# THE POTENTIAL ROLE OF PLANTATIONS IN FUTURE TIMBER SUPPLY

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## ABSTRACT

This paper presents results from a recently developed dynamic timber market model of the world. The baseline results suggest that prices will rise 0.8% per year between 1995 and 2050. Harvests will rise to meet demand, although most of the growth in timber harvests is predicted to result from the expansion of emerging subtropical region plantations. This growth in harvests from emerging subtropical region plantations reduces pressure on currently inaccessible forests, and leaves them largely intact. Several alternative scenarios are presented to show how these results are sensitive to the rate of growth of timber demand, prices, and costs of establishing plantations and harvesting inaccessible forests.

## INTRODUCTION

As global population and consumption have increased, mature forest stocks have been replaced with farms, houses, and younger stands. Recent reports on global forest inventories by FAO (1995, 1993), for example, suggest that the area of land in closed forests has declined in many regions, and in particular in tropical regions. These losses can have important consequences for both biodiversity (Skole and Tucker, 1993) and carbon sequestration (Dixon et al., 1994).

While forest loss is a concern in many regions, some areas have recently experienced a growth in the area of land in forests. North America, Europe, and the Former Soviet Union, for example, have seen the area of forest land expand in recent decades (Lowe et al., 1994; Powell et al., 1993; and FAO, 1995), reversing long term trends in forest losses. In addition to changes in overall area of forests, forestland management in some regions has been increasing as well. Moulton et al. (1995) show that annual tree planting has increased from 56,000 hectares in 1930 to 981,000 hectares in 1995 in the United States, and many sub-tropical regions, often called the emerging plantation region, have continued to increase the area of land in forest plantations in recent years(FAO, 1993).

There are at least two interesting questions that arise as one considers how markets will respond to changes in demand and supply. The first relates to the conversion of land from forests to other uses: Are industrial timber markets causing deforestation in tropical or boreal forests which have previously been considered inaccessible? The second question relates to the issue of future supply: Which regions will supply industrial timber in the future? This question is important because future supply could include harvests in inaccessible tropical or boreal forests, harvests in newly established plantations, or some of each. While other studies have examined these issues in general (see for example, Hyde et al., 1996), few have provided empirical predictions based on optimal economic behavior. This paper uses a newly developed dynamic timber market model of the world to investigate how markets will adjust timber supply as demand for industrial wood products continues to rise.

The results suggest that timber markets will cause little additional deforestation in inaccessible forested regions. These regions are inaccessible mainly because they are costly to harvest relative current global timber market prices and the costs of harvesting forests in more accessible regions. Unless prices increase dramatically, the model does not predict that industrial timber markets will advance more deeply into inaccessible forests in the tropical or boreal regions. In order to concentrate on which forests would be harvested under economic efficiency alone, we have ignored inefficiencies created by inefficient subsidies, although we acknowledge that these subsidies can have an affect on harvests in particular regions.

The model predicts instead that markets will increase management intensity in existing forests, such as pine forests in the southern region of North America, and emerging subtropical region plantations. Forest expansion is also predicted to occur in regions where fast growing plantations are suitable, such as Australia, New Zealand, Chile, Argentina, South Africa, and Iberia. In these regions, land productivity is high enough and land costs are low enough to justify additional establishment. Despite increases in management, prices are predicted to increase over the next 50 years, approximately 0.8% per year.

The remaining paper is organized as follows. The next section briefly describes the modeling effort. The third section presents our results for a baseline case and three alternative scenarios. The final section discusses the findings and presents our concluding remarks.

## A DYNAMIC TIMBER MARKET MODEL OF THE WORLD

This paper presents the results of a recently developed dynamic timber market model of the world (Sohngen et al., 1998). The model builds on earlier efforts by Walker (1971), Sedjo and Lyon (1990), Lyon and Sedjo (1983), Brazee and Mendelsohn (1990), and Sohngen and Mendelsohn (1998). As the model uses dynamic optimization techniques, all decisions (harvest, regeneration, management intensity) are made in a forward looking manner. The model differs from previous dynamic optimization timber market models in three ways.

