Timber Investment Returns in Paraguay

A Report Prepared for the World Bank

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EXECUTIVE SUMMARY

The past few decades have seen tremendous growth in investment in the forestry sector in South America. In particular, the southern countries of Chile, Argentina, Uruguay and southern Brazil have invested heavily in plantation forestry, mostly of eucalypts (*Eucalyptus* spp.) and pines (*Pinus* spp.). In addition, Bolivia has become an international model of management of native forest for sustainable timber production.

Paraguay appears to be lagging its neighbors in forestry investment. Paraguay only has 43,000 hectares of plantation forests (FAO 2005) and probably only a similar area of sustainably managed native forest. Paraguay's economy is still dominated by agriculture, livestock and destructive exploitation of the remaining native forests. Changing Paraguayan culture to one of appreciation of sustainability and long-term investments will take time. Foreign investors continue to be discouraged by bureaucracy and corruption, biased or inconsistent enforcement of laws and a general lack of infrastructure.

Paraguay's economy relies heavily on forest exports, mostly from destructive harvesting of native forests. It is clear that at some point Paraguay will need to begin investing in future production in order to stabilize its precarious environmental position. Professionals in the forestry sector hope that recent and future political changes, such as the restructuring of the National Forestry Service into the National Forestry Institute, will create positive momentum towards reforestation.

This study estimates the financial returns to potential forestry investments in Paraguay. The study utilizes estimates of costs and returns obtained from interviews with forest managers, consultants, researchers and government and non-profit employees, under the assumption of good sites and typical management regimes. The analysis began with a base case under the assumptions of no land costs, 100% of land area being plantable, a distance of 45 km from forest to market, standard site preparation costs, no subsidies or loans and current prices. Sensitivity analyses were then conducted under altered assumptions.

In the Eastern Region of Paraguay, I found that the species *Eucalyptus grandis* and *Melia azedarach* had the highest returns, with land expectation values (LEVs, calculated using 8% discount rate) between \$4200 and \$4700 per hectare and internal rates of return (IRRs) both above 21% in the Paraná River Basin under the base case assumptions. These are excellent levels of returns. *M. azedarach*, however, is highly susceptible to disease, which reduces returns significantly. In the Paraguay River Basin, these two species had LEVs between \$2800 and \$3200 per hectare and IRRs of approximately 19%. Other species with good rates of return (LEV > \$0, IRR > 8%) are exotic plantation species *E. camaldulensis* and *Pinus taeda*, cultivation of yerba mate (*Ilex paraguariensis*) and sustainable management of native forest.

In the Western Region, or Chaco, fewer species are likely to be appropriate because of the arid climate and poor soils. Still, *M. azedarach* and *E. camaldulensis* had good levels of returns (LEVs $800-$1000, IRRs around 12%) in the Lower Chaco, and reasonable levels in the more arid Central Chaco (LEVs near $0, IRRs near 8%). *M. azedarach* is susceptible to disease in the Lower Chaco, reducing returns significantly, but is unaffected by the most important disease in the Central Chaco (probably because the dry conditions do not favor the disease). Also in the Central Chaco, this study suggests that management of native, naturally-regenerated *Prosopis* spp. in pastures can produce moderate returns.

This study presents sensitivity analyses regarding changes to several of the assumptions mentioned above. In all cases, returns moved in the expected direction when the underlying parameters were changed. That is, returns were decreased by including land costs, reducing plantable area, increasing distance from forest to market and increasing site preparation costs, while returns were increased by policies to promote forestry such as cost-share payments or low-interest loans and by an increase in real timber prices. In most cases, the relative ordering of returns was fairly unchanged.

Most importantly, this study considers returns including the cost of land and a plantable area that is less than 100% of the total land area (due to physical impediments, environmental protection, buildings and roads, etc.). Including the cost of land is important not only because some investors may not already own the land, but because the market price of land is a good proxy for the opportunity cost of the land, its value in the best alternative use. Subtracting out land costs from returns provides a good basis for comparing forestry to alternative uses (such as soybean cropping in the Eastern Region). Even after considering land costs and reduced plantable area, a few species, including *E. grandis* in the entire Eastern Region and *E. camaldulensis* in the Paraguay River Basin and Lower Chaco, had positive LEVs. These species are likely to be the best forestry alternatives to agriculture in the absence of policies to promote forestry.

This study also considers two policy options for promoting forestry and the effect of increased real timber prices. The first policy option is a cost-share mechanism which is law in Paraguay since 1995, but has never been funded. This policy greatly increases the value of most forestry investments. The second option is a system of low-interest (5% annual) loans for forestry, which is a proposal by the Paraguayan Timber-Merchant Federation (FEPAMA). Interestingly, the loans provide high returns for the best species (similar to the cost-share option) but do not make the less-appropriate species profitable in the same way as the cost-share payments. In addition, the loans would be at a lower cost to the state or implementing organization, and would therefore be more likely to be funded.

Increased timber prices obviously increases returns. Less obvious, however, is the fact that under higher prices, management of *E. camaldulensis* for fuelwood (biomass energy) rapidly becomes one of the management regimes with the highest returns, despite having the lowest returns in the base case.

In general, this report shows that returns to forestry investments in Paraguay can be reasonably good, both when compared to alternative land uses and compared to forestry investments neighboring countries. However, Paraguayan institutions and infrastructure currently are not favorable to the implementation of sustainable forestry investments. It seems that this situation is improving and forestry will increase in Paraguay, but only very slowly if current trends continue.

Rentabilidad de la Inversión Forestal en Paraguay

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RESUMEN EJECUTIVO

Durante las últimas décadas se ha visto un enorme crecimiento de las inversiones en el sector forestal en Sudamérica. Especialmente en los países del Cono Sur, como Chile, Argentina Uruguay y el sur de Brasil, se han hecho fuertes inversiones en plantaciones forestales, principalmente de eucaliptos (*Eucalyptus* spp.) y pinos (*Pinus* spp.). Además, Bolivia se ha convertido en un modelo internacional del manejo sostenible de bosques nativos para la producción de madera.

Paraguay sin embargo, se encuentra rezagado en comparación con sus países vecinos en cuanto a la inversión forestal. Solamente tiene 43.000 hectáreas de bosques plantados (FAO 2005) y probablemente una superficie semejante con bosques nativos bajo manejo sostenible. La agricultura, la ganadería y la explotación destructiva de los bosques nativos remanentes siguen dominando la economía de Paraguay. Cambiar la cultura paraguaya actual a una de apreciación de la sustentabilidad y de inversiones a largo plazo, llevará tiempo. Los inversionistas extranjeros siguen desanimados por la burocracia y la corrupción, la aplicación parcial e inconsistente de las leyes y la carencia general de infraestructura.

La economía paraguaya depende mucho de las exportaciones forestales, provenientes de un aprovechamiento destructivo de los bosques nativos. Está claro que en algún momento el país tendrá que empezar a invertir en la producción futura para estabilizar su precaria situación ambiental. Profesionales del sector forestal tienen esperanza en que los recientes cambios políticos y los que se den a futuro, como la creación del Instituto Forestal Nacional a partir de una reestructura del Servicio Forestal Nacional, puedan impulsar la reforestación.

El presente estudio estima la rentabilidad financiera de potenciales inversiones forestales en Paraguay. Se utilizan estimaciones de costos y rendimientos obtenidos mediante entrevistas con administradores forestales, consultores, investigadores y funcionarios de Gobierno y de organizaciones sin fines de lucro. El análisis empezó con un caso base, bajo las suposiciones de costo cero de la tierra, un 100% de tierra utilizable, una distancia de 45 Km desde el bosque hasta el mercado, así como costos estándares de preparación del sitio, subsidio cero y precios actuales. Después, se realizaron análisis de sensibilidad bajo otros supuestos.

En la Región Oriental del Paraguay, se encontró que las especies *Eucalyptus grandis* y *Melia azedarach* fueron las que tuvieron los mayores retornos, con Valores Esperados de la Tierra (VET, calculados con una tasa de descuento de 8%) entre US$ 4.200 y US$ 4.700 por hectárea y Tasas Internas de Retorno (TIR) mayores de 21% en la cuenca del Río Paraná bajo las suposiciones base. Estos son excelentes niveles de rentabilidad. Sin embargo, la especie *M. azedarach* es propensa a enfermedades, lo cual reduce considerablemente los retornos. En la cuenca del Río Paraguay, las mismas especies tuvieron VET entre US$ 2.800 y US$ 3.200 por hectárea y TIR de aproximadamente 19%. Otras especies con buenas tasas de retorno (VET > $0,

TIR > 8%) son las plantaciones de las exóticas *E. camaldulensis* y *Pinus taeda*, el cultivo de yerba mate (*Ilex paraguariensis*) y el manejo sostenible del bosque nativo.

En la Región Occidental o Chaco, es probable que menos especies sean apropiadas por el clima árido y los suelos pobres. Sin embargo, *M. azedarach* y *E. camaldulensis* tuvieron buenos retornos (VET de $800-$1000, TIR aproximadamente del 12%) en el Bajo Chaco, y niveles razonables en el Chaco Central árido (VET cerca de $0, TIR cerca de 8%). *M. azedarach* es propensa a una enfermedad en el Bajo Chaco, reduciendo así considerablemente los retornos, pero no es afectada por la principal enfermedad en el Chaco Central (probablemente por las condiciones secas que no favorecen a la enfermedad). También en el Chaco Central, este estudio demuestra que el manejo de las especies nativas *Prosopis* spp. con regeneración natural en áreas con pasturas pueden tener retornos moderados.

Se muestran análisis de sensibilidad respecto a cambios en varios de los supuestos anteriormente mencionadas. En todos los casos, los retornos se movieron en la dirección esperada cuando se cambiaron los parámetros subyacentes. Es decir, por un lado los retornos bajaron por incluir los costos de la tierra, por reducir la superficie utilizable para plantaciones, por aumentar la distancia desde el bosque al mercado y por aumentar los costos de preparación del sitio, mientras que por otro lado los retornos subieron por las políticas para promover inversiones forestales como subsidios o préstamos con bajas tasas de interés y por aumento de los precios reales de la madera. En la mayoría de los casos, el orden relativo de los retornos fue básicamente el mismo, sin grandes cambios.

El estudio considera también retornos que incluyen el costo de la tierra y una superficie utilizable menor del 100% de la superficie total (debido a impedimentos físicos, protección ambiental, edificaciones y caminos, etc.). Incluir el costo de la tierra es importante no solamente porque algunos inversionistas tal vez no sean propietarios, sino también porque el precio de mercado representa el costo de oportunidad de la tierra, su valor con el mejor uso alternativo. Restar los costos de la tierra de los retornos proporciona una manera de comparar el manejo forestal con usos alternativos (como el cultivo de soja en la Región Oriental). Aun después de considerar los costos de la tierra y una superficie utilizable reducida, algunas especies como *E. grandis* en toda la Región Oriental y *E. camaldulensis* en la cuenca del Río Paraguay y Bajo Chaco, tuvieron VET positivos. Es probable que estas especies sean las mejores alternativas forestales a la agricultura, en ausencia de políticas para promover inversiones forestales.

También se consideran dos opciones de políticas para promover inversiones forestales y el efecto de un aumento en los precios reales de la madera. La primera opción de política es un subsidio que desde 1995 tiene fuerza de ley en Paraguay, aunque hasta hoy en día no se ha cumplido. Esta política proporcionaría un gran aumento en el valor de la mayoría de las inversiones forestales. La segunda opción es un sistema de préstamos de baja tasa de interés (5% anual) para inversiones forestales, una propuesta de la Federación Paraguaya de Madereros (FEPAMA). Se observa que los préstamos proveen altos retornos para las mejores especies (parecido al subsidio), pero no hacen que las especies menos apropiadas sean rentables en la misma manera que los subsidios. Además, los préstamos tendrían un costo menor para el estado u organización de aplicación; entonces, es más probable que se cumplan.

