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Timber investment returns for selected plantations and native forests in South America and the Southern United States

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Abstract Timber investment returns were estimated for the principal exotic and selected native species in the Southern Cone of Latin America and in the Southern United States. Exotic eucalyptus plantations in South America were most profitable, with internal rates of returns (IRRs) ranging from 13% to 23%, followed by exotic loblolly pine, with IRRs from 9% to 17%. Average loblolly pine plantation returns in the US South were less profitable, with an IRR of about 9.5%, and natural forest management in the South had IRRs of 4% to 8%. Subtropical native species plantations of the best araucaria and nothofagus species had reasonable financial returns, with IRRs ranging from 5% to 13%. Subtropical or tropical native forests had fewer commercial timber species, and had much lower growth rates and returns. Their IRRs were less than 4%, or even negative for unmanaged stands. State subsidy payments for forest plantations or for timber stand improvements increased IRRs somewhat and reserving areas for environmental protection reduced their IRRs slightly. Including land costs in the cash flows decreased these internal rates of return substantially. Natural stand returns in Latin America were much less than those of plantations, but management of those stands offered better rates of return than only holding the land.

Keywords Financial analyses · Forest plantations · Native forests · Latin America · Biological and financial risk

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Introduction

Financial returns from planted and native forests are one of the most important factors driving forest management, conservation, and investments throughout the world. Periodic studies examine these returns for individual species or countries, especially for plantation species, but there is a relative scarcity of current public information about timber investment returns at the aggregate level. Some consulting studies examine these questions, but they do not provide widely disseminated knowledge or details of the inputs. Furthermore, there is a dearth of financial analyses of potential returns for natural tropical forests or native species plantations in the tropics or subtropics. Accordingly, the objective of this study was to provide better information about potential financial returns for exotic plantations and for native forest investments in the subtropics and temperate forests in the Americas. This research can help individuals and firms make forest investment decisions, and inform public policy decisions about the merits of plantation and native forest management.

Forests, plantations, investments, and conservation

Forests comprise 37% of the land base in the Americas. Table 1 summarizes selected data on forests and plantations for the major countries in the Americas with significant forest plantation areas, based on Food and Agriculture Organization data (FAO 2003, 2005). Brazil has the most forest area, followed by Canada and the US Plantations comprised 29.8 million ha as of 2005, although the plantation area in Venezuela and Canada was not reported in the FAO data source. Per the 2005 FAO data, the US has the most forest plantation area, with about 17.1 million ha. Natural forests comprise 98% of the total forest area in the Americas.

A number of articles have examined the returns to forest plantations and their role in forest conservation and protecting biodiversity. Most posit that fast-growing plantations can help produce industrial wood fiber at growth rates that greatly exceed natural forests, and thus lessen pressure to harvest those forests. Evolving theory and practice also suggests that plantations can provide incentives to protect

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Table 1 Land, forest, and plantation statistics for selected countries in the Americas, 2005

Country	Land area (000 ha)	Total forest area (000 ha)	Percent of total land area	Natural forest area (000 ha)	Planted forest area (000 ha)
Canada	922,097	310,134	33.6	310,134	n.r.
Mexico	190 869	64,238	33.7	63,180	1,058
USA	915,895	303,089	33.1	286,028	17,061
N America	2,069,330	677,461	32.7	659,342	18,119
Costa Rica	5,106	2,391	46.8	2,387	4
C America	51,073	22,411	43.9	22,137	274
Argentina	273 669	33,021	12.1	31,792	1,229
Bolivia	108,438	58,740	54.2	58,720	20
Brazil	845,942	477,698	56.5	472,314	5,384
Chile	74,880	16,121	21.5	13,460	2,661
Colombia	103,870	60,728	53.5	60,400	328
Ecuador	27,684	10,853	39.2	10,689	164
Paraguay	39,730	18,475	46.5	18,432	43
Peru	128,000	68,742	53.7	67,988	754
Uruguay	17,502	1,506	8.6	740	766
Venezuela	88,205	47,713	54.1	47,713	n.r.
S America	1,753,646	793,597	45.2	782,240	11,357
Total Americas	3,856,488	1,493,469	38.7	1,463,719	29,750
World	13,067,421	3,952,610	30.2	3,809,839	142,771

Source: FAO (2005), Global Forest Resource Assessment; n.r. = not reported

natural forests as part of the intensively managed landscapes. However, the merits of this premise are controversial.

Sedjo (1983), (Binkley 1997) and Sedjo and Botkin (1997) state that plantations will decrease pressure on the harvest of natural forests, noting that the high growth rates can supply an increasing proportion of the world's wood fiber needs, both for domestic production and for export. In particular, they can supply the increase in fiber demand in the future (Sayer et al. 2001). In addition, plantations have been suggested as a promising means to store carbon and reduce global warming (DiNocola et al. 1997, cited in Tomberlin and Buongiorno 2001; Carle et al. 2002). On the other hand, Carrere and Lohman (1996), the World Rainforest Movement (2005), and Oyarzún et al. (2006), and other critics state that plantations have negative impacts on indigenous people, biodiversity, and hydrological processes, especially water quantity.

Research by Tomberlin and Buongiorno (2001) compared harvest projections from a timber supply model with estimates of timber production in plantations. They found that in most countries, plantation production is unlikely to increase enough to reduce harvest pressure on natural forests. Similarly, Cossalter and Pye-Smith (2003) found that plantations might contribute to industrial forestry production and profits, but they were unlikely to be able to provide all the wood supply needed in developing countries, usually provided few local community benefits, and often were not useful for forest conservation.

