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THE TREE NURSERY ... MOTHER OF PLANTATIONS

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ABSTRACT
Of the more than 6 billion people in the world, there are a relatively small number of nursery managers. These individuals are responsible for producing the nursery stock needed to establish plantations (a source of wood for firewood, lumber, furniture, charcoal and pulp). The establishment of plantations helps take some of the pressure off logging natural stands. It is remarkable that so few individuals have produced enough seedlings to cover approximately 1% of this planet's land base.

INTRODUCTION
Throughout the world, civilisation has converted forested land into farmland, pasture land (for cows, sheep and goats), roads, homesites, and cities. Trees harvested from natural stands have been used for firewood and for making charcoal, lumber, furniture, and paper. When wood is not in short supply, many regions of the world consume wood at a rate of about 1 m3/person/year. Presently, the majority of this wood comes from natural stands. As a result, some developed countries, once bountiful in native forests, now have less than 10% of their original forests. The current net rate of deforestation is around 5 million ha/yr (Mather 1990). Due to increasing population pressures, increasing demand for cleared land, and increasing demand for firewood, deforestation will continue in many countries well into the 21st century. Nursery managers can play an important role in supplying wood to the public on a sustainable basis.

Although mankind has been planting trees for thousands of years, the profession of nursery manager is relatively new. This is because many indigenous people do not have a tradition of large-scale tree planting (e.g. the first Gaelic guide to tree planting was published in 1992). Although there were relatively few nursery managers prior to 1800, their numbers increased as Europeans began to colonise the world during the 19th and 20th centuries.

Nursery managers produce seedlings for a variety of purposes. Tree stock is planted in plantations for fuelwood, pulpwood, timber and cellulose. Trees are also planted for wind and avalanche control, erosion control, for agroforestry and to produce pine needles. Some government officials are now considering establishing plantations to sequester carbon. Due to population growth, some plantations have been converted into city parks, recreational areas and residential areas. Some plantations eventually evolve into community forests complete with undergrowth, wildlife, and hiking trails (e.g. Glentress Forest in Scotland).

Nursery managers play an important role in the economies of countries like New Zealand and South Africa. For example in 1989, only seven other countries exported more wood than New Zealand (FAO 1991). Major wood exporters like Canada, Russia and the United States (US) rely on exporting wood harvested from natural stands. In contrast, almost all of the wood exported from New Zealand and South Africa originated from seedlings grown in tree nurseries. Export of plantation wood helps the balance of trade for these countries. Establishment of plantations helps reduce the need to import wood from natural stands in other countries. For example, even though the United Kingdom (UK) produces about 0.11 m3/person from plantations, this country still has to import about 0.84 m3/person from other countries' forests. Much of the wood the UK imports comes from natural stands in Canada and Russia.

PLANTATIONS: HOW MUCH IS ENOUGH?

Currently, the worldwide ratio of natural forests to plantations is about 26/1 (Table 1). This ratio will likely decrease if the present rate of deforestation of natural stands continues. The ratio is already 1/13 in the UK (Savill and Evans 1986). One question that needs to be addressed is how much land should be planted with nursery stock? Is 1% of the world's land base too much or too little? Should we have 5% of the world's land in plantations and 26% in natural stands? In contrast, should we stay with just 1% in plantations and continue in the tradition of the British to consume wood from natural stands until the plantation/natural stand ratio is 13/1? World leaders need to ask this question now if the answer requires the creation of more nurseries and more plantations. Sudden increases in planting rate are practical only if there is a sound basis of research and if experienced nursery managers are available.

Table 1. The percentage of land in forests and plantations, the production of roundwood for 1989 and the estimated firewood/charcoal usage for 2010 (FAO 1991; USDA 1988; Suchek 1991). (The term forest here includes both natural forests and plantations).

Country	Forest	Plantations	Roundwood production per year	Roundwood production per capita per year	Firewood use per year
	% of landbase	% of landbase	m^3 X 1,000	m^3	m^3 X 1,000
World	**27**	**1.0**	**3,462,639**	**0.66**	**2,395,000**
Sweden	59	11.1	55,740	6.62	4,555
UK	9	8.4	6,462	0.11	377
USA - South	35	4.0	161,000	2.70	30,223
NZ	26	3.7	10,557	3.07	55
S. Korea	66	2.9	6,803	0.15	4,219
China	13	2.9	272,665	0.24	232,579
Japan	63	26	31,936	0.62	985
Chile	11	1.7	16,864	1.28	7,234
Canada	28	1.5	176,976	6.60	8,073
Argentina	16	1.4	10,819	0.33	5,869
USA	24	1.3	533,168	2.11	129,574
Australia	5	1.1	20,041	1.19	3,236
S. Africa	1	1.1	19,361	0.50	10,783
Malawi	46	1.0	7,621	0.77	12,509
Brazil	61	0.6	220,623	1.40	182,679
Zambia	40	0.1	12,204	1.46	22,886

