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Effect of land prices, transportation costs, and site productivity on timber investment returns for pine plantations in Colombia

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Abstract The relative importance of land costs, site quality, and forest location are major concerns in forestry investments, but little research has been done to assess the impacts of these or other factors on financial returns. In response to this issue, the effects of land prices, wood transportation costs, site productivity, and discount rates on timber investment returns for pine plantations in the Andean Region in Colombia were estimated. For all the scenarios analyzed, the internal rate of return varied between 6.4 and 15.6%. High site quality with high growth rates were profitable in all scenarios at real discount rates ranging from 8 to 12%, but low site qualities seldom had positive net present values. Less expensive land and locations close to mills had better rates of return. More distant locations, poor quality sites, or areas with high land costs generally did not meet the discount hurdle rates. Site quality, which is the factor most easily manipulated by intensive forest management and improved technology, was substantially more important than land prices and transportation differences in determining timber investment returns.

Keywords Forest investments · Location · Intensive management · Plantations

Introduction

Forest plantation investments are continuing to increase throughout the world as demand for forest products, wood fiber, and forest biofuels increases. Commercial plantations of

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pines and eucalypts in the tropics and subtropics continue to expand the most, fulfilling the growing demand for wood products in the global market. Investors are seeking appropriate locations and opportunities for timber investments, and this sector remains comparatively attractive as the stock market and other sectors faltered in late 2008. The rapid increase in many commodity prices such as minerals and food suggests that timber for pulp, paper, and construction may offer related investment opportunities. In fact, timber prices increased significantly in Latin America in the last decade, although this trend has not occurred in the United States.

For example, in 2007, Carter stated that a Merrill Lynch survey identified about $4 billion of potential net institutional capital inflows into timberland over the next 3–5 years, representing a 10–11% increase in the $35–$40 billion currently invested in the timberland asset class. However, this is only about 0.3% of the approximately $60 trillion global wealth portfolio. He estimated that there was more than $10 billion of committed but un-invested capital targeted at the timberland asset class, particularly by many Timberland Investment Management Organizations (TIMOs).

Latin America offers an attractive investment opportunity for investors in particular, with large increases in production and demand in recent decades (Gonzalez et al. 2008), productive land with rapid growth rates at reasonable prices, lower operating costs (Forgach 2008) and good timber prices and better investment returns than North America (Cubbage et al. 2007). Leading TIMO investors such as Harvard, Hancock, Global Forest Partners, and RMK have made significant investments in Latin America, and many others are seeking to do so as well (Forgach 2008). Many other major foreign and domestic investors have sought or made forest land investments in Latin America as well.

This increase in investments prompts many questions about buying and managing forests and the tradeoffs between location, site productivity, and management intensity. Leal (2008) noted the importance of localized markets in Brazil in determining investment returns, while Stape (2008) discussed the returns to intensive silvicilture in Brazil for a variety of exotic timber plantations. Investors are acutely interested in assessing the advantages of such market location and silvicultural opportunities. Furthermore, current forest land owners also are uncertain about the relative merits of making investments in intensive forestry in expensive locations proximate to mills versus less intensive forestry at cheaper, but more distant sites.

Few assessments have analyzed these questions of land quality, location, and silvicultural intensity with empirical data in any country. As a model for further analyses for exotic tropical and subtropical plantations, we estimated the effects of four crucial variables—land prices, wood transportation costs, site quality, and discount rates—on pine plantation returns in Colombia. We could obtain excellent estimates of input costs, silvicultural variation, log hauling rates, and product markets in the country, which provide the bases for answering the questions of location and productivity tradeoffs well.

Research by Sedjo (1999, 2001) established that investments in exotic species timber plantations in the Southern Hemisphere were generally much better than plantation or natural stands in the Northern hemisphere. FAO (2002) and Cubbage et al. (2007) extended this research, calculating the returns on investments on plantation forestry in the Americas. Cubbage et al. (2007) provided information on the net present value, land expectation value and internal rate of return for different forestry species at the stumpage level in different countries. Plantations of exotic species continued to offer much better financial returns than plantations of native species or natural stand management. Other global timber supply models and analysis have consistently shown that the southern hemisphere and

Latin America have competitive advantages in timber production and prices (Tomberlin and Buongiorno 2001; Daigneault et al. 2008).

However, none of these studies provide details on the comparative factors of production in determining timber investments returns at specific site quality and field locations. Investors seek to take advantage of these opportunities based on different factor costs in order to receive better profits. This research examined these factors to provide more detailed breakdowns of opportunities for selecting among investment location, quality of land, and management intensity to maximize forest investment returns.

Methods

This research examined the contribution of land costs, site quality, distance to the mill, and the discount rate on forest investment returns. We analyzed these factors using data on pine plantations in the Andean region of Colombia (Figs. 1, 2). We used different annual growth rates as a reflection of site quality, sales of wood by the tree grower at the mill gate, based on market prices for different forest products, wood transport costs, and bare land costs to calculate the comparative returns to representative forest investments in Colombia.

