. Bagaimanapun sumber daripada ladang kian bertambah. Di Amerika Latin terdapat kecenderungan yang kuat untuk menggunakan spesies eksotik di ladang hutan dengan jayanya. Baru-baru ini terdapat kemajuan dalam penyelidikan untuk menganalisis keadaan yang sesuai dan tidak sesuai bagi menjayakan pengenalan kepada spesies eksotik. Kami telah meningkatkan lagi keupayaan untuk meramalkan terlebih dahulu masalah yang mungkin dihadapi dengan menggunakan model yang dapat membezakan sama ada sesuatu spesies menawarkan risiko yang rendah, sederhana atau tinggi jika ia menceroboh tapak eksotik yang kami perkenalkan. Tidak syak lagi, satu program penanaman ladang secara intensif yang menggunakan tanah marginal

tidak berhutan dapat membekalkan sebahagian besar keperluan kayu kepada masyarakat, serta manfaat lain, termasuk tekanan yang semakin berkurangan terhadap hutan asli. Satu gabungan hutan yang ditanam secara intensif, hutan asli di bawah pengurusan secara meluas, dan kawasan yang dilindungi untuk faedah biodiversiti serta faedah bukan-kayu yang sama merupakan model yang dijangka akan mencapai kejayaan pada abad akan datang.

Introduction

In Latin America and elsewhere there are various subjects of great importance in the field of forestry. These include the subject of plantations, which is no more, nor less, important than the others. Forest plantations constitute an integral part of ecosystem management. In this paper I will emphasize plantations (as opposed to native forests), mainly in Latin America. Included will be the environmental and social aspects, with the economic considered as part of the latter.

Until the demand for wood products is reduced, these will have to be produced more and more in forest plantations. This is true for two reasons: a) with an increasing world-wide population, there is an increasing demand while at the same time the quantity and quality of the forests are decreasing; and b) there is an increasing tendency world-wide to utilise the forest for its non-wood benefits, resulting in an enormous pressure to not harvest trees in native forests.

This pressure is not new and to a certain point it is easy to understand. There are important reasons for protecting a portion of the native forests in each country and using the other portion for the production of wood-related benefits, at least in countries blessed by an adequate amount of forest resources. But the controversy begins in reaching agreement on the definition of "adequate" and in determining how large the portions should be.

Those who reject the harvesting of trees in native forests claim that, without this harvesting, the forests will be saved. Unfortunately, in the majority of countries the harvesting of trees is not the main reason for the destruction of forests. There are other major problems that influence the destruction of forests in Latin America, Asia, Africa and other continents that have nothing to do with tree harvesting. These include poverty, which leads to the well-known and traditional "felling and burning", and the conversion of forests for cattle ranches or for other reasons. These two factors constitute the main reason for deforestation in countries of the third world, although tree harvest is the main cause in a few countries.

Sooner or later, the persons who oppose plantations with the idea of preserving nature and natural forests will have to support forest tree plantations. Protecting natural areas and their germplasm is an excellent goal, but achieving this will depend on the productivity of plantations in order to satisfy human needs such as wood, paper and renewable construction materials. It is simply impossible to preserve all the forests or even half of them. But it is possible to manage them in a controlled and sustainable manner by utilising intensive silviculture techniques for plantations where there are no longer healthy forests; extensive silviculture techniques in areas declared as forests for sustainable production based on natural

regeneration; and techniques for the protection of natural areas where there are species in danger of extinction or to preserve examples of ecosystems and their germplasm.

These days we know how to manage our forests. However, many forests are being exploited without the benefit of silvicultural methods designed to maintain the productivity and sustainability of the site (Whitmore 1992). It is also important to emphasize that it is not necessary to destroy a healthy and diverse natural forest in order to put in its place a forest plantation. There are many sites in most countries where plantations can be established without removing the original forest. Every year we see more sites like this due to deforestation (Sedjo & Botkin 1997, Bowyer 1998). The successful case of Jari in the Brazilian Amazon, where native forest was converted to planted forest, is an exception that does not have to be repeated (McNabb *et al.* 1994). In the case of a native forest that exists on soils truly appropriate for agriculture in a country with a shortage of food, it is assumed that there will be a justification for converting it to agricultural use, but these days it is rare to find soils of this quality under a forest. Of course, in a country such as Guyana or a region such as the State of Amazonas in Brazil, where there are many forests and few people, there is little need to establish forest plantations (Franco 1997).