First, it captures additional global regions, allowing us to specify essential differences in the ecology and economics of each region. Sohngen and Mendelsohn (1998) considered only the United States, and Sedjo and Lyon (1990) captured only 23 regions of the globe. The current model captures 46 different timber types in 9 major industrial timber producing regions. A wide range of different ecological production functions, management intensities, and other factors are therefore modeled directly. For example, the model explicitly accounts for harvests and management of both inaccessible forests and emerging subtropical region plantation forests. Harvests and management are balanced in these diverse types.

Second, the decision to invest in forest regeneration management is determined optimally in all regions. A previous effort by Sedjo and Lyon (1990), for example, left many regions of the globe unresponsive. Although the bulk of current harvests may come from accessible temperate and emerging subtropical regions (90% in 1995), as demand continues to increase, it would be unclear how this will affect harvests and management of inaccessible forests if these regions were left unresponsive.

Third, the decision to increase the area of plantations is endogenously determined. Rather than relying on assumptions about how many new hectares will be planted in the future, the model instead predicts new hectares based on current land and conversion costs, as well as future prices and interest rates. Thus, establishing new hectares of plantations are determined optimally at the same time as decisions are made to harvest and manage temperate and inaccessible forests.

As a dynamic optimization model, it is distinguished from static simulation models, such as the CINTRAFOR Global Trade Model (see for example Kallio et al. 1987), because it incorporates forward looking economic behavior. Static simulation and dynamic optimization models have recently been compared by Sohngen and Sedjo (1998). Forward looking behavior allows the model to choose harvests in inaccessible forests, timberland management, and plantation expansion, optimally, rather than by assumption from outside the model. The CINTRAFOR model, however, does track changes in bilateral trade, and the dynamic optimization model used in this paper does not.

The model has recently undergone two types of sensitivity analysis (Sohngen et al., 1998). First, the endogenous predictions on investments in regeneration were compared to the results of Wear (1994) and Wear and Newman (1991). For southern US pine, the price elasticity of regeneration management is consistent with empirical predictions from the literature. Second, the 12 different sensitivity analyses were conducted on model assumptions (i.e. rate of growth of demand, interest rates, cost parameters, etc.). The results vary quantitatively, although the qualitative results are strikingly similar.

## MARKET SCENARIOS

### *Baseline Case*

The baseline case assumes that global timber demand grows initially at 1.0% annually, although it is declining by approximately 0.7% per year between 1990 and 2050. Solving the model under these conditions reveals that real global prices rise from $72 per m$^3$ to $115 per m$^3$ over this time period, or approximately 0.8% per year (Figure 1). Prices rise more than demand, particularly during the early periods, as older stocks continue to be drawn down. Over time, new plantations in the emerging subtropical region become a more significant factor in global markets, and prices begin to stabilize.

Supply responds to these future price increases. Harvests increase from 1.6 billion m$^3$ per year to 2.2 billion m$^3$ per year in 2050. Figure 2 shows that these increases do not occur equally in all regions. There is a dramatic increase in harvests in the emerging region, while harvests temperate zones remain fairly constant, and harvests in inaccessible forests decline.

This change in production occurs as plantation establishment in recent decades affects global timber production, and as future plantation establishment occurs. Due to high productivity and relatively low costs of purchasing land and establishing plantations, the subtropical areas of Central America, Southern Brazil, Argentina, and Chile, South America experience the greatest gain in plantation lands. The area of industrial wood plantations is predicted to increase from 42 million hectares in 1990 to 70 million hectares in 2050 (table 1), and emerging region plantation harvests rise from 22% of global harvests today to nearly 41% by 2050.