Colombia was the focus of the study based on our integrated field and analytical experience and professional contacts there, and the ability to gather reliable data on input costs and output prices. Colombia has had substantial new interest in new forest investments, including by existing firms, and has hosted several forest sector investment tours since 2006.

Data

We collected data for factor costs and product prices and used discounted cash flow analyses to estimate timber investment returns using a range of input productivity and cost assumptions. Data on forest productivity, typical location and transport distances, costs and prices were collected from a range of foresters and experts in Colombia. The data were checked for accuracy and revised in several iterations of review by these individuals. Data included a range of tree growth, establishment and management costs, and timber product prices of representative pine plantations in Colombia (Table 1). The management regime assumed representative intensive site preparation, tree planting, and other silvicultural practices and costs (fertilization, herbaceous weed control, pruning, and ant control), including two thinnings at 10 and 15 years and a final harvest at 20 years of age. Administration and overhead costs of 20% for the silvicultural regime were included.

Pine trees in the Andean Region of Colombia are typically planted in slopes over 20% at elevations between 1,400 and 2,500 m above sea level. Thus, the harvesting systems considered in this analysis are a combination of skyline harvest system, animal logging and manual labor with a cost varying between \$19 and \$23/m^3, depending on the harvested product and logging distance. Four ranges of transportation distances from the tract to the mill were examined: (1) 0–50 km, (2) 50–100 km, (3) 100–150 km, and (4) 150–200 km, with corresponding average market transportation costs to a mill location of at \$6.50, \$8.60, \$12.90 and \$14.20/m^3.

A range of forest land values were considered for this study, with prices changing between \$0 and \$2,000/ha, in increments of \$200. The cost of land used for this analysis was its opportunity cost of capital, including the purchase price at the beginning of the

Fig. 1 Map of Colombia http://www.worldcountries.info/Maps/Region/SouthAmerica-450-Colombia.jpg

project and removing it out at the end of the rotation at the same price, at the final harvest age.

The base silviculture for this study assumed intensive management, including thorough site preparation, fertilization when planting, frequent herbicide spraying during the first years of growth, pruning at year five, and two thinnings. Growth rates of pine plantations may be affected by site quality, genetic improvement, and silvicultural practices, which we proxied by a general growth rate per ha per year for three levels of site quality—20, 30, and