Carle et al. (2002) estimated that of the 187 million ha of plantation forests (per the 2003 FAO report), 89 million ha were for industrial purposes, 48 million ha were for nonindustrial purposes, and 49 million ha of plantations had unspecified purposes. Carle et al. noted that the plantations provided one-third of wood harvested

Table 2 Timber investment mean annual increments from Tomberlin and Buongiorno (2001), and Sedjo (1983); annual internal rates of return (IRRs) for forest plantation investments from Sedjo (2001)

Country/Species	Mean annual increment (m^3/ha/year)		Internal rate of return (%) Sedjo (2001)	
	Tomberlin and Buongiorno (2001)	Sedjo (1983)	Pulpwood	Sawtimber
US South—*Pinus taeda*	10	11.9	12.0–13.9	12.4–14.1
US Pacific Norhwest—*Pseudotsuga menziesii*	Na		7.1–8.8	7.1–9.6
Brazil Central—*Eucalyptus sp.*	30–70	25.0	20.2	15.5
Brazil South—*Pinus taeda*	16	20.0	15.6	17.5
Chile—*Pinus radiata*	20–24	22.0	23.4	16.0–17.5
New Zealand—*Pinus radiata*	20–24	25.0	11.9	11.1–13.1
South Africa—*Pinus patula*	10–25	16.1	19.3	16.2–17.7
Europe—*Picea abies*	2.5	5.0	4.6	5.6

for industrial purposes. This level of plantation fiber has reduced harvests of natural stands, especially in countries with large plantation sectors.

Sedjo (1983) and Tomberlin and Buongiorno (2001) summarized data on average plantation growth rates from the 1980s and 1990s, respectively (Table 2). The growth rates at that time were generally less than 30 m^3/ha/year except for *eucalypts* in the 1990s. Sedjo (1983, 2001) calculated average investment returns for selected plantation species, management regimes, and intensities (Table 2). He found that internal rates of return (IRRs) in the southern hemisphere were significantly greater than those in the northern hemisphere. Pulpwood and sawtimber rates of return were generally comparable, and in several cases pulpwood IRRs were greater.

This literature indicates that forest plantations offer good investment opportunities. Little, if any, forestry literature has compared financial returns from exotic species plantations, native species plantations, and native stand management in the world. Our research analyzes these comparative investments for the principal exotic and selected native species in the Southern Cone of Latin America and the Southern United States, and discusses the implications for timber investments, timber supply, and management of native species.

Methods

This study consisted of cooperative research that we performed in various countries in the Americas. We selected the countries and regions of Argentina, Brazil, Chile, Uruguay, and the US South because they are the most important areas in the Americas, and perhaps in the world, for production of industrial timber, and have the best prospects for increasing contributions to world trade in forest products in the future. The US South produces about 15% of the industrial roundwood in the world (FAO 2003; Smith et al. 2001), and had 16.2 million ha of forest plantations as of 2002 (Smith et al. 2004). The four selected Latin American countries together produce about as much timber from plantations annually as the US South now, and have a total of 9.445 million ha of industrial wood plantations (Carle et al. 2002).

Species and growth data

We identified the dominant exotic forest plantation species in each country and developed typical natural stand management regimes for them. Species selected for analysis included loblolly pine (*Pinus taeda*) in the northeastern subtropical area of Argentina, in southern Brazil and in Uruguay, radiata pine (*Pinus radiata*) in Chile, and in eucalyptus (*E. globulus*, *E. grandis*, and *E. dunnii*) in the countries where they are common. In addition, potential returns for native forest plantations or for natural forests were calculated for general species in the Latin America subtropics, and for erva mate (*Ilex paragurariensis*) and araucaria (*Araucaria angustifolia*) in Brazil. We also examined an araucaria native species plantation in Argentina, as well as native nothofagus (*N. dombeyi* and *N. nervosa*) plantations in Chile. Returns were calculated for planted and natural forests in the southern US for comparison, including loblolly pine, longleaf pine (*Pinus palustris*), and natural hardwoods.

We analyzed investments assuming typical or representative forest management regimes with good sites and good management—a method similar to that used by Sedjo in his initial research on this subject (1983). These plantation management practices and intensity levels were similar to those practiced by forest industry in the respective countries. Natural stand management regimes were based on typical nonindustrial private forest growth rates and management. Better sites and management could yield significantly higher growth rates than those that we used as our base case, and vice versa. We used these representative management regimes since the study objective was not to calculate optimal investment returns, but rather compare typical current conditions and returns.

The base case timber investment returns were made without any land costs—simply assuming that landowners already had purchased forest land and needed to make reinvestment decisions. Nor were government policy interventions included in the base case. Environmental regulation and subsidies affect investment returns, as does systemic financial and political risk in countries.

Typical forest species and average forest productivity rates were determined based on available literature and the knowledge of the authors in each country. We checked these assumptions with several individuals and organizations in each country as well. Our typical growth rates, including bark, were usually larger than those reported in prior literature, but reflect the current state of the art with good forest management practices in 2005. Older plantations will grow at rates less than those we assumed as the typical or representative case, and high technology, intensively managed new plantations will exceed our typical rates.

Base management regimes, factor costs, and stumpage prices

Table 3 summarizes the forest management scenarios we analyzed for plantations of exotic and native species and for natural stands, and the typical growth rates assumed. The typical management regimes for all forest species vary widely among and within countries, and evolve over time with changes in costs, prices, technology, and markets. There are not any standard forest management regimes for all species in each country. Evans and Turnbull (2004) discuss plantation forestry in the tropics in detail, including organization, planning, species selection, seed and clonal material, and forest management and timber stand improvement techniques. The selection of these techniques varies by species, land quality, climate, timber markets, and capital, among other factors.

