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Plantation forestry in Paraguay emerges

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ABSTRACT

Over the last two decades, investors in the forestry sector have been increasingly active in Paraguay, establishing tree plantations with the aim of profiting from the burgeoning global demand for wood and fiber. Growth rates for commercial tree species are good to excellent, and the country has over 7.6 million hectares (Mha) of land with high to very high potential for cultivating them. Since 2010, Paraguay's plantation area has quadrupled to more than 204,631 ha and planting rates accelerated sharply in 2023. This wave of planting and related forest industries is bringing jobs to rural communities and helping to diversify the country's economy. Despite these positives, plantation forestry in Paraguay faces some hurdles: high transportation costs from this landlocked country to overseas markets, time-consuming bureaucratic processes, and governance issues. Another challenge is mainstreaming plantation-grown wood into the domestic supply chain, especially for fuelwood, one of the most important sources of energy for Paraguayan households and industry. With native wood now in short supply due to decades of heavy deforestation and overcutting, sustainable fuelwood plantations are needed to fill the gap. Major investments are nevertheless moving ahead. A new multibillion-dollar pulp mill under construction, an uptick in tree planting, the resolve to address domestic needs, especially for fuelwood, and decades of experience managing modest-sized plantations suggest that Paraguay's plantation forestry sector is poised to expand. Bolstering this expansion with environmental and social best practices will help underpin its sustainability over the long term.

INTRODUCTION

Paraguay is the fifth smallest country in South America, comprising an area of about 406,752 sq km (40.7 Mha) and sharing borders with Argentina to the south, Bolivia to the northwest, and Brazil to the east and northeast (United Nations Statistics Division 2014). In 2024, the country had a population of 6.9 million inhabitants, with 37 percent living in rural areas (United Nations Population Fund 2024; World Bank 2022). In 2022, Paraguay had a Gross Domestic Product (GDP) of US $41.7 billion and an inflation rate of 9.8 percent (World Bank 2024a; World Bank 2024b). Some 80 percent of the country's exports come from hydropower, agriculture, and livestock (World Bank 2024c).

Commercial forestry with plantations, long a backwater in the country's economy, has evolved slowly until recently. In 1990, the country had only 13,000 ha of plantations and planted an average of less than 1,400 ha annually until 2010 (FAO 1981; FAO 1993; FAO 2010). From 2010 to 2022, planting rose dramatically to approximately 13,000 ha per year (FAO 2010; Instituto Forestal Nacional [INFONA] 2023a). By 2022, the country had 204,631 ha of commercial plantations, and planting rates accelerated sharply again in 2023 to an estimated 50,000 ha annually (INFONA 2023a; Federacion Paraguaya de Maderaros [FEPAMA] 2023). Two ventures are driving this most recent acceleration. One involves planting 114,000 ha to supply fiber for a new pulp mill, while another will plant 80,000 ha as a resource for future forest industries (Paracel S.A. n.d.; EUWID 2022; FEPAMA 2023; Astarte Capital Partners LLP 2024).

Managed properly, commercial tree species, mostly eucalypts from Australia and pines from North America, commonly achieve growth rates of 20-38 m^3 ha^{-1} $year^{-1}$ in eastern Paraguay, making them highly desirable for forestry enterprises (Frey 2007; Monges 2017; Cubas-Báez 2020; Vargas 2021). Financial rates of return (FRR) for plantation-grown eucalypts in Paraguay at 15-22 percent are among the highest in the region (Frey 2007; Monges 2017; Cubas-Báez 2020; INFONA 2022; Cubbage et al. 2022). Prices for land appropriate for forestry are low to moderate at about US $1,000-$3,000 per ha, and establishment costs at US $1,300-$2,609 per ha are comparable to those in other countries in the Southern Cone (INFONA 2022; Ortiz and Molinas 2022; Cubas-Báez 2020; Cubbage et al. 2022; Yanosky 2024).

Although risks to investors in plantation forestry still exist in Paraguay, the overall investment setting in the sector has improved over the past two decades. The number of landholders with formal land titles has increased significantly, country investment risks have declined, and riverports out of this landlocked country have been upgraded to handle the shipping of large volumes of commodities by barge (Ministerio de Agricultura y Ganadería [MAG] 2023; Durand-Morat 2019; REDIEX 2021; S&P Global 2022). Other conditions attractive to investors include the forestry sector's decades of experience with small- to medium-scale plantation management and its extensive results from species trials.

The threat of pest outbreaks in plantations is low, with the exception of leafcutter ants (*Atta* and *Acromyrmex spp.*), and theft of plantation-grown wood in Paraguay is relatively uncommon, although the risk of wildfires is high (Frey 2007; Ramírez 2017; INFONA 2024). Other issues affecting the sector include time-consuming bureaucratic processes, a complex regulatory framework, and various governance concerns (US Department of State 2022; US Department of State 2023; Transparency International 2023). Nevertheless, according to civil society groups and non-governmental organizations (NGO), more tools and regulations promoting access to information, prioritizing transparency, and combating corruption have been developed over the past few years (US Department of State 2022)[1]. With land for planting trees at a premium worldwide, increasing global demand for wood products, an improved investment climate and urgent need to shore up national wood supplies, along with millions of hectares with favorable conditions for tree cultivation, Paraguay's potential as an attractive location for plantation forestry appears to be coming into focus.[2]

[1] Notably, Paraguay increased its ranking on the Council of the America's Capacity to Combat Corruption Index for the second consecutive year in 2022, with strong scores in overall government transparency (US Department of State 2023).

[2] Korhenen et al. (2021) and Nepal et al. (2019) estimate that by 2070, 379-475 Mha of planted forests may be needed to satisfy global demands for forest products and services – an increase of 31-64 percent over 2020 levels (290 Mha) (FAO 2020).

MATERIALS AND METHODS

This article summarizes a review of existing information from 136 sources concerning Paraguay's forests and its potential for supporting industrial-scale tree planting. Sources for this article include information from journals, government and industry websites, grey literature, and personal communications from experts in the field (see References). Some of the insights are based on the authors' on-the-ground forestry experiences in Paraguay, as well as nearby Brazil, Chile, Uruguay, and Argentina.

Because consistently reliable statistics on forest industries and forestry in Paraguay can be difficult to obtain, reliable time series for the sector's growth are often impossible to compile. The constantly changing situation, including high levels of deforestation and rapid increases in plantation establishment, can also render relatively recent documents and reports obsolete. On a positive note, the country's forestry agency, INFONA, has recently released more timely reports and data related to forestry on its website.

The authors have made an effort to utilize only the best available information. Original reports and primary sources were favored over secondary sources. Statistics found to be outside expected ranges were checked and verified, or discarded if they could not be supported by corroborating evidence. In general, more recent statistics were favored over older ones, unless older references were the only or best sources available for particular parameters. In some situations, older data were also used to illustrate important points that otherwise could not be brought forward.

RESULTS AND DISCUSSION

Investments in the Paraguayan landscape

The backdrop for investments in commercial forestry in Paraguay's landscape is complex, involving an interplay of economic interests, societal needs, and environmental conditions. The country's economy is inextricably linked to its natural resources, particularly its fertile soils, dense forests, and rivers (Szulecka and Monges 2017; International Monetary Fund [IMF] 2023). Drawing on these assets over the past two decades, Paraguay's economy has ballooned, with its

GDP rising from US $8.9 billion in 2000 to $41.7 billion in 2022 (World Bank 2024a). Agriculture and ranching make up 30 percent of Paraguay's Gross Domestic Product (GDP), provide jobs for some 400,000 Paraguayans, and contribute to reducing poverty (World Bank 2024d; INFONA 2023a; UNDP 2024). Globally, Paraguay is now the sixth-largest exporter of soybeans and the eighth-largest exporter of beef (UNDP 2024).

Much of this economic progress, however, has exacted a toll on the country's natural ecosystems, particularly on its forests. From 2005 to 2022, 5.7 million ha of forests were converted to croplands and pasture. From 2021 to 2022, the annual deforestation rate in Paraguay stood at 1.5 percent (225,236 ha per year), which is extremely high; and by 2022, only 14.7 Mha of its native forests were still standing compared to 25.5 Mha in 1990 (INFONA 2023a; FAO 2020)[3,4]. The impact of deforestation in Paraguay has had serious consequences, including the loss of biodiversity, destruction of carbon sinks that regulate the climate, shortages of wood needed for fuel and lumber, and disruptions in the hydrologic cycle, including more severe flooding (World Bank 2020; IMF 2023).

These changes could affect Paraguay's economy, which relies heavily on its water resources to power a major hydroelectric project and transport agricultural goods by river to ocean ports and overseas markets. Fuelwood from native forests, which most Paraguayans households and many industries depend on for a large portion of their energy needs, is also in short supply due to decades of heavy deforestation and unsustainable cutting (MOPC 2019; IMF 2023). The ramifications of this shortage extend to the agricultural sector, which relies on biomass (mainly wood fuels) to dry soybeans and grains prior to export[5].

Broadening the scope of tree planting in Paraguay beyond its focus on producing timber and fiber has important implications for the long-term economic welfare of Paraguay. A more comprehensive approach would include more sustainably managed fuelwood plantations and restoring forest cover to protect critical watersheds. Establishing plantations for fuelwood,

[3] INFONA (2023a) reports that between 2010 and 2020, the country lost 226,197 ha per year (1.3 percent annually). This amount is different from FAO's estimate for deforestation of 347,000 ha per year (1.7 percent annually) over the same timeframe (FAO 2020). While the difference is significant, both estimates represent some of the highest deforestation rates in the world for that time period (INFONA 2023a; FAO 2020).

[4] About 95 percent of the original forest cover east of the Paraguay River has been lost to deforestation (Klein 1947; FAO 2018; INFONA 2023a).