Un aumento en los precios de la madera obviamente aumentaría el retorno de la inversión. Menos obvio es el hecho de que con mayores precios, el manejo de *E. camaldulensis* para leña (energía de biomasa) rápidamente llegaría a ser uno de los regimenes de manejo con mejor tasa de retorno, a pesar de que tiene el peor retorno en el caso base.

En general, este informe demuestra que los retornos en inversiones forestales en Paraguay pueden ser razonablemente buenos, cuando se compara con los usos alternativos de la tierra y con las inversiones forestales en países aledaños. Sin embargo, las instituciones e infraestructuras en el país, actualmente no son favorables para la implementación de inversiones forestales sostenibles. Esta situación aparentemente está mejorando y el manejo forestal aumentará, pero muy paulatinamente si las tendencias actuales continúan.

Acronyms

AEV ....Annual equivalent value
BAAPA.......................Bosque Atlántico del Alto Paraná (Alto Paraná Atlantic Forest)
BCR............................Discounted benefit-cost ratio
EIU.............................Economist Intelligence Unit
FAO............................Food and Agriculture Organization of the United Nations
FEPAMA ....Federación Paraguaya de Madereros (Paraguayan Timber-Merchant Federation)
IADB..........................Inter-American Development Bank
IAIF............................Indice de atracción a la inversión forestal (Forestry Investment Attractiveness Index) of the IADB
INFONA ....Instituto Forestal Nacional (National Forestry Institute)
INTA..........................Instituto Nacional de Tecnología Agropecuaria (Argentina) (National Agricultural Technology Institute)
INTTAS ....Iniciativa para la Investigación y Transferencia de Tecnología Agraria Sostenible (Sustainable Agricultural Technology Research and Extension Initiative)
IRR.............................Internal rate of return
JICA ....Japan International Cooperation Agency
LEV............................Land expectation value
NCSU.........................North Carolina State University, Raleigh, NC
NPV............................Net present value
MAG ....Ministerio de Agricultura y Ganadería (Ministry of Agriculture and Livestock)
Mercosur ....Mercado Común del Sur (Southern Common Market)
MFN...........................Mesa Forestal Nacional (National Forestry Roundtable)
REDIEX.....................Red de Inversiones y Exportaciones (Investment and Export Network)
SFN ....Servicio Forestal Nacional (National Forestry Service)
UNA...........................Universidad Nacional de Asunción (National University of Asunción)

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I. Introduction and Background

Financial returns for forestry activities can play a large role in determining the extent and types of management activities in forests, and the sustainability of those practices. The primary objective of this report is to provide an updated estimate of financial returns to potential forestry investments in the various regions of Paraguay.

In recent decades many South American countries have invested heavily in the forestry sector, including all of Paraguay's neighbors. Argentina, Brazil, Chile and Uruguay have invested heavily in plantation forests of pines (*Pinus* spp.) and eucalypts (*Eucalyptus* spp.), while Bolivia has staked significant resources on the sustainable management of its native forests for timber.

South America, accounts for over 11 million hectares of plantation forests, about 8% of the world's total (FAO 2005). Most of South America's plantation forests are in Brazil, Chile, Argentina and Uruguay. Plantation forests in South America have grown by nearly 200,000 ha/yr from 1990-2005, an indication of the extent of interest in forest investments there (FAO 2005). Information about investments in sustainable management of native forests is more difficult to obtain, but Bolivia has become an international model of the practice.

Paraguay has lagged behind its neighbors in terms of forestry investments. Plantation forests have grown in Paraguay by only about 1300 ha/yr during 1990-2005 up to 43,000 ha total. Uruguay, for instance, has managed nearly 38,000 ha/yr over the same period, and is a much smaller country (FAO 2005).

Paraguay's native forests, particularly in the Eastern Region (i.e. east of the Paraguay River, as explained in more detail below), have served as a major source of timber exports, but have been rapidly deforested and degraded over the last 40 years (Huang et al. 2007).

The first known comprehensive study estimating returns to forestry investments in Paraguay was the JICA (2002) study conducted by the Japan International Cooperation Agency (JICA) in conjunction with the now defunct National Forestry Service (*Servicio Forestal Nacional*, SFN) of Paraguay, the Japan Forest Technology Association and Pasco International, Inc. In many ways, my report updates and investigates in more depth the financial analysis portion of the work of JICA (2002).

JICA (2002) uses financial estimates, surveys, and policy analysis to outline the potential for reforestation and afforestation in the Eastern Region of Paraguay. Indeed, the Eastern Region is the area where most of Paraguay's population lives, has the best soil and climatic conditions for forestry, has the most research available, and has historically suffered the greatest amount of deforestation. It is logical to begin with the Eastern Region; however, to fully understand the situation of forests and forestry in Paraguay, one must consider the Western Region (the Chaco).

The Chaco has over half of Paraguay's land area and the vast majority of Paraguay's remaining native forests.

This study estimates financial returns to common timber investments in four distinct agro-ecological regions of Paraguay. In most cases, these include exotic plantation species, but also include some native species, including management of native forest for timber in one region and management of a naturally regenerated native species in pasture in another. I use estimates of costs and returns from interviews with forest managers, consultants, researchers and government and non-profit employees, under the assumption of good sites and typical management regimes.

A. Factors affecting forestry in Paraguay

i. Legal and political framework for forestry in Paraguay

Paraguayan Law No. 422 of 1973 ("*Ley Forestal*") established the first national policy regarding the use of Paraguay's forests. It created the SFN as the institution to direct and enforce policy with regards to the regulation of forestry-related activities. The law indicates that any forestry activity must be approved by the SFN and have an appropriate management plan. In addition, the law requires that landholdings greater than 20 ha in forestry regions must maintain at least 25% in forest cover, or reforest 5% of the land area (Macedo and Cartes 2006).

Law No. 536 of 1995 ("*Ley de Fomento a la Forestacion y Reforestacion*") offered financial incentives in the form of cost-share payments to landholders who invest in reforestation or afforestation. These incentives are in the amount of 75% of the cost of site preparation and plantation, and 75% of the costs of maintenance during the first three years after plantation, as estimated by the SFN (Gonzalez Gimenez 2002). Also, reforested or afforested land receives a 50% property tax reduction. Under Law 536/95, plantation forests in forest priority areas are not subject to expropriation by the state except for immediate infrastructure purposes (Gonzalez Gimenez 2002). This, of course, provided a perverse incentive to deforest native forestland, which could be subject to expropriation.

Law No. 2524 of 2004 ("*Ley de Prohibición en la Región Oriental de las Actividades de Transformación y Conversión de Superficies con Cobertura de Bosques*") prohibited new deforestation of native forestlands in the Eastern Region for conversion to other uses. The law was re-authorized in 2006.

Despite these well-intentioned laws, the past conditions have not been favorable to forests and forestry. Neither the 25% forest cover requirement from Law 422/73 nor the forestry cost-share incentive payments from Law 536/95 have ever been enforced or funded to any extent. Perverse incentives continue, both within these laws, and with policies related to agriculture and cattle-ranching. Illegal logging and illegal exportation of timber and charcoal continue. There are concerns about the under-valuation of charcoal on "legal" export invoices to Brazil, causing a low tax value and depressing prices in Paraguay.

However, the conditions for forestry do seem to be improving. In the past two years, deforestation has been reduced in the Eastern Region in absolute numbers of hectares (WWF

2006), whether because of Law 2524/04 and the work of extra-governmental organizations, or simply because there is not much unprotected forest left in the Eastern Region to deforest.

There are a few initiatives, primarily by non-governmental organizations (NGOs), to change future forest policy in order to provide incentives for forestry and reduce perverse incentives, stabilize the sector and reduce risks. First, the National Forestry Roundtable (*Mesa Forestal Nacional*, MFN) has been creating proposals to re-organize the political framework to eliminate forestry disincentives and make the current policies more sustainable and enforceable. Changes to Laws 422/73 and 536/95 have been proposed by the MFN to reorient the forestry sector in Paraguay towards production and sustainability rather than exploitation and degradation.

One of the changes is to create a new, more autonomous National Forestry Institute (*Instituto Forestal Nacional*, INFONA) to replace the SFN, which did not have the capacity to enforce the current forestry laws. INFONA is structured in a manner that separates it somewhat from the present governmental hierarchy in the MAG and Paraguay, with an advisory board with representation from the public sector; associations of forestry professionals, landholders and businesses; and academia. As of 2008, the law creating INFONA has been passed and signed, creating INFONA. INFONA is currently in a state of transition from the old SFN to its more autonomous state, with some of the budgetary power still under MAG. It remains to be seen whether the change of name and structure will be accompanied by a change in substance.

Second, the World Wildlife Fund (WWF) has begun a pilot-level project to implement tradable rights for forests to maintain a minimum level of forest, mitigate deforestation and ensure that landowners who maintain forestland will receive benefits for doing so. Third, some have suggested creating a legal framework for forest investors to "rent" or purchase rights to use the land for an extended period of time rather than having to purchase land itself. The goal of the "*derecho a vuelo forestal*" would be to reduce the risk involved with possible future expropriation of land.

Finally, the Paraguayan Timber-Merchant Federation (*Federación Paraguaya de Madereros*, FEPAMA) is negotiating the funding for and implementation of an incentive scheme that would essentially act as a low-interest credit program for forestry investments. The Ministry of Agriculture and Livestock (MAG) and the SFN have agreed in principle to support this initiative. Funding would come from a duty on the sale of charcoal. FEPAMA has proposed using the funds to support loans for forest plantations at an annual interest rate of 5%. This scheme is similar in nature to a policy proposal in the JICA (2002) report, which calls for loaning 75% of establishment costs at an annual interest rate of 4-8%.

ii. Demographic and social factors

A brief review of statistics about demographics and forestry in Paraguay reveals cause for concern about the sustainability of its future for natural resources. Paraguay has the largest population growth rate (2.4%) in South America (FAO 2005; Macedo and Cartes 2006). Currently, Paraguay is the third-largest producer of wood products on South America based on both dollar value and volume (after Brazil and Chile), which is mostly from native forests (FAO 2005). Additionally, Paraguay has encouraged economic growth by opening new areas to agriculture, implying the clearing of forestland (Macedo and Cartes 2006). Indeed, many of Paraguay's rural policies have been driven by interest in agriculture and livestock, with little thought to sustainability of forests.

These three trends (population growth, destructive harvesting of native timber, and growth in agriculture) have led to the rapid degradation of native forests. Paraguay has the second-highest rate of deforestation in South America (0.9%) (FAO 2005). By the year 2000, the Eastern Region's Atlantic Forest had been decreased to one-third of the 1973 level, or one-fourth of the historical coverage (Huang et al. 2007). Currently, there may be less than 10% of the original forest remaining in the Eastern Region (Macedo and Cartes 2006). Furthermore, Paraguay only has approximately 43,000 hectares of productive plantation forests (FAO 2005), far too little to satisfy internal needs for timber and fuelwood, much less any desire for export timber. It is obvious that, if these trends continue, Paraguay will rapidly harvest and deteriorate its remaining forests.

A social factor that can affect all investment decisions in South America is that of safety and security. While Paraguay has had a few high-profile kidnappings and armed robberies in the past decade, in the general context of South America, Paraguay should be considered a relatively secure place to do business. Large gangs and armed militias do not exist in Paraguay in the same way as in some other South American nations.

iii. Market factors

Forest plantations and forest industry are presently stuck in a chicken-and-egg dilemma in Paraguay. There are few or no industrial and manufacturing plants designed to take in plantation species. While there are a seemingly endless supply of small sawmills and carpentry shops, most are based on the native forest species and for small local markets. In terms of export, Paraguay produces very few value-added forest products.