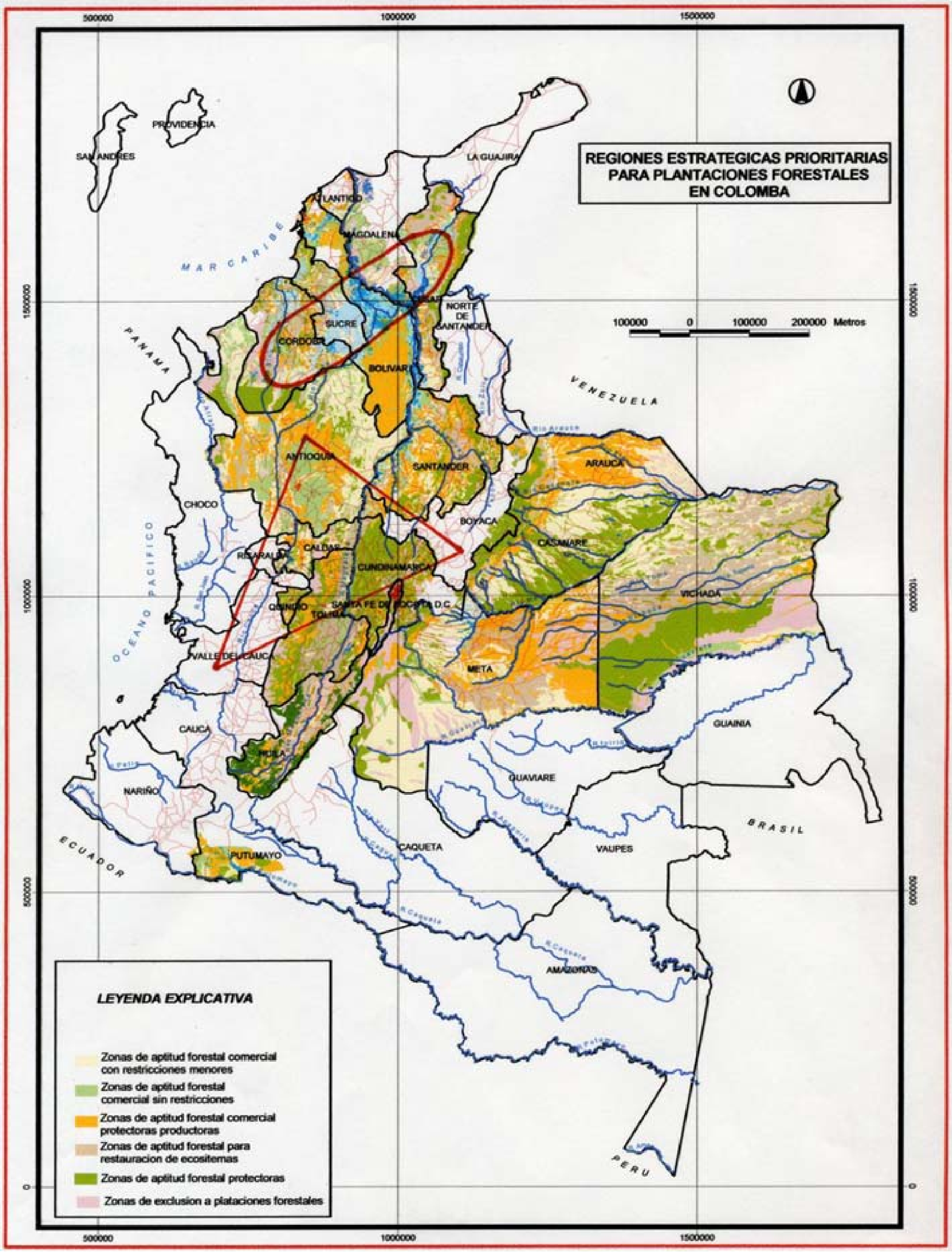

Fig. 2 Map of Andean region of Colombia and zones for commercial plantation production (FAO and CONIF 2006)

40 m^3/ha/year. Wood volumes were estimated on the local custom of cubic meters, outside bark. One cubic meter is equal to approximately one green ton outside bark.

Forest income was estimated based on harvested wood sales and the typical government economic incentive received by tree growers during the first 5 years of the project (Year1 \$350/ha, Year2 = \$94/ha, Year3 = \$66/ha, Year4 = \$42/ha, Year5 = \$80/ha). Mean prices of timber per cubic meter at the mill gate were assumed to be \$33 for pulpwood, \$74

Table 1 Establishment and management cost of a typical hectare of pine plantations in Colombia with intensive silviculture ($/ha)

Activity	Year 0	Total year 1–20
Site preparation	137	
Planting	800	
Stand treatment		
Ant control	32	296 (16 Each year)
Herbicide	389	546 (Years 1 and 2)
Pre-commercial thinning		46 (Year 5)
Pruning		167 (Year 5)
Management		
Roads and fences	102	296 (16 Each year) + 61 (years 4, 9, and 14)
Fire control/breaks	16	296 (16 Each year)

for wood to be treated, and $66 for sawtimber. The exchange rate used was US$1 = Col$2,252 computed as an average from January 1999 to January 2008 (Banco de la República, Col 2008).

Input costs and timber return prices were held at constant prices throughout the analysis. While both costs and prices may vary, predicting these changes is untenable, and would detract from the analysis and results. Land costs are apt to increase based on historical trends and the opportunities for higher and better use (HBU) sales in developing urban areas, but estimating the trend is moot, so it was not used here.

Capital budgeting calculations

The input data were entered into spreadsheet and used to calculate net present value (NPV), internal rate of return (IRR), and other capital budgeting results. These were calculated for all the possible combinations of 11 land prices, 4 distances to the mill, and 3 growth rates. Real discount rates of 8, 10 and 12% were used to calculate the NPV. The capital budgeting results were estimated directly with the four factors at each of their different levels.

Then the NPVs were re-calculated with normal distributions of the input assumptions using Monte Carlo simulation with 10,000 iterations (scenarios) to consider variation in input productivity and costs. The distribution characteristics (mean and standard deviation) for each variable (land price, MAI, and distance to the mill) were defined using the same middle value as in the capital budgeting analysis with the following means and standard deviations: land price (LP) = $1,000/ha and standard deviation (SD) = $300/ha; mean annual increment (MAI) = 30 m^3/ha/year and SD = 10 m^3/ha/year; and distance to mill (DM) = 100 km and SD = 30 km. For each iteration, the Monte Carlo simulation selected a random value for each variable, based on the defined characteristics, and calculated the corresponding outcome. After all iterations, the probability distribution of possible outcomes was computed assuming the three variables are independent.

Regression analysis of the simulated data was performed using *Proc Reg* in SAS (SAS 2008) to develop a response surface that would estimate the relative interactions among the three factors that affected net present values. The models were based on the whole preceding data set. They estimated NPV at 8, 10 and 12% discount rates, respectively, as a function of the mean annual increment (MAI), land price (LP), and the distance to the mill (DM), as shown in Eq. 1.

$$NPV = \beta_0 + \beta_1 \times MAI + \beta_2 \times LP + \beta_3 \times DM + \varepsilon. \quad (1)$$

The marginal effect of each of these variables on timber returns for pine plantations was estimated as the coefficients of the model. This response surface regression approach provides a means to integrate the relative effect of the different independent variables. The regressions integrate the results of the probabilistic Monte Carlo NPV scenarios, which generate high coefficients of determination.