Table 3 Forest management regimes for selected exotic plantations and native species in the Americas

Country	Species	Rotation (year)	Thinnings and harvests (years)	Growth (m^3/ha/year)	Total yield per rotation (m^3)
Argentina	*Pinus taeda*—Misiones	20	5, 8, 12, 20	30	600
	Pinus taeda—Corrientes	20	7, 12, 20	35	700
	Eucalyptus grandis	14	5, 9, 14	40	560
	Araucaria angustifolia	28	10, 15, 20, 25	15	420
	Native forest unmanaged	80	20, 40, 60, 80	1	80
	Native forest best management	80	20, 40, 60, 80	2	160
Brazil	*Pinus taeda*	18	18	30	540
	Eucalypytus grandis	15	7, 11, 15	40	600
	Eucalyptus dunnii	7	7	43	301
	Araucaria angustifolia	25	10, 16, 21, 25	18	450
	Ilex paragurariensis	10	Leaves, all	Na	Na
Chile	*Pinus radiata*	22	7, 11, 15, 22	22	484
	Nothofagus dombeyi	30	10, 15, 22, 30	18	540
	Nothofagus nervosa	35	12, 18, 26, 35	16	560
Uruguay	*Pinus taeda*	22	11, 15, 22	20	440
	Eucalyptus grandis	16	6, 11, 16	30	480
	Eucalyptus globulus	10	10	18	180
Subtropical optimal	Native forest optimal management	80	20, 38, 50, 65, 80	4	320
USA	*Pinus taeda* planted	30	17, 24, 30	12	360
	Pinus taeda natural	40	25, 33, 40	7.4	300
	Pinus palustris	80	38, 50, 65, 80	4	320
	Hardwood sp.	80	38, 50, 65, 80	4	320

The natural forest regimes were more speculative than the plantations. To represent a spectrum of native forest management growth rates and management alternatives, we developed a range of three sets of management regimes and associated practices. These relied on conversations with foresters in our respective countries; general literature on tropical forest management by Lamprecht (1990) and Wadsworth (1997); and an empirical study in Misiones, Argentina by Riegelhauppt and Burkart (2002). It is worth noting that Lamprecht writes that typical neotropical forests have only 0% to 20% of the species that have commercial timber value; a pervasive silvicultural objective is to increase this share.

Riegelhauppt and Burkart (2002) and Rivero et al. (2004) found average natural stand growth rates in Misiones of 1.1 m^3/ha/year. They found that selecting desirable species and culling poor species and vines could increase this growth rate to 2.2 m^3/ha/year. Lamprecht (1990) suggests similar practices for management of forests in the tropics. He lists monocyclical (even age) and polycyclical (two or three age) stand management of principally desirable species as one of the alternatives for good forest management. Thus we used this management regime as one other hypothetical approach to silviculture in these subtropical countries. This provided a spectrum of three natural tropical forest management regimes—natural stands with only periodic harvests; improved natural stands; and ‘‘perfectly’’ managed even aged stands comprised of many species. We also analyzed natural stand management for temperate forests in the Southern United States.

Discussions among the authors and other scientists in Argentina and Uruguay indicated that average natural forest growth rates are only about 1 m^3/ha/year, and that in Argentina typical timber harvests remove about 5 m^3/ha of commercial species every 20 years or so. Limited experience in Paraguay has shown that well managed native stands can produce 3–4 m^3/ha/year of timber. Thus we developed a hypothetical ''optimal'' subtropical natural stand regime that could produce 4 m^3/ha/year of merchantable timber based on discussions with foresters from these three countries.

Table 4 summarizes the factor costs and stumpage prices assumed by species and country. The information for each country on general costs for forest plantation establishment and management costs is relatively straightforward. Surprisingly, there seemed to be moderately similar total costs for initial plantation establishment in the

Table 4 Factor costs and stumpage prices by species and country for selected exotic plantations and native forests in the Americas, 2005

Country	Species	Establish costs, years 0–5 ($US/ha)	Products	Product prices ($US/m^3)	Harvest sale (years)	Harvest price at year ($US/ha)
Argentina	*Pinus taeda*—Misiones	1,125	Pulp	2.00	5	16
			Small saw	12.00	8	316
			Med saw	15.00	11	455
			Big saw	25.00	20	5,931
			Veneer	30.00		
	Pinus teada—Corrientes	602	Pulp	0.35	7	30
			Small saw	3.61	12	236
			Med saw	5.55	20	5,124
			Big saw	7.22		
			Veneer	30.00		
	Eucalyptus grandis	787	Pulp	0.00	5	76
			Small saw	3.30	9	620
			Med saw	5.00	14	4,445
			Big saw	10.00		
			Veneer	13.33		
	Araucaria angustifolia	870	1st thin	2.00	10	100
			2nd thin	5.00	15	250
			3rd thin	10.00	20	750
			Final cut	20.00	25	5,900
	Native forest unmanaged	0	All cuts	20.00	20,40,60,80	100
	Native forest best mgt.	14 each 6 years	All cuts	20.00	20, 40, 60, 80	300
Brazil	*Pinus taeda*	636	Final cut	20.00	18	10,800
	Eucalypytus grandis	600	1st com thin	2.00	7	160
			2nd thin	15.00	11	1,800
			Final cut	30.00	15	12,000
	Eucalyptus dunnii	800	Final cut	12.00	7	3,612
	Mate-*Ilex paragurariensis*	600 + 200/year	Leaf price US$/kg	0.08	3 Increase each year to:	240
			More vol each year		10	1,200
	Araucaria angustifolia	636	1st thin	2.00	10	600
			2nd thin	5.00	16	1,200
			3rd thin	10.00	21	2,800
			Final cut	20.00	25	3,400
Chile	*Pinus radiata*	547	1st com thin	20.00	11	1,000
			2nd thin	20.00	15	2,000
			Final cut	45.00	22	14,850