[5] Biomass includes fuelwood, charcoal (from wood), residues from wood and agricultural processing, and alcohol (Lucantonio et al. 2022).

however, has been a hard sell to investors, who can make about six times the amount of profit by growing plantations for quality timber (FEPAMA 2022). And consumers still prefer fuelwood from native forests, which is 6 to 18 times less expensive than plantation-grown wood (FAO 2018). To scale up tree planting for fuelwood and watershed protection, approaches such as public-private partnerships and payment for environmental services schemes may be needed to complement commercial efforts.

Geography and ecology

Flowing north to south, the Paraguay River divides the country into two major geographic and ecological regions: the humid Región Oriental in the east and the mostly arid region in the west, generally referred to as the Región Occidental (Figure 1). Köppen Climate Zones in Paraguay are tropical rainforest, monsoon, and savannah; arid steppe; and temperate regions (Figure 2) (Beck et al. 2018). About 18 percent of the country's 14.7 Mha of forests are in the Región Oriental and 82 percent in the Región Occidental (figure 3) (INFONA 2023a).

The Región Oriental is the original home of several Indigenous peoples, including the Mbya Guaraní, Ava Guaraní, and Ache, and was once covered by the lush tropical Alto Paraná Atlantic Forest, one of the most biodiverse forests in the world (International Work Group for Indigenous Affairs 2023; World Wildlife Fund 2006)[6]. Today only about five percent (2.7 Mha) of the Alto Paraná Atlantic Forest's original forest cover remains, with the few remnant patches having been mostly logged out or placed under protection for conservation and legally off limits to cutting (INFONA 2023a, FAO 2018) [7]. The predominant land uses in the Región Oriental are now soybean cultivation and ranching.

For forestry purposes, Frey (2007) divides the Región Oriental into two subregions, the Paraguay River and the Paraná River basins. Rainfall in the Paraná basin frequently exceeds 1,800 mm annually, while the Paraguay basin receives up to 1,600 mm on its eastern flank with wide seasonal variation (Pasten et al. n.d.). These river basins and the overall Región Oriental have highly

[6] According to the World Wildlife Fund (2006), the remaining fragments of the Alto Paraná Atlantic Forest have very high rates of endemism, with some 90 percent of its amphibians and 50 precent of its plants found nowhere else in the world.

[7] Lopez et al. (2002) report that eastern Paraguay's forests have over 250 different species of trees. Paraguay's protected areas still host many of these species and provide an important source of germplasm for restoring native tree cover in the future.

favorable conditions for tree growth and plantation forestry: warm temperatures, ample rainfall, gentle terrain, and fertile soils.

The Región Occidental has 11.9 Mha of mostly xerophytic forests and three major natural ecosystems: the Humid Chaco (or Bajo Chaco), Dry Chaco (or Chaco Central), and Pantanal (wetlands) (Cervantes et al. 2023; Frey 2007; INFONA 2023a). The Humid or Bajo Chaco receives only about 700 mm of rainfall annually, while the Dry or Chaco Central is even dryer, receiving only 600 mm (Frey 2007; Pasten et al. n.d.). Unlike Región Oriental's fertile environment, the Chaco ecosystems and Pantanal wetlands are not conducive to cultivating most tree crops. Long distances to major markets in the east, where most of the population resides and industries are located, also hinder commercial forestry development in the Región Occidental.

In 2022, some 88 percent of the country's deforestation occurred in the Chaco, mainly due to the conversion of forest to agriculture and pastureland (INFONA 2023a). Most of this deforestation is legal and sanctioned by Decree 175/18, which regulates Article 42 of Law 422/73 (i.e., the Paraguayan Forest Law) (INFONA 2023a, Cervantes et al. 2023; República de Paraguay 2018)[8].

Plantation forestry and its potential

Overview

To assess Paraguay's potential suitability for tree planting, INFONA (2023b) conducted a countrywide spatial analysis using a geographic information system (GIS). Their assessment included biophysical factors that affect tree growth, distances to roads and ports, locations of forest industries, and socioeconomic variables (INFONA 2023b). Results from the analysis indicated that Paraguay has about 20.1 million ha with varying degrees of suitability for tree planting, although only 7.6 million ha are considered to have high-to-very high suitability (Table 1) (Figure 4) (INFONA 2023b).

[8] The decree requires that all rural properties larger than 20 ha preserve 25 percent of their forests in a natural state, in addition to 15 percent in protection strips separating agricultural plots. An additional 5 percent of the forest cover must be retained to protect riparian zones for properties with streams (República de Paraguay 2018).

Figure 1. Map of Paraguay (Adapted from Mappr.com n.d.).

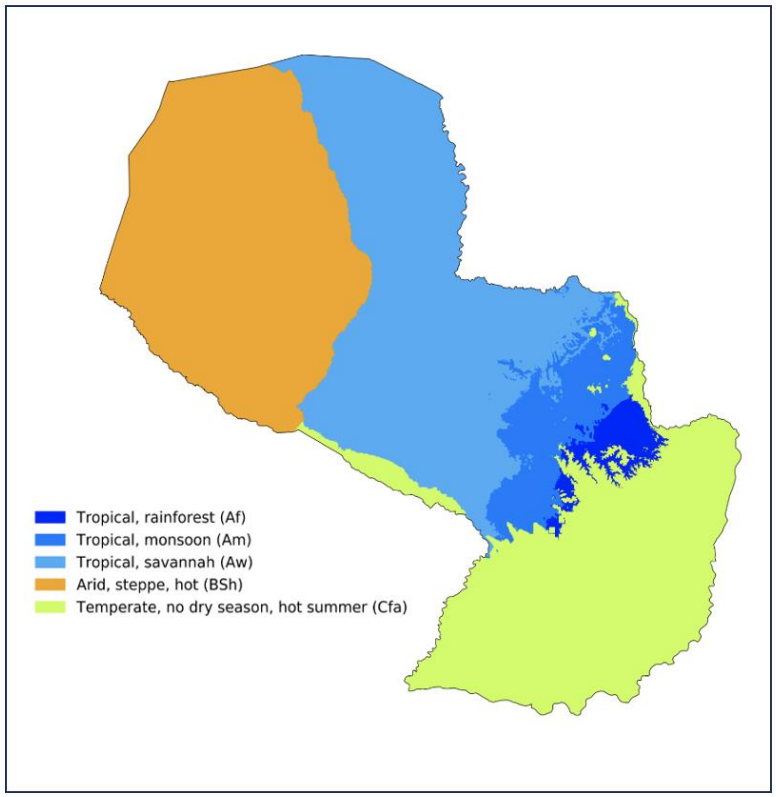

Figure 2. Köppen-Geiger climate classification map for Paraguay (1980-2016) (Beck et al. 2018).

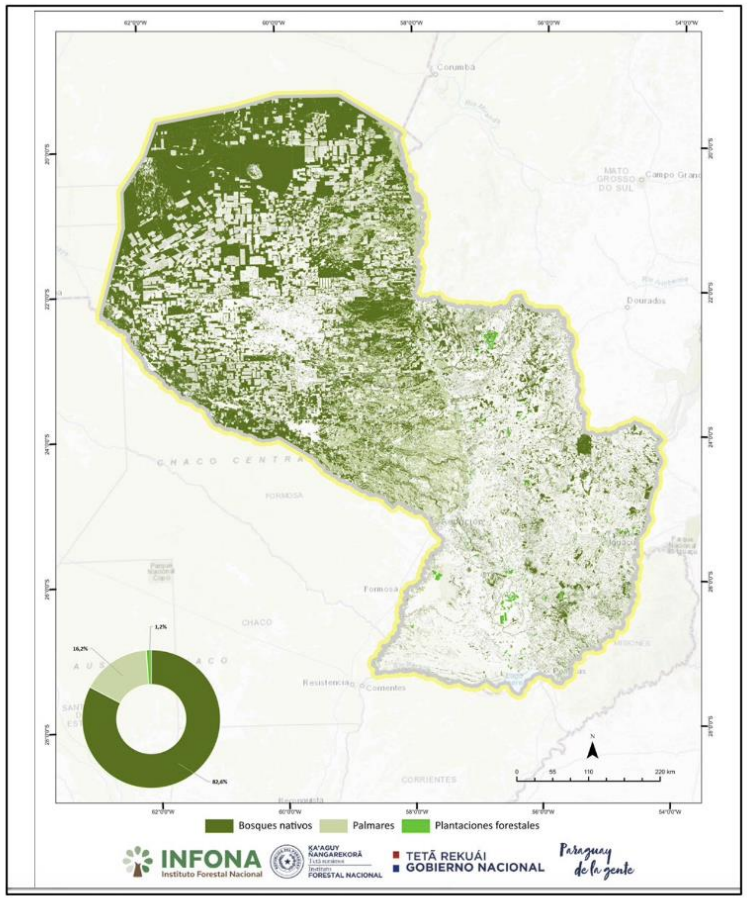

Figure 3. Forest cover map of Paraguay (INFONA 2023a).

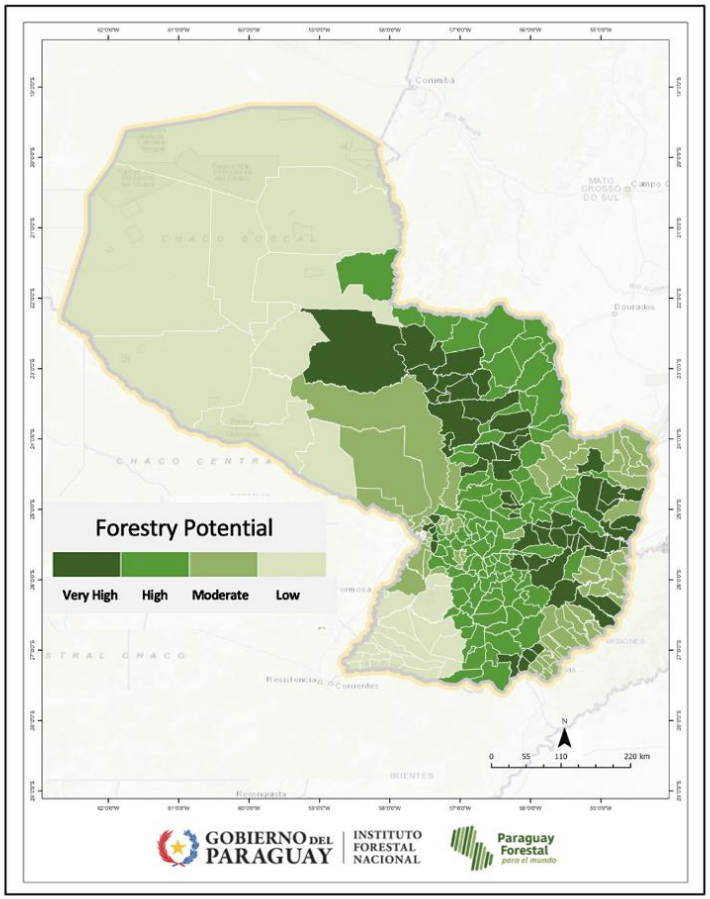

Figure 4. Areas suitable for plantations by district (Adapted from INFONA 2023b).