The only hope for forests is good management (Gómez-Pompa & Bainbridge 1995). The conservation of forests implies rational long-term use, and requires sustainable forest management, normally for various purposes, one of which will be predominant. For example, a forest near a city is a critical area for the production of water and this would be the primary use. But perhaps the site is also used as a home for wildlife and for the limited harvesting of wood and non-wood products. It will possibly be used for limited recreation as well.

But there are political forces that prefer preservation to conservation, insisting that there is little place in sustainable management for the harvesting of wood products. This controversy is not new; it is more than one hundred years old. The well-known United States forester Aldo Leopold (1949) wrote the following ideas (paraphrased) on this subject:

> We foresters consist of two groups. Group A considers land as soil with the principal function of production. Group B considers the land as a biota with a broader function. The question is how broad is that function, and that is where the doubt and confusion begin.
>
> Group A is content to produce trees as if they were agricultural produce, with cellulose as the basic product. Its ideology is agronomic. On the other hand, group B considers the practice of forestry as different than agronomy since it manages species and natural environments instead of artificial ones. This group prefers natural regeneration. They are concerned, for biotic and economic reasons, with the losses of species such as the American chestnut. They are also concerned about a range of functions of secondary forests, e.g. wildlife, recreation, drainage basins and wild areas. All of this implies the beginnings of ecological awareness.

At the same time as Leopold, an ecologist at the Panamerican Union warned us about the "agronomic ideology", with several examples in Latin America (Vogt 1948). More than 80 years before Leopold and Vogt, George Perkins Marsh wrote about the subject (Marsh 1864). And, at the same time as Marsh, President Tomás Cipriano de Mosquera of Colombia approved a forest law to protect Colombian forests (Castrillón Arboleda 1994).

What does all of this have to do with forest plantations? It seems to me that Leopold's group A is right provided some of the forests are managed as natural sites without changing them. And it seems to me that group B is right in the sense that without any control all the forests in the world are in danger, which harms all of us. It also seems to me that the two groups have to cooperate to resolve the matter and that plantations could be, and will have to be, the common ground between them. It is quite certain that in the next century there will be a scarcity of food without agronomists. Also, without the silviculturists' plantations it is very probable that there will be a great scarcity of wood, and many more forests ruined by over-exploitation. Although techniques exist for managing native forests sustainably, many forests continue to be exploited without using these techniques, and plantations can alleviate this problem.

The purpose of forest plantations

Evans (1992) states there is no scarcity of wood in the world and thus asks why there is so much emphasis on planting forest trees? Obviously, there is a scarcity in some regions and an excess in others. However, Evans's analysis indicates various possible purposes for forest plantations. His ideas on purposes, and those of others, are summarised below.

- To correct a lack of resource caused by deforestation. Previously certain countries had many forests but are now left with very few. Some of them are trying to supplement their needs with tree plantations.
- The need for pulp and paper products. Utilising sophisticated techniques, the annual per hectare yield in plantations is frequently very high (Bowyer 1998). In addition, the option of installing plantations costs more than natural regeneration (see, for example, Tables 1a and 1b), which requires high yields for these products.

Table 1a. Requirements for establishing forest plantations at the industrial level (Ladrach, in Wadsworth 1997)

— Public relations	— Fertilisation
— Land acquisition and tenancy	— Mapping
— Protection of existing natural forests	— Maintaining boundaries
— Planning roads and firebreaks	— Selecting species
— Determining rotation	— Estimating yields
— Seed source	— Establishing nursery
— Site preparation	— Spacing and thinning
— Planting methods	— Fire control
— Pest control	— Good record keeping
— Training the crew	— Training the contractors

Table 1b: Principal risks in forest planting (Ladrach, in Wadsworth 1997)

— Wildlife	— Pests
— Mistake in choosing site-suitable species	— Quantity and quality of seed
— Problems in nursery and planting	— Unsatisfactory wood quality
— Poorly trained crew	