Until some industry becomes established to produce value-added products from plantation species and native species, potential forestry investors are likely to continue believing that the market for their products will be small and have low prices. However, unless forests are planted, industrial investors will likely continue believing that there is not enough raw material to support the industry. Governments in other South American nations have found their way out of this dilemma by providing financial incentives to forestry investors. Paraguay, on the other hand, seems to be following the slow, arduous, and environmentally-unsound route of planting new forests only as the native forests become deforested and degraded.

The demand for plantation timber is already growing in Paraguay because of the vast degradation of the traditionally-exploited forests of the Eastern Region. In the Chaco, where forests are more pristine and high-quality, large-diameter logs are still available; however, recent years have seen Paraguayan logging firms repositioning to harvest from the Chaco, and large-scale degradation could occur very rapidly given the current socio-political situation.

The relative lack of medium- and large-diameter saw-logs in the Eastern Region has forced many sawmill owners to look for wood supply from non-traditional sources. There still is, however, an abundance of small-diameter timber for charcoal and fuelwood, and this abundance depresses the market for biomass energy from plantations. In addition, unlike Argentina, Uruguay, Brazil and Chile, Paraguay has no pulp mills. The problem is compounded by the lack of a seaport (Brazil, for instance exports eucalyptus chips to the US for pulping). Again, it probably would be feasible to ship finished paper or other finished products from Paraguay, but perhaps not wood chips.

Because of these difficulties, the only markets for small-diameter logs in Paraguay are the internal fuelwood market and perhaps export of products like charcoal to Argentina or Brazil. The effect of the lack of good markets for small diameter logs is double. First, the low price of small-diameter logs negatively affects returns. Second, the low price serves as a disincentive for thinning stands. Without sufficient thinning, many landowners may end their timber rotation with high numbers of trees per acre and thus only medium-diameter logs rather than the high-value, large-diameter saw or veneer logs that would be the product of an intense thinning regime.

Despite this, the general market trend for small-diameter plantation timber seems to be that the demand is growing. There are indications that a several major industrial corporations in Paraguay are seeking a more constant and reliable source of fuelwood. Some industries seem interested in transitioning from electric or petroleum energy sources to biomass to reduce costs. Preliminary estimates indicate that generating energy by woodchips can be much cheaper for Paraguayan firms than alternative methods, as long as they can obtain a steady stream of biomass. Movements in this direction are beginning to increase the price of small-diameter logs from plantation thinnings. Furthermore, unforeseen circumstances, such as the installation of a major pulp or panel mill in or near Paraguay, could rapidly push up the price of small-diameter pine and eucalyptus.

The market is very delicate for products from the sustainable management of native forests. Sustainable managers obviously cannot compete on a volume-for-volume basis either with traditional native forest high-grading or with plantation forests. Therefore, sustainably-managed native forests will have to seek out upper-end niche markets. These markets exist mostly in Europe and North America, and likely will require FSC certification.

Furthermore, many of these export markets will demand relatively large volumes of one or a few species, which can only be achieved over large land area, perhaps a minimum of 5,000 or even 10,000 hectares in the Eastern Region. Few contiguous forest tracts of this size remain in the Eastern Region of Paraguay. In addition, the forest tract would have to be relatively pristine, as a degraded stand would offer very little in the way of returns in the short-run. Cubbage et al. (2007) offers an analysis of returns to management of highly degraded forests in nearby Misiones, Argentina, and concludes that returns are small or non-existent.

The Chaco Region has more large, contiguous, relatively-pristine forest areas, which, in theory could be managed sustainably. However, because of the lower forest productivity in this semi-arid climate and poor soils, the minimum necessary forest size would need to be even greater than in the Eastern Region. To my knowledge, only one firm in Paraguay is positioning itself to produce sustainably-managed native wood products from the Chaco.

One of the principal factors affecting Paraguay's market for timber, especially for export, is the country's landlocked status. Exports to countries other than the immediate neighbors in Mercosur must first travel to Buenos Aires or Montevideo via river, an added cost. This means that exports to countries outside of Mercosur must be relatively high-value products, lest the timber value be severely reduced be high transportation costs. For instance, it would be reasonable to ship sawn timber for furniture or flooring, or manufactured wood products via river. While sawmills are plentiful in Paraguay, the manufacturing sector is less well-developed.

A similar factor affecting the timber market is Paraguay's relative lack of infrastructure. Compared to other countries in South America, fewer roads are paved. This leads to higher transportation costs, in general.

A relative advantage for forestry investments in Paraguay is the low cost of labor. In most of the country, labor costs are relatively lower than in other neighboring countries. This is less true, however, in the soy-producing eastern Paraná River basin, where wage rates have been driven up by the boom in soybean production.

B. Firm-level considerations for forestry investments

There are several factors which a forestry firm in Paraguay should consider, which can have a dramatic impact on the results of a financial returns study. First, a firm must consider the distance from forest to market and the public infrastructure available for transportation. Large distances for transportation, especially on dirt roads, can have a large impact on stumpage values. This is especially true for lower-end products like fuelwood, posts or small-diameter sawtimber, which are typical products from thinnings.

Second, the size of the establishment can have a large impact on the per-hectare returns. For plantation species, dividing administrative costs over larger numbers of hectares reduces costs. Also, larger firms may be better able to market their products. This is especially true for the relatively extensive sustainable management of native forests. As described in more detail below, the upper-end niche markets necessary for this practice to be profitable require relatively large volumes of particular species.

Third, a technique which forestry investors (whether large- or small-scale) should consider and which I analyze only in one special case here, is the use of silvopastoral practices. Silvopastoral practices involve the combination of forage, livestock and forestry. If managed effectively, silvopastoral systems can provide numerous advantages, such as reducing the risk of forest fires, lowering costs for weed control and providing a secondary revenue source (Frey et al. 2007). Silvopastoral systems have been shown to be an efficient way to manage forests for high-quality timber in Argentina (Esquivel et al. 2004; Fassola et al. 2004).

C. Differentiation of major agro-ecological regions in Paraguay

Paraguay has a diversity of agro-ecological regions, ranging from the arid deserts of the northwest to the subtropical humid forests of the southeast. With the goal of trying to be realistic while at the same time keeping the calculations relatively simple, I have elected to divide Paraguay conceptually into four distinct regions: two agro-ecological regions east of the Paraguay River, and two to the west.

The Paraguay River roughly divides Paraguay in half. Traditionally, the Eastern Region (*Región Oriental*) of Paraguay is the most populated, most researched and most exploited for agriculture and forest products. The Western Region, or Chaco, (*Región Occidental* or *Chaco Paraguayo*) has been explored and settled more recently, with large, relatively undisturbed areas still existing.

I divide the Eastern Region into two agro-ecological regions. For lack of a better boundary definition, I denote these regions as the Paraná River basin and the Paraguay River basin. The Paraná River basin is relatively more humid with rainfall reaching 2000 mm annually and no distinct dry period, and is characterized by deep red soils. The Paraná basin is extensively used for soybean cultivation. Paraguay's recent increase in soy production for export has driven up the price of land and labor in the Paraná basin. The Paraguay basin has relatively less precipitation with less rain in the winter months, and has shallower, sandier soils.

I divide the Chaco into the Lower Chaco and the Central Chaco. The Lower Chaco is characterized by moderate rainfall, flat land and high water tables. The Central Chaco has rainfall amounting to only about 700 mm annually with a strong dry season in the winter months (the Northern Chaco is even drier but I do not consider it in this study as it is probably unsuitable for most forestry activities).

II. Major timber species in Paraguay

A. Native species

A large portion of Paraguay's eastern region, particularly the Paraná River basin, was covered until recent decades by a native forest known as the Alto Paraná Atlantic Forest, which is an inland extension of Brazil's Atlantic Forests. There are several commercially important species, including *Tabebuia* spp. (lapacho), *Cedrela* spp. (cedro), *Myroxylon balsamum* (incienso colorado), *Balfourodendron riedeliamum* (guatambu), *Apuleia leiocarpa* (grapia), and many others.

During recent years, however, most of Paraguay's Atlantic forests have been deforested for conversion to agriculture or degraded by unsustainable logging practices. This study considers returns for the long-term, sustainable management of these forests for timber. A model for this type of practice is Bolivia, which, in recent years, has begun the large-scale sustainable management of its Chiquitano and Amazon forests for timber production. To date, only a very few firms have attempted sustainable native forest management for timber in Paraguay. Paraguay may or may not be able to follow the Bolivian model because of the relative lack of large contiguous forests remaining. I describe the sustainable management of native forests practice as might be feasible in Paraguay in more depth below.

Paraguay's western, or Chaco, region is covered by a mosaic of arid forest and savannahs with scattered trees. While there are no sustained experiences or research related to the management of the Chaco forests for timber, there are some experiences with the management of naturally-regenerated *Prosopis* spp. (carob tree [Eng.], algarrobo [Esp.]) in cattle pastures, which I consider in this study.

There are several native species that may be possible to grow in plantation in Paraguay, although they have been studied very little. Because commercial plantations of these species do not yet exist in Paraguay, and because research on these species is extremely limited, I do not consider them in this study. Below is a partial list of potential native plantation species:

- *Amburana cearensis* (trébol)
- *Anadenanthera colubrina* (kurupa'y kuru)
- *Balfourodendron riedeliamum* (guatambu)
- *Cabralea canjerana* (cancharana)
- *Cedrela* spp. (cedro), including *C. fissilis*
- *Cordia trichotoma* (peterevy)
- *Peltophorum dubium* (yvyra pyta)
- *Prosopis* spp. (algarrobo), including *P. alba* and *P. nigra*
- *Pterogyne nitens* (yvyra ro)
- *Tabebuia* spp. (lapacho [Esp.], tajy [Gua.]), including *T. heptaphylla*

In addition, there are a few native plantation tree species that can produce non-timber forest products. Most importantly, *Ilex paraguariensis*, or yerba mate, is a traditional product from southern and eastern Paraguay. Yerba mate is a tree or large shrub, whose leaves are ground up to produce an infusion drink which is popular in Paraguay, Argentina, Uruguay and southern Brazil. Even though *I. paraguariensis* is not a species used for timber, I consider it in this study because it is a plantation tree species with precedent in Paraguay.

Another tree species with potential for plantation for non-timber products is *Acrocomia aculeata* (gru-gru palm [Eng.], cocotero [Esp.], mbokaja [Gua.]). *A. aculeata* produces a drupe with a nut-like seed that can be used to produce oils for biofuels.

B. Exotic species

There are a number of exotic tree species that have been planted in Paraguay and other similar tropical to subtropical locations. This study considers four species that are the most commonly planted species in Paraguay: *Pinus taeda*, *Eucalyptus grandis*, *Eucalyptus camaldulensis* and *Melia azedarach*.

Pinus taeda, or loblolly pine, is native of the southern USA, and is widely planted in subtropical to temperate South America, particularly in Uruguay, Argentina and southern Brazil. *P. taeda* has also been planted in Paraguay for some time (Macedo and Cartes 2006), but never in large

(>500 ha) plantations. However, noting the large extent to which *P. taeda* is planted in the nearby province of Misiones, Argentina, it is likely to have good potential in Paraguay.

Eucalyptus grandis, or flooded gum, is a native species of eastern Australia. *E. grandis* is probably the most commonly planted *Eucalyptus* species planted in tropical and subtropical regions throughout the world, and can be considered the “gold standard” by which other tropical plantation species are measured. The wood is quite good for a number of purposes, including pulp, energy, construction timber and furniture.