Table 1. Suitability for tree planting in Paraguay by region.

Region	Suitability for tree planting (ha)				
	Very high	High	Moderate	Low	Total
Región Oriental	2,218,180	3,688,311	1,504,009	1,305,915	8,716,416
Región Occidental	975,593	748,727	1,748,995	7,920,864	11,394,180
Total	3,193,773	4,437,038	3,253,004	9,226,779	20,110,596

Source: Data from INFONA (2023b). Note: Totals may not tally due to rounding.

While in 2001 the country had only 29,827 ha of commercial tree plantations, by 2022 the total area of plantations had reached 204,631 ha, though this is still small compared to neighboring countries (Table 2) (JAFTA 2002; INFONA 2023a). The rise in plantation establishment is attributed to several factors, including an overall improvement of the investment climate and decreased risks, decades of promotion from Paraguay's *Federacion Paraguaya de Madereros* (FEPAMA), a growing recognition of the potential financial benefits of plantation forestry, and, to a much lesser extent, the need to shore up local sources of wood for domestic use. According to the Ministerio de Agricultura y Ganadería's census of 2022, some 13,566 farmers had tree plantations on their properties throughout Paraguay (MAG 2023).

Table 2. Area of tree plantations in the Southern Cone and Brazil.

Country	Commercial Tree Plantations (Mha)
Brazil	9.93
Chile	2.39
Argentina	1.32
Uruguay	1.10
Paraguay	0.20

Sources: Ministerio de Economia de Argentina (2023); Brazilian Tree Industry (2022); Instituto Nacional Forestal (2024); Ministerio de Ganaderia, Agricultura, y Pesca (2022).

The distribution of plantations by size of landholding is unequal in Paraguay. About 70 percent of the country's plantations are on holdings of 1,000 ha or larger, while only 12 percent are on holdings of less than 100 ha (MAG 2023). The largest share of plantations by landholding size is located in holdings of 1,000 to less than 5,000 ha (MAG 2023) (Figure 5).

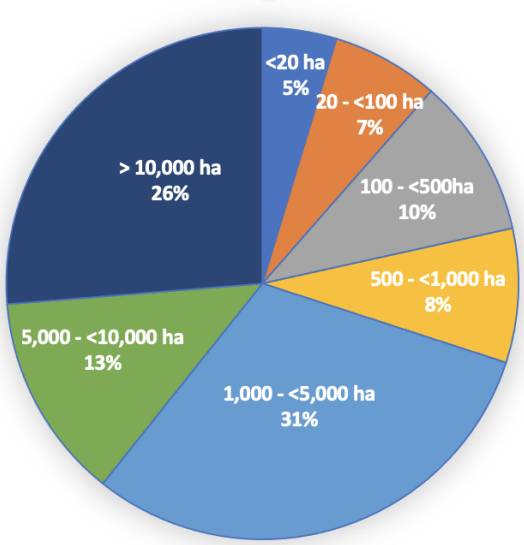

Figure 5. Distribution of plantation area by size of landholding. Source: MAG 2023.

Evolution of tree planting

Tree planting in Paraguay (mostly of exotics with a small fraction of natives) started around 1947, and by 1975 the country had roughly 1,500 to 2,000 ha of plantations (FAO 1980; INFONA 2018). Planting rates continued to be low through 2010, averaging only about 1,400 ha annually (FAO 1981; FAO 2006; FAO 2010). From 2010 to 2022, however, planting accelerated dramatically to approximately 13,000 ha per year (Figure 6) (FAO 2010; INFONA 2023a). While definitive statistics for the plantation area in 2023 are still pending at the time of publication, FEPAMA (2023) estimates an additional 50 thousand ha of plantations had been established that year and that planting will be even higher in 2024. Considering the rapid pace that Paracel S.A. is planting about 114,000 ha of trees to provide fiber for its new mill and a separate venture by Silvipar AB and Astarte Capital Partners' *Silvipar Astarte Impact Forestry Fund* (SAIFF) to plant another 80,000 ha, the general thrust of FEPAMA's projections seem reasonable (Paracel S.A. n.d.; FEPAMA 2023; Astarte Capital Partners LLP 2024).

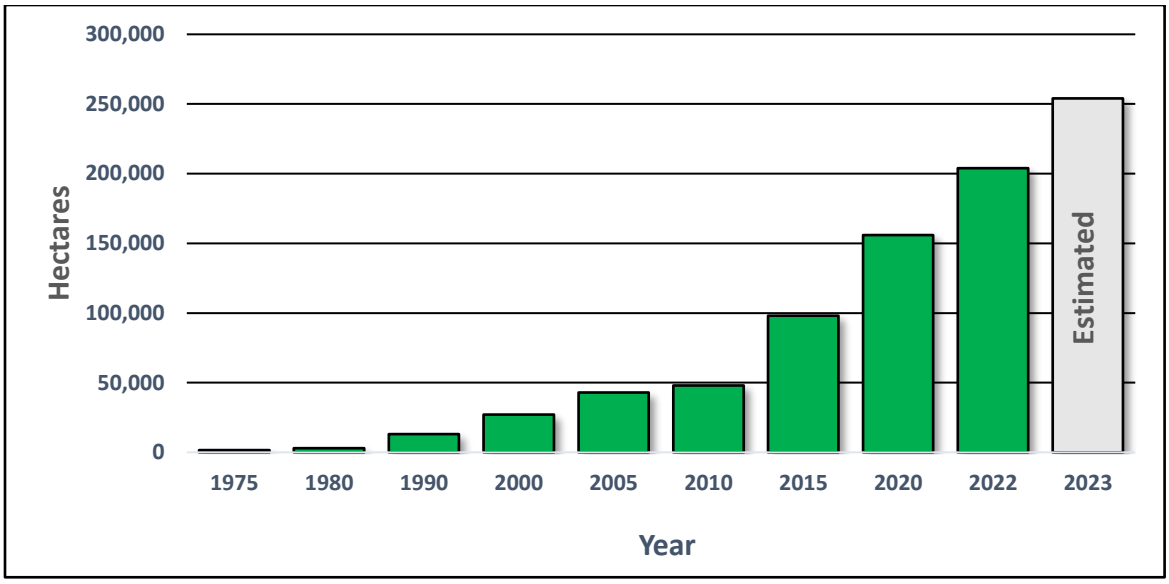

Figure 6. Plantation Area in Paraguay (FAO 1981; FAO 1993; FAO 2001; FAO 2010; FAO 2016; FAO 2020; INFONA 2018; INFONA 2023a; FEPAMA 2023).

The Government of Paraguay has played an important role in promoting tree planting, though its initiatives have had only limited success. According to INFONA (2018), the major government planting programs from 1975 to 2004 resulted in establishing only about 47,000 ha over the course of almost 30 years (Table 3) (INFONA 2018). As mentioned previously, the largest share of trees planted during this period were exotics (eucalypts and pines), although a small fraction (about 10 percent) of plantations included native species (INFONA 2018).

Table 3. Results of Government-Led Tree-Planting Programs 1975-2004.

Government Program	Time Frame	Area Planted (ha)
Plan Nacional de Reforestación, Ley 422/73	1975-1985	10,025
Fines Energéticos	1991-1994	1,763
Fines Compensatarios	1992-1993	1,227
Bosques Modelos	1997-1998	115
Ley de Reforestación y Forestación No. 536/95	1995-2004	34,023

Source: INFONA (2018).

Notes: The Forestry and Reforestation Law No. 536/95 was never properly funded, failed to reimburse many participants for planting costs, and thus may have discouraged investments in plantation forestry for a time (UN-REDD 2010; Mansourian et al. 2014). In addition, Frey (2007) points to perverse incentives in the law that may have actually encouraged the conversion of native forests to plantations.

Since the early 2000s, tree planting has been driven increasingly by the private sector, with large government support mostly absent[9]. One exception is the recently launched project PROEZA, which draws US $90.3 million in financing from both government sources and the Green Climate Fund and includes a goal of planting 24,000 ha of trees by 2027 (FAO 2018; Green Climate Fund n.d.). According to FAO's latest report, however, PROEZA had only planted 434 ha by the end of 2022 (FAO 2023).

The government has two strategic plans for guiding reforestation and plantation development, though their impact so far seems to have been negligible. The first, INFONA's *National Plan for Reforestation*, elaborated in 2012, focuses on the productive aspects of the plantation sector and proposes planting trees on 450,000 ha by 2027, with 290,000 ha going to producing solid wood products and fiber and 160,000 ha dedicated to fuelwood production (Durruty 2016). In contrast, the second plan, the *National Plan for Restoration*, still under development in 2024, centers on restoring forest cover for conservation. It recommends reestablishing 115,063 ha of forest cover to protect watersheds and riparian zones (116,732 ha) and rehabilitating degraded or deforested lands within protected areas (38,332 ha). About 70 percent of the restoration would be carried out in the Región Oriental and 30 percent in the Región Occidental using a combination of tree planting and natural regeneration techniques (INFONA 2023c)[10].