In addition to the core economic analysis described above, we performed sensitivity analyses on for the basic model to examine the impacts of being unable to plant trees on less productive forest areas, not receiving the state subsidy to plant forest land, or changes in timber prices. The impacts on NPV and IRR were estimated for each of these cases at the base case of $1,000/ha for the land price.

Results

The results of the capital budgeting analyses are summarized in Tables 2 and 3, and synthesized in Figs. 3a–c and 4a–d. The tables summarize all the base calculations, and figures provide a means to examine the results holding one factor constant at a given discount rate, and varying the other two. These results provide the basis for the regression analysis that allows comparison of the relative importance of the three principal factors of plantations costs—land, site quality, and transportation.

Capital budgeting

Under the assumption of equal growth potential in all land prices, obviously the less expensive land would be more profitable than more expensive land. Less expensive land might be associated with good purchase prices, lower site quality land and growth rates, more rural areas, or greater distance from the mill or an urban area. Figures 3a–c graph the NPVs at a 10% discount rate for different MAI and transport distance levels. The break-even point on the graphs can be considered the point at which NPVs are positive. At a land price of $600, NPVs are positive for all MAI levels of 30 or 40 m^3/ha/year, and MAI 20 m^3/ha/year within 50–100 km from a mill. As anticipated, higher price land reduces these breakeven points. A land price of $1,200/ha makes all MAI 20 land unprofitable at a 10% discount rate, as well as 30 MAI land that located more than 150 km from a mill. Land costs of $1,800/ha prompt 30 MAI land of greater than 100 km from the mill or more to be unprofitable. Table 2 summarizes these breakeven points in results for major categories.

With a timber investment discount rate of 12%, the profitable distances would change dramatically. The low and mid value land would not be profitable at any distance from the mill because all the NPVs would be negative, while the high valued land with 40 m^3/ha/year MAI only would be profitable at distances <75 km from the mill. These results suggest that it is more profitable to buy highly productive more expensive land than low price land with low productivity, despite the initial expense.

When the land cost is zero, the IRR varies between 10.6 and 18.1% among the worst and best case scenarios. At a 10% discount rate, the NPV ranges from $165/ha with MAI 20 m^3/ha/year and 200 Km distance, to $3,595/ha with MAI 40 m^3/ha/year and less than

Table 2 Net present value at 8, 10 and 12% discount rates for four land prices, three growth rates and four distances from pine plantations to the mill in Colombia, 2008

Land price ($/ha)	Mean annual increment (m^3/ha/year)	Distance to the mill (km)											
		Net present value at 8% discount rate ($/ha)				Net present value at 10% discount rate ($/ha)				Net present value at 12% discount rate ($/ha)			
		0–50	50–100	100–150	150–200	0–50	50–100	100–150	150–200	0–50	50–100	100–150	150–200
600	20	1,127	895	421	278	170	(4)	(358)	(465)	*	*	*	*
	30	3,025	2,678	1,966	1,751	1,573	1,313	782	621	540	344	(58)	(180)
	40	4,906	4,444	3,498	3,212	2,964	2,619	1,911	1,697	1,580	1,319	784	622
1,000	20	733	501	27	(116)	(251)	(424)	(779)	(886)	*	*	*	*
	30	2,631	2,283	1,572	1,357	1,153	893	361	200	102	(94)	(497)	(618)
	40	4,512	4,050	3,104	2,818	2,544	2,198	1,491	1,277	1,142	880	345	183
1,400	20	338	107	(367)	(511)	(672)	(845)	(1,199)	(1,306)	*	*	*	*
	30	2,236	1,889	1,178	963	732	472	(60)	(220)	(337)	(533)	(935)	(1,057)
	40	4,118	3,656	2,710	2,424	2,123	1,778	1,070	856	703	442	(93)	(255)
1,800	20	(56)	(287)	(761)	(905)	(1,092)	(1,265)	(1,620)	(1,727)	*	*	*	*
	30	1,842	1,495	784	569	311	52	(480)	(641)	(775)	(972)	(1,374)	(1,495)
	40	3,724	3,262	2,315	2,029	1,703	1,357	650	436	264	3	(532)	(694)

* Negative net present values not included in the Table

Table 3 Internal Rate of Return (IRR) for four land prices, three growth rates and four distances of pine plantations to the mill in Colombia, 2008

Land price ($/ha)	Mean annual increment (m^3/ha/year) Distance to the mill (km):	IRR (%)			
		0–50	50–100	100–150	150–200
600	20	10.4	10.0	9.0	8.7
	30	13.4	12.9	11.8	11.5
	40	15.6	15.1	13.9	13.6
1,000	20	9.4	9.0	8.1	7.8
	30	12.2	11.8	10.8	10.4
	40	14.3	13.8	12.8	12.4
1,400	20	8.6	8.2	7.3	7.0
	30	11.3	10.9	9.9	9.6
	40	13.3	12.8	11.8	11.5
1,800	20	7.9	7.5	6.7	6.4
	30	10.5	10.1	9.2	8.9
	40	12.5	12.0	11.0	10.7

50 km distance from the mill. If the hurdle rate is 12%, the NPV is negative only in those cases where the MAI is <20 m^3/ha/year and the distance from the mill is greater than 100 Km. At 12% the maximum NPV is $2,238/ha when the MAI is 40 m^3/ha/year and the distance is <50 km.