Eucalyptus camaldulensis, or river red gum, is native of central Australia and is a species that has relatively dense wood and can survive and grow well under difficult environmental conditions. In particular, *E. camaldulensis* can grow well in poor soils, arid climates and in areas with a high water table. Because of its adaptability, *E. camaldulensis* was widely planted in Paraguay in the 1990s and 2000s. The dense wood is especially good for fuelwood and charcoal, and may have some important specialty uses such as furniture and hardwood floors, although it is somewhat difficult to work.

It should be noted that there is something of a debate being waged among forestry professionals and potential forestry investors about the appropriateness of *E. camaldulensis* for Paraguay. On the one hand, some say that *E. camaldulensis* is appropriate because of its adaptability to a wide range of sites and because it can survive and even thrive in some of Paraguay’s harshest conditions, such as lowland savannahs in the Eastern Region and dry sites in the Chaco. On the other hand, others believe that on any particular site, some other species will be better suited (e.g. *E. grandis* on good sites, *P. taeda* on poor soils with good rainfall, *E. citriodora* on dry sites). Also, *E. camaldulensis* tends to have fairly poor form, especially when care is not taken to prune. Regardless of these varying opinions of *E. camaldulensis*, it is likely to be a major plantation species in Paraguay for some time, especially if the market for plantation fuelwood and charcoal grows.

Melia azedarach, or chinaberry (Eng.), paraiso (Esp.) (native of South and Southeast Asia), is a species that, while not known as a timber species in much of North America, is known for high-quality furniture wood in South America, Asia and parts of Europe. It produces a rosy-colored wood that is comparable to the native *Cedrela* spp., which is highly sought-after.

It should be noted that *M. azedarach* is not likely to be planted on such large scales as *Eucalyptus* spp. or *Pinus* spp. The demand for fine furniture wood on the local market is much smaller, in terms of volume, than, for instance, the demand for construction timber or fuelwood. A 10,000-hectare plantation of *M. azedarach* would quickly saturate the local market. However, there may be potential for export. Also, *M. azedarach* is very demanding in terms of site quality; it is not nearly as adaptable as *E. camaldulensis* or *P. taeda*.

There are a variety of other exotic species that appear to have good potential as plantation species in Paraguay. Many of these species have been tested for establishment and early growth in small, research-level plots, but have neither been planted commercially nor grown to the completion of a timber rotation. Because this study is only of limited scope, I have not calculated potential returns for these species. They merit further investigation. Below is a partial list of potential species:

- *Acacia* spp., including *A. mangium* (natives of Australia and Asia)
- *Eucalyptus* spp., including *E. citriodora*, *E. dunnii*, *E. globulus*, *E. robusta*, *E. saligna*, *E. tereticornis*, *E. urophylla* (natives of Australia)
- *Grevillea robusta* (silky-oak, native of Australia)
- *Leucaena leucocephala* (leadtree, native of the Caribbean region)
- *Paulownia tomentosa* and *P. elongata* (princess-tree [Eng.], kiri [Esp.], native of China)
- *Pinus* spp., including *P. elliottii* (slash pine), *P. caribaea* (Caribbean pine) (natives of North and Central America)
- *Tectona grandis* (teak [Eng.], teca [Esp.], native of South and Southeast Asia)
- *Toona ciliata* (native of Australia)

III. Risks of forestry investments in Paraguay

A. Financial risks

The underdeveloped nature of Paraguay's infrastructure, forestry policy, etc., as well as on-going state corruption, insecure financial institutions and other factors has led the Economist Intelligence Unit (EIU 2005) and the Inter-American Development Bank (IADB 2005) to give Paraguay low ratings for investment. The EIU ranks countries based on perceived financial risk. EIU (2005) rated Paraguay with a score of only 62, 85th out of 100 underdeveloped countries, but better than Nicaragua (63), Cuba (64), Ecuador (66) and Argentina (72).

Paraguay's IADB Forestry Investment Attractiveness Index (*Indice de atracción a la inversión forestal* IAIF) rating for 2002 was 31, tied with Honduras and Belize and ahead of only Guatemala, Ecuador and Haiti among Latin American and Caribbean nations (IADB 2005). However, Paraguay would appear to have improved somewhat substantially since 2002, both with macroeconomic variables (e.g. the exchange rates for the Guarani have been maintained fairly constant since 2002 after they were impacted heavily by the 2001 Argentine financial crisis) and direct forestry sector factors. By using the simulator provided on the IADB website, I was able to verify that relatively small changes in a few variables such as stability of exchange rates, political stability, growth rate of *Eucalyptus* (which appeared low by the IADB's estimates) and rate of deforestation can easily push Paraguay up to 34 or 35 points on the IAIF scale, and into the top 50% of Latin American and Caribbean countries. I believe Paraguay is moving in this direction.

Because markets for plantation timber in Paraguay are relatively undeveloped, they could be unstable. Prices for timber could go up or down. Probably, prices for timber will not decrease, and they will likely increase as Paraguay becomes increasingly deforested. On the other hand, the push for production of agricultural crops, particularly soybeans in the Eastern Region, could drive up the cost of land and labor. The risk of reduced profits from lower future timber prices is very low, and the risk from higher costs is moderate.

Invasions of land by landless farmers, leading to expropriation and redistribution of forestland by the state, can be a risk in some situations in Paraguay. This is true if nearby communities believe that the land is not being used to its full economic potential. Expropriations, when they occur, generally are instigated by groups of farmers who invade and squat on the land, rather than through an orderly process by the government. If land is not being cultivated for an annual crop, then culturally, it is plausible that the land is not fulfilling its "social and economic function" as described by Law 1863 of 2002 ("*Que Establece el Estatuto Agrario*"). In this case, invasion by landless can culturally be seen as legitimate, even if illegal.

The current Agrarian Statute (Law 1863/02) and Law 536/95 prevent redistribution of "productive" forestland and plantation forests, and protected wilderness areas. Unfortunately, native forests can be seen as "unproductive", even if they are managed for timber or non-timber products, and have been invaded in the past. However, while highly publicized in Paraguay, the risk of invasion by landless is probably not any higher than in other Latin American countries, and the current administration of President Nicanor Duarte Frutos seems to be trying to make reforms to encourage investment. Furthermore, if a native forest is being managed for timber, then it runs less risk of being seen as unproductive. In the future, it would seem that expropriations of managed forestland, whether plantation or native, will not be a common occurrence. I would classify the risk involved with invasion by landless for plantation forests as very low, and the risk for managed native forests as moderate-low.

B. Physical and biological risks

Fire can be a threat to forest plantations and native forests in Paraguay. For the most part, fires are lit intentionally either to burn cut forestland to clear for agriculture, or to burn off dried savannah grasses so that the grasses will re-sprout with green shoots that are more palatable to livestock (Flinta 1960; Rodas and Cartes 2006). Among the general population, there is little awareness of the negative impacts of fires, especially for plantation forests. Large expanses of the native Atlantic forest in the Eastern Region are probably not at risk because of the soil and forest characteristics (Rodas and Cartes 2006). However, native forest edges and plantation forests in and around savannahs and pastures in the Eastern Region and most forests in the Western Region (Chaco) are vulnerable. Forestry investors must be sure to invest in firebreaks and other preventative measures. I would rate the risk of forest fire for native forests as low and for plantation forests in savannah regions as moderate-high.

Drought is another significant risk factor, particularly in the Chaco. The Chaco can have a strong dry season for up to 8 or 9 months during the year. Plants that are not well adapted to these conditions will not survive. If proper plant selection is used, risk of reduced plant yield because of drought is low in the Eastern Region, moderate-high in the Chaco.

Disease and pests can play a role in the risk for forest investments in Paraguay. By far the most significant pest affecting forest plantations in Paraguay are leaf-cutter ants of various species (Flinta 1960; Schultz 1999). Plantations in all regions of Paraguay must use some form of ant control several times during the first three years while the trees are relatively small. In some regions in the far eastern part of the country, ant control must continue every year until the trees are clear-cut, as these regions can have a particular species of ant that can climb tall trees to cut leaves. When chemical control is used regularly, leaf-cutter ants do not seem to cause serious problems.

Pinus and *Eucalyptus* species do not appear have any major pests or diseases in Paraguay to date besides ants. Pests will probably not be a big problem for *Pinus* spp. and *Eucalyptus* spp. as long as plantations are relatively spread-out and isolated and located on good-quality sites. The best prevention for pest and disease problems is a vigorous stand (Lanfranco and Dungey 2001). If and when plantations grow more common and are established on more marginal sites, it is likely that a number of pests, which have been recorded in neighboring countries (Argentina, Brazil, Chile, Uruguay), will become established. Paraguayan firms and governmental institutions should be vigilant in order to prevent and contain future outbreaks. While Paraguay has a good track record of controlling and preventing the spread of disease in the agriculture and livestock sectors, Paraguayan forestry agencies do not appear ready for such a task. Forestry investors should be prepared, be alert for warning signs and meanwhile push government agencies in the forestry sector to strengthen protective measures and learn from the successes and failures of agricultural and livestock agencies.

In their native ranges, *Pinus* spp. have been affected by diseases such as pitch canker (*Fusarium circinatum*) and fusiform rust (*Cronartium quercuum*) (Schultz 1999; Wingfield et al. 2006). Pitch canker, which can cause mortality in seedlings and reduce growth in adult trees, has been discovered in nurseries in Chile and South Africa (Wingfield et al. 2006). Probably the biggest threat to pine plantations in Paraguay, however, is the *Sirex noctilio* wasp, which has invaded numerous pine plantations in several countries in South America since the 1980s (Allard et al. 2003). Paraguay presents geographic and climatological conditions that suggest *Sirex noctilio* invasion is likely (Carnegie et al. 2006). While some fairly successful methods of biological control have been deployed in other countries, *Sirex* has the potential to cause great damage (Allard et al. 2003). Risk of severe disease or pest infestation for *Pinus* spp. in Paraguay is moderate-high, mostly because of *Sirex*.

Eucalyptus plantations in South America have been affected *Phoracantha* spp., species of bark borers, which can cause tree mortality or reduction of wood quality (Lanfranco and Dungey 2001). *Phoracantha* spp. are most harmful in semi-arid climates and with *Eucalyptus* species that are not drought-tolerant (Lanfranco and Dungey 2001), so care should be taken if drought-intolerant species are planted west of the Paraná River basin, where there can be several dry months in the winter. In addition, *Gonipterus scutellatus* is a defoliator that has been recorded in Paraguay's neighboring countries. Native termites are abundant, especially in the Paraguay River basin and Chaco (Constantino 2002), but do not seem to have caused many problems to date. Risk of severe disease or insect infestation for *Eucalyptus* spp. in Paraguay is moderate-low.

Despite extract from *Melia azedarach* being used in many cultures as a botanical pesticide, *M. azedarach* seems to have more problems with pests and diseases than either *Pinus* spp. or *Eucalyptus* spp. in Paraguay. In humid parts of Paraguay (from the Lower Chaco to the east), *M. azedarach* often is infected with a type of mycoplasma which can slow growth and eventually kill the entire stand at seven to ten years of age. Fortunately, mycoplasma is not a problem in the Central Chaco, but should be considered the main threat to *M. azedarach* everywhere else. The disease appears to be transferred through seed and other vectors (including soil). Investors interested in *M. azedarach* should take care that their seed comes from a mycoplasma-free source and should talk to nearby landowners to see if mycoplasma has already affected the area. In my financial analysis, I compute estimated returns for *M. azedarach* under both possible scenarios: healthy and diseased with mycoplasma.

M. azedarach can be infected by other pests, as well. Observations have noted mites and woodlice, which can cause problems such as fasciation. Risk of disease or pests for *M. azedarach* is high.