Growth rates

Many commercially important tree species in the Región Oriental exhibit fast growth, making them highly desirable for forestry enterprises. *Eucalyptus* plantations, for example, commonly have growth rates of 25-38 $m^3 ha^{-1} year^{-1}$, compared to average rates in Chile and Uruguay of about 20-24 and 25-28 $m^3 ha^{-1} year^{-1}$, respectively (Frey 2007; Monges 2017; Vargas 2021; Tomberlin and Buongiorno 2001; Silvipar n.d.; Dieste et al. 2018; Cubas-Báez 2020; Cubbage et al. 2022). Exotic pines in Paraguay, though growing slower than eucalypts, also show good growth rates of

[9] Although not backed by government financing, Paraguayan Law No. 4890, *Derecho Real de Superficie Forestal*, promulgated in 2013 and known locally as the *vuelo forestall*, promotes plantation forestry. The law allows plantations to be owned separately from the land they are established on (República de Paraguay 2013). Consequently, landholders taking advantage of the law can make income from idle land by contracting third parties to cultivate tree crops on it. Forestry operators also benefit by being able to grow and sell timber without purchasing additional land (Silvapar 2016).

[10] INFONA's *National Plan for Restoration* uses the concept developed by the Global Partnership on Forest and Landscape Restoration: "Forest and landscape restoration is the process of reversing the degradation of soils, agricultural areas, forests, and watersheds thereby regaining their ecological functionality" (Besseau et al. 2018).

20-32 $m^3 ha^{-1}year^{-1}$ (Frey 2007). Compared to the Región Oriental, the Región Occidental has few plantations due to its largely unfavorable climate and long distances to markets. Only 1,643 ha of plantations were accounted for in the west in 2022 (INFONA 2023a). Commercial species in the Región Occidental, such as *Eucalyptus camaldulensis*, grow much slower, reaching only about 15 $m^3 ha^{-1}year^{-1}$ (Table 4) (Frey 2007).

Table 4. Growth rates for commercially important tree species.

Geographic Region	Species	MAI ($m^3ha^{-1}yr^{-1}$)	Rotation (years)
Paraná River Basin	*E. grandis**	38	12
	E. grandis and E.grandis clones†	30	10
	*E. camaldulensis**	28	12
	*P. taeda**	32	20
	*P. taeda**	20	20
Paraguay River Basin	*E. grandis**	12	25
	*E. camaldulensis**	12	20
	E. grandis, E. urograndis clones†	30	10
	E. grandis clones†	38	12
Bajo Chaco	*Eucalyptus spp.* ‡	45	--
	Eucalyptus spp. ‖	25	12
	*E. camaldulensis**	15	15
Chaco Central	*E. camaldulensis**	15	12
	E. grandis x E. camaldulensis§	12	--
	E. urophylla x E. grandis§	10.3	--
	A. botryoides x A. saligna§	14.5	--

*Sources: Data from *Frey (2007), †Monges (2017), ‡Silvipar (n.d), §Vargas (2021), and ||Cubas-Báez (2020).*

Establishment costs

The most recent estimates of costs for plantation establishment, from INFONA (2022)[11], Ortíz and Molinas (2022)[12], and Cubas-Báez (2020), ranged from US $1,300 to $2,609 per ha (excluding land and administration costs)[13]. Estimates for establishment costs vary according to several factors: type and number of items included, number of years of management, end-purpose of the plantation, species, location within Paraguay, and year in which the estimates were calculated (Table 5). INFONA's numbers were the most costly for investors but also the most recent and extensive. They included multiple items not found in the estimates by Cubas-Báez (2020) nor in the older estimates from Monges (2014) and Frey (2007) such as establishing and maintaining firebreaks, deep subsoil plowing, labor and material for fencing, and additional prunings. An itemized breakdown of costs was not available for estimates reported by Ortíz and Molinas (2022), though their figures fall within the expected range.

[11] Refer to: https://nube.infona.gov.py/index.php/s/KWsY3gM99sE6sPJ?path=%2F2022
[12] Refer to: https://www.unique-wood.com/es/wp-content/uploads/sites/3/2023/08/15-anos-ForCerPa.pdf
[13]Cubbage et al. (2022) reports an average plantation establishment cost of $1,534 per ha for 16 countries and 47 planted species/management regimes.

Table 5. Plantation establishment costs in Paraguay.

Source	Reference Year	Establishment Costs (US $ per ha)	Years of Management Included in Costs	Costs for Harvesting, Firebreaks, and Fencing Included	Land and Administration Costs Included
		Región Oriental			
INFONA	2022	$1,851-$2,609 *	6-10	yes	no
Ortíz and Molinas	2022	$1,300-$2,500 †	not indicated	not indicated	no
Cubas-Báez	2020	$1,610 ‡	6	no	no
Monges	2014	$1,194-$1,310 §	5	no	no
Frey	2007	$655-$1,040 ‖	5	no	no
		Región Occidental			
Frey	2007	$570-$708 #	5	no	no

Sources: INFONA (2022), Ortíz and Molinas (2022), Cubas-Báez (2020), Monges (2017), Frey (2007). Notes: Establishment costs shown are for plantations grown for sawtimber, veneer (including plywood), fuelwood, and chips, unless indicated below. Plantation establishment for pulpwood is relatively new, beginning about 2022, and no establishment costs could be found for these. Inputs to individual estimates vary and include different amounts of site preparation, pest and weed control, fertilization, thinnings, and prunings. Readers should consult the individual references for more specific information. Ortiz and Molinas (2022) do not provide details on the inputs used in their calculations. Estimates are not adjusted for inflation.

** Low is for E. spp. fuelwood plantations (with 6 years' management) and high is for E. spp. sawtimber plantations (with 10 years' management).*

† Low is for E. spp. biomass plantations and high is for E. spp. sawtimber plantations.

‡ E. spp.

§ Low is for plantations of E. grandis clones (Paraguay and Paraná basins) and high is for a mix of E. grandis and E. urograndis clonal plantations (Paraguay basin).

‖ Low is for P. taeda and high is for E. camaldulensis.

 # Low is for E. camaldulensis in the Bajo Chaco and high is for E. camaldulensis in the Chaco Central.

Environmental and social concerns

In 2022, Paraguay completed its interim national certification standards with the Forest Stewardship Council (FSC), and had 62,353 ha of forests certified as sustainably managed in 2023 (FSC 2022; FSC 2023). Although compared to Uruguay, with 724,455 ha certified, and Chile, with 2,333,045 ha certified, this amount is still quite small (FSC 2023). FSC management standards to obtain and maintain certification require forestry operations to meet strict criteria; namely, to justify, monitor, and control exotic tree species to ensure they do not become invasive and to adhere to other good social and environmental practices (FSC 2010). For wood exports to markets in the European Union (EU) and the United States, growers will also need to ensure their wood is legal and in the case of the EU, has not resulted in deforestation (EUR-LEX 2023; Timbertradeportal.com 2023). Nevertheless, some organizations still criticize the widespread planting of exotic pines and eucalypts in Paraguay.

According to the Centro de Estudios Heñoi (n.d.), Environmental Justice Atlas (2023), and United Nations (2022), opposition comes from NGOs, local peoples (including rural and Indigenous communities), and independent researchers. Some opponents to commercial and exotic plantations contend that forestry companies initially present their investments in an overly favorable light, exaggerating positive local impacts. Other issues reported include environmental degradation and contamination, land-use conflicts, privatization of public roads by companies, health risks to locals from the incorrect or excessive application of pesticides, and unfair financial distributions to local people (Centro de Estudios Heñoi n.d.; Environmental Justice Atlas (2023); United Nations 2022). Applying high environmental and social standards for forestry operations in Paraguay and engaging honestly and meaningfully with local communities, nearby farmers, and NGOs, among others, clearly matters for successful operations in the country's plantation sector.

Región Oriental

About 79 percent (5.9 Mha) of the best planting sites sit east of the Paraguay River in the Región Oriental, which is also the location of 95 percent of the country's 204,631 ha of plantations (Figure 7) (INFONA 2021; INFONA 2023b). Some 13,498 farmers had tree plantations on their properties in the Región Oriental in 2022 (MAG 2023). A convergence of environmental conditions there produces some of the best tree growth in the world: favorable rainfall regimes, soil conditions, physiography, and year-round tropical-to-subtropical temperatures. About 88 percent of tree

planting in the region is with fast-growing eucalypts, principally *Eucalyptus grandis, Eucalyptus urograndis clones, Eucalyptus camaldulensis,* and *Eucalyptus urophylla,* along with smaller areas of *Pinus taeda, Pinus elliotti,* and *Melia azedarach* (MAG 2023; Frey 2007; Monges 2017). In addition, the country's newest and most ambitious forestry operation, Paracel S.A., plans to plant *Eucalyptus dunii* and *Eucalyptus saligna* to provide fiber for its new mill in the region (Poyry 2021).

In the Región Oriental, the Departments of San Pedro, Concepción, Caaguazá, Amambay, and Caazapá have over 66 percent of the best planting sites (INFONA 2023b). Although tree planting has been robust in these departments, with the exception of Amambay, large areas with good potential for planting remain (Tables 6 and 7; Figure 8). Figures 9 and 10 illustrate the exceptional tree growth possible in well-managed plantations in the Department of Caazapá.

Figure 7. Map of forestry plantations (Adapted from INFONA 2021).