Table 4 continued

Country	Species	Establish costs, years 0–5 ($US/ha)	Products	Product prices ($US/m^3)	Harvest sale (years)	Harvest price at year ($US/ha)
	Nothofagus dombeyi	600	1st thin	6.00	10	300
			2nd thin	22.00	15	1,540
			3rd thin	22.00	22	3,300
			Final cut	37.00	30	12,210
	Nothofagus nervosa	600	1st thin	6.00	12	300
			2nd thin	22.00	18	1,650
			3rd thin	22.00	26	1,980
			Final cut	37.00	35	12,395
Uruguay	*Pinus taeda*	500	1st com thin	5.00	11	250
			2nd thin	20.00	15	2,500
			Final cut	30.00	22	8,700
	Eucalyptus grandis	500	1st com thin	2.00	6	100
			2nd thin	10.00	11	1,000
			Final cut	25.00	16	8,250
	Eucalyptus globulus	500	Final cut	9.00	10	1,600
Sub-tropical optimal	Native species optimal management	15 every 6 years	1st com thin	2.00	20	60
			2nd thin	5.00	38	185
			3rd thin	8.00	50	320
			4th thin	10.00	65	380
			Final cut	15.00	80	2,475
USA	*Pinus taeda* planted	600	1st thin	5.00	17	325
			2nd thin	20.00	24	2,000
			Final cut	40.00	30	7,800
	Pinus taeda natural	200	1st thin	5.00	25	300
			2nd thin	20.00	33	1,200
			Final cut	40.00	40	6,400
	Pinus palustris	200 + 10 burn every 3 years	1st thin	5.00	38	250
			2nd thin	25.00	50	1,250
			3rd thin	50.00	65	2,500
			Final cut	60.00	80	10,200
	Hardwood sp.	100 in years 15 and 25	1st thin	5.00	38	250
			2nd thin	10.00	50	500
			3rd thin	20.00	65	1,000
			Final cut	40.00	80	6,800

Americas, ranging from $300 to $800 per ha, with a mean close to $500. This did vary by country, and would vary by intensity of management as well. Costs estimated in Argentina were somewhat higher. The specific practices also varied considerably by country. For example, ant control was not important in North America, and absolutely necessary in most of Latin America. More expensive containerized seedlings and clones prevailed in much of tropical Latin America, while bare root seedlings still prevail in the United States. Heavy site preparation equipment and practices were common in the United States and Chile, and less common in Uruguay since the planted land usually was old pastures. Pruning was common in sawtimber rotations in Latin America, but rare in the US. We assumed a constant $20 per ha cost for management and administration costs for plantation species, and lowered this to $10 per ha for natural stand administration, since it should be less intensive.

We assumed that for the base case in these analyses that landowners already owned the land, so it was a sunk or not relevant cost in the analysis. New landowners would obviously have to add these costs as part of their initial investment, and subtract land sales at the end, as appropriate. Land prices were used as one of the sensitivity analyses for at least one species in each country.

We used timber stumpage prices—"valor de madera en pie"—as the base for our timber investment calculations. We had relatively good information on average plantation timber or stumpage prices in Argentina, Brazil, Chile, and the United States. Prices in Uruguay depend more on development of timber markets in the future. All of the plantation stumpage prices depend on well-developed markets for external wood purchases, or on transfer prices within a company, so are somewhat imprecise. The basis for our native species and natural stand timber prices was more speculative, other than in the US, since these markets are fairly "thin" or small. Argentina has active native species timber markets for many species, especially for Araucaria. The other native species average prices were based on sales from the Guarani Reserve forests managed by Universidad Nacional de Misiones (UNAM) in eastern Misiones province. Nothofagus markets in Chile also had good price information.

Capital budgeting analyses and sensitivity analyses

We analyzed the returns to these timber investments using typical capital budgeting techniques and criteria. Capital budgeting criteria analyzed included net present value (NPV), land or soil expectation value (LEV, SEV, or the Faustman formula), internal rate of return (IRR), equivalent annual income (EAI), and benefit:cost ratio (B:C). Standard references for such approaches include Davis et al. (2001), Klemperer (1996), Gregory (1987), and Brealey and Meyers (1991). A current summary of these and other modern approaches for portfolio analyses is contained in Zinkhan and Cubbage (2003). In brief, all the references describe these capital budgeting criteria that employ discounted cash analyses to determine the desirability of an investment.

At a known discount rate, NPV and LEV are the theoretically best criteria for ranking alternative forestry investments. However, seldom is there a given discount rate. We had at least three different annual, real discount rates commonly employed by companies in our respective countries—8%, 10%, and 12%. Long-term real rates of return are probably only 4% or 8% for most investments, despite higher corporate hurdle rates. We chose to use 8% as a common metric for analyses. Given the problems in determining the best discount rate, many analysts use the IRR as a ranking criterion. This is theoretically inferior if one has a known discount rate, but useful if discount rates are variable or not specifically set by corporate or government policy. IRR also is easy to compare with investments and assets other than those in forestry. The B:C ratio is easy to calculate, but seldom used in practice. The equivalent annual income (EAI) is useful as a comparison with other land uses that generate annual incomes, such as farming, or indeed such as government payments to withdraw land from production.

We developed computer spreadsheets for each species/country combination, and developed the inputs independently as analysts for each country in most cases, or via interviews and revisions. We used an iterative process of developing each spreadsheet, reviewing the results with other experts in each country, comparing those with the results from other countries, and revising the typical case to be sure that we had representative scenarios.