IV. Forest investments in Paraguay

A. Methodology and Assumptions

The main purpose of this study is to estimate general financial returns for major timber species in the main agro-ecological regions of Paraguay. As a general tool, our study does not presume to use data on costs, growth and yield from any specific site, but rather uses the estimates of numerous forestry experts to generate approximate average rates of return. Following the work of Cubbage et al. (2007), I asked experts to estimate typical costs, growth and yield of various plantation species and management of native forest, assuming good sites and good management under representative management regimes.

Because the forest industry is relatively underdeveloped and forest plantations cover a relatively small area of land in Paraguay when compared to the other countries studied in Cubbage et al. (2007), in many cases it is hard to define *any* particular management regime or price structure as "typical". Furthermore, the vast majority of plantation forests that currently exist in Paraguay have never completed one full timber rotation. In some cases I was forced to redefine the estimates under "hypothetical, good" management regimes, and speculate about future markets.

On the other hand, in the places where I was able to get concrete figures, for timber sales prices, for instance, I found that prices and growth rates were similar to nearby areas in bordering countries, particularly in the parts of Paraguay near Argentina and Brazil (which have more developed forestry markets). This reinforced the consistency of the data.

For each tree species in each agro-ecological region, the base case assumed no land costs or subsidies. Zero land cost would be consistent with investment decisions by a landowner who already owns the land in question. Lack of subsidies is consistent with the current *status quo* in Paraguay: while cost-share payments are authorized under the Forestry Law No 536 of 1995, they have rarely, if ever, been paid to forest landowners. Also, forest owners may be exempt from part or all of the property tax they owe for the forested land; however, property taxes are so small relative to other expenses that most landowners probably do not consider the costs of time necessary to navigate the bureaucracy to be worth the benefits received. After considering the base case, I then conducted sensitivity analyses which included land costs and subsidies.

B. Establishment and management costs

Table 1 shows the establishment costs and thinning regimes for the species and agro-ecological zones in question. Establishment costs include costs for site preparation, planting, ant and weed control, and pruning during the first 5 years. They do not include costs for yearly administration, fire control, thinning, etc.

I assumed higher yearly administrative costs than the $20 per hectare assumed by Cubbage et al. (2007). These costs include infrastructure such as roads, protection against fire and disease, consultancy and general accountancy and management fees. Many of these costs per hectare are highly sensitive to scale (for instance the cost of flying or driving an administrator or consultant to the forest from Asuncion would be much lower on a per hectare basis for a large establishment than for a small one), and since large-scale forestry firms are not established in Paraguay, yearly costs would be higher per hectare for most "typical" forestry operations. In addition, there are higher costs associated with the lack of information about forestry management in Paraguay. In total, these yearly costs added up to $47 per hectare. I believe that large-scale plantation forestry firms in Paraguay probably could reduce these costs substantially.

Other costs of forestry management that rely heavily on labor are affected by two opposing forces when compared to other neighboring countries. Importantly, the general cost of labor in Paraguay is relatively low, especially outside of the eastern soy-producing areas (Paraná River basin). On the other hand, because of the small extent of forestry operations currently, there is very little or no market for labor that specializes in forest management, which could drive the cost up for specific specialized tasks, such as pruning. In general, the more similar a task is to an established agricultural task, the more likely it is to have a low cost relative to surrounding countries.

Except in the case of cultivation of *E. camaldulensis* for energy, I consider pruning as an important management activity in all species in all regions in Paraguay. Although many landowners who have planted trees in the past ten years have neglected pruning and thinning of their stands, it is accepted universally among forestry professionals in Paraguay that if the end goal is sawtimber, it is necessary to produce large-diameter logs that are free of knots.

Because coppicing is currently not a typical practice for *Eucalyptus* spp. grown for timber in Paraguay, I assumed no management for coppicing, except for one hypothetical case in which I consider cultivation of *E. camaldulensis* for fuelwood (biomass energy). In the case of growing eucalyptus for biomass energy, I assume a thinning at age 3 and 4 and then a coppicing clear-cut at age 6 and 7 in the Paraguay and Paraná River basins, respectively. Plants would be coppiced twice (for a total rotation of 18-21 years) before replanting. While, in general, reducing the costs associated with site preparation, planting and establishment, coppicing does imply some costs associated with managing sprouts, estimated at $20 (Paraguay River basin) to $30 per hectare (Paraná River basin).

For management of native forests, because of the difficulties in working with export markets noted above, probably a sustainably-managed native forest needs a minimum of 5,000 hectares to be profitable. My estimate for returns for management of native forests should be seen as an estimate for such a large (> 5,000 ha), extensive and certified forest. My assessment assumes costs for certification ($2.75 per m^3 of commercial timber) and relatively high costs of harvesting, on a per-volume cut basis ($9/$m^3$). Other costs (silvicultural management, worker safety, roads and administration) total to $13 per m^3 of commercial timber. Because of the extensive nature of the regime, costs and revenue on a per-hectare basis are relatively low.

I should emphasize that with native forests, each situation will be highly distinct. The extent of degradation from previous logging, differences in soil and rainfall, and random variation mean that costs and benefits will vary greatly from site to site. A firm considering investment in native forest management should conduct a financial analysis after researching the site through on-the-ground timber cruises and aerial photos. Hopefully, however, my estimates can provide a baseline value for returns on good sites.

The base case for each plantation species assumed the plantation will be established on old agricultural fields. There is no cost assumed for clearing secondary growth or scattered trees. In many cases, this assumption may not be realistic. Often tree plantations in Paraguay may be established on old livestock pastures or natural savannahs with scattered trees. Removal of these trees, which may have little or no commercial value, can occasionally increase establishment costs by upwards of US$ 100 per hectare. I performed a sensitivity analysis including site preparation costs increased by $100 /ha for sites with difficulties such as scattered trees.

C. Growth and yield

Table 1 outlines the growth scenario assumptions for each species in each ecological zone. Except in the case of the Central Chaco region, I analyzed *M. azedarach* assuming two possible conditions: a healthy stand and a stand affected by the mycoplasma disease. In addition, the Central Chaco analysis represents the “paraiso común” rather than the “paraiso gigante” variety of *M. azedarach* used in the other regions, as it has been shown to have better growth characteristics in the Central Chaco.

For the Paraná River basin region native forest management, it has been shown that silvicultural treatments can bring the total forest growth per hectare up above 5 m^3/ha/yr. However, of this total growth, only about 3 m^3/ha/yr are commercially valuable species. Native forests are assumed to be harvested every seven years. Results for financial returns are highly dependent on the assumed initial state of the forest. I assume a forest in relatively good condition, which could produce timber beginning immediately in a sustainable fashion. If, however, I were to assume a degraded stand, with the forest owner waiting several years before the first sustainable harvest (as in Cubbage et al. 2007), returns would be reduced dramatically.

Table 1. Establishment costs, thinning and clear-cut regimes, and growth assumptions for base case.

Region	Species	Notes	Trees planted per hectare	Establish costs, years 0-5 ($US/ha)	Thinning (years)	Clear-cut (year)	Growth (m^3/ha/yr)	Total yield per rotation (m^3)
Paraná Basin	*P. taeda*		1111	959.99	5, 10, 15	20	32	640
	E. grandis		1111	1013.32	3, 6, 9	12	38	456
	E. camaldulensis		1333	1039.96	4, 8	12	28	336
	E. camaldulensis	fuelwood (with 2 coppices) - hypothetical	2222	872.64	3 (thin), 6 (coppice), etc.	18	32	576
	M. azedarach	Healthy	625	1025.00	4, 7	12	18	216
	M. azedarach	diseased (mycoplasma)	625	1025.00	4	8	12	96
	Managed native forest		N/A	183.75	every 7 years	7	5	37
	I. paraguariensis	*yield represents maximum green-leaf production in kg, reached in years 8-15	2222	1534.60	harvest every yr starting yr 3	30	7000*	147000
Paraguay Basin	*P. taeda*		1111	654.99	5, 10, 15	20	20	400
	E. grandis		1111	708.32	4, 8	12	25	300
	E. camaldulensis		1333	734.96	4, 8	12	20	240
	E. camaldulensis	fuelwood (with 2 coppices) - hypothetical	2222	656.64	4 (thin), 7 (coppice), etc.	21	23	483
	M. azedarach	Healthy	625	710.00	5, 8	14	15	210
	M. azedarach	diseased (mycoplasma)	625	710.00	5	8	10	80
Lower Chaco	*E. camaldulensis*		1111	708.32	5, 10	15	15	265
	M. azedarach	Healthy	625	710.00	5, 8	14	10	140
	M. azedarach	diseased (mycoplasma)	625	710.00	5	8	8	64
Central Chaco	*E. camaldulensis*		500	570.00	5, 10	15	12	180
	M. azedarach	Paraiso comun	175	610.20	5, 10	14	7	98
	Prosopis spp.	natural regeneration, with cattle grazing and seed pod collection	50	367.00		30	2	60

D. Revenues

Table 2 shows the prices assumed for various products from the different species. Except where noted, prices reflect the price per cubic meter (m^3) of non-processed roundwood delivered to mill. A transportation cost of US$ 0.08 /m^3/km was used, assuming the forest is located 45 km from the mill, as in the JICA (2002) study. Thinning and clear-cut costs (including skidding and loading) were $6 and $6 respectively per cubic meter in the Paraná River basin and $4 and $3 /$m^3$ respectively in all other regions. Prices (at mill) were assumed not to vary from region to region, as this did not appear to be the case after conversations with forestry professionals from the various regions.

Prices for each species varied for product categories, determined by the small-end diameter of the log. For plantation species, I made estimates of the percentage of volume for each harvest that would be located in each product category, based on conversations with forest managers and simulations of timber growth from Misiones, Argentina, using INTA's Simulador Forestal program (Crechi, Fassola and Freidl 1997). Generally speaking, for plantation species half to two-thirds of the total volume at final harvest (clear-cut) would be sold in one of the top two diameter classes.

For management of native forest, diameter was not a determining factor. However, because of the various types of species, form classes, etc., not all timber harvested would be merchantable on the highest-level export market. I assumed, based on conversations with forest managers, that half of volume harvested from native forest would be sold on export markets, half domestic.

I conducted a sensitivity analysis assuming potential higher timber and fuelwood prices. It seems that there is good potential for increase in prices in both markets in the future, for reasons mentioned above. I believe the reduced supply of native sawtimber will have the greatest effect on the price of native species, perhaps 25%, possibly doubling the price, whereas prices of exotic plantation species may increase by 10%. Also, if plantation forests of *Eucalyptus* spp. come to be seen as a reliable source of fuelwood for a wide array of industries, or if a paper mill is installed Paraguay, for instance (purely speculative), small-diameter log prices could easily double. Indeed, some preliminary negotiations between industries looking for biomass energy and forest owners indicate that this could rapidly become the case, and indeed, price increases have already begun. Table 2 shows the prices used for the sensitivity analysis.

Table 2. Prices used for base case and sensitivity analysis.
Unless otherwise noted, values represent the price for roundwood delivered to mill in US$ per cubic meter.