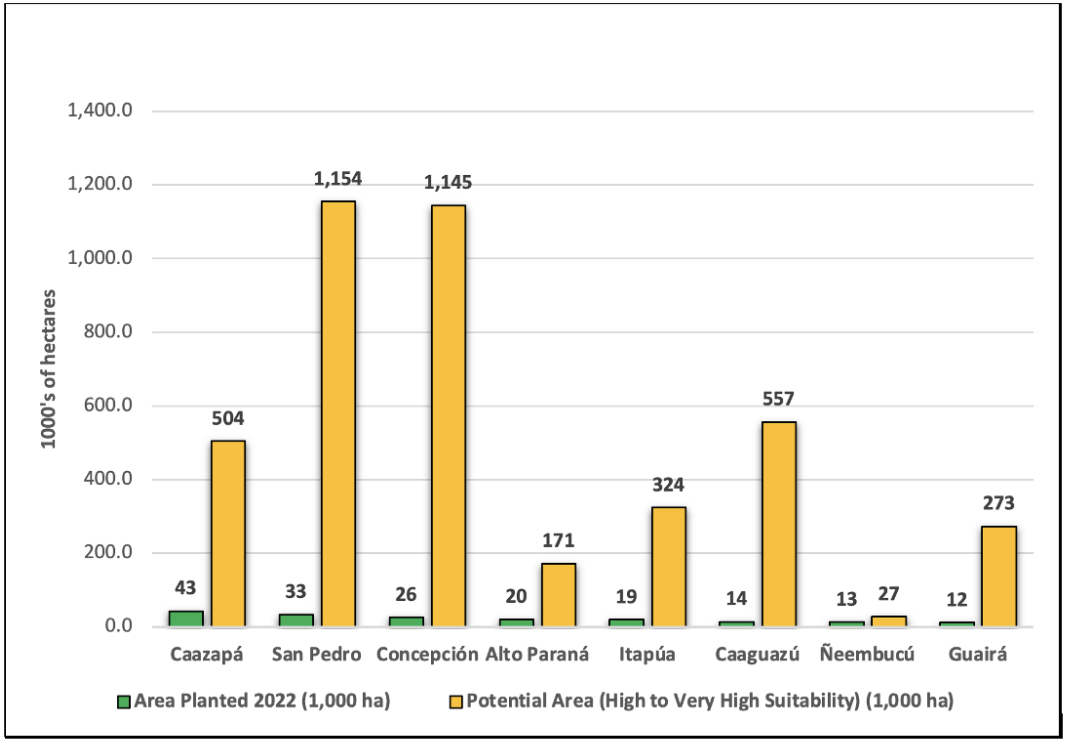

Figure 8. Land area with high-to-very high suitability for tree planting in departments in the Región Oriental with over 10,000 ha of plantations (INFONA 2023a; INFONA 2023b).

Figure 9. Three-year-old fast-growing Eucalyptus urograndis plantation near Caazapá. Photo credit: Robert Davis (World Bank 2019).

Figure 10. The diameter at breast height of a three-year-old Eucalyptus urograndis tree from the plantation in figure 7 is 22 cm (8.7 inches). Photo credit: Robert Davis (World Bank 2019).

Table 6. Suitability for tree planting in departments in the Región Oriental.

Department	Suitability for Tree Planting (ha)				
	Very High	High	Moderate	Low	Total
San Pedro	628,124	526,365	122,612	284	1,277,385
Concepción	806,116	338,457	14,155	77	1,115,806
Ñeembucú	0	27,087	55,198	879,095	961,380
Amambay	10,995	543,912	180,377	667	735,951
Misiones	37,702	242,703	154,132	245,422	679,958
Paraguarí	358	367,097	147,762	143,427	658,643
Caaguazú	206,181	350,597	85,274	1,696	643,748
Itapúa	120,918	202,746	227,544	1,792	552,999
Caazapá	113,830	390,204	36,550	1,490	542,075
Canindeyú	73,813	134,646	274,220	9,103	491,781
Cordillera	26,084	265,418	83,854	15,429	390,785
Guairá	59,406	213,388	6,524	1,754	281,073
Alto Paraná	123,652	47,732	63,589	123	235,095
Central	11,002	37,959	52,220	5,558	106,738
Total	2,218,181	3,688,311	1,504,009	1,305,915	8,716,416

Source: Data from INFONA 2023b. Note: Totals may not tally due to rounding.

Table 7. Land area with high-to-very high suitability for tree planting in the Región Oriental and plantation area 2022.

Departments of Eastern Paraguay	Area Planted 2022 (ha)	Potential Planting Area (High-to-very high Suitability) (ha)
San Pedro	42,637	504,034
Concepción	32,768	1,154,489
Caaguazú	25,978	1,144,573
Amambay	20,340	171,384
Caazapá	19,183	323,664
Paraguarí	13,984	556,778
Itapúa	12,776	27,087
Cordillera	11,588	272,794
Misiones	8,226	367,455
Guairá	3,835	291,502
Canindeyú	3,745	208,459
Alto Paraná	3,645	554,907
Central	2,936	280,405
Ñeembucú	1,347	48,961
Asunción	0	0
Total	202,989	5,906,492

Source: Data from INFONA (2023a) and INFONA (2023b). Note: Totals may not tally due to rounding.

Región Occidental

Hot, arid conditions; low rainfall; and poor soils characterize most of the Región Occidental (i.e., areas west of the Paraguay River), limiting its usefulness for industrial-scale cultivation of tree crops. In 2022, there were only 1,643 ha of plantations in the Región Occidental and just 68 farmers had tree plantations, with about 47 percent of these established with eucalypts (INFONA 2023a; MAG 2023). Vargas (2021) reports plantations of *E. camaldulensis* and *M. azedarach* as preferred species in the region's plantations. Although the region is not generally considered to be the best location for tree planting, it still has 1.7 Mha with high-to-very high suitability for tree planting (Table 8) (INFONA 2023b). A large area with very high suitability is located just west of the Paraguay River in the Department of Presidente Hayes (INFONA 2023b).

Table 8. Suitability for tree planting in departments in the Región Occidental.

Department	Suitability for Tree Planting (ha)				
	Very High	High	Moderate	Low	Total
Alto Paraguay	464,442	670,250	42,287	1,482,711	2,659,691
Boquerón	2,884	438	140,673	3,986,465	4,130,460
Presidente Hayes	508,267	78,039	1,566,035	2,451,688	4,604,029
Total	975,593	748,727	1,748,995	7,920,864	11,394,180

Source: Data from INFONA (2023b). Note: Totals adjusted for rounding. Totals of columns for suitability classes were summed based on data from departments and differ from totals reported in the source document that are assumed to be in error. The grand total is consistent with INFONA's report (INFONA 2023b).

Native species

Planting of native tree species is not common due to their relatively slow growth rates compared to exotics and, generally, lower investment returns. According to MAG (2023), less than 2 percent of all plantations have been established with native tree species, with the most frequently planted being *Handroanthus spp.* (Lapacho) with 1,913 ha, *Peltophorum dubium taubert* (Yvyra pyta) with 1,807 ha, and *Cedrela spp.* with 819 ha (Cedro). Other indigenous species that may hold potential for plantation forestry include *Amburana cearensis* (Palo trébol), *Anandenanthera colubrina* (Kurupáy kuru), *Apuleia leiocarpa* (Grapia or Yvyra pere), *Balfourodendron riedeliamum* (Guatambu), *Copernicia alba* (Caranday), *Cordia trichotoma* (Peterevy), *Cordia alliodora* (Peterebí), *Enterolobium contortisiliquum* (peterevy), *Myroxylon balsamum* (Incienso colorado), *Prosopis spp.* (Algorrobo), *Pterogyne nitens* (Yvyra ro), *Salix humboldtania* (Ipará-

pucú), *Schinopsis balansae* (Quebracho colorado), and *Tabebuia spp. and* (Braun et al. 2017; Flinta 1960; Frey 2007; JAFTA 2002; International Tropical Timber Organization 2024).

Although incentives for large-scale planting of native trees in Paraguay are uncommon, as is the case in many countries, there are options for promoting their use[14]. Approaches to encourage plantation establishment of these trees might include, for example, requiring large operators to plant a portion of their land with native trees, incorporating native species into stands of exotics (where feasible and economical), interspersing native trees in rows between planted exotics, and underwriting by the government of the additional costs of planting and managing native species (World Bank 2007). More research is needed to address technical issues associated with the plantations of native species. The focus of such studies could include seed collection and storage methods; nursery, planting, and management techniques; economic analyses; and wood characteristics, with the goal of better integrating native tree planting into Paraguay's commercial forestry sector and restoring native forest cover.

Forest industries

Estimated at US $83.8 million, Paraguay's recorded wood exports in 2021 were low, mainly going to the US (20.4 percent), the UK (11.7 percent), and Chile (8.7 percent) (Brun 2021). INFONA's latest reporting, presumably for 2024, indicates 464 forest industries operating in the country (INFONA n.d.a.). Jorge Guillen's earlier report, from 2022, provides more detail, indicating that of the 424 forest industries identified in 2022, 67 percent operated sawmills, 25 percent produced chips, and 5 percent manufactured plywood, while the remaining 3 percent were dedicated to fine wood products and flooring (Guillen 2022)[15,16]. According to Guillen (2022), 68 percent of the wood supply for these industries came from planted exotics, with 32 percent from native forests.

The forestry sector employs about 4,000 workers and officially generates about US $720 million in revenue annually, although the amount is likely much higher, considering the abundance of illegal wood in the local market not captured in official statistics (Brun 2021). Tomaselli and Vidal

[14] Paraguay's PROEZA Project includes funding from government sources and the Green Climate Fund for the planting of several thousand ha of native tree species (FAO 2018).
[15] Guillen's survey covers the Departments of Canindeyú, Curuguaty, Concepción, Caaguazú, Itapuá, Coronel Oviedo, Central y Cordillera, equivalent to roughly 90 percent of all of Paraguay's forest industries (Guillen 2022).
[16] Jorge Guillen was the Chief of INFONA's Forest Industry Unit in 2022.

(2013) report that in 2013 there were about 1,500 fuelwood vendors in Paraguay, about half of which operated illegally.