Table 5 Assumptions for sensitivity analyses of timber investment returns

Country/Species	Effective plantable area (%)	Timber land costs ($/ha)	Subsidy payments (% of cost)	Increased MAI (M^3/ha/year)	Increased sawtimber prices (%)
Brazil—*P. taeda*	60	2,500	Na	40	10
Brazil—*E. grandis*	60	2,500	Na	50	10
Uruguay—*P. taeda*	70	1,000	39	30	25
Argentina—*P. taeda*	70	800	50	40	50
Chile—*P. radiata*	70	1,500	50	30	10
US South—*P. taeda*	70	1,500	50	18	10

We also calculated timber investment returns with several alternative assumptions. Uruguay, Chile, and Argentina, and in the past, Brazil, have provided varying levels of plantation subsidies—about half the establishment costs—for exotic species timber plantations. The U.S has federal subsidies, but little funding. Each country also has various environmental laws or customary practices that require some of the land that is planted to be reserved, with Brazil generally having the largest reserve requirements. We also included at least one species analysis in each country with land purchase costs included as an initial cost, and then sold at the same value at the end of the rotation as revenue. Growth rates and stumpage prices also may be significantly greater than currently.

The sensitivity analyses performed were: (1) the withdrawal of some land from the plantable land area because of environmental restrictions, operating difficulties, or standard practices; (2) the inclusion of land costs as a factor of production; (3) the combination of (1) and (2); (4) the use of state subsidies for planting as available; and (5) the case of higher yields and prices. These sensitivity analyses were only applied to a few species with the greatest initial returns. Table 5 summarizes the assumptions for these sensitivity analyses.

Results and discussion

Base case financial returns

These financial calculations generally found the ordinal ranking one would expect regarding financial benefits (Table 6). Excluding land costs, exotic plantations in South America of *Eucalyptus grandis* and *E. dunnii* were most profitable with an internal rate of return (IRR) of more than 20%, followed by exotic loblolly and radiata pine, with IRRs of about 9–18%. Loblolly pine plantations in the US South were less profitable, with about a 9.5% IRR. Native timber forest plantations of *Araucaria* and *Nothofagus* in South America had rates of return ranging from 5% to 13%. These rates of return were less than exotic plantations, but certainly reasonable. Many native plantation species also might grow on a broader range of sites than exotics. Erva mate for mate/tea had high rates of return and could be a good alternative for export and medium size producers, but market demand has not grown much in recent years, so prices could decrease if production increased much.

The variation in timber investment returns, excluding the price of land, indicates that fast growth rates and reasonably good markets in Latin America do make their financial investment returns better. Brazil has the highest plantation growth rates

Table 6 Financial returns to exotic and native forest plantations and stands in the Americas by capital budgeting criteria with a 8% discount rate, 2005

Country	Species	Net present value ($/ha)	Land expectation value ($/ha)	Annual equivalent value ($/ha)	Benefit: cost ratio	Internal rate of return (%)
Argentina	*Pinus taeda*—Misiones	1,148	1,462	117	1.73	12.9
	Pinus teada—Corrientes	370	471	38	1.42	10.5
	E. grandis	819	1,241	99	1.77	13.8
	Araucaria a.	–169	–215	–12	0.85	7.2
	Native forest unmanaged	–97	–19	–11	–22	< 0
	Native forest best mgt.	–91	–111	–9	0.47	1.7
Brazil	*Pinus taeda*	1,870	2,495	200	3.25	16.0
	E. grandis	3,716	5,427	434	4.99	22.7
	E. dunnii	1,196	2,872	230	2.31	22.9
	Ilex p.	1,061	1,976	158	1.41	19.0
	Araucaria a.	823	963	77	1.96	12.4
Chile	*Pinus radiata*	2,729	3,345	268	3.57	16.9
	N. dombeyi	1,581	2,012	161	2.82	13.6
	N. nervosa	792	1,009	81	1.91	10.9
Uruguay	*Pinus taeda*	1,634	2,003	160	2.90	15.1
	E. grandis	2,890	4,081	327	5.15	21.9
	E. globulus	319	593	47	1.49	12.8
Subtropical optimal	Native species optimal mgt	–113	–138	–11	0.25	3.6
USA	*Pinus taeda* planted	333	408	33	1.39	9.5
	Pinus taeda natural	–25	–31	–2	0.94	7.8
	Pinus palustris	–413	–507	–41	0.16	4.3
	Hardwood sp.	–270	–331	–27	0.14	3.6

and the highest timber prices for exotic species at this time. Many new solid wood plants and pulp mill lines are being built in Brazil, which will continue to improve their wood fiber markets. Chile has good growth rates and good prices as well, and has built two new pulp mills recently. Both countries have excellent stumpage prices because they have large and expanding timber markets, creating large demand for stumpage and wood delivered to their mills.

The results from Uruguay place it third in comparative timber investment returns of the four Southern Cone countries examined. However, while its timber investment returns excluding the price of land seem attractive, the market prices for stumpage or delivered wood are less certain. The Uruguayan plantation timber sector really just began in 1987 with the new national forestry law, so the timber markets are very thin now. They depend on a small domestic solid wood market, pulpwood exports, and a potentially larger local pulp mill market. New planned processing facilities should come on line, including two pulp mills, two plywood/panel mills, and other plans. However, the pulp mills are under challenge by the government of Argentina and its province of Entre Rios across the Rio Uruguay, which claims that problems such as acid rain, water pollution, and foul smells will ruin their environment (Egan 2005). This has led to a major bilateral controversy, which is still under debate and discussion between the presidents of both countries (Yahoo Noticias 2006).

Plantations in Argentina have excellent growth, technology, well defined markets, and moderate timber prices. The exotic plantation returns were very good, ranging from 10% to 14% IRRs. Argentina has few large firms and a relatively large amount of fiber supply at the present, but supply is becoming tighter. A new pulp mill was planned for northeastern Argentina in the early 2000s, but was stalled due to the economic crisis of Argentina in 2001. The long distance from the fertile timber-growing regions of Misiones and Corrientes to major international markets may contribute to lower residual-value timber prices.