Species	Product	Small-end diameter (cm)	Base case price ($)	Increased price for sensitivity analysis	Notes
P. taeda	fuel/charcoal/pulp	5	0.00	5.00	
	tongue-and-groove panelling	15	20.00	22.00	
	tongue-and-groove panelling	25	25.00	28.00	
	tongue-and-groove panelling	30	35.00	39.00	
	tongue-and-groove panelling	35	50.00	55.00	
E. grandis	fuel/charcoal/pulp	5	12.00	24.00	
	post/sawtimber	15	25.00	28.00	
	post/sawtimber	25	31.00	34.00	
	Sawtimber	30	35.00	39.00	
	Veneer	35	42.00	46.00	
E. camaldulensis	fuel/charcoal/pulp	5	12.00	24.00	
	post/sawtimber	15	25.00	28.00	
	post/sawtimber	25	31.00	34.00	
	Sawtimber	30	35.00	39.00	
	Veneer	35	42.00	46.00	
M. azedarach	fuel/charcoal/pulp	5	0.00	10.00	
	Sawtimber	15	40.00	45.00	
	Sawtimber	25	50.00	55.00	
	Sawtimber	35	80.00	90.00	
	Sawtimber	40	90.00	100.00	
Prosopis spp.	Cattle	N/A	0.10	0.11	/kg live wieght, gross margin, on farm
	Seedpods	N/A	0.04	0.05	/kg, gross margin, on farm
	Timber	N/A	60.00	66.00	
Native forest mgmt	Domestic	N/A	10.00	12.50	on farm
	Domestic	N/A	17.00	22.00	on farm
	Export	N/A	28.00	35.00	on farm
	Export	N/A	43.00	54.00	on farm
	Export-parquet flooring	N/A	54.00	67.50	on farm
I. paraguariensis	Green leaf	N/A	0.09	0.12	/kg, on farm

E. Financial calculations

For each species in each agro-ecological region, I calculated the net present value (NPV), land expectation value (LEV) and annual equivalent value (AEV) in values of US$/ha; discounted benefit to cost ratio (BCR); and internal rate of return (IRR). I used an 8% real discount rate for all calculations. All financial calculations were made in real terms (i.e. excluding inflation) in 2007 dollars.

NPV is a financial returns criterion for comparing a particular project to others, given its particular time horizon. NPV measures returns on a per-hectare basis. This means it is appropriate for firms that have limited access to land, but (virtually) unlimited access to capital (credit), as would often be the case for large firms. NPV is the sum of discounted benefits minus costs over all years of the project.

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t}$$

Where T is the total number of years in the project's time horizon, r is the discount rate, and B_t and C_t are the benefits and costs per hectare in year t, respectively.

NPV, however, is not appropriate for comparing projects with different time horizons. For these purposes, LEV or AEV are more appropriate. LEV is a return on a per hectare basis as if the project, once finished, would be repeated over and over to an infinite time horizon. AEV splits up the returns as if they were paid out on a yearly basis. AEV is especially appropriate for comparing the land use in question to other uses with yearly returns, such as agriculture.

$$LEV = NPV\left[1 + \frac{1}{(1+r)^T - 1}\right]$$
$$AEV = (LEV) \cdot r$$

The BCR is a comparison of discounted benefits to costs using a proportion rather than a difference as in the NPV calculation.

$$BCR = \frac{\sum_{t=0}^{T} \frac{B_t}{(1+r)^t}}{\sum_{t=0}^{T} \frac{C_t}{(1+r)^t}}$$

IRR is the discount rate that would make the present value of the benefits exactly equal to the present value of the costs. IRR is often used in practice, even though it is not as theoretically appropriate as NPV for most firms with limited land and relatively high levels of access to capital. IRR has intuitive appeal and is appropriate when a firm does not have a set discount rate it uses for comparing projects. IRR is generally calculated using a computer algorithm.

F. Sensitivity analyses

As mentioned in several earlier sections, I performed sensitivity analyses on a number of parameters. The changes in parameters I analyzed were: (1) including land costs in the returns calculation, (2) assuming a reduced plantable area for each hectare of land use, (3) both (1) and (2), (4) increased distance from forest to market (from 45 km in the base case to 100 km), (5) increased site preparation costs, (6) including cost-share payment subsidies to forest landowners as authorized in Law 536/95, (7) low-interest loans to landowners for reforestation and (8) increased fuelwood and timber prices.

In the case of including land costs, I assumed that the firm would purchase land in year 0 and resell at the end of the timber rotation for the same price. For the calculation of LEV or AEV, this is conceptually consistent with purchasing land and maintaining it permanently under the management regime. It also means that the difference in LEV between the base case and the case of including land costs will be exactly the cost of the land.

Particular attention should be paid to the returns when including land costs, since land costs are a good proxy for relative site quality. In theory, when markets operate well, the market cost of land should represent the opportunity, i.e. the value of the land in its best alternative use. In our case, the value of the land is represented by the LEV, so any LEV that is greater than $0 after subtracting out land costs should be considered a good investment compared to alternatives.

Assuming a reduced plantable area per hectare of land is logical in many situations. Many firms will protect a certain portion of their land in ecological reserves (to maintain water quality, native flora diversity, fauna habitat, etc.), and some sites actually have physical impediments (rocks, wetland areas, etc.). The sensitivity analysis assumed a plantable area of 70%. Most per hectare costs and yields were reduced by 70%, except where I believe that costs are tied to the real area rather than the planted area, such as construction of roads, protection against fire, etc.

Forestlands may, in many cases in Paraguay, be relatively far from timber markets, increasing the costs of transportation. Most saw and veneer mills, and markets for fuelwood, will be located in the departmental capitals or a very few satellite communities. It is not unreasonable to assume a distance of up to 100 km from forest to market, which is the distance I used in the sensitivity analysis (rather than 45 km used in the base case). Also, even for forests that are relatively close to market, there is a possibility that a high proportion of the distance will be on dirt roads, which would increase transportation costs in a similar manner.

As mentioned above, there is also a possibility of higher site preparation costs than is normal, often because of scattered trees in natural savannahs or in old cattle pastures. I assumed a site preparation cost $100 per hectare higher than in the base case. I would assume that this high site prep cost would only occur in the first rotation; however, if the extra $100 per hectare cost is added in year 0 and the LEV is calculated, it is as if we are assuming the extra $100 for *every* rotation. In this case, it is important to add back the present value of the periodic $100 at the end of the rotation, to cancel out future increased costs. The LEV will be exactly $100 less than the base case LEV, since the additional $100 is a one-time cost in the present. This is the same method as I used for the land-cost case.

I also considered the effect of a functional incentive-payment mechanism, as authorized in Law 536/95. This scheme pays 75% of site preparation and plantation costs in the first year and 75% of maintenance costs for years 1-3, as estimated by SFN. The most recent estimates of costs available are from 2002 (Gonzalez Gimenez 2002), which are the figures I used although the estimates seem somewhat lower than the assumptions I have made about costs for the base case. Table 3 shows the incentive payment figures I used for the sensitivity analysis. In addition, plantation forests receive a 50% property tax exemption. For managed native forest, the only type of subsidy assumed was a 100% exemption from property taxes. Management of natural regeneration of *Prosopis* spp. in the Chaco probably would neither qualify for the cost-share payment nor the 100% tax exemption. The only subsidy for *Prosopis* spp. was the 50% tax exemption. *Ilex paraguariensis* (yerba mate) received no subsidy.

Another potential financial support policy is to provide low-interest loans for forest plantations, which is the method suggested by JICA (2002) and proposed by FEPAMA, as noted above. I considered the effect of this type of policy on financial returns for plantations (as I understand, there is no proposal to provide loans for native forest management). I consider a loan scheme which uses elements from both the JICA and FEPAMA proposals. The loan would provide 75% of actual first-year costs (site preparation, plantation, and weed and ant control) and would be paid back at the end of the timber rotation at a 5% annual interest rate.

Table 3. Incentive cost-share payments for forestry plantations used for sensitivity analysis. Payments are equal to 75% of costs estimated by the SFN for 2002.

Trees per hectare	Site prep & plant (US$/ha)	Yr 1 maintenance	Yr 2 maintenance	Yr 3 maintenance
175	122.63	51.93	54.94	57.95
500	136.80	54.94	63.97	66.98
625	158.75	57.95	69.99	76.01
1111	202.24	63.97	85.04	94.07
1333	215.32	66.98	91.06	100.09
2222	341.09	77.51	107.62	131.70

V. Results

A. Base case timber investment financial returns

Table 4 shows the results calculated for net present value (NPV), land expectation value (LEV) and annual equivalent value (AEV) in values of US $/ha; discounted benefit to cost ratio (BCR); and internal rate of return (IRR) for each species in each agro-ecological region at the 8% discount rate.

When land costs are not taken into account, as in the base case, we see that the highest returns are in the Paraná River basin. This is because of the deep, red soil and relatively high rainfall. The Paraná basin is followed, as we expect, by the Paraguay River basin, the Lower Chaco and finally the Central Chaco.

In the Paraná and Paraguay River basins, *Eucalyptus grandis* and healthy *Melia azedarach* have the highest returns, with IRRs near 20% and LEVs near $4000 in the Paraná basin and IRRs between 15 and 18% and LEVs around $1500-$2500 in the Paraguay basin. The returns for the two seem about the same in the Paraná basin, with *M. azedarach* slight higher in the Paraguay basin. However, I should note that *M. azedarach*'s high returns come with substantial risk: in both regions, disease would reduce financial returns. I should be careful to emphasize that this does not mean that *E. grandis* or *M. azedarach* will provide higher returns or is more appropriate for all sites or all situations in the Eastern Region of Paraguay. This study assumes good sites for each species, good access to markets, and various other assumptions noted above. In any particular site, some other species may perform better. In addition, this study only estimates financial returns. In any particular situation, there may be other social, environmental, biological, market or political concerns that influence decision-making.

In the Chaco, *E. camaldulensis* and *M. azedarach* both seem to have reasonable rates of return, given the harsh conditions.

Managing *E. camaldulensis* for fuelwood did not seem to be a very profitable scheme, given the base-case prices. In both the Paraná and Paraguay River basins, NPVs, LEVs and AEVs for fuelwood management were negative. This means that discounted costs outweigh discounted benefits a an 8% real discount rate.

The IRR for native forest management was extremely sensitive to changes. Slightly raising administrative or certification costs, decreasing the proportion of wood sold for export, or lowering prices, for instance, can have a profound negative impact on the IRR, whereas slight changes in the opposite direction can easily push the IRR upwards of 30, 40 or even 50%. On the other hand, criteria based on values per hectare, such as NPV, LEV and AEV are low and will always seem very low when compared to agriculture or plantation forestry, because management of native forests is a relatively extensive proposition.

The annual equivalent value (AEV) for several of the species, in particular *E. grandis*, *M. azedarach* (if it could be maintained healthy) and *I. paraguariensis* (yerba mate), appeared competitive with agriculture, on a per-hectare basis.

Table 4. Base case financial return results for various timber species in various agro-ecological regions. 8% discount rate.

Region	Species	Notes	Net present value ($/ha)	Land expectation value ($/ha)	Annual equivalent value ($/ha)	Benefit: cost ratio	Internal rate of return
Paraná Basin	*P. taeda*		1294.43	1648.01	131.84	1.42	12.00%
	E. grandis		2552.27	4233.43	338.67	1.75	21.36%
	E. camaldulensis		1207.22	2002.40	160.19	1.42	15.38%
	E. camaldulensis	Fuelwood	-301.55	-402.19	-32.18	0.91	4.47%
	M. azedarach	Healthy	2796.42	4638.39	371.07	2.27	21.11%
	M. azedarach	Diseased	101.71	221.24	17.70	1.06	9.32%
	Managed native forest		32.11	77.10	6.17	1.08	15.66%
	I. paraguariensis		1943.18	2157.59	172.61	1.71	17.56%
Paraguay Basin	*P. taeda*		679.21	864.74	69.18	1.36	11.10%
	E. grandis		1718.08	2849.75	227.98	1.85	19.57%
	E. camaldulensis		947.32	1571.31	125.71	1.51	15.33%
	E. camaldulensis	Fuelwood	-448.03	-559.10	-44.73	0.83	1.89%
	M. azedarach	Healthy	2111.41	3201.35	256.11	2.33	18.98%
	M. azedarach	Diseased	90.90	197.73	15.82	1.07	9.52%
Lower Chaco	*E. camaldulensis*		654.48	955.78	76.46	1.37	12.25%
	M. azedarach	Healthy	571.49	866.50	69.32	1.40	12.07%
	M. azedarach	Diseased	-212.63	-462.52	-37.00	0.82	4.00%
Central Chaco	*E. camaldulensis*		-26.98	-39.40	-3.15	0.98	7.74%
	M. azedarach		13.72	20.81	1.66	1.01	8.13%
	Prosopis spp.	nat. regen., silvopastoral	-171.84	-190.80	-15.26	0.83	6.39%

B. Sensitivity analyses

Tables 5 and 6 show the results of the sensitivity analyses on the calculated IRRs and LEVs for the various species in each agro-ecological region. In most cases (with a few exceptions noted below), changing individual parameters affected the returns in the expected direction, but did not affect the relative ordering of species in terms of their financial returns.