Exactly how much land would be needed to supply all the world's wood needs from plantations? If the world consumes 3.5 billion m3/yr, then we might be able to supply this amount with 350 million ha of intensively managed plantations (assuming an average mean annual increment [MAI] of 10 m3/ha/yr). This would amount to 2.7% of the world's land base. However, if we need to produce 7 billion m3/yr (to meet the future demand for wood) then 5.5% of the world's land base might be able to produce a "sustainable" supply of wood. These percentages would be maximum percentages since indigenous peoples would likely continue to salvage wood from

indigenous woodlands. This appears to be the case even when laws are enacted to discourage such use (Mather 1990).

On the other extreme, tree nurseries would not be necessary if a large portion of natural woodlands were managed on a sustainable basis. However, the MAI of indigenous woodlands is not as high as for plantations (Evans 1982; Burley *et al.* 1989; Mather 1992). For example, in Latin America, plantations make up less than 1% of the productive forest area but account for 30% of industrial wood production (Evans 1987). In some areas in Africa, plantations produce at least five times as much as the original forest. Managed natural forests in the Ivory Coast yield from 1.5 to 2.0 m3/ha/yr (Burley *et al.* 1989). If it were possible to manage indigenous forests for wood production on a sustainable basis, and the "sustainable" MAI was 3 m3/ha/yr, then we would need to manage 2.3 billion ha to supply 7 billion m3/yr. This would equate to about 58% of the world's forest and woodlands. A more realistic question is where should the wood to be consumed in 2010 come from? How much should come from managed naturally regenerated stands and how much should come from plantations?

The answer to whether the world needs more nurseries and plantations will vary depending upon the point of view of the individual. Those with a long-term, global view see an important role for plantations (e.g. Eckholm 1975). Those with a short-term, parochial view may not see a need for more plantations. For example, some relatively wealthy individuals (who usually live in developed countries and rely heavily on burning fossil fuels) believe there are currently too many plantations. Some individuals, in countries where 3 to 11% of the land base is covered with conifer plantations (Table 1), believe that agricultural fields should not be planted with conifers. Some believe that conifer stands will harm water quality more than farmland (where agrochemicals are used). A few even believe that wood production is not increased when using plantations. This idea was supported by a recent statement by the Chief of the US Forest Service. In June of 1992, Chief Robertson indicated that timber yields from naturally regenerated stands "will be about the same" as those from plantations of genetically improved stock. As a result, the "New Perspectives" in management of publicly owned woodlands in the US will de-emphasise the use of nursery stock.

In contrast, many individuals from relatively poor regions of the world believe there need to be more plantations. Many people spend a good portion of their time and income obtaining wood. In many developing countries, wood is so scarce that manure is used for fuel (which depletes the soil of nutrients). Since about 81% of the plantations are in developed countries, should charitable organisations consider redistributing surplus plantation wood in the same fashion as surplus food? Currently, wood and wood products are easily redistributed to countries that are wealthy. Although neither the UK nor Pakistan have enough plantations to meet the demand for wood, the UK can afford to import more than 0.8 m3/person/yr from other countries. Many developing countries do not have enough plantations to meet the demand for wood and cannot afford to import large quantities. For example, one Indian official said that "Even if we somehow grow enough food for our people in the year 2000, how in the world will they cook it?" (Ayensu et al. 1980).

Fuelwood Plantations

Much of the world's annual consumption of wood is for fuel for cooking, heating and power production. Of the approximately 3.45 billion m3 consumed annually, about 52% is used for fuel (FAO 1991). By the year 2010, it is predicted that the volume of wood harvested for fuel will increase by 34% to 2.4 billion m3/yr. The increase in demand for energy in developed countries will be met by an increase in mining fossil fuels and radioactive ores. For developing countries, the increase will be met in part by the burning of more wood.

The concentrations of carbon dioxide (CO2) in the atmosphere have been rising steadily and are likely to continue to do so as more and more coal and petroleum are burned. Developed countries burn most of the world's fossil fuels while developing countries burn about 85% of the world's fuelwood. For example, in Somalia, fuelwood accounts for 82% of the country's energy consumption (Burley *et al.* 1989). In Somalia, the per capita fuel consumption was 1.03 m3 in 1984. More than 2.5 billion people in the world derive at least 50 percent of their energy needs from wood (Ayensu *et al.* 1980).