Foreign direct investment in the forestry sector has historically been low, amounting to only about US $100 million in 2020, though in 2023 this situation began to change with an influx of funding from international investors (REDIEX 2021; IMF 2023). The US $2.5-$3.0 billion pulp mill, for example, is under construction by the Paraguayan firm Paracel S.A. and Grindus Investments in Sweden, and the separate US $325 million venture to establish 80,000 ha of plantations is being financed by Astarte Capital Partners LLP in the United Kingdom and Silvipar AB (REDIEX 2021; EUWID 2022; EUWID 2023; FEPAMA 2024; Astarte Capital Partners LLP 2024).

Paracel's mill, located in the Department of Concepción along the Paraguay River bordering Brazil, is in one of the country's most favorable areas for tree growth. The mill and associated forest-management activities constitute the single largest private investment in Paraguay's history, aiming to produce 1.8 million tons of pulp annually (Paracel S.A. n.d.). An estimated 114,000 ha of new FSC-certified *Eucalyptus* plantations will be planted to supply the mill, with 46,829 ha already established by March 2024 (Poyry 2021; Paracel S.A. n.d.). About 20 percent of the fiber will come from plantations held by private landholders and contracted through out-grower schemes. The mill and associated forestry activities are expected to create nearly 4,000 direct and 16,000 indirect jobs. Some 8,000 people could be employed in its mill construction (Paracel S.A. n.d.)[17]. Earthmoving at the construction site commenced in 2024 (Econojournal 2024).

Wood fuels play a critical role in Paraguay's economy, with approximately 42 percent of the country's total energy coming from biomass, mainly forest biomass (Table 9) (Lucantonio et al. 2022)[18]. The Ministerio de Obras Publicas y Comunicaciones [MOPC] (2019) estimates that 79 percent of Paraguay's 13.9 million cubic meters of fuelwood consumed annually originates from native forests, while only 21 percent comes from plantations.

Much of the forest biomass, in the form of fuelwood, is harvested illegally from native forests and 6-18 times cheaper than legal wood sources (FAO 2018; Tomaselli and Vidal 2013)[19]. Currently,

[17] SilviPar AB's new US $325 million tree planting operation is estimated to generate 3,000 direct jobs and 30,000 indirect jobs (FEPAMA 2023).
[18] MOPC (2020) estimates that fuelwood comprises 65 percent of all biomass used for energy.
[19] The IMF (2023) estimates that 90 percent of the industrial sector consumes biomass along its value chain.

most fuelwood comes from the Chaco forests in the Región Occidental, but remnant forests in the Región Oriental are still susceptible to illegal exploitation, and most cutting goes unchecked (MOPC 2019; IMF 2023). Shortages of native wood have been growing for decades along the corridor between Asunción and Ciudad del Este, where industry and household needs are greatest.

Table 9. Utilization of energy sources in Paraguay.

Source	Percent
Biomass	42
Fossil Fuels	39
Hydropower	19

Source: Lucantonio et al. (2022). Note: Biomass includes fuelwood, charcoal (from wood), residues from wood and agricultural processing, and alcohol (Lucantonio et al. 2022).

Every year households consume the greatest share of wood fuels in the country (Table 10). About 30 percent of all households use either wood or charcoal for cooking, with rural households consuming 88 percent (4.82 million m^3yr^{-1}) of the wood used as fuel and urban homes consuming 12 percent (0.63 million m^3yr^{-1}) (MOPC 2019). According to MOPC (2019), virtually all of the wood and charcoal consumed by households comes from native forests, not from plantations.

Table 10. Annual consumption of wood fuels in Paraguay by user.

Utilization	Percentage of total	m^3yr^{-1}
Households	51	7,119,394
Industrial Processes (Various)	28	3,862,826
Industrial Drying of Grains	16	2,283,653
Charcoal Exports	5	691,788
Total	100	13,957,661

Source: MOPC (2019). Note: Amounts consumed by households include 39% from wood and 12% from charcoal produced from wood.

Paraguay's industries rely heavily on these wood fuels as well. Some 16 percent of all fuelwood used each year go to drying grains and other crops, including soybeans, corn, sunflower seeds, wheat, canola, and rice. Another 28 percent is used in various industries, mainly for processing agricultural products, smelting iron ore, and firing kilns for ceramics. Unlike most households, some industries have begun to move toward using sustainable plantation-grown wood for fuels (Table 11) (MOPC 2019).

Table 11. Percentage of fuelwood consumed by origin.

Utilization	Percentage of fuelwood from native forests	Percentage of fuelwood from plantations
Household use	100	0
Industrial processing (various)	58	42
Industrial drying of grains	42	58
Charcoal exports	100	0

Source: MOPC (2019).

Taking into account the country's deforestation, lack of fuelwood plantations, and high levels of domestic consumption of fuelwood, Paraguay appears to be headed toward an energy crisis. To address this situation, MOPC (n.d.) estimates the country should establish at least 27,000 ha of new fuelwood plantations annually. Despite the great need, stimulating large-scale plantation establishment for fuelwoods has been difficult. Profits from fuelwood plantations are significantly lower than for plantations grown for sawtimber, and plantation-grown wood costs 6-18 times more than native wood, which consumers still prefer, as they have for generations (FEPAMA 2022; FAO 2018).

Although the government passed Decree No. 175 in 2018 requiring the certification of biomass sources for energy, the decree has yet to be enforced (República de Paraguay 2018). To help regulate the use of biomass use, the government announced it would develop a registry of biomass consumers in 2024 (IMF 2023). A concerted government-led campaign is needed to address the growing shortage of fuelwood and promote the development and use of sustainable sources[20]. Public-private partnerships, involving multiple stakeholders (including government agencies, industries consuming fuelwood, plantation owners, vendors, communities, NGOs, and landowners), may help to finance, organize, and carryout the establishment of fuelwood plantations. Subsidies, credit schemes, and soft loans may be needed to help underwrite investments, especially for low-income farmers and communities. In the meantime, measures such as using wood residue from mills, prunings, thinnings, and harvesting as alternative fuel sources can help alleviate shortages.

[20] The government is currently promoting the sustainable use of wood fuels through its program "Promotion of the efficient use of biomass in Paraguay," which includes diagnostic tools for users (Euroclima 2023).

With wood also a fuel source to generate electricity, Paracel S.A., the new mill operator, reports that it will use forest biomass from its operations to generate 220 megawatts per hour of electricity. As this amount is more than sufficient for its own needs, the company plans to release the excess electricity (about 50 percent) to the regional grid (Paracel S.A. n.d.; Gateway to South America [GTSA] 2022a; Agencia de Información Paraguaya 2022).

Investment returns

Financial rates of return for plantation forestry in the fertile Región Oriental range from 15 to 22 percent for eucalypts and from 11 to 12 percent for exotic pines (Table 12) (Frey 2007; Monges 2017; Cubas-Báez 2020). The plantations in the Región Occidental region showed FRRs of 8-12 percent (Frey 2007). Land Expectation Value (LEV) is generally a better tool than FRRs for comparing forestry investments with different rotation lengths. In this case, however, the FRR provides the best criterion for measuring investment returns, not Net Present Value (NPV) or LEV, since some of the studies cited use different discount rates. The largest FRR indicates the best investment here, regardless of NPV or LEV. Because Paraguay currently lacks a pulp mill and has not historically produced or exported pulpwood, the financial returns shown only reflect investments in sawtimber, posts, veneer, and chipwood (Frey 2007; Monges 2017; Cubas-Báez 2020).

Table 12. Investment returns for select commercial tree species.

Geographic Region	Species	Establishment Costs (US$)	MAI ($m^3ha^{-1}yr^{-1}$)	Rotation (Years)	FRR (%)	NPV (US$)	LEV (US$)
Paraná River Basin (Región Oriental)	*P. taeda**	$959	32	20	12	$1,294	$1,648
	*E. grandis**	$1,013	38	12	21	$2,552	$4,233
	*E. camaldulensis**	$1,040	28	12	15	$1,207	$2,002
	E. grandis clones†	$1,194	38	12	21	$2,630	$4,363
Paraguay River Basin (Región Oriental)	*P. taeda**	$655	20	20	11	$679	$864
	*E. grandis**	$708	12	25	20	$1,718	$2,850
	*E. camaldulensis**	$735	12	20	15	$947	$1,571
	E. grandis, E. urograndis clones†	$1,310	30	10	22	$2,651	$4,938
	E. grandis clones†	$1,194	34	14	18	$2,197	$3,330
	E. spp. ‡	$1,610	25	12	22	$2,535	$6,754
Bajo Chaco (Región Occidental)	*E. camaldulensis**	$708	15	15	12	$654	$956
Chaco Central (Región Occidental)	*E. camaldulensis**	$570	15	12	8	-$27	-$39

*Sources: Data from *Frey (2007); †Monges (2017); and ‡Cubas-Báez (2020). Notes:*
a. Frey and Monges used an 8 percent discount rate, while Cubas-Báez used a rate of 4 percent.
b. Frey and Monges estimates include 5 years of management in the establishment costs, whereas Cubas-Báez estimates include 6 years of management.
c. Monges (2017) uses a slightly different geographic notation in her publication which has been adjusted to fit with the geographic regions used by Frey (2007).
d. Figures have not been adjusted for inflation. Cubas-Báez's estimates from 2020 are the most recent.

Carbon finance

Over the past few years, Paraguay has made significant progress in implementing carbon finance projects to address climate change and promote sustainable development through the forestry sector. Trees grow fast in Paraguay, so they sequester carbon fast as well. The average volume of carbon in its plantations is estimated at 83.9 tons of carbon per ha (INFONA n.d.b.).

The country presently has eight Afforestation, Reforestation, and Revegetation (ARR) carbon projects listed under the Verra Verified Carbon Standard, the world's largest voluntary carbon standard (Verra 2023). ARR projects focus on restoring and expanding forested areas to mitigate greenhouse gas (GHG) emissions by planting trees and protecting existing forests. These projects operate in both the Región Oriental and the Región Occidental, with five already registered and three in the process of registration (Verra 2023). Individually, their estimated annual emission reductions range from 254 to 204,819 Verified Carbon Units, or VCU, with one VCU representing a reduction or removal of one ton of carbon dioxide equivalent (CO_2e). A review of the three largest ARR projects by volume of CO_2e showed mainly plantings of *E. grandis, E. urophylla, E. saligna, E. citriodora* and various *Eucalyptus* hybrids, along with the exotic pines *P. ellioti* and *P. taeda* (SILVICARBON 2022; South Pole Carbon Asset Management Ltd. 2021; Swiss Carbon Value Ltda. 2023).