Timber investment returns excluding land prices in the US are less than in Latin America, because growth rates are less, while the prices may be only slightly better than in Latin America. Typical returns for natural stand management in the temperate forests of the US are not high, at about a 4% IRR per annum. The typical internal rates of return for the natural stands in subtropics were low, at only 4% for a stand that might be managed under optimal conditions, 2% for well-managed stands, and a negative IRR for unmanaged stands. The small periodic harvests, few merchantable species, moderate timber prices, and some annual expenses make holding natural forests a poor investment compared to other plantation alternatives. Their LEVs were negative at the 8% discount rate, but actually better than some of the native plantation species, since the input costs were small.

Plantation sensitivity analyses

The results of sensitivity analyses of the effects of land purchase, timber growth and prices, and policy subsidies provide important perspective and balance on the comparative returns among countries (Table 7). The rates of return calculated reflect the current factor (input) and product prices, including land, and current government policy. The effect of these market prices and government policies determine investment returns, and changes will alter those returns. Land markets generally reflect the ability of owners to produce goods and services, which is reflected in land prices. Competing uses for land will be incorporated into land prices. For individuals who already own land, land prices and price increases are

Table 7 Sensitivity analyses of timber investment returns with land costs and subsidy payments—internal rate of return (%) and land expectation value ($/ha, 8%)

Country/ Species	Criteria	Base without land costs	Base, reduced plantable area	Base with land costs	Base with land costs, reduced area	Base with subsidy payments	Base with high yields, prices
Brazil	IRR	17.0	16.1	8.8	6.4	Na	23.7
P. taeda	LEV	3,095	1,578	595	–922		9,704
Brazil	IRR	22.7	21.7	11.7	7.7	Na	27.5
E. grandis	LEV	5,427	2,859	2,927	–159		9,788
Uruguay	IRR	15.1	14.5	10.2	8.9	17.3	18.8
P. taeda	LEV	2,003	1,320	1,003	320	2,293	4,514
Argentina	IRR	12.9	11.7	9.9	8.3	15.9	19.8
P. taeda Misiones	LEV	1,462	808	762	108	1,958	4,924
Chile	IRR	16.9	16.1	10.8	9.3	23.5	38.0
P. radiata	LEV	3,345	2,218	1,845	718	3,938	16,605
US South	IRR	9.5	9.2	5.9	5.0	11.0	12.3
P. taeda	LEV	408	241	1,137	–1,304	–702	1,749

“sunk” costs, and as such were not considered relevant for the base case used in this research. However, new owners must purchase land at its current market price before beginning a plantation, which is a significant investment cost.

The inherent advantages of fast growth rates and good timber prices for exotic species on existing forest land in Brazil and Chile give them tremendous advantages. However, like all economic activities, these high profits for forest investments have attracted more competition as well as capital, thus driving up the costs of the factors of production, especially land. Policy interventions—subsidies or regulations—also can make significant differences.

Required reserves of land for natural forests and for environmental laws in Brazil would reduce the effective plantation area to 60% of the gross land area. This would not have large adverse impacts of timber investment returns if one already owns the land—reducing IRRs from 17% to 16% for *Pinus taeda*. But land reserves made net returns much worse if one must buy unproductive natural forest or abandoned farm land and only get returns on the new plantations, reducing them to a 6% IRR. The reductions in IRRs for *Eucalyptus grandis* in Brazil are similar, but the IRRs remain greater than those for *Pinus taeda*. Adding land cost to the *Pinus radiata* analyses in Chile reduced the net IRRs from 17% to 11%. Chile also has significant environmental laws. In net, Chile’s requirements may reduce the effective planted area out of the total area to about 70%, which does reduce net returns for existing land owners to about 16%, and to about 9.3% for new owners.

Annual internal rates of return for *Pinus taeda* in Uruguay without land costs were 15%. With land costs, the net IRRs in Uruguay were 10%. Without land costs, but with 70% net effective plantable area, the IRR was 14.5%. With both land costs and decreased area, the IRR was 8.9%. In Argentina without land costs, but with 70% net effective plantable area, the *Pinus taeda* IRR was 11.7%. With both land costs and decreased area, the IRR is 8.3%. Without land costs, but with 70% net effective plantable area, the US IRR was 9.2%, compared to 9.6% for the base case. With both land costs and decreased area, the IRR was 5.0%. Higher yields or prices could make large improvements in IRRs and LEVs in Latin America, and slight improvements in the southern US

The scenarios with increased yields and prices for each selected country and species further increased the advantages of *Pinus taeda* and *Eucalyptus grandis* in Brazil, with the exception of Chile. Chile had spectacular increases in internal rates of returns and land expectation values if yields increase significantly, mostly because stumpage prices were already relatively high. We did not run scenarios of low yields and stumpage prices, nor for the sensitivity of the investment returns for native plantations and natural stands. Land costs and land reserves reduced even the best exotic plantation returns; they would probably force the returns for the other country native species combinations to be very low or negative.

Biological and financial risk

Biological risks differ by species and country. Surprisingly, risks for exotic plantations to date have not been great, or perhaps have even been less than for native species. This is largely because exotic plantations have fewer adapted predators or pathogens than native species so far. Brazil and Argentina have had some problems with *Sirex noctilio* wood wasps in loblolly pine, and have introduced natural predators to help control this. Tip moths are common in pine plantations throughout

Latin America, and may be controlled with pesticides depending on the severity of the attack. Needle cast (*Sphaeropsis pinea*) is a significant problem in Chile. Leaf-cutting ants are a huge problem in young plantations throughout Latin America (except in the temperate South), and are controlled with considerable effort and expense with biological and pesticide traps scattered throughout the stands as needed.