Including the cost of purchasing land decreased IRR and LEV significantly, especially in the easternmost regions where land is relatively more expensive because of its value for agriculture. Including land costs had the effect of making returns in the different agro-ecological regions more similar, with good IRRs in most regions being in the range of 8-12% and good LEVs reaching $1500/ha. Including the cost of land is important not only because some investors may not already own the land, but because the market price of land is a good proxy for the opportunity cost of the land, its value in the best alternative use. Subtracting out land costs provides a good basis for comparing to alternative uses (such as soybean cropping in the Eastern Region). The species that had LEVs greater than $0 are good alternatives to agriculture.

Reducing the plantable land area to 70% of the actual land area did not have a large effect on IRR, but had a more noticeable effect on LEV (because IRR is independent of land area while LEV is on a per-hectare basis). When considering both reduced plantable land area and land costs, only a few species had IRRs greater than 8% or positive LEVs. These species represent good investments relative to production alternatives because they return greater than 8% even after considering the cost of land (a proxy for the value of alternatives) and low plantable area. Those species include *E. grandis* in the Eastern Region, *M. azedarach* in the Eastern Region and Lower Chaco (when unaffected by disease), and *E. camaldulensis* in the Lower Chaco. *E. camaldulensis* was negative but close to zero in the Paraguay River Basin, as well.

An increased distance from forest to market (100 km rather than 45 km) has the largest negative effect on management plans that rely on income from volume rather than quality products. *M. azedarach* was not affected greatly because the income is from a relatively small volume of high-quality wood. Cultivating *E. camaldulensis* for fuelwood, however, was severely negatively affected because it relies on producing large quantities. I did not conduct the analysis for managed native forest or for yerba mate (*I. paraguariensis*) because the prices were on-farm.

In general, cost-share incentive payments (with property tax exemptions), loans and increased prices for forest products increased the IRRs and LEVs. Cost-share payments and low-interest loans had similar effects on the IRRs and LEVs of most potential forestry investments. Usually, the loans created a slightly lower IRR and LEV than the cost-share/property tax exemption combination; however, the difference in most cases was minimal and in some cases the loan actually produced higher IRRs. Given this fact, and that the cost-share policy has never been implemented effectively because of lack of funding and political will, the low-interest loans may be a good option for promoting timber investments. This loan proposal is still in its initial stages and there are major questions about its implementation.

Apparently, the loan also produces the advantage (from an economic efficiency standpoint) of not promoting otherwise poor investments. Management regimes which produce poor returns in the base case, such as cultivating *E. camaldulensis* for fuelwood, continue to be poor investments with a loan, unlike with direct cost-share payment to landowners (Law 536/95).

The most noteworthy change was the extent to which an increase in prices increased the profitability of cultivating *E. camaldulensis* for fuelwood and the sustainable management of native forests. *E. camaldulensis* for fuelwood rapidly becomes one of the most competitive forms of forestry management on per-hectare terms. Native forest management in Paraguay will never compete on a per-hectare basis with intensive plantation forestry. However, with the higher prices, and not considering the cost of land, managed native forest was calculated to have the highest return on investment (IRR) of any forestry activity in Paraguay. However, to reiterate, returns on native forest management are highly dependent on the initial state of the plantation, and I have assumed that timber harvest is possible from the first year of the investment.

Table 5. Sensitivity analyses with parameters that negatively affect financial returns.
(1) including land costs in the returns calculation, (2) assuming a reduced plantable area for each hectare of land use, (3) both (1) and (2), (4) increased distance from forest to market and (5) increased site preparation costs.

Region	Species		Base case	With land costs	Reduced land area	Reduced area, land costs	Increased distance	Increased site prep cost
Paraná Basin	*P. taeda*	IRR	12.00%	6.94%	11.55%	5.83%	10.44%	11.60%
		LEV	1648.01	-851.99	1043.61	-1456.39	919.75	1548.01
	E. grandis	IRR	21.36%	10.51%	20.65%	8.60%	17.31%	20.36%
		LEV	4233.43	1733.43	2852.59	352.59	2739.60	4133.43
	E. camaldulensis	IRR	15.38%	7.20%	14.69%	5.73%	11.83%	14.64%
		LEV	2002.40	-497.60	1290.87	-1209.13	943.52	1902.40
	E. camaldulensis	IRR	4.47%	1.17%	3.13%	0.62%	-26.42%	4.02%
	fuelwood	LEV	-402.19	-2902.19	-391.66	-2891.66	-1852.88	-502.19
	M. azedarach	IRR	21.11%	10.88%	20.45%	9.02%	20.05%	20.19%
	healthy	LEV	4638.39	2138.39	3136.06	636.06	4118.93	4538.39
	M. azedarach	IRR	9.32%	3.33%	8.36%	2.38%	7.02%	8.67%
	diseased	LEV	221.24	-2278.76	42.98	-2457.02	-155.20	121.24
	Managed native forest	IRR	15.66%	0.48%	15.66%	0.48%	N/A	15.66%
		LEV	77.10	-2422.90	77.10	-2422.90		77.10
	I. paraguariensis	IRR	16.94%	7.06%	16.22%	5.31%	N/A	16.09%
		LEV	2022.59	-477.41	1306.16	-1193.84		1922.59
Paraguay Basin	*P. taeda*	IRR	11.10%	7.69%	10.48%	6.58%	9.66%	10.58%
		LEV	864.74	-135.26	497.34	-502.66	424.45	764.74
	E. grandis	IRR	19.57%	12.60%	18.71%	10.71%	16.42%	18.43%
		LEV	2849.75	1849.75	1886.04	886.04	1915.09	2749.75
	E. camaldulensis	IRR	15.33%	9.59%	14.47%	7.97%	12.23%	14.40%
		LEV	1571.31	571.31	991.14	-8.86	833.32	1471.31
	E. camaldulensis	IRR	1.89%	0.78%	0.27%	0.09%	-30.36%	1.66%
	fuelwood	LEV	-559.10	-1559.10	-499.29	-1499.29	-1560.70	-659.10
	M. azedarach	IRR	18.98%	12.78%	18.22%	11.05%	18.01%	17.99%
	healthy	LEV	3201.35	2201.35	2132.46	1132.46	2806.60	3101.35
	M. azedarach	IRR	9.52%	4.91%	8.31%	3.61%	7.38%	8.68%
	diseased	LEV	197.73	-802.27	28.54	-971.46	-76.52	97.73
Lower Chaco	*E. camaldulensis*	IRR	12.25%	9.52%	11.40%	8.19%	9.91%	11.56%
		LEV	955.78	455.78	543.42	43.42	391.01	855.78
	M. azedarach	IRR	12.07%	9.27%	11.27%	8.00%	11.08%	11.35%
	healthy	LEV	866.50	366.50	499.68	-0.32	626.04	766.50
	M. azedarach	IRR	4.00%	2.63%	2.09%	1.21%	1.87%	3.62%
	diseased	LEV	-462.52	-962.52	-480.19	-980.19	-669.35	-562.52
Central Chaco	*E. camaldulensis*	IRR	7.74%	6.27%	6.80%	5.14%	2.71%	7.17%
		LEV	-39.40	-339.40	-133.11	-433.11	-646.45	-139.40
	M. azedarach	IRR	8.13%	6.61%	7.20%	5.48%	7.13%	7.54%
		LEV	20.81	-279.19	-91.08	-391.08	-130.92	-79.19
	Prosopis spp.	IRR	6.39%	5.60%	6.39%	5.60%	6.08%	6.39%
	nat. regen., silvopastoral	LEV	-190.80	-340.80	-190.80	-340.80	-219.93	-190.80

Table 6. Sensitivity analyses with parameters that positively affect financial returns. (1) cost-share subsidy payments (Law 536/95), (2) low-interest loans (FEPAMA/JICA proposal) and (3) increased prices for forest products.

Region	Species		Base case	With cost-share and tax exempt'n (536/95)	With loan (FEPAMA proposal)	Increased prices
Paraná Basin	*P. taeda*	IRR	12.00%	14.11%	13.74%	13.23%
		LEV	1648.01	2159.11	1863.12	2307.13
	E. grandis	IRR	21.36%	26.02%	27.59%	26.87%
		LEV	4233.43	4896.45	4439.08	6046.42
	E. camaldulensis	IRR	15.38%	19.84%	19.82%	19.73%
		LEV	2002.40	2706.62	2217.56	3342.87
	E. camaldulensis	IRR	4.47%	13.25%	4.27%	27.25%
	fuelwood	LEV	-402.19	386.65	-294.76	3554.21
	M. azedarach	IRR	21.11%	24.53%	26.16%	23.35%
	healthy	LEV	4638.39	5180.19	4828.58	5789.55
	M. azedarach	IRR	9.32%	14.41%	11.71%	12.41%
	diseased	LEV	221.24	928.84	396.70	793.03
	Managed native forest	IRR	15.66%	17.47%	15.66%	42.23%
		LEV	77.10	95.85	77.10	367.72
	I. paraguariensis	IRR	16.94%	16.94%	16.94%	22.43%
		LEV	2022.59	2022.59	2022.59	3753.75
Paraguay Basin	*P. taeda*	IRR	11.10%	14.16%	12.84%	12.27%
		LEV	864.74	1372.70	1033.37	1267.34
	E. grandis	IRR	19.57%	25.50%	25.25%	23.51%
		LEV	2849.75	3509.65	3015.08	3949.87
	E. camaldulensis	IRR	15.33%	21.32%	19.98%	19.16%
		LEV	1571.31	2272.41	1746.15	2506.67
	E. camaldulensis	IRR	1.89%	11.62%	0.83%	22.14%
	fuelwood	LEV	-559.10	176.43	-461.67	2172.54
	M. azedarach	IRR	18.98%	22.98%	23.31%	20.96%
	healthy	LEV	3201.35	3694.29	3357.01	4024.44
	M. azedarach	IRR	9.52%	16.41%	12.09%	12.52%
	diseased	LEV	197.73	902.20	335.98	631.97
Lower Chaco	*E. camaldulensis*	IRR	12.25%	16.57%	15.16%	14.89%
		LEV	955.78	1535.02	1130.67	1644.09
	M. azedarach	IRR	12.07%	15.64%	14.63%	13.82%
	healthy	LEV	866.50	1356.94	1022.15	1322.66
	M. azedarach	IRR	4.00%	10.54%	3.37%	7.16%
	diseased	LEV	-462.52	239.45	-324.26	-104.90
Central Chaco	*E. camaldulensis*	IRR	7.74%	11.03%	8.74%	10.85%
		LEV	-39.40	379.49	82.26	472.82
	M. azedarach	IRR	8.13%	11.08%	9.05%	9.85%
		LEV	20.81	408.91	127.36	313.87
	Prosopis spp.	IRR	6.39%	6.41%	6.39%	8.33%
	nat. regen., silvopastoral	LEV	-190.80	-188.92	-190.80	39.63

VI. Comparison of forestry returns in Paraguay to other countries in the Americas

Forestry returns in Paraguay compare favorably to other countries in the Americas. Tables 7 and 8 show the LEV and IRR values for timber species in the four regions of Paraguay compared to other countries in the Americas from the work of Cubbage et al. (2007) and Cubbage et al. (2008). In general, returns in Paraguay are similar to, but slightly less than, those in neighboring countries.