If fuelwood is harvested on a sustainable basis, then harvesting wood for fuel will not appreciably affect the CO2 levels since the amount released would be captured later during tree growth. In terms of being "environment friendly," harvesting plantations for fuelwood on a sustainable basis is more "friendly" than using coal or oil to produce electricity to cook food. Unfortunately, there are not currently enough plantations to meet the demand for fuelwood. Despite warnings about the need to plant trees for firewood plantations (Eckholm 1975), many people in developing countries are still walking further each day to collect firewood from indigenous forests. How much of the future demand for fuelwood comes from natural stands and how much comes from plantations will depend on how many new nurseries are established.

TREE NURSERIES

In theory, nursery managers produce enough seedlings to plant more than 10 million ha/yr (Mather 1990). If the average outplanting density were 1,200 trees/ha, then tree nurseries throughout the world should have a total annual production of more than 12 billion seedlings. In the US alone, about 300 tree nurseries produced 1.6 billion seedlings in 1991 (Mangold *et al.* 1992). If the world's leaders set a goal of 700 million ha of plantations, how many more nurseries would be required? The answer would depend on the average rotation length. If plantations were harvested on a 20-year cycle, we would need to plant about 35 million ha each year. This would mean we would need 3.5 times as many nurseries as today. However, if the rotation cycle was every 10-years, then we would need 7 times as many nurseries.

The size and number of nursery operations vary by country. For example, Comores has over 100 village nurseries (Burley *et al.* 1989). This equates to one nursery manager for every 5,000 people. In 1987, Ethiopia was expected to have 1,000 nurseries (1 manager per 50,000 people). New Zealand has about 25 bare-root nurseries that produce a total of about 36 million seedlings (1 manager per 140,000 people). In South Africa, there are about 63 tree nurseries (about 1 nursery manager per 500,000 people). In 1990, these nurseries produced about 242 million seedlings (Donald 1991). The largest nursery in Ngodwana produces about 24 million container grown seedlings. Bare-root nurseries in the southern US are relatively large. Most have an average production of more than 20 million seedlings. One nursery in South Carolina has the

capability of producing 100 million seedlings. Number-wise, this is one of the largest nurseries in the world. In the southern US, there is about one nursery manager for every million people.

Some government leaders have questioned whether large-scale tree planting programs are even feasible. Some do not know what can be accomplished if the correct incentives are provided. For example, recently in the southern US, more than 1.5 billion seedlings were planted during a three-month planting season. This equates to more than 25 million seedlings per day. Half of these seedlings were machine planted and half were planted by hand. At a rate of 800 trees per person per day, this would require more than 15,600 hand planters. If there were 15 persons per crew, this would total more than 1,000 planting crews. When the infrastructure and nursery systems are in place and social attitudes permit, large-scale planting programs are possible.

Research

Developed countries

In the developed regions of the world, nursery research appears to be decreasing. For example, in the southern US, nursery research was at a peak during the 1970's and 1980's. Research was conducted by several universities, forestry companies, the US Forest Service, and several State Forestry Organisations. A Nursery Weed Control Project was started at Auburn University and this later evolved into the Auburn University Southern Forest Nursery Management Cooperative. The Institute for Mycorrhizal Research was started by the US Forest Service. Although the US Forest Service and the Nursery Cooperative at Auburn University are still active, nursery research in general has declined. Many believe nursery researchers have solved all the big problems and therefore research is no longer required. Industry in the southern US now gives nursery research a low priority and believes that current research in nursery practices and seedling quality is over-funded (SIFRC 1991). As a result, I know of only one forest industry in the southern US that still employs a nursery researcher. Most State Forestry Commissions no longer conduct nursery research. The US Forest Service no longer has an Institute for Mycorrhizal Research. In general, Forest Service research has shifted away from plantation management and now is conducting more research on "environmentally sensitive forestry."

New Zealand's nursery research during the 1970's and 1980's was known worldwide. The "New Zealand" undercutter/wrencher, lateral root pruner, and vacuum precision seeder are now in use at various nurseries throughout the world. For example, in the southern US, about 25 nurseries are now sowing with vacuum sowers. In particular, New Zealand was the first country to fully integrate nursery management with reforestation practices. However, privatisation and contestable government funding has resulted in a reduction in research funds. Competition among nurseries keeps profits low and therefore most nursery budgets do not include monies for research. Since nurseries are not funding research, the Government has taken the attitude that nursery research is not a problem. In addition, nursery research has not been rated highly by industry cooperatives. As a result, emphasis on nursery research has declined. The 1991/92 FRI budget for nursery research was NZ $357,000. This was mainly for vegetative propagation by cuttings, nursery systems for minor species and a limited amount of nursery herbicide research. FRI has no current research on conventional topics such as improving seed efficiency or improving plant performance. Current seed efficiency is often not much above 50% (Trewin and Mason 1991).