Policy and political risks also vary by country, such as withdrawal of financial subsidies, drastic changes in political stability, or major changes in environmental laws. One would assume that the US has less risk of major political upheaval, but federal subsidies for intensive pine plantations are essentially gone, and state subsidies are at risk given very tight budgets. Brazil seems to have the most environmental laws and requirements that are enforced, at least in the South. Chile has established laws and a stable policy environment at present, and Uruguay seems stable and supportive of forest industry and external investments, although its planting subsidies were phased by 2006. Argentina seems to have less environmental regulations and a favorable forest industry climate, but more national political instability.

Financial risk can be measured in various manners. We obtained country risk ratings scores from the Economist Intelligence Unit (2005), which provides average scores periodically for 100 countries, excluding western Europe, the US, and Canada. In March 2005, the average score was 47 and the range was 17–91, with lower scores indicating less financial risk. For the 100 countries scored, Chile received a 22, and was the fourth best country rated. Brazil received a 46, and was 51st of all the countries. Uruguay had a 53, and ranked 65th. Argentina received a 72, and ranked 97th of the 100 countries—with only Myanmar, Zimbabwe, and Iraq being ranked worse. These risk scores certainly favor Chile, Brazil, and perhaps Uruguay. One would presume that the US and Europe country risk is less.

On the other hand, The InterAmerican Development Bank (IADB 2005) completed a comprehensive study and developed and index for forestry investments (El Índice de Atracción a la Inversión Forestal (IAIF)) for ranking of the opportunities for forestry investments throughout Latin America. The study analyzed factors outside the forestry sector, within the sector, and relations with other sectors. They also developed a spreadsheet simulator that can be used to analyze various assumptions about forestry investments. Factors included in the ranking and simulator include internal and external investment environment; macroeconomic, demographic and infrastructure characteristics; tariffs and regulations; labor costs, productivity, and technical skills; finance, loan, and market access; and forest sector land, area, volume, plantation, and wood product market statistics. Their index ranked 26 countries, with a range from 23 to 60 points, with more points indicating a more favorable investment climate. Brazil ranked first, with 60 points, followed by Chile (53), Argentina and Uruguay (44), Costa Rica (41), and Colombia and Mexico (40).

In another source, according to the United Nations Program for Development, Argentina ranked as the most developed country in Latin America, at number 34 in the world. It was followed by Chile (37), Uruguay (46), Costa Rica (47), and other countries (Yahoo Noticias 2005).

These somewhat disparate rankings suggest that Chile has the best overall country risk rating; overall levels of development were high in Argentina; and that Brazil ranked highest for forestry investments. However, all countries seemed to offer excellent opportunities for forestry investments, as was also reflected in our investment return calculations.

Conclusions

These analyses estimated the financial returns to forestry investments in Latin America and the southern US for many exotic and native species, in plantations and in natural stands. They extend the research reported in earlier articles such as Sedjo (1983, 2001) and Tomberlin and Buongiorno (2001). Our results provide more current analyses of comparative returns to timber investments in the Americas, and extend the analyses to cover a wider range of countries, and add native as well as exotic species. We also included sensitivity analyses of the investment returns to land costs, subsidy payments and forest reserves, and discussed the forestry investment situation in each country. In addition, our cooperation among scientists from each of the relevant countries provides for robust estimates and credibility for the analysis and interpretation.

The base results from our research generally conform with the comparative results reported in prior research, and add currency and depth to the analyses of the factors affecting the entire investment picture for planted and native timber and land investments. Our estimated growth rates were similar to the ranges reported by Tomberlin and Buongiorno (2001), and significantly greater than those reported by Sedjo (1983) two decades ago, reflecting the success of tree improvement and silviculture since then. Our estimated internal rates of return varied somewhat from those reported by Sedjo (1983, 2001), but have not changed dramatically over the intervening 23 years. Thus even though growth rates have increased, IRRs have increased only moderately because input costs have risen as well. Our estimates of native planted species and natural stands provide much more depth than prior analyses.

Our estimated IRRs were greater for eucalypts in Brazil, less for southern pine in the US, and similar for radiata pine in Chile to those of Sedjo (1983, 1999, 2001). Perhaps continuing changes in factor costs and stumpage prices can account for these differences. Furthermore, Sedjo (1983) found that pulpwood rotations were often more profitable than sawtimber rotations. Our analyses included mixed product scenarios in all but a few cases because stumpage prices have increased and sawtimber products and rotations are more profitable, as confirmed by our calculated rates of return and present values. This trend has increased more in 2006 as well as large timber products prices have increased more rapidly.

For existing owners, without land costs, timber investment returns for exotic timber plantations in Latin America are generally much greater than those for the native species of loblolly pine in the southern US. Brazil had the greatest investment returns generally, based on excellent growth rates and good prices for timber. Growing eucalypts for sawtimber was the most profitable plantation wherever that was possible. Radiata pine in Chile had excellent returns as well, based on good growth rates and excellent timber prices. Uruguay has prospects of good investment returns as long as satisfactory markets and prices develop. Argentina has excellent growth rates and moderate timber prices. Better markets and higher prices could enhance their returns. With fairly plentiful and cheap land in Misiones and northern Corrientes, Argentina offers fast growth rates and attractive investment returns, especially if more wood processing capacity is added. Plantations in the US have growth rates of about one-third to one-half of those exotic plantations in Latin America, which dampens investment returns despite relatively high prices.

Rates of return for native species plantations without land costs, in Latin America and in the US, were fairly similar, with IRRs ranging from about 4% to 10%. However, araucaria in Brazil and nothofagus in Chile had IRRs between 10% and 14%. The key to receiving good investment returns for native species was reasonable growth rates, of say at least 5 m^3 per ha per year. These rates of return are comparable to those of other capital assets, excluding land costs.