Figures 4a–d illustrate the effect of distance from the stands to the mill on the net present value at the 8% discount rate at four land prices and three growth rates. The difference between the first and fourth graphs illustrates the effect of transportation costs on the profitability of the pine stand when wood is sold at mill gate. Tree growers with forest land close to the mills are more profitable than those far from mills. When the distance from the pine stand to the mill is 50 km, the net present value of the project is positive for all possible combinations of land prices and tree growth rates examined at the 8% discount rate, except for one—when land price $1,800/ha or more.

This means that almost all the timber investments close to a mill would be profitable at 8%, including those with expensive land and low productivity. When the distance increases to 200 km, those timber growers with land productivity below 20 m^3/ha/year and land value over $1,000/ha would not receive an 8% rate of return. According to this study, pine stands with growth of 30 m^3/ha/year or more, even in the most expensive land, can be profitable to distances over 200 km from the mill at 8% discount rates.

The increase of discount rates to 10 and 12% significantly decreases the NPV. At the 12% discount rate, all land with productivity of <20 m^3/ha/year, independent of the distance, is not profitable. Similarly, pine plantations with mean annual increment of 30 m^3/ha/year are profitable only in a few cases where land value is $1,000/ha or less and distance to the mill is less than 50 km (Table 2).

These results are consistent with those observed for the internal rate of return, with higher values when distance to the mill is shorter, land price is lower, and growth rate is higher (Table 3). The IRR varied between 6.4% for the worst-case scenario (150–200 km, $1,800/ha and 20 m^3/ha/year) and 15.6% for the best-case scenario (0–50 km, $600/ha and 40 m^3/ha/year).

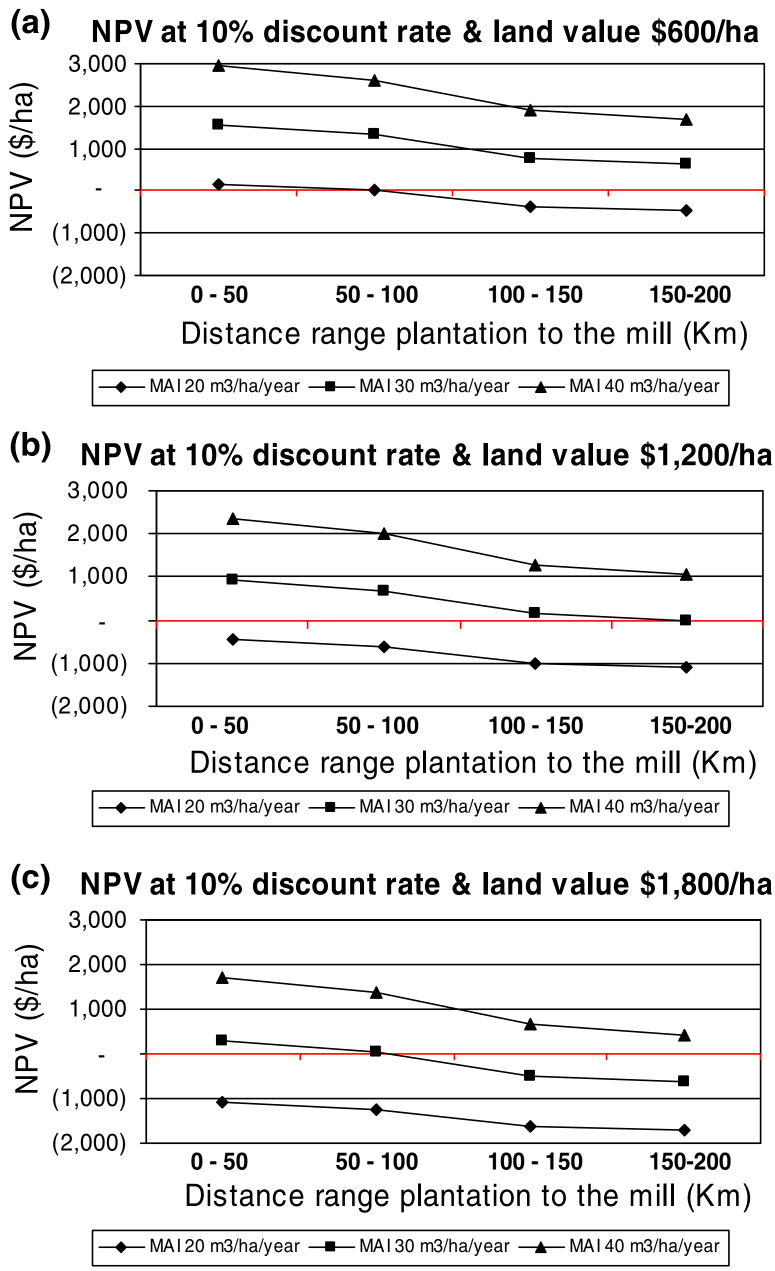

Fig. 3 Change of NPV (10% discount rate) for three growth rates, four distances to the mill and a land price of **a** \$600/ha, **b** \$1,200/ha, and **c** \$1,800/ha