- An increase in the demand for high-quality products. Plantations of teak, mahogany, Spanish cedar and other fine species have the purpose of satisfying part of this demand (Sedjo & Botkin 1997).
- The need to export. Some countries have the opportunity to develop a forest-products export industry and sometimes this industry is based principally on forest plantations. Chile and New Zealand are two of the best examples.
- Domestic uses. In some countries almost all of the wood that is harvested is used for firewood, posts and home fences. Some populations suffer from an acute scarcity of wood and it is here that the forest plantation can have a very positive and beneficial effect for the community and for the country.
- Degraded sites. Forest plantations, sometimes jointly with agricultural crops, can restore a site that has been ruined by a previous inappropriate use (Haufe 1981, Parrotta 1992).
- The danger of gene extinction. The forest species most used for plantations are very valuable. Stands of superior trees should be protected for the seeds they provide. But sometimes these stands are in danger, for example from the invasion of agriculture. In such a case, it is appropriate to conserve its genes *ex situ,* in plantations far removed from danger (Gallegos *et al.* 1981).
- Lack of access. Even in countries that have forests in large quantity, problems can occur if the forest is not accessible. In cases like this, it may be that the plantations established on those marginal sites with no higher use can solve two problems: the lack of accessible products and the lack of use of previously unproductive sites.
- Lack of success in natural regeneration. In forests that are managed on the basis of natural regeneration, this regeneration sometimes fails to become established. In some cases, especially where the cost of manpower is not very high, an enrichment plantation can be established to renew the forest.
- Little population per unit of land area. In some countries there is much underutilised, unforested land, such as the llanos of Venezuela, for example. Planting forest trees in such areas can be of great use for future production and can protect the land from erosion. Even in overpopulated countries, such as China for example, plantations established on very degraded sites can improve such sites for future uses (Lugo & Liegel 1987, Parrotta 1992, Lugo 1997, Parrotta *et al.* 1997b) and at the same time protect watersheds (Burley *et al.* 1992, 1994).

- Advantages of forest plantations:

  * Plantations can produce wood ten or even up to twenty times more rapidly than the native forest under optimal conditions (Bowyer 1998), although some estimates are lower than this (Sedjo & Botkin 1997).

  * Normally they consist of a single species (although there are many examples of success with mixed plantation (Wormald 1992, Smith *et al.* 1997) that provides a source of uniform wood that is easy to process and sell.

  * A plantation uses the site to the maximum from the commercial point of view, compared to a natural forest, which utilises it to the maximum from the viewpoint of biodiversity. The former maximises the profit, with more risk, and the second minimises the risk, usually with less profit.

  * The cost of harvesting per cubic meter of wood is minimised with plantations.

  * Spacing, thinning and rotation factors can be easily manipulated in plantations.

  * Genetic improvements can be applied in plantations in order to select against insects, diseases or defects, or in favour of shape, rate of growth, density of the wood or other factors.

  * Plantations in tropical zones have the advantage of growing continually for twelve months a year where water is not a limiting factor.

- Non-traditional purposes:

  * The traditional purpose of planting forest trees is to produce wood for local use and/or export. However, plantations can serve other purposes as well, together with or apart from the goal of wood production.

  * As Lugo (1997) has indicated, various purposes can be assigned to plantations: to maximise the production of benefits such as wood, or for restoration objectives, protection against erosion, etc.

  * Rural development is another purpose. A plantation project may generate jobs, create resources where there were none before, improve the quality and quantity of the water produced in a watershed, utilise low-value land, help create infrastructure in underdeveloped zones and supplement agricultural efforts through agricultural, silvicultural and grazing methods (agroforestry).

* Plantations can provide firewood, forage, shade and home construction materials.

* In order to support agriculture, plantations are used as windbreaks and protection of water sources for irrigation.

* There are uses for improvement of urban sites as well. The majority of the citizens of many countries live in urban areas. Planting of trees can improve the quality of life. Urban shade is a very important "forest" product (Schubert 1979).

* Plantations may improve the biodiversity of a site previously ruined by agriculture, animal grazing or cutting of the forest.

* Recently, in the Kyoto Agreement (1997), the industrialised countries that contribute to most of the world's pollution proposed to finance action plans in tropical countries in order to capture the carbon produced by industry. Called "carbon offset", it is a very controversial idea. However, at present thousands of hectares of plantations are being established in tropical areas, for example in Costa Rica, under similar programmes for the purpose of capturing in one country the carbon produced in another.

A large degree of the variation in the purposes of forest plantations is due to the various goals among owners of forest land and among political groups interested in the forest resource. Other variation may be due to the many species and ecosystems involved. Despite so much variation, the future of plantations points to a large increase in the rate they are established during the next several years.

Woody agriculture or sustainable forest?

At present, the world wood harvest comes from three principal sources: 1) the primary forest (e.g. Canada, Russia, the Amazon, Indonesia and Malaysia), 2) the secondary forest (e.g. the United States, Canada, Russia and Europe) and 3) plantations (e.g. Scandinavia, the southeastern United States, Japan, China and India with regard to indigenous species, and Brazil, Chile, Venezuela, Uruguay, Argentina, New Zealand, Australia, South Africa, Indonesia, Thailand and the Iberian Peninsula with regard to exotic species). Each of these three sources produces approximately one-third of the overall harvest (Table 2). The proportion produced in plantations is increasing (Sedjo & Botkin 1997).