According to Forest Trend's Ecosystem Marketplace (2022), the average price for one ton of CO_2e sequestered from forestry and land use projects in the Voluntary Carbon Market is about US $5.80. In stark contrast, the World Bank (2023) recommends a price range of US $61-$122 per ton of CO_2e to provide enough financial incentive for investors to justify developing carbon projects. Higher market prices for carbon sequestered through plantation forestry are needed to compensate investors for significant upfront costs such as site preparation, tree planting, management, additional transaction costs, and the number of years needed to sequester carbon through tree growth before carbon credits can be traded.

Land

Paraguay occupies an area of about 40.7 Mha of land, an estimated 90 percent of which is privately owned (United Nations Statistics Division 2014; World Bank 2020). In 2022, there were some 30.4 Mha of farmland, with 13.4 Mha located in the Región Oriental and 17.0 Mha in the Región Occidental (MAG 2023). Although the Región Occidental has more farmland than the Región

Oriental, only 3 percent of farms (8,445) are located there. These holdings tend to be larger to compensate for the region's comparatively lower capacity for growing crops and raising livestock. In contrast, some 97 percent of farms (283,052) are located in the humid, fertile Región Oriental, which also has 5.9 Mha of land with high-to-very high suitability for plantation forestry (MAG 2023; INFONA 2023b). Some 13,566 farmers cultivate tree crops on their properties throughout Paraguay, 99 percent of whom have farms located in the Región Oriental (MAG 2023).

The distribution of farmland in Paraguay is highly unequal. According to the government's 2022 farm census, less than 3 percent of Paraguayan farmers owned 83 percent of all farmland in holdings of 500 ha or more. On the other end of the spectrum, 82 percent of farmers held only about 4 percent of the country's farm area on holdings of 20 ha or less (Figures 11 and 12; Table 13) (MAG 2023). The census revealed 617 farms over 10,000 ha in size accounted for over 40 percent (12.1 Mha) of the country's farmland. Indigenous communities owned some 629,437 ha of farmland in 252 holdings, 34 of which were 5,000 ha or larger (MAG 2023).

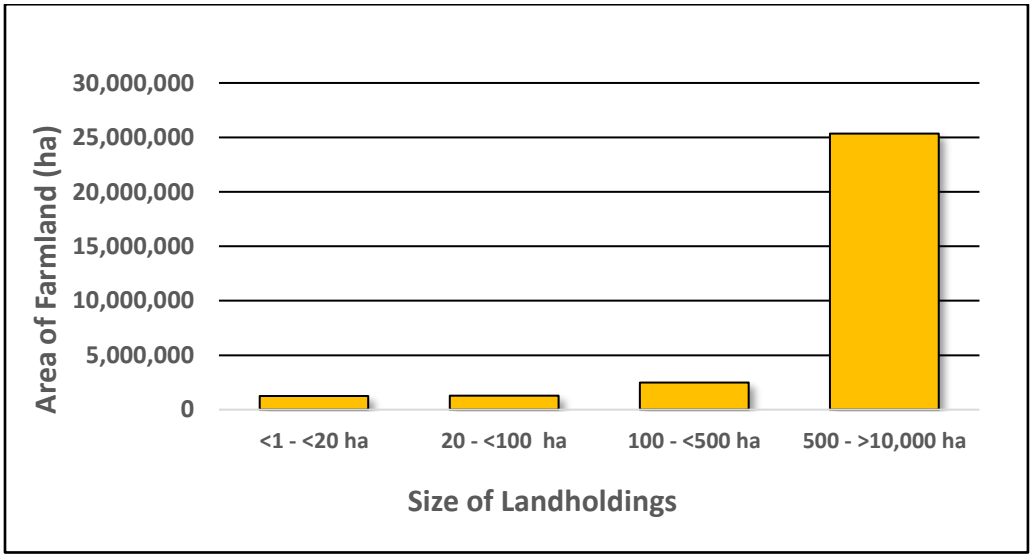

Figure 11. Distribution of Farmland by Size of Holdings (MAG 2023).

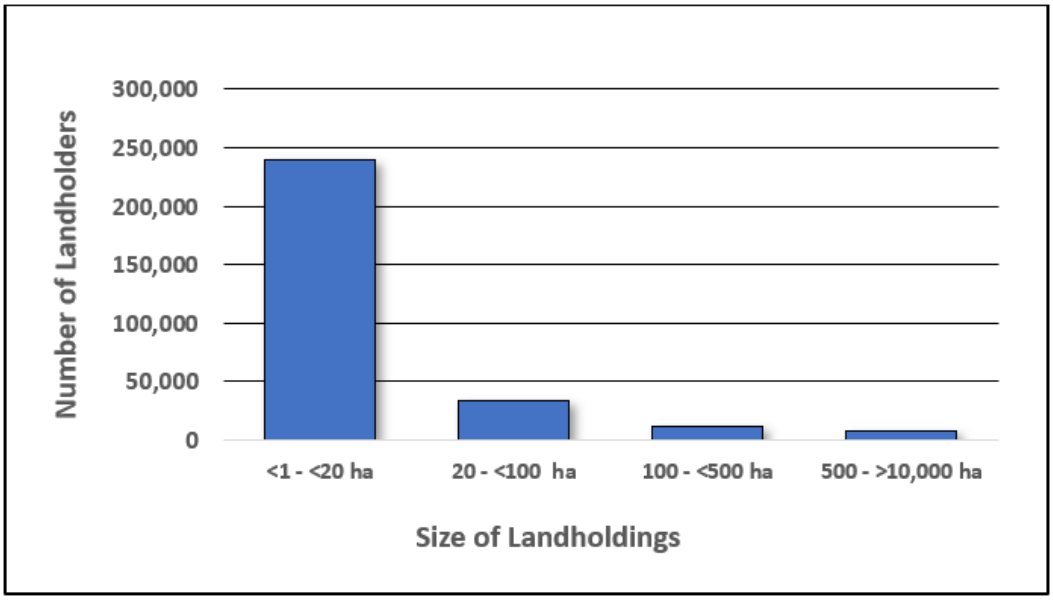

Figure 12. Number of Landholders by Size of Holdings (MAG 2023).

Between the 2008 census and the 2022 census, formal titling for ownership of farmlands rose by 19 percent, with an additional 31 percent more farmers having provisional documentation that can help with acquiring formal titles (MAG 2023). MAG (2023) reports that by 2022, 55 percent of rural landholders possessed formal land titles, while another 29 percent had provisional documents demonstrating ownership.

Table 13. Distribution of farmland by size of landholding.

Size of landholding	Area of farmland (ha)	Percentage of land area	No. of holdings	Percentage of landholders
500 to >10,000 ha	25,347,614	83	7,302	3
100 to <500 ha	2,499,759	8	11,369	4
20 to <100 ha	1,285,809	4	33,614	12
<1 to <20 ha	1,268,478	4	239,212	82
Total	30,401,660	100	291,497	100

Source: MAG (2023).

Of particular relevance to plantation forestry, the Región Oriental presents opportunities to create economies of scale by forming large-scale plantations composed of multiple holdings. In this region, there are about 19,000 holdings ranging in size from 50 to 500 ha, and about 74,000 holdings from 10 to 50 ha. If organized and managed strategically by locale, these holdings could

increase local production, lower costs for growing tree crops, and improve the producers' position for negotiating sales (MAG 2023). INFONA (2016) demonstrates such cost-savings, reporting that large plantations (500-2,000 ha) were 15 percent less expensive to establish and manage than medium-sized plantations (50-499 ha) and 31 percent less expensive than small-sized plantations (50 ha or smaller) (INFONA 2016).

According to Paraguayan land specialists, forestry land in the southern part of the Región Oriental (i.e., western Itapúa, Caazapá, eastern Ñeembucú and eastern Misiones) typically sells for an average of US $3,000 per ha, whereas land for forestry in the northern parts of the region are selling from US $1,000 to $2,000 per ha (Segovia 2024; Osuna 2024; Yanosky 2024). Prices for forestry land in the southern areas of the Región Oriental have increased about 36 percent since 2022 (Segovia 2024)[21]. In the Región Occidental, where site quality is comparatively poor and rainfall low, land suitable for tree planting sells from US $750 to $1,200 per ha (Dueck 2024; Yanosky 2024).

Paraguay Investment Law No. 117 guarantees foreign investors the right to own land (República de Paraguay 1991). Noncitizens considering buying land in Paraguay frequently hire a lawyer specialized in land acquisitions to review and, if needed, propose corrections to the existing title prior to the purchase. The cost for the legal review and correction or *sanamiento* of a single land title costs about US $2,000, though costs may vary according to the size of the holding and complexity of any issues identified. The experience of the authors of this article indicates that the cost of the *sanamiento* is roughly the same as a title search and insurance costs in the US, especially when investors are dealing with inherited properties where potential conflicts may arise or some of the owners cannot be located.

Transportation and shipping

Transporting wood and fiber to international markets and ocean ports from landlocked Paraguay poses a major challenge for forestry operators. Although the country shares borders with Argentina and Brazil, moving wood products to market overland can be problematic. The country's roads are

[21] In general, prices for agricultural land suitable for cultivation and grazing in the Región Oriental run somewhat higher than prices for forestry land, averaging about US $5,360 per ha, and prices for premium agricultural land can go as high as US $11,000 per ha or more (GTSA 2022b; Maidana 2017).

overall in poor condition and it has no viable rail system[22]. The World Economic Forum (WEF) ranked Paraguay's road infrastructure quality a low 128 out of 141 countries surveyed (The Global Economy.com 2024a). While major highways are paved, 84 percent of rural roads, needed to service forest plantations, are not (Camara Vial Paraguaya 2023). During the rainy season, unpaved roads can quickly turn into muddy tracks, slowing or even halting the movement of logs and other wood products, thereby increasing shipping costs and reducing profits. Roads in poor condition also increase the wear and tear on vehicles, adding more maintenance costs to operations.