The sensitivity analyses indicated that the relative order of NPVs is quite stable even under the different assumptions. As expected, the NPV decreases if a part of the land is taken out of production, or if the state subsidy for plantations is terminated. Timber price decreases of 10% decreased NPVs moderately as expected, but timber price increases of 10% actually increased NPVs more. A 10% decrease in timber prices decreased NPVs from \$134 to \$467/ha. Conversely, a 10% increase in timber prices had a larger effect, increasing NPVs by \$534–\$867/ha. Removing the state subsidy for pine plantations would be a direct reduction in the NPV for all scenarios since it is the same for each one. If only 70% of the land purchased were available for plantations, due to environmental rules, roads, infrastructure, or losses to pests, disease, fire, or storms, it would reduce the NPV from as much as \$905/ha for the 40 m^3/ha/year site, 50–100 km distance class (from

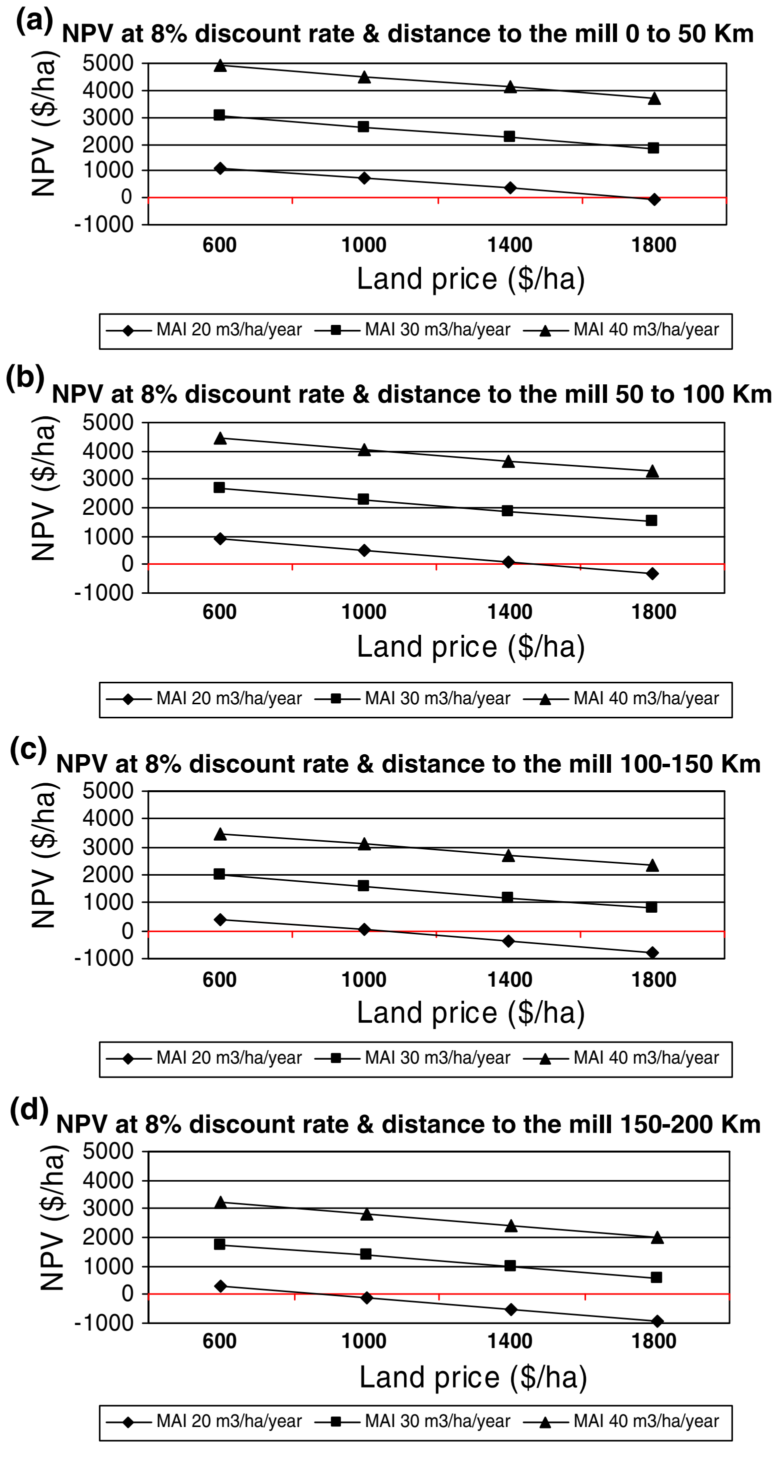

Fig. 4 Change of NPV (8% discount rate) for three growth rates, four land prices and a distance to the mill from **a** 0 to 50 km, **b** 50 to 100 km, **c** 100 to 150 km, and **d** 150 to 200 km

$2,198 to $1,293/ha) to as little as $118/ha in the 20 m^3/ha/year site, 50–100 site class (from −$424/ to −$542/ha).