In the debate over exotic versus indigenous species, it is argued that exotics are always better than indigenous species, or that exotics should never be used, or that the truth falls between these two extremes. In Latin America there has existed a very strong tendency to use exotic species in plantations, for the most part with great success. There have been problems with plantations of indigenous species, for example with mahogany and Spanish cedar (Whitmore 1976 a & b). But for

the last twenty years research on the use of indigenous species in forest plantations has been rather successful, especially in tropical areas. There are now good options that compete with exotic species (Espinoza & Butterfield 1989, Russo & Sandi 1995, Prebble & Leigh 1997).

Table 2. Total industrial wood harvest, by forest type (Sedjo & Botkin 1997)

Type	Harvest (percentage of total)
1. Primary forests	30*
2. Secondary forest, minimum management	14
3. Secondary forest, managed	22
4. Industrial plantations, native	24
5. Industrial plantations, exotic	10
Total	100

1. Includes forests in Canada, Russia, the Amazon, Indonesia and Malaysia
2. Includes forests in parts of the United States, Canada and Russia
3. Includes forests in North America, Europe and Russia
4. Includes plantations in the Nordic regions, much of Europe, the southern United States, Japan and parts of China and India
5. Includes plantations in Brazil, Chile, Venezuela, Uruguay, Argentina, New Zealand, Australia, South Africa, Indonesia, Thailand and the Iberian countries

* The percentages are *estimated*.

There has been a lack of silvicultural information on native species. For the high Andean zone there are now good data on 40 native species that have been abused for centuries (Loján Idrobo 1992). But more study is needed on how to manage them in plantations. These species are adapted to high altitudes where very few exotic species can grow. The zone is an agricultural area with human populations that depend greatly on the wood resource, up to the point of having destroyed it in many cases. Planting of some of these species could substantially alleviate the pressure on the little resource that is left, and enhance the quality of life for many people.

But perhaps we need to analyse what we mean by "indigenous species". For example, let's say that *Swietenia macrophylla,* or Honduras mahogany, existed for thousands of years on a certain hill in Costa Rica until the year 1966 (a hypothetical case). In 1966, a rancher felled the entire forest on this hill in order to pasture his cattle there. For seven years it was highly overused by the cattle, with a load double what it could support. The rancher went bankrupt and the hill was very degraded. The new owner of the hill tried to plant mahogany on the site, recalling that there was a mahogany forest there before. But the plantation failed!

The question is: should or should not the mahogany be considered indigenous to this site under these conditions? Possibly what was indigenous before may not be so any more. Possibly, in order to restore a site that has been degraded in this way more drastic measures are required. For example, it may be necessary to plant a species that never before existed on this site but that has earned a reputation for facilitating recovery of degraded sites (Parrotta 1992, Brown & Lugo 1994, Lugo 1997, Parrotta *et al.* 1997a, 1997b).

Concerning monocultures, Ewel (1991), an ecologist, analysed the issue and recommended to his colleagues that they take a "balanced" attitude, i.e. to not automatically reject a project only because it involves use of monoculture. Others have also studied the question of forest monocultures (Popovich 1980, for example). The principal points they make include the following:

- Whether for grapes, bananas, pine, teak, eucalyptus or other products, much land has been devoted to commercial crops for socio-economic purposes through the use of monocultures and frequently exotic species. This can be justified, even if many times these activities require the best land.

- There are large differences between forest monocultures and agricultural monocultures. For example, forest species monocultures usually use several genotypes instead of just one (Popovich 1980), and these often are wild, rather than domesticated genotypes. Genetic diversity has not been bred out.

- Considering the hundreds of thousands of square kilometers that are planted in monocultures every year, it is surprising there are not more problems with diseases and insects (Ewel 1991). Obviously a plantation using intimate mixtures or small mixed blocks of monoculture will have more protection against these problems. In the case of a forest species with its complete and original genetic complement (which is the case with the majority of species used in plantations), this species may be very attack-resistant compared to an agricultural species or a highly modified forest species, such as certain eucalyptus clones for example.

- In cases where a native forest has been felled in order to establish these activities, a diverse forest has been changed into a very "simplified" ecosystem, which involves advantages and disadvantages. Generally, this practice should be avoided, given the advantages inherent to native forests.