The costs for establishing timber plantations and stumpage prices among different species—exotics or natives—were not all that different. Establishment costs in the first five years ranged from about $600 to $1000 per ha in all countries. Stumpage prices varied some, but first thinnings were usually worth very little in any country, at about $2 to 5 per ton. They increased to approximately $5 to $10 per ton for second thinnings; $10 to $20 for third thinnings, and perhaps $20 to $40 for final harvests. The higher timber prices in Brazil and Chile helped yield higher net investment returns.

Native forest stands in subtropical Latin America take longer to grow and have much lower growth rates and returns than plantations. Their internal rates of return for degraded stands were generally only 2% per year at best, and could be negative—that is they cost more for taxes and administration than they return on average. However, despite these low IRRs, the negative LEVs at 8% are small, since only small administrative costs are incurred. The LEVs for most native stand plantations at 8% are actually more negative, despite their higher IRRs, since large investments must be made initially. The immediate harvest of well-stocked native stands would be far more attractive financially, but is not likely to be sustainable without good management, as suggested by our results.

The assumptions on growth rates and management costs for subtropical native stands were less definitive, with less actual market information available. The US rates of return for natural stands were actually the best, with about 4% IRRs. The poor financial returns are apt to be a key reason that subtropical forests are not managed much. The returns for better managed subtropical stands suggest that they are better than losing money, and do not require much capital. Natural stands still comprise about 98% of the forests in the Americas, so managing them well certainly is important, and much better than neglect. One might presume that subsidies for natural forests might help them a lot, but their low establishment costs reduce the benefit of these payments. Perhaps most useful policy tool for natural forests would be the elimination or significant reduction of annual property taxes, which we assumed were about $10 per ha per year, and decreased natural stand returns the most. Cost-share payments for culling non-commerical trees and cutting vines could help improve natural stand investment returns. Certification may help market natural stands as well, such as in Bolivia. Payments for environmental services have also been promoted as a means to enhance financial returns from and to protect natural neotropical forests.

It should be noted that there are many financially attractive opportunities in natural forests in the subtropics other than these general regimes we analyzed. Teak has been a principal species for decades with good potential for harvesting and management. Exploitation of native forests and replanting on a sustainable basis also can offer immediate income opportunities and may allow for sustainable forest management in the long run. Our natural stand scenarios are representative of management of common degraded subtropical forests. The plantations of native species are apt to have greater growth rates and financial returns.

The sensitivity analyses indicated that land costs, government subsidies, and reserve areas affect timber investments significantly. State subsidies generally could increase the rates of return about 2–3% when they were available, or the land expectation values about $300 to $500—the share of the establishment costs that was cost shared. Forest reserve areas decreased rates of return about 1%, excluding the costs of land. So the requirements for forest reserves per se for existing owners did not seriously affect the calculated investment returns. They also were fairly comparable among all countries except Brazil, which had the strictest forest reserve requirements and environmental laws. These policy factors would eventually be incorporated into land prices along with the opportunity costs for other agricultural or urban land uses.

The need to purchase land would have extremely large negative effects on plantation investment returns. Brazil and Chile had the highest land costs and thus the greatest reductions in IRRs and LEVs, but the effects in all countries were substantial. IRRs decreased to 10% or less for all plantations when the land purchase costs were included, with the same value of sales at the end of the rotation investment. Uruguay fared best when land costs were included, because of relatively inexpensive land. If land appreciated at rates greater than real prices, then land could increase investment returns. This has probably occurred in most of these countries, but we did not use this assumption since it was too speculative.

Certainty and risk also differ by country and species. The growth rates, management techniques, timber prices, and financial returns are probably much more certain for plantations. Plantations do require more knowledge to manage well, but forest science and technology have made large advances here. The state of silvicultural knowledge for natural forests is much less, surprisingly. Variation among natural stands is huge as well, and commercial species comprise only a small portion of the stand usually in the subtropics. Occasionally prices may be much greater for native species of good quality, in the US or in Latin America. But this is not a general rule, just an occasional event.

Financial and political risks are generally considered to be less in the US than anywhere else in the world, although the recent wars, increasing budget deficit, natural disasters, and national debt could reverse this conventional wisdom. Chile is widely considered the most stable Latin America country and this was borne out strongly by the Economist Intelligence Unit (EIU) scores. Brazil has done exceptionally well in recent years, but has more environmental regulation and more complex policies for external investors. Uruguay has had stable governments and friendly policies for external investors, but has a large debt and more financial risk, and is fighting a major, unprecedented challenge by Argentina to the construction of the pulp mills in Uruguay. Argentina partially defaulted on all of its private debt in the 2000s, and has had considerable political upheavals, leading to the fourth worst EIU score in the world. However, the IADB investment simulator and ranking suggests that for forestry investments, the countries we have examined were the most important, and that when all factors are considered, Argentina provides a strong forestry sector investment opportunity.

These results provide more specificity to the probable financial returns of exotic plantations, and merits of managing native species for timber investments. We calculated average returns for typical or representative sites and conditions. However, the variation among sites, factor costs, growth rates, and timber prices could generate financial returns within species that were greater than the typical returns among species. While our calculations of native species returns are preliminary, they do help explain pervasive problems in conservation of these forests, and suggest a goal for improved management.

The requirements of forest reserve areas have moderate effects on forest investment returns, as do plantation subsidies. Land purchase costs, however, have substantial adverse effects on forest plantation (or natural stand) investment returns. This indicates that as always, those who made early investments such as in timber plantations in Latin America will garner the greatest returns, like many other attractive investments. There still are better opportunities for much higher returns in Latin America, but they will require careful attention to details and management costs for success. Conversely, superb management in the US can allow comparable investment returns to average cases in Latin America, with less quantifiable risk of variability in returns.

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