To overcome transportation challenges in this landlocked country, workarounds exist for moving wood products to ocean ports and overseas markets. Paraguay has five major river ports and over a dozen smaller ones on the Paraguay and Paraná Rivers, which lead to Atlantic seaports in Posadas, Argentina, and Nueva Palmira, Uruguay (International Registry of Shipping Admin [IntlReg Admin] 2023; Durand-Morat 2019). Paraguay's port facilities on the two rivers have improved substantially in the past two decades to accommodate the export of soybeans, with about 80 percent of agricultural exports now shipped by barge via the Paraguay-Paraná River waterway (Durand-Morat 2019). Notwithstanding, the WEF in 2019 gives its port infrastructure quality a modest ranking of 94 out of 139 countries surveyed (The Global Economy.com 2024b). Moreover, transporting agricultural commodities out of Paraguay by barge translates to high costs, and the same would likely hold for transporting wood products. Durand-Morat (2019), for example, reports that costs for shipping soybeans from Caazapá, Paraguay, to Shanghai, China, run 90 percent higher than from Trinidad, Uruguay, and 53 percent higher than from Rafaela, Argentina. Finally, low rainfall in the Southern Cone can affect shipping out of the country when transporting commodities by river. Droughts have plagued the region since 2019, dropping water levels in both the Paraguay and Paraná Rivers and constraining barge traffic from Paraguay to ocean ports in Argentina and Uruguay (DeSantis and Elliot 2024; Reliefweb 2021).

Given the complexities of transportation and shipping, Paracel S.A. positioned its operations strategically to ensure various routes to market. Their mill will be located on the Paraguay River, adjacent to the Brazilian border to facilitate overland shipping, and they will build and operate

[22] Only one short rail line exists between the border town of Encarnación, Paraguay, and Rosario, Argentina (International Railway Journal 2022). The rest of Paraguay is not serviced by rail.

their own riverport. The company reports that two-thirds of the roads in its working area are paved (Paracel S.A. n.d).

Risks to investments

Although Paraguay has made significant progress in reducing risks over the last two decades, investors must still contend with some troublesome issues. The Organisation for Economic Cooperation and Development (OECD) (2022) gives Paraguay its highest risk rating of five and the Forest Trends (2022) considers the country at high risk for illegal logging and associated trade. Other issues include time-consuming bureaucratic processes, a complex regulatory framework, a weak judicial system, and a lack of oversight of public institutions (US Department of State 2022; US Department of State 2023; Transparency International 2023). The World Bank (2021) rates Paraguay's ease of doing business as 125 out of 190 countries and its ease of establishing contracts as 72 out of 190 countries. Transparency International (2023) gives Paraguay an overall poor score of 28 out of 100 possible points on its corruption perception index. On a positive note, S&P Global (2022) rates the overall country risk as BB/B, an improvement over their rating of CCC+ in 2006 (REDIEX 2021).

Even though private property rights are protected by law, there are accounts of expropriations without fair compensation and land invasions (US Department of State 2021). In the early 2000s, land purchases in Paraguay were considered extremely risky due to reports of conflicting or otherwise problematic land titles and overlapping property surveys. This situation seems to have improved over the past 15 years. Compared to 2008, 19 percent more landholders now have formal titles for their holdings, and 31 percent more have provisional documentation demonstrating ownership (MAG 2023). Regarding travel, the US Department of State's Overseas Security Advisory Council encourages visitors to Paraguay to exercise caution throughout most of the country. There are some important exceptions, however. For the Departments of Amambay, Alto Paraná, Canindeyu, San Pedro, and Concepción, a level 2 advisory cautions travelers to maintain increased vigilance (US Department of State 2022).

While Paraguay's *Eucalyptus* plantations have so far escaped major outbreaks of diseases, the risk does exist and is likely to increase. According to Silva et al. (2020), the most prevalent diseases affecting eucalypts in the country include *Botryosphaeria spp.*, *Chrysoporthe spp.* and *Teratosphaeria spp.* (stem cankers), *Calonectria spp.* (leaf blotch), *Coniella spp.* (leaf spot), and

Mycosphaerella spp. (leaf spot and myrtle-eucalypt rust). The stem canker, *Teratosphaeria zuluensis*, known locally as "ox foot," was reported to be the most serious, especially to forest industries. *T. zuluensis* can impact wood quality and yield, increasing the costs of pulping (Silva et al. 2020). Although fusiform rusts, *Cronartium spp.*, are known to be a serious pest affecting *P. taeda* in other countries, no reports were found indicating their presence in Paraguay (Cubbage et al. 2000).

Infestations from leafcutter ants, *Atta* and *Acromyrmex spp.*, are common and occur widely in newly established and young *Eucalyptus* plantations, requiring control and monitoring for the first few years (Frey 2007; Ramírez 2017; Poyry 2021). Other pests occasionally found in these plantations include the bronze bug or brown stink bug, *Thaumastocoris peregrinus;* the psyllids, *Glycaspis brimblecombei* and *Blastopsylla occidentalis;* the gall wasp, *Leptocybe invasa*; and the Rhomboid mite, *Rhombacus eucalypti* (Machado et al. 2020; Díaz et al. 2013; Díaz et al. 2014; Queiroz et al. 2012).

Eucalyptus plantations in nearby countries suffer from other pests, raising the possibility that they will expand their range into Paraguay. The regional intergovernmental organization, Comité de Sanidad Vegetal del Cono Sur (n.d.a.), or COSAVE, publishes an extensive list of pests and diseases affecting eucalypts[23] in the Southern Cone, including additional pests and diseases present in Paraguay but not covered here. COSAVE's mission[24] is to coordinate regional initiatives to help control pests and diseases that affect plants (Comité de Sanidad Vegetal del Cono Sur n.d.b).

The popular practice of planting seedling clones in monocultures elevates the risk of catastrophic loss from diseases, pests, and infection. This vulnerability has been lessened only coincidentally as Paraguay's tree crops are presently dispersed widely across the landscape, reducing the transmission of pathogens and vectors. As the sector expands, however, and the distance between plantations is reduced, disease and infestations may increase. Silva et al. (2020) underscore the importance and urgent need to establish good mechanisms and mobilize resources for the monitoring and control of pests and diseases in Paraguay's plantations.

[23] Refer to: http://www.cosave.org/sites/default/files/resoluciones/anexos/Anexo%20Resol%20214_%20Plagas%20presentes%20en%20Eucalyptus%20spp.pdf
[24] Refer to: http://www.cosave.org/pagina/acerca-de-cosave

Another pervasive threat is wildfire, usually originating from the burning of crop residue in farmlands or the use of fire to clear natural forests for crops and pasture. In 2023, Paraguay recorded more than 11,000 wildfires in the country, affecting 1.1 million ha of forests (INFONA 2024). To mitigate this threat, producers should include firebreaks in their plantations and have fire detection and suppression measures in place. INFONA (2022) emphasizes the importance of firebreaks in plantation establishment and management estimates that include yearly maintenance costs. The risk of major theft from plantations appears low, with reports uncommon. This could likely change in the future with the growing scarcity of wood from the disappearing native forests that Paraguayans have always relied on for cooking, heating, and local construction, as well as for drying soybeans and other crops. The risk of drought has historically been low in the Región Oriental, where most tree planting is done. Evidence suggests, however, that the risk may be increasing, with several major droughts hitting the country in 2019 and 2022 that had significant impacts on agricultural production (Reliefweb 2021; IMF 2023).

Institutions

The Instituto Forestal Nacional (INFONA) is the government agency for forestry; the Ministerio del Ambiente y Desarrollo Sostenible (MADES) is responsible for designing, supervising, and evaluating national environmental policies (concerning climate change and environmental impacts) and promoting sustainable management of natural resources; and the Viceministerio de Minas y Energia (VMME) promotes policies and projects to generate energy from renewable sources, which includes forestry biomass for energy. The Ministerio de Agricultura (MAG) oversees the country's sustainable agricultural development (including agroforestry), and the FEPAMA is the main nonprofit organization supporting wood industries. Although not presently active in forestry, the Instituto Paraguayo de Tecnología Aplicada (IPTA) works in applied agricultural research and has a mandate for forestry research. The regulatory setting for forestry and plantations is articulated in over one hundred different laws, decrees, and resolutions. A comprehensive set of documents underpinning the regulatory framework[25] for forestry appears on INFONA's website, along with a subset of documents oriented specifically to the plantation sector[26].

[25] Refer to: https://nube.infona.gov.py/index.php/s/4cDcLjmNjffFnTc
[26] Refer to: https://nube.infona.gov.py/index.php/s/2bA5ZLBryCKq7ir

CONCLUSIONS

The backdrop for investments in commercial forestry in Paraguay is complex, involving an interplay of economic interests, societal needs, and environmental conditions. Over the past two decades, Paraguayans have transformed the Región Oriental into an agricultural landscape, helping to lay the foundation for one of the fastest-growing economies in Latin America, creating a significant number of jobs and reducing poverty (World Bank 2024d). This highly productive region also hosts outstanding conditions for tree crops, raising the prospect that commercial plantation forestry becomes an important element of the economy as well. In the last two years, over US $2 billion in investments have been committed to Paraguay's plantation forest sector to finance large-scale tree planting and construction of a pulp mill.

The country's Región Oriental includes many characteristics advantageous for commercial plantation forestry:

- About 5.9 million ha of land with high-to-very high suitability for tree plantations (INFONA 2023b);
- Some of the highest investment returns in the region for *Eucalyptus spp.* plantations, boasting