- Imitating the structure and function of natural communities in our agricultural (and silvicultural) systems may be desirable ecologically, but involves serious management problems (Ewel 1991).

- Without employing monocultures and exotic species, we would have to use many more hundreds of thousands of square kilometers of native forest to satisfy human needs. For this reason it may be that monocultures are justified even if the price we pay — the biodiversity of some sites — is high (Ewel 1991).

The purpose of using exotic species varies in each case, but it normally includes many of the advantages mentioned earlier (Table 3). The main danger in using an exotic species is the possibility that it will adapt to the site with such success that it turns into a weed. An exotic species can begin reproducing uncontrollably and

do great damage to the indigenous flora under certain conditions. There are a number of examples, including *Melaleuca quinquenervia* in Florida, *Leucaena leucocephala* in the Virgin Islands, *Ailanthus altissima* in the eastern United States and various species introduced into the Hawaiian Islands. How to define these conditions has always been a challenge and remains so. We have sometimes depended on "luck" and the result, in addition to the damage to the ecosystem, has been political pressure against the introduction of exotics.

Table 3. Why exotic species tend to have better yields than native species (Wright 1976, in Wadsworth 1997)

— Natural selection favours survival more than economic factors.
— Environmental changes proceed faster than the evolutionary response.
— Human-induced changes do not produce an evolutionary response.
— Evolutionary possibilities are limited by the native flora.
— Native species may be destroyed by introduced pests.
— Native species may be sensitive to the shock of planting.
— The natural distribution of a species may be limited by factors unrelated to its yield.

Recently there has been progress in the analysis of suitable and unsuitable conditions for the successful introduction of an exotic species. Our capability of predicting in advance the probability of problems has been considerably improved with the use of models prepared at the University of Washington which help determine if a species offers a low, medium or high risk of invading the site when introduced as an exotic (Reichard & Hamilton 1997). Also, Australia has implemented similar procedures to reduce the risk of introducing pests (David Flinn, personal communication).

There are various levels of intensity in forest planting. One very low intensity level is the practice of enrichment. When regeneration has failed in a secondary forest, it is sometimes possible to improve the composition of the forest by planting seedlings of desirable species among the secondary vegetation. This requires much manpower in order to cut strips or lines in the forest perhaps 2–3 meters wide with 5, 10 or 15 meters between lines. It also requires quite a bit of cleaning during the early years to avoid having weeds dominate the plantation (Smith *et al.* 1997). There are various examples of success, such as mahogany in the Caribbean National Forest in Puerto Rico, a mixture of five species (including mahogany) in the Tapajos National Forest south of Santarem, Brazil, and in Surinam with Spanish cedar and other species.

Agrosilviculture in its various forms represents another intensity level. The use of trees planted among crops or on grazing land has a variety of purposes and methods and is described in dozens of publications, including Valdivia & Cueto 1979, Denevan *et al.* 1987, Vega Condori 1987, Smith *et al.* 1997, Wadsworth 1997, Hartshorn & Whitmore 1998.

The planting of forest trees sometimes requires many years to achieve a harvestable product. During this time, the landowner will want to receive some profit from the land before the tree rotation is completed (Smith *et al.* 1997).

Agrosilviculture is a method for achieving this and is an attractive method, not only for the farmer. Large industries sometimes use agrosilviculture to receive income from the land during the first few years after trees are planted. An example in Chile has been the El Tollo farm near Quirihue (Whitmore & Burwell 1986).

At the higher level of intensity, plantations can have the characteristics of "woody agriculture" rather than silviculture. Some use agricultural land, pesticides, fertilisers and perhaps irrigation. The rotation lasts longer than one year and the plant that is harvested normally (but not always) measures ten meters or more in height, which distinguishes this practice from agricultural crops. In the future, we will see much more use of "woody agriculture" to satisfy the world's need for fibre.

This should result in a more sustainable native forest because it should reduce the need to harvest such forest intensively. But how sustainable will intensive plantations be? The answer depends perhaps on each person's point of view. Those who compare it with a native forest will remain dissatisfied. Those who recognise the need to produce fibre on currently unproductive land that has little biodiversity may justify intensive planting in order to protect the native forests . Those who compare it with activities that are truly agricultural and intensive, such as sugar cane and rice, will have to declare that it is a more sustainable and less damaging system than many alternatives. The Forest Stewardship Council (FSC) recognises that plantations can serve an important, and sustainable, role, under conditions which are described in their "Principle 10" (FSC 1996).