Relative factor importance

The capital budgeting and Monte Carlo simulation results provided useful information regarding the impacts for three factors of pine plantation wood production—land costs, transportation costs, and site quality. In order to examine the relative magnitude of these costs, we used regression analysis of those results to estimate regression equations and coefficients. One can then compare these coefficients to ensure that they do have the anticipated direction of effects on plantation production financial returns, and more importantly, to determine the relative magnitude of importance of the three factors.

The results of the regression analyses as modeled in Eq. 1 to estimate the NPV at the three discount rates are shown in Table 4.

The model had a high coefficient of determination ($R^2 > 0.99$) due to its basis in simulated data. As expected, the parameters of the model reflect the magnitude of change in the profitability of pine plantations in direct relation to increasing growth, and inverse proportion to increasing land values and transportation costs.

The proportion of the change in NPV associated with the three input factor variables by at their median values is shown in Table 5. At the 10% discount rate, the median land price is $1,000/ha, median distance to mill is 100 km, and median MAI 30 m^3/ha/year. At the 10% discount rate, the computed contribution to NPV at it the mean value for each factor is: −$1,051 for land price; −$785 for the distance to the mill; and +$3,875 for site quality as measured by MAI. The relative magnitude between these factor coefficients at their mean values indicates their relative importance in determining the NPVs for pine plantations in Colombia.

Table 4 Regression results of factors effect on net present values by discount rate used

Variable	Parameter estimate	Standard error	*T* value	*P* > |*t*|
Discount rate = 8%				
Intercept	−1,005.299	7.754	−129.64	<0.001
Land price	−0.985	0.004	−231.81	<0.001
Distance to mill	−10.502	0.039	−263.64	<0.001
Mean annual increment (MAI)	174.860	0.164	1,062.98	<0.001
Discount rate = 10%				
Intercept	−1,204.561	5.7991	207.72	<0.001
Land price	−1.051	0.003	−330.70	<0.001
Distance to mill	−7.854	0.030	−263.64	<0.001
Mean annual increment (MAI)	129.183	0.123	1,050.09	<0.001
Discount rate = 12%				
Intercept	−1,341.932	4.385	−306.02	<0.001
Land price	−1.096	0.002	−456.05	<0.001
Distance to mill	−5.939	0.023	−263.64	<0.001
Mean annual increment (MAI)	96.446	0.093	1,036.77	<0.001

Table 5 Effects of land price, site quality, and distance from the mill at median value analyzed on pine plantation investments net present values in Colombia, 2008

Discount rate	Net present value of investment factor at median ($/ha)		
	Land price	Transportation distance	MAI
8%	−985	−1,050	5,238
10%	−1,051	−785	3,875
12%	−1,096	−594	2,893

The fairly substantial differences in NPV indicate that very achievable differences in site quality—which is subject to silvicultural, genetic, and management manipulation—can make large differences in potential returns to forestry investments, perhaps up to proportionately two to five times as much as land price alone, at a 12–8% discount rate, respectively. And the comparative effect of site productivity is even larger compared to transportation distance, with site quality being more than four times more important in determining NPV than transportation distance at all discount rates. This is certainly encouraging for forest managers and investors, suggesting that management is more important than location alone, even at historically high transport prices as of mid 2008.

Discussion and conclusions

The results provide new insights about the factors of land costs, site quality, and location that contribute to financial returns from forestry investments in Colombia. They have specific implications about the results for investments in Colombia; provide a useful example for the relative importance of these factors in general; and provide a model for making similar analyses in other regions.

Implications for Colombia forest investments

The calculated marginal effect of site productivity was very large, increasing NPV from two to five times more than land costs, and more than four times transport costs at the median values analyzed. This finding is encouraging for forest investors and land managers. As such, efforts to increase site productivity through technology and better management can yield excellent payoffs, despite potential adverse effects of greater land prices and fuel costs. Higher site quality land can be profitable under most scenarios analyzed except extreme distance and land prices, so there should be considerable potential for continued expansion of forest plantations in Colombia.