For *Pinus taeda* in Paraguay, returns were somewhat lower than for *P. taeda* in Argentina, Brazil and Uruguay or *P. radiata* in Chile. However, returns in Paraguay are of a similar magnitude to those in other South American countries, and are substantially higher than in the USA. A similar trend is observed for *E. grandis*

Other *Eucalyptus* spp. have found niches in plantations in South American countries. *E. camaldulensis* has been planted relatively extensively in Paraguay, *E. dunnii* has been planted in Brazil and *E. globulus* in Uruguay. In my analysis, Paraguay's *E. camaldulensis* in the Eastern Region achieved rates of return lower than, but similar to, *E. dunnii* in Brazil and *E. globulus* in Uruguay. In the Chaco, rates were lower, reflecting the arid conditions and poor soil.

Cubbage et al. (2007) did not analyze returns for *M. azedarach* in the Americas. It seems that this species is not commonly planted in other South American countries, or it is not considered a major plantation species for whatever reason. However, in Paraguay, *M. azedarach* seems to have high rates of return, comparable to some of the best species in other countries. Even in difficult Central Chaco conditions, *M. azedarach* can have decent rates of return, near the 8% real discount rate.

Sustainable management of native forests in Paraguay seemed to have rates of return noticeably higher than in Misiones, Argentina. This is partly because of differing assumptions between my analysis and Cubbage et al. (2007). My analysis assumes a relatively pristine stand that can be harvested for commercially valuable timber immediately, whereas Cubbage et al. (2007) assumes that the landowner must wait several years after a silvicultural investment before receiving the first commercial timber harvest. Also, I assume access to export markets, which is probably only feasible for a large-scale (>5,000 has) operation, whereas Cubbage et al. (2007) uses local markets. It may also be true that even Paraguay's limited experience with sustainable management of native forests and markets for native forest products is more advanced than in Argentina. Both countries, certainly, could learn from the model being developed in Bolivia.

Returns for yerba mate (*Ilex paraguariensis*) in Paraguay were similar to Brazil. Several countries have important native species either grown in plantation or single-species managed from natural regeneration. Of these, management of natural regeneration of *Prosopis* spp. in the Paraguayan Central Chaco had the lowest rates of returns, but actually had fairly good returns given the difficult conditions in the Chaco. Unfortunately, since I was not able to find reliable data on single-native species management in the other regions of Paraguay, I could not compare them here. I would expect returns for *Araucaria angustifolia* in the Paraná River basin to be similar to returns in Misiones, Argentina.

A. Key differences between Paraguay and other countries in South America

In general, it seems that returns in Paraguay are comparable to other South American countries, but slightly lower. A comparative review of the data used to calculate the returns indicates that the slightly lower returns are caused by several factors, as indicated in prior sections:

1. Transportation infrastructure. Paraguay's system of paved roads is significantly less developed than in other South American countries. Also Paraguay has the disadvantage of being distant from the nearest seaport (though Corrientes and Misiones, Argentina are a similar distance from ports in Buenos Aires and Montevideo).

2. Institutional infrastructure. The forestry sector is undeveloped, and there is little external support for forestry enterprises from government agencies, industry associations, etc.

3. Lack of a market for small-diameter logs, such as a paper mill. The only market for small-diameter *Eucalyptus* spp. would be for charcoal or woodchips, and there is probably no market for small pines.

4. Lack of a capacitated workforce for specialized jobs such as pruning, thinning and timber harvesting. This drives up the cost of those particular tasks

5. Research and development. Paraguay has only a few public institutions involved in researching forestry issues, and, to my knowledge, none involved in tree improvement and similar issues.

Fortunately, factors 2 through 5 can be influenced by work within the forestry sector. In particular, once plantation investments in Paraguay reach a critical mass, they will begin to attract investment in forest products industry and will develop a workforce specialized in silvicultural activities.

Paraguay does have some relative advantages over neighboring countries.

1. Climate. The climate is warmer than Chile, Argentina and Uruguay and the Eastern Region of Paraguay generally receives more rain than Chile or Uruguay.

2. Relatively cheap labor for tasks that are similar in nature to agricultural work.

VII. Conclusions and summary

My research indicates that forestry investments can be very productive in Paraguay. Internal rates of return (IRRs) on various investments, on good sites with good management under typical management regimes can be in the range of 10-20%, or even higher. Land expectation values (LEVs) at an 8% discount rate in many cases were higher than the cost of land, indicating that those forestry investments are good when compared to alternative land uses.

In the Eastern region, *Eucalyptus grandis* had the best returns under the given conditions. *M. azedarach* also had high returns, but with significant risk of disease, which would reduce returns substantially. Management of native forests in the Eastern Region, cultivation of yerba mate (*I. paraguariensis*), *E. camaldulensis* and *Pinus taeda* all had good rates of return (LEV greater than 0, IRR greater than 8%). Returns to management of native forests are sensitive to assumptions about the present state of the forest (pristine or degraded). This ordering does not mean that *E. grandis* is best in all situations. If one were to consider poor or shallow soils, for instance, *E. camaldulensis*, *P. taeda*, or some other species may perform better.

The only management regime I considered under the good site condition that appeared poor at the 8% discount rate was the management of *E. camaldulensis* for fuelwood (biomass energy). However, if prices for fuelwood increase substantially, as appears to be the current trend, the fuelwood management regime becomes highly profitable.

In the Chaco, several possible forestry investments demonstrate reasonable rates of return. *E. camaldulensis*, *M. azedarach* and management of natural regeneration of *Prosopis* spp. all appear to be reasonable investments, on appropriate sites and good management.

When considering the opportunity cost of land and a reduced plantable area, only a few species have positive LEVs, indicating that they are the most competitive with agriculture. These include *E. grandis* in the Eastern Region, *M. azedarach* (when healthy) in the Eastern Region and Lower Chaco, and *E. camaldulensis* in the Paraguay basin and Lower Chaco.

Despite these good rates of return on these various timber investments in Paraguay and diminishing native forest resources, I do not believe that forestry is about to explode in size in Paraguay over the next five or ten years. Rather, it appears that interest in forestry investment is increasing slowly and incrementally and will continue to do so. Paraguay's economy is still dominated by agriculture, livestock and destructive exploitation of the remaining native forests. Changing Paraguayan culture and policies to support sustainability and long-term investments will take time. Foreign investors continue to be discouraged by bureaucracy and corruption, biased or inconsistent enforcement of laws, and a general lack of infrastructure. On the other hand, many investors may be seeking new investment opportunities and Paraguay may offer them some advantages such as low labor costs, a favorable climate, etc.

This study lends itself to many possible extensions of research. First, one important future study would be to analyze returns for other non-traditional forestry species. Ideally, these estimates would include several native species grown in plantation. Second, as new forest technologies become available and commonly used in Paraguay, they should be analyzed and compared financially (as well as environmentally and socially) to existing practices. Such technologies would include the use of clones, etc.

Third, more research in the forestry and environmental realm in Paraguay must take the Chaco into account. While research about the Chaco is very scant, many forest-product firms in Paraguay are poised to move into the Chaco. While a few of these firms will attempt to manage forests in the Chaco for long-term sustainability, the majority probably operate with dubious standards. Non-governmental and governmental institutions, researchers, and others must act quickly to prevent large-scale degradation and even destruction of the natural resources of the Chaco.

Finally, a player in the forest products market for sustainably-managed native forest with great and increasing importance is Bolivia. Future financial research in the vein of this study and Cubbage et al. (2007) should take into account the Bolivian experience with managed native forests in comparison with plantation investments that have taken hold in the rest of southern South America.

In general, forestry investments in Paraguay appear to offer good rates of return. However, in order for Paraguay to experience major investment in the forestry sector in the near future, there must be major reforms and improvements including reducing governmental corruption, improving infrastructure, removing incentives that benefit agriculture or the degradation of native forests at the expense of sustainable forestry practices, etc. Paraguay appears to be making small steps in the right direction for sustainability.

Table 7. Land Expectation Values (LEVs) for forestry investments in various countries in the Americas.

Species	**Argentina**	**Brazil**	**Chile**	**Colombia**	**Paraguay (Paraná R. basin)**	**Paraguay (Paraguay R. basin)**	**Paraguay (Lower Chaco)**	**Paraguay (Central Chaco)**	**Uruguay**	**USA**	**Vene-zuela**
Pinus spp. *	3202	2495	2781	5353	1648	865				171	2095
E. grandis	4598	5427		5380	4233	2850			1804		
Other *Eucalyptus* spp. **		2872			2002	1571	956	-39	2358		2095
M. azedarach					4638	3201	866	21			
I. paraguariensis		1976			2023						
Native plantation spp. ***	-215	963	2012					-191		171	

	Intact UPAF (Par/Arg)	Degraded UPAF (Par/Arg)	USA Natural *P. taeda*	USA *P. palustris*	USA hard-woods
Managed native forest	77.10	-111	-31	-507	-331

All LEVs in US$, 8% discount rate.

Information for Brazil, Uruguay (pines) and USA (native forests) from Cubbage et al. (2007) with data from 2005. Information for Argentina, Chile, Colombia, Uruguay (eucalypts), USA (plantation forests) and Venezuela from Cubbage et al. (2008) with data from 2008. Information for Paraguay from this report with data from 2007.
* *P. radiata* in Chile, plantation *P. taeda* in all other countries.
** *E. camaldulensis* in Paraguay, *E. dunnii* in Brazil, *E. globulus* in Uruguay.
*** *Prosopis* spp. in Paraguay (Central Chaco), *Araucaria angustifolia* in Argentina and Brazil, *Nothofagus dombeyi* in Chile, *Pinus taeda* in USA.

Table 8. Internal Rates of Return (IRRs) for forestry investments in various countries in the Americas.

Species	Argentina	Brazil	Chile	Colombia	Paraguay (Paraná R. basin)	Paraguay (Paraguay R. basin)	Paraguay (Lower Chaco)	Paraguay (Central Chaco)	Uruguay	USA	Venezuela
Pinus spp.	20.0%	16.0%	15.6%	16.6%	12.0%	11.1%			15.1%	8.5%	15.0%
E. grandis	26.0%	22.7%		16.60%	21.4%	19.6%			21.4%		
Other *Eucalyptus* spp. **		22.9%			15.4%	15.3%	12.3%	7.7%	22.9%		22.4%
M. azedarach					21.1%	19.0%	12.1%	8.1%			
I. paraguariensis		19.0%			16.9%						
Native plantation spp. ***	7.2%	12.4%	13.6%					6.4%		8.5%	

	Intact UPAF (Par/Arg)	Degraded UPAF (Par/Arg)	USA Natural *P. taeda*	USA *P. palustris*	USA hard-woods
Managed native forest	15.7%	1.7%	7.8%	4.3%	3.6%

Information for Brazil, Uruguay (pines) and USA (native forests) from Cubbage et al. (2007) with data from 2005. Information for Argentina, Chile, Colombia, Uruguay (eucalypts), USA (plantation forests) and Venezuela from Cubbage et al. (2008) with data from 2008. Information for Paraguay from this report with data from 2007.
* *P. radiata* in Chile, plantation *P. taeda* in all other countries.
** *E. camaldulensis* in Paraguay, *E. dunnii* in Brazil, *E. globulus* in Uruguay.
*** *Prosopis* spp. in Paraguay (Central Chaco), *Araucaria angustifolia* in Argentina and Brazil, *Nothofagus dombeyi* in Chile, *Pinus taeda* in USA.

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