Using already existing silvicultural techniques (fallow land, crop rotation, fertilisers, etc.) based on ecological science, we can produce intensive forest plantations on any given site, probably forever. And plantations that use longer rotations of some 10–30 years, for example, can promote or improve the biodiversity of a degraded site (Lamb 1997).

Conclusion

The forests have always been heavily used by human beings. They provide us with food, construction materials and other resources and benefits. They also play a very important role in the health of the biosphere since they affect the atmosphere, erosion, the hydrological cycle, the carbon cycle and other biochemical cycles (Sedjo & Botkin 1997). Plantations provide us with many of these same benefits, but not all of them. A well planned plantation can provide us with many more benefits than one planned for a single purpose.

Some suggest that almost all of the wood we need could be produced on intensive plantations, requiring very little land, less than 10% of the planet's surface (Sedjo & Botkin 1997). Possibly they are right about this estimate. However, if the primary or secondary purpose of this plan is to prevent any harvesting in native forests, it is doubtful that plantations can satisfy that objective. Conservation does not mean "don't touch", except in certain protected natural areas.

Undoubtedly, a massive programme of intensive plantations using marginal unforested areas, could supply a large part of the wood we need, along with other benefits as well, including reducing the pressure on the native forest. But for centuries we have seen in many parts of the world that forests are going to provide tangible benefits or they are going to disappear. The tendency is to convert a forest that is seen as unproductive into a site that is productive in human terms, even if it is a plot of corn that produces no yield after three years. A combination of intensive plantations, extensively managed native forests, and special areas protected for their biodiversity is the model most probable to succeed as we manage our landscapes and ecosystems.

If we accept the idea of intensive and massive plantation, it would be much easier to accept the idea of more extensive protected areas: perhaps a goal of 30% of the native forest instead of 10% or less. However, the factor of the poverty of a community near the protected forest can often make the protection of the forest difficult or impossible. It is no accident that the tropical world has lost 20% of its forests during the years 1960–1990 (Sedjo & Botkin 1997).

There is much social resistence to the idea of intensive plantations. Some people are concerned that plantations could first require felling the native forests (Smith *et al.* 1997). Given that the native forest gives us important benefits that plantations do not offer and given that there is much underutilised land that does not have forests, it should not be necessary to fell a healthy forest in order to find a good site for plantations. It certainly does occur and therefore the concern is a valid one. However, it would be more productive to promote well planned plantations rather than oppose all planting of forest trees.

What will the role of plantations be for the 21st century? I assume and believe the following. Forest plantations will be the source of 40–50% of the fibre harvested during the 21st century, and perhaps more than 50%. They will have a key importance, both environmental and socio-economic. They will serve to improve degraded sites, to protect natural areas and watersheds, to produce paper pulp and other wood products, as a critical habitat for certain wildlife species, for recreation purposes and for other uses. They will have to be established and managed using environmentally and economically suitable techniques. They will have to use pesticides and fertilisers in acceptable ways. It is probable that 30–60% of them will use carefully selected exotic species. Biotechnology and other advances will bring us very productive plantations, some yielding more than 100 m^3 ha^{-1} y^{-1}. Part of the secret of success will be maintaining a broad genetic base, using the advantages of a biodiversity that can help to reduce the risk. Even in the case of clonal plantations, there are techniques that can provide an advantage over agricultural plantations in this sense.

Plantations will be established on marginal sites under strict standards. As Sedjo and Botkin (1997) point out, if these guidelines are not followed, there will be a political reaction against plantations that will be detrimental to society and to the environment. We need to establish plantations in the most professional and responsible manner possible.

As to Mr. Leopold and his groups A and B, perhaps we now need for the 21st century a group C. This group would consist of a new generation of foresters who are able to better integrate socio-economic and environmental values in their management of the forest resource. This new professional would be capable of applying the wisdom we foresters have accumulated during the last two centuries and managing the resource at the landscape or ecosystem level to the benefit of the individual and the society, without losing the intrinsic values of each forest. It is a large goal, but if we do not attain it, we are going to lose more forests. Plantations, along with research, will be important factors in the future of all of us. Sometimes research brings us knowledge without bringing us wisdom. If we merely strive for knowledge, we will lose the battle! One of the challenges facing us is to assure that we all understand the difference between the two: knowledge and wisdom.

References

BOWYER, J. 1998. Viewpoint: TFF Board states position on tree plantations within tropical regions. *Tropical Forest Foundation News*, February, 1998. Alexandria, Virginia (USA): 1 & 4.