The land prices in the Andean region of Colombia, where most of the environmental conditions are adequate for pine plantations, vary widely. Sites close to urban areas and highly productive soils with agricultural aptitude usually have prices of at least $1,800/ha. Some of this land is used for coffee crops and other agricultural products as well as real estate development and recreational services. Forestry land is frequently located farther from the large consuming centers and/or on poorer soils. The results indicate that investors should obtain more precise information to match land prices with soil productivity. Higher site quality land at cheap prices close to a mill is ideal, but of course often not available. Early investors benefit most from initially low land prices, although our results indicate substantial opportunities for attractive returns remain in Colombia. The NPV and regression analyses indicate that much of the differences of land costs or distant locations can be compensated for increases in site quality, which may be achieved through intensive management.

Traditional pine species planted in the Andes of Colombia like *P. patula* and *P. oocarpa* are starting to be replaced at commercial scale by other species with faster growth like *P. maximinoi* and *P. tecunumanii*. The amount of genetic improved seeds is still very limited and tree growers keep on using seeds from the natural forest in Central America. Large growth rates of more than 25 m^3/ha/year have been reported for the latter two species in Colombia with unimproved seeds (Dvorak et al. 2000a, b). Genetic gains in volume after the first cycle of improvement in pine trees usually vary between 10 and 20%

(Porterfield 1979; Carlisle and Teich 1978; Talbert et al. 1985; Li et al. 1999). Results of second-generation trials show additional similar gains (Li et al. 1999). We estimated the gain in volume growth from 30 to 40 m^3/ha/year (33.3%), representing genetic gains obtained with seeds collected in seed orchards after two breeding cycles.

A few tree growers in Colombia own seed orchards for production of genetically improved seeds of pine trees. Most of the seed they produce is for their own use, especially seeds of *P. maximinoi* and *P. tecunumanii*. Establishment of new seed orchards and second-generation trials with these species as part of genetic improvement programs is financially attractive for large forestry projects. Our results indicate that small tree growers should buy improved seeds when possible in order to increase their site productivity, even though they may have to pay considerably more for improved seeds and seedlings. Future economic analyses can examine the effects of this and other increased forest management options.

Demand for land by the forest product industry is expected to grow with expansion plans and new investments in forestry projects. Under this expectation it is reasonable to assume that land prices will go up, but that is still uncertain. Availability of land area with forest aptitude is still large in Colombia. According to FAO and CONIF (2006) (National Corporation for Research and Forest Development), Colombia has 4.0 million hectares that can be managed in intensive silviculture programs for commercial plantations in the Caribbean and Andean region (Mendell et al. 2006). A portion of this falls within the land with aptitude for pine plantations. With a fast growing economy and new investments, and expansion of the forest products industry in Colombia, it is possible to assume that expected demand for wood will continue to increase, as well as wood prices.

Relative importance of factors affecting forest plantation investment returns

As noted, all three factors of site quality, land costs, and transportation distance to a mill were important in determining pine plantation investment returns. Of those factors, growth rates, which are the only one that can be changed significantly through management interventions, were the most important, by two to five times as much as the other two production factors. To the extent that these findings are generalizable, similar opportunities may exist in other countries. Cubbage et al. (2007) estimated timber returns and prices for other countries in Latin America, and the input costs we used for the Andean region in Colombia were similar to those countries. The results about the effects of relative factor costs in investment returns in Colombia also should be similar to the case of plantations in other countries, which could be analyzed in future research.

Our calculation of sensitivity analyses also indicated that our results were robust, and comparative ranking among factors affecting returns remained stable regardless of variation in key assumptions. Overall, changes in input costs and output prices affect the magnitude of the NPV results as anticipated, but not the relative relationships among land costs, transportation distance, and site quality. They could in fact be substantial, with the loss of 30% of the land base having the largest negative effect on our results. This would be much greater than the potential for biological pest or climate disasters, which are usually <2–3% for a forest stand in its rotation. On the other hand, the potential for much greater returns also exists if even a moderate 10% increase in timber prices occurs.

The price of oil and gasoline rose dramatically in 2008, and we used transportation costs at the historic high petroleum levels then, of about \$120–\$140 per barrel. Despite recent price decreases, it still seems that petroleum prices will return to relatively high levels or perhaps increase somewhat in the future. Greater prices of fuel and transportation costs will affect the profitability of the forest investments. The growth rate of labor cost and fuel prices will have to stay below the growth rate of wood prices to maintain current profitability of plantation forestry. If fuel prices decline, intensive silviculture will be even more financially beneficial—both from the reduced transport costs and reduced fertilizer costs.

This research provides a well grounded comparison of the effects of land prices, distance from markets, and site quality for representative pine species on timber investment returns in Colombia. We used reliable estimates of forest management practices and input costs, so the findings should be accurate and relatively robust. Substantial changes in input costs or market prices could alter these results, but the estimates we used should be representative.

Timber growers owning timberlands close to a manufacturing facility with high productivity will enjoy the most benefits of excellent early investments. However, new investments that improve productivity through improved genetic selection and seedling production and intensive silviculture can achieve high rates of return exceeding most customary discount rates. The results of this analysis demonstrate the benefits of using this approach as the methodological framework for additional forest species in other regions and countries.

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