These results, however, mask much of the variation in harvests that occurs from region to region (Figure 3). Over the time period considered, for example, North American harvests are predicted to decline while harvests in Europe remain fairly stable. Harvests in North America decline slightly as older stocks are drawn down and replaced with younger stocks. Chinese harvests, on the other hand, increase as a result of predicted increases there in the establishment of plantations in the southern subtropical regions.

Changes in regeneration management also vary substantially across the globe, as forest managers respond to both ecological and economic conditions. The most intense forest management concentrates on productive lands in accessible regions. These are the emerging plantation forests and southern forests in the US and China. Forest investments in less productive lands, such as the northern US and southern Canada, as well as Europe and the Former Soviet Union, increase, but not as dramatically. The model also predicts that the least productive lands are regenerated completely naturally. These lands occur throughout the globe, in forests that are difficult to manage.

Fairly large areas of natural forests in the boreal and tropical zones remain economic wilderness in the baseline scenario (Table 1). In our model, the costs of accessing these regions are assumed to be increasing with an increasing area of land harvested. Thus, as price growth is slowing over time, harvests in these regions begins to decline. Compared to increasing the area of plantations or increasing management in the temperate and subtropical zone, harvesting large areas of "inaccessible" forests for industrial timber is not a good investment.

*High Demand Scenario*

While a 1.0% annual increase in timber demand is certainly plausible, population growth rates and economic growth in some regions of the globe is anticipated to expand fairly rapidly in the future. Further, the baseline demand scenario includes assumptions about technological change which may not bear out to be true. Certain technologies which reduce the use of virgin wood products may not become available within the 50 year timeframe of this analysis. As an alternative, we explore a scenario where the demand for forest products increases more rapidly (1.5% annually). We include the same assumption that demand growth declines to 0. Under this scenario, prices increase to $139 (Figure 1), suggesting a 1.1% annual increase, and harvests increase to 2.4 billion $m^3$ per year.

Higher prices lead to higher harvests in all regions, greater harvests of inaccessible forests (Table 1), more land in plantations, and greater management of existing forest stocks. The changes vary across the globe, however. Management intensity is boosted relative to the baseline case initially in regions like North America and China because these regions are best suited to respond to higher prices, but management intensity does not increase substantially in the Former Soviet Union. This results from generally lower productivity in forests in that region. Management intensity in the emerging plantation regions increase slowly over time, as managers adapt gradually to higher levels of demand.

*Costly Emerging Region Plantations*

There are two important assumptions embedded in the plantation establishment cost function. The first is that new land for plantations is as productive as previous land. Finding new land of the same quality however, may be more costly and require extra resources today. For example, while there have been large successes in plantation establishment in the past 20 years, there have been some large historic failures. In some regions, such as tropical rainforests, exotic plantation species have failed because many exotic mono-cultures are susceptible to bug infestations and other pathogens that are not present in their traditional climates. The second is that it is costly to find and protect these resources against political instability. To assess the potential effects of these two alternative assumptions on our model, we explore what would happen if plantations turn out to be more expensive to establish than in the baseline. For this scenario, cost functions for establishing new plantations are doubled across the board.

Such a scenario leads prices to rise to \$123 per $m^3$ (Figure 1). Timber production increases, but not as much as in the baseline case -- to 2.0 billion $m^3$ per year. While harvests still expand in the emerging region, this region plays a smaller part in the global market: In year 2050, the emerging region accounts for 35% of total harvests, compared to nearly 40% in the baseline case. This leads to several substitutions. First, additional inaccessible forests are harvested, although the area of land harvested increases less than 1% above the baseline (Table 1). Second, the temperate zones respond by harvesting existing stocks more heavily and increasing the intensity of management. Finally, while new emerging region plantations are more costly to establish, management intensity increases on those that have already been established.