BROWN, S. & LUGO, A. E. 1994. Rehabilitation of tropical lands: a key to sustaining development. *Restoration Ecology* 2:97–111.

BURLEY, J., TURNBULL, J. & WHITMORE, J. 1992. *National Afforestation Project, China.* Report of the World Bank International Advisory Panel. 19 pp.

BURLEY, J., TURNBULL, J. & WHITMORE, J. 1994. *National Afforestation Project, China.* Second report of the World Bank International Advisory Panel. 24 pp.

COSTRILLÓN ARBOLEDA, D. 1994. *Tomás Cipriano de Mosquera: Biografía.* Planeta Colombiana Editorial, S. A. Bogotá, Colombia. 713 pp.

DENEVAN, W. M., PADOCH, C. & FLORES PAITAN, S. 1987. Swidden-fallow agroforestry, Iquitos, Peru. Pp. 8–9 in Lugo, A. E. (Ed.) *People and the Tropical Rain Forest.* U.S. Man and the Biosphere Program.

ESPINOZA, M. & BUTTERFIELD, R. 1989. Adaptabilidad de 13 especies nativas maderables bajo condiciones de plantación en las tierras bajas húmedas del Atlántico, Costa Rica. Pp. 159–172 in Salazar, R. (Ed.) *Manejo y Aprovechamiento de Plantaciones Forestales con Especies de Uso Múltiple.* Actas de la Reunión IUFRO (S1.07-09), Antigua, Guatemala, April 1989.

EVANS, J. 1992. *Plantation Forestry in the Tropics.* 2nd edition. Clarenden Press, Oxford, United Kingdom. 403 pp.

EWEL, J. J. 1991. Diversity: yes, we got some bananas. *Conservation Biology* 5:423–425.

FRANCO, W. 1997. Bases estratégicas para el desarrollo sustentable del Estado de Amazonas de Venezuela. *Interciencia* 22(4):184–193.

FSC. 1996. *Principles and Criteria for Forest Management, as Ratified by Forest Stewardship Council Members and Board of Directors, February 1996.* 11 pp.

GALLEGOS, C., ZOBEL, B. & DVORAK, W. 1981. Formación de una cooperativa de recursos de coníferas de Centro América y México por los esfuerzos combinados del gobierno, la industria y la universidad. Pp. 375–381 in Whitmore, J. L. (Ed.) *Producción de Madera en los Neotrópicos via Plantaciones.* Actas, IUFRO/MAB/Servicio Forestal (EE-UU) Simposio. IUFRO S1.07–09. Septiembre 1980. Instituto de Dasonomía Forestal. Río Piedras, Puerto Rico.

GÓMEZ-POMPA, A. & BAINBRIDGE, D. A. 1995. Tropical forestry as if people mattered. Pp. 408–422 in Lugo, A. E. & Lowe, C. (Eds.) *Tropical Forests: Management and Ecology.* Springer-Verlag, New York

HARTSHORN, G. S. & WHITMORE, J. L. 1998. Anthropogenic disturbance and tropical forestry: implications for sustainable management. Walker, L.R. (Rd.) *Ecosystems of Disturbed Ground.* Elsevier Publ., New York. [In press].

HAUFE, H. 1981. Parámetros conducentes a la definición de prioridades para la rehabilitación agroforestal de laderas degradadas en los neotrópicos. Pp. 349–355 in Whitmore, J. L. (Ed.) 1981. *Producción de Madera en los Neotrópicos via Plantaciones.* Actas, IUFRO/MAB/Servicio Forestal (EE-UU) Simposio. IUFRO S1.07–09. Septiembre 1980. Instituto de Dasonomía Forestal. Río Piedras, Puerto Rico.

LAMB, D. 1997. Biodiversity restoration by plantation. *ITTO Tropical Forestry Update* 7(2):3–5.

LEOPOLD, A. 1949. *A Sand County Almanac; with Essays on Conservation from Round River.* Sierra Club/ Ballantine Books. New York. 295 pp.

LOJAN IDROBO, L. 1992. *El Verdor de los Andes: Árboles y Arbustos Nativos Para el Desarrollo Forestal Altoandino.* Proyecto Desarrollo Forestal Participativo en los Andes. Quito, Ecuador. 217 pp.

LUGO, A. E. 1997. The apparent paradox of reestablishing species richness on degraded lands with tree monocultures. *Forest Ecology and Management* 99:9–19.