In Canada, nursery management is receiving low priority. In 1990, it was no longer considered an important research topic for any of the 12 provinces (Anon 1991). Use of container grown stock has increased and this may help explain a declining interest in nursery management. However, interest in seedling quality is still high and this topic is still considered important. Popular environmental matters skew research priorities away from less glamorous topics like nursery management.

In the past, nursery research in South Africa was conducted by a few companies and at the University of Stellenbosch. Advances in germinant sowing were made by one company and several nurseries now use this technique to increase seed efficiency. Machines for germinant sowing are manufactured in South Africa and this technology is now spreading to other container nurseries throughout the world. However, government funding of nursery research is now almost non-existent. This is partly due to changes in government policy, as well as an increase in container nurseries. Most nurseries now use copper coated polystyrene trays (550 cavities/m2) and sell seedlings from NZ $60 to $85/thousand. Since many foresters in South Africa believe that field performance cannot be improved with changes in nursery management practices, many container seedlings range from 2 to 3 mm in root collar diameter. Some recommend that larger plants must not be planted or purchased. In my opinion, nursery management in South Africa is becoming less and less integrated with silviculture. Several recent papers on intensive silviculture in South Africa do not even mention nursery management. Many companies no longer produce their own plants but purchase from private nurseries. In some respects, nursery management is almost the responsibility of the horticultural industry (Seedling Growers Association of SA).

Developing countries

In contrast, nursery research is often mentioned as a priority in developing countries. For example, one of four research priorities for Somalia is the development of nursery production procedures (Burley *et al.* 1989). Nursery research is viewed as important in Botswana, Burundi, Ethiopia, Kenya, Lesotho, Madagascar, Rwanda, Somalia, Sudan and Tanzania. Although there are many international aid organisations operating in developing countries, I know of no "Tropical Nursery Cooperative" which is seeking to coordinate nursery management research. Due to the apparent need for nursery research and extension in developing countries, it would seem appropriate for the World Bank or some other international agency to promote the development of a Tropical Nursery Cooperative.

Is there a need for more seedling research?

Some claim that we now know how to grow seedlings and therefore do not need to continue to spend limited research monies on seedling research. It is certainly true that in the southern US, bare-root seedling production costs (including the cost of producing genetically improved seed) are less than NZ $60/thousand and seed efficiency is usually greater than 80% (South 1990). However, *Pinus taeda* L. cuttings in the US cannot yet be produced for less than NZ $700/thousand. In contrast, research in New Zealand has helped reduced cost of *Pinus radiata* D.Don cuttings to NZ $190/thousand. There is no doubt that more is known about propagating conifer seedlings than about propagating conifer cuttings. As a result, nursery research has shifted away from seedlings and toward cuttings and micropropagation.

Some contend that seedling research should not cease. Although the technology for pine nurseries is well developed, knowledge about large-scale production of hardwoods (both tropical and temperate) is lacking. As a result, hardwoods often cost about three or four times as much to produce as conifers. Some important practices such as irrigation are difficult to research and have received little attention. Researchers still do not fully understand the controlling mechanisms regulating seedling storage. Even with conifers, there are still several management practices that are derived from old-wives-tales. Such practices will continue until research demonstrates otherwise. Nursery technology developed for temperate zones may not be appropriate for many developing countries in the tropics. For many tropical species, there are no spacing studies designed to determine the optimum number of plants/m2. Poor performance of some species in species trials could be due to a lack of research to define an appropriate nursery management regime.

Some seedling research has shown an opportunity for reducing establishment costs. For example, few foresters realise that the need for weed control in plantations depends upon nursery management practices. Poor nursery practices can produce weak seedlings that do not compete well with herbaceous vegetation. In many countries, nursery managers produce thin seedlings with root collar diameters of only 2 to 4 mm. To have these seedlings survive and grow well after outplanting, herbaceous weed control is often mandatory. However, in some situations, 7 mm seedlings without weed control can outperform 4 mm seedlings given spot applications of herbicides (Balneaves 1989). This type of research can show how establishment costs can be reduced without reducing yields (South *et al.* 1994). However, these opportunities will most likely only be realised in countries where nursery research is emphasised.

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