*Lower Access Costs to Inaccessible Forests*

In the baseline scenario, markets harvest some of the large stocks of timber in inaccessible regions, but the economic incentives to harvest large portions of these forests remain fairly small. While higher demand and lower plantation establishment do increase the incentive to harvest more from these regions by increasing prices, they do not spur large-scale harvests in these regions. In this scenario, we look at what would happen if the access costs in this region fall in half either because of new technologies or public policy.

Lower access costs result in a small adjustment of both prices and global harvest quantities. Prices rise to \$111 per $m^3$ (Figure 1), while production increases to 2.2 billion $m^3$ per year. The model does not adjust substantially to changes in the harvest costs in the inaccessible regions because of the low productivity inherent in these regions. Low productivity limits their ability to contribute to supply. The change does cause the natural forest that is accessed for timber to increase by 11% relative to the baseline case in northern inaccessible forests, and 7% in tropical inaccessible forests. Thus, lower access costs can increase the incentive to access these regions substantially, but the effect of these changes on the global market is minimal.

## CONCLUSION

This paper presents several scenarios from a dynamic timber market model of the world. The model scenarios predict that future increases in the demand for timber will spur additional forest management today. Even the modest price predictions in these results suggest substantial new investments in plantations in emerging regions and additional management intensity of temperate forests in the next century. Unlike previous predictions (such as Sedjo and Lyon, 1990), these increases in plantation establishment and timberland management occur only if the future benefits of additional plantations outweigh existing costs.

These increases in forest investment lead to increased timber harvests in the future, although these harvests are focused on the emerging plantation region. New plantations allow emerging countries to expand their share of global production from around 23% to nearly 40%. Indeed, most of the growth in timber harvests is expected to arise in emerging plantation countries.

The increase in timber plantations can help conserve inaccessible forests. Because of low timber productivity and high access costs, we predict that inaccessible ecosystems in the boreal and tropical forests will remain intact in the future without additional forest conservation measures. These results do not capture the possible distortions caused by subsidies or other government policies which might provide inefficient incentives to harvest timber in these regions, but they do provide a measure of security. Compared to investing in other productive regions of the globe, however, accessing inaccessible forests is not a good investment. Left alone, timber markets would more likely choose productive plantations than inaccessible forests for future supply.

The alternative scenarios show that the results are sensitive to alternative assumptions. In particular, they show that prices are very sensitive to the rate of growth of demand and to potential failures in emerging region plantations. Prices are not sensitive to changes in harvest levels in inaccessible forests. While inaccessible forests will be more heavily harvested if prices rise, large areas of these forests remain intact even with strong price increases. Plantation establishment is also sensitive to price and establishment costs. Despite the quantitative differences, the qualitative results are robust, suggesting that the model is operating as we would expect.

In addition to explaining the behavior of prices and harvests in global timber markets, the model can also serve as an important tool for policy analysis. For example, the model predicts that some areas of the globe are likely to remain as economic wilderness even without explicit protection policies which is important for biological conservation as well as carbon sequestration policy. The model further predicts that any attempt to increase forest conservation will require a system-wide approach as conservation measures in selected places will cause increased harvesting in other areas. Future applications of the global timber model could explicitly address the design of global conservation efforts.

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TABLES

Table 1: Area of land in northern inaccessible forests, tropical inaccessible forests, and emerging region plantations in 1990 and 2050 in the baseline case and three alternative scenarios.

| | Inaccessible Forests | | Emerging Region |
|---|---|---|---|
| | Northern | Tropical | Plantations |
| | | Million Hectares | |
| 1990 | 528.5 | 826.3 | 41.9 |
| 2050 | | | |
| Baseline | 480.2 | 766.5 | 69.6 |
| High demand | 470.0 | 750.8 | 80.6 |
| Low plantation | 477.2 | 763.4 | 56.3 |
| Low access cost | 425.9 | 705.9 | 68.1 |