LUGO, A. E. & LIEGEL, L. H. 1987. Comparison of plantations and natural forests in Puerto Rico. Pp. 41–44 in Lugo, A. E. (Ed.) *People and the Tropical Forest.* US Man & the Biosphere Program, Washington, DC.

MARSH, G. P. 1864. *Man and Nature; or, Physical Geography as Modified by Human Action.* Cambridge. Republished by Harvard University Press, 1965. 472 pp.

MCNABB, K. L., BORGES, J. & WELKER, J. 1994. Jari at 25: an investment in the Amazon. *Journal of Forestry* 92:21–26.

PARROTTA, J. A. 1992. The role of plantation forests in rehabilitating degraded tropical ecosystems. *Agriculture, Ecosystems and Environment* 41:115–133.

PARROTTA, J. A., KNOWLES, O. H. & WUNDERLE JR., J. M. 1997a. Development of floristic diversity in 10-year-old restoration forests on a bauxite mined site in Amazonia. *Forest Ecology and Management* 99:21–42.

PARROTTA, J. Q., TURNBULL, J. W. & JONES, N. 1997b. Catalyzing native forest regeneration on degraded tropical lands. *Forest Ecology and Management* 99:1–7.

POPOVICH, L. 1980. Monoculture: a bugaboo revisited. *Journal of Forestry* 78(8):487–489.

PREBBLE, C. & LEIGH, J. 1997. Putting a model into practice in Peru. *ITTO Tropical Forest Update* 7(3):5–8.

REICHARD, S. & HAMILTON, C. 1997. Predicting invasions of woody plants introduced into North America. *Conservation Biology* 11(1):193–203.

RUSSO, R. & SANDI, C. L. 1995. Early growth of eight native timber species in the humid tropic region of Costa Rica. *Journal of Sustainable Forest Management* 3:81–84.

SCHUBERT, T. 1979. *Trees for Urban Use in Puerto Rico and the Virgin Islands.* Institute for Tropical Forestry, Río Piedras, Puerto Rico. GTR SO-27. 91 pp.

SEDJO, R. A. & BOTKIN, D. 1997. Using forest plantations to spare National·Forests. *Environment* 39 (10):14–20, 30.

SMITH, D. M., LARSON, B. C., KELTY, M. J. & ASHTON, P. M. S. 1997. *The Practice of Silviculture: Applied Forest Ecology.* Ninth edition. John Wiley & Sons, New York. 537 pp.

VALDIVIA, S. & CUETO, L. 1979. Settlement and rural development in the eriazas zones of the north coast of Peru. Pp. 163–169 in De Las Salas, G. (Ed.) *Proceedings, Workshop on Agroforestry Systems in Latin America.* 26–30 March 1979. Turrialba, Costa Rica. CATIE and UNU.

VEGA CONDORI, L. 1987. *Crecimiento de Cedro Cedrela odorata Manejado en Fajas de Rastrojo y en Asocio inicial con Cultivos. CONIF INFORMA,* No. 10. Bogotá, Colombia. 20 pp.

VOGT, W. 1948. *Road to Survival.* William Sloan Associates, New York. 335 pp.

WADSWORTH, F. H. 1997. *Forest Production for Tropical America.* Agriculture Handbook 710. USDA Forest Service, Washington, D.C. 563 pp.

WHITMORE, J. L. (Ed.). 1976a. *Studies on the Shootborer Hypsipyla grandella (Zeller) Lep., Pyralidae.* Volume II. IICA Misc. Publ. No. 101. Turrialba, Costa Rica. 139 pp.

WHITMORE, J. L. (Ed.). 1976b. *Studies on the Shootborer Hypsipyla grandella (Zeller) Lep., Pyralidae.* Volume III. CATIE Misc. Publ. No. 1. (IICA Misc. Publ. No. 101). Turrialba, Costa Rica. 116 pp.

WHITMORE, J. L. 1992. Advances in sustainable forest management of natural tropical forest, and in plantation of native species. Pp. 1–9 in Wan Razali, W. M., Shamsudin, I., Appanah, S. & Mohd. Farid, A. R. (Eds.) *Proceedings International Symposium on Harvesting and Silviculture for Sustainable Forestry in the Tropics.* Oct. 5–9, 1992, Kuala Lumpur, Malaysia.

WHITMORE, J. L. & BURWELL, B. 1986. Industrial agroforestry. *Unasylva* 38:28–34.

WORMALD, T. J. 1992. *Mixed and Pure Forest Plantations in the Tropics and Subtropics.* FAO Forestry Paper 103. FAO, Rome. 152 pp.