FIGURES

Figure 1: Price paths under the baseline and the three alternative scenarios

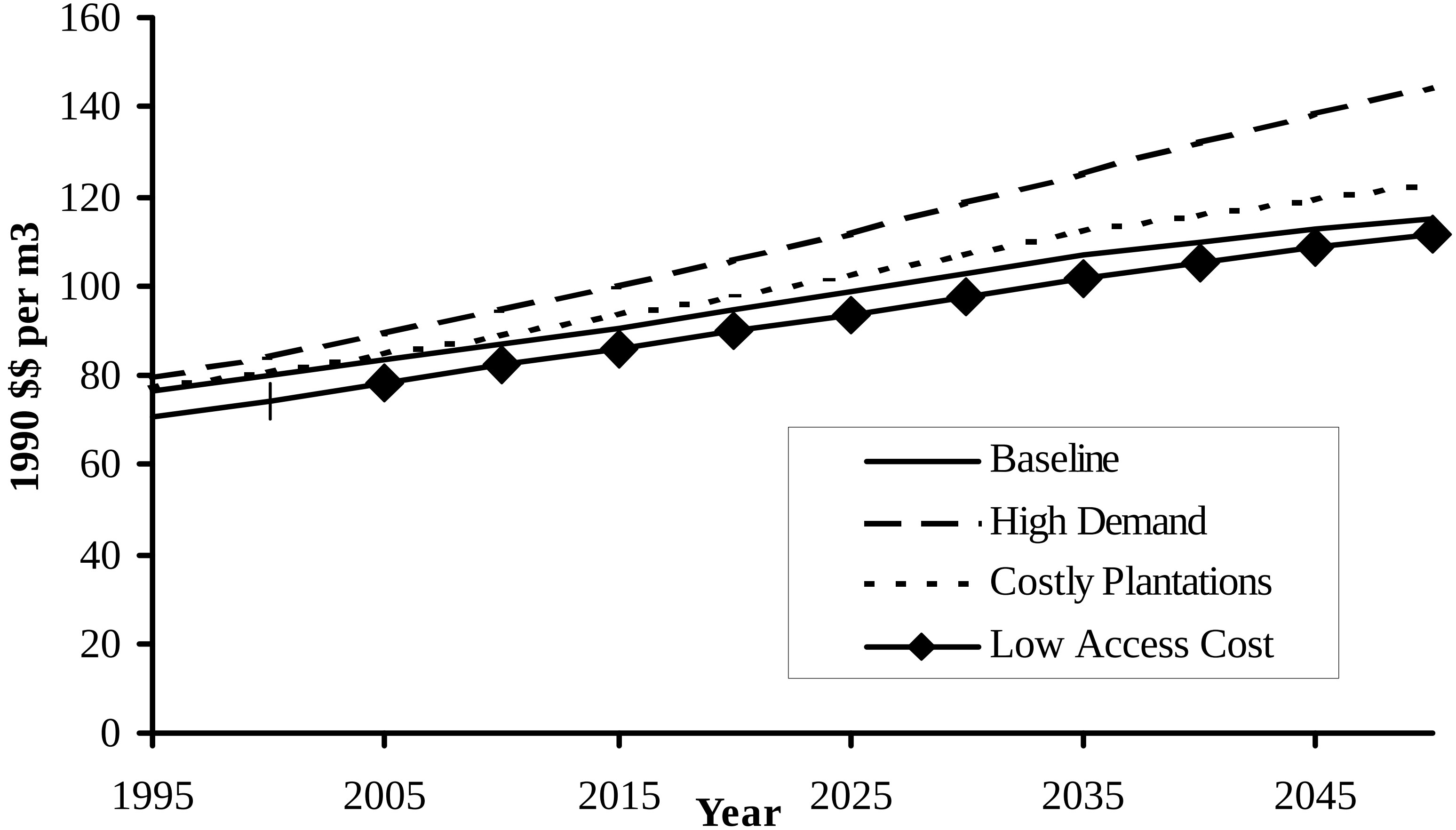

Figure 2: Harvests in aggregated global regions for the baseline case, 1995 - 2050.

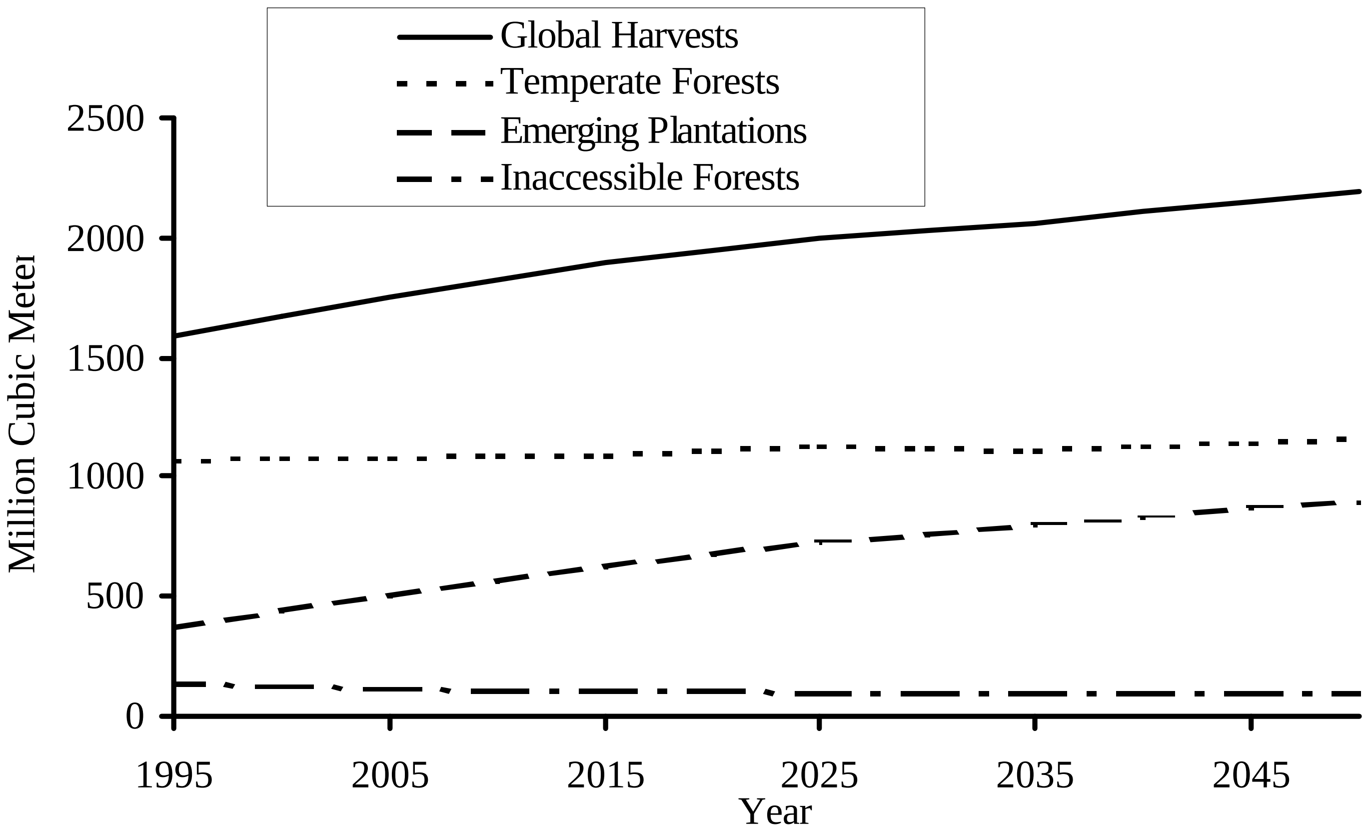

Figure 3: Harvests in 9 regions of the world in the baseline case, 1995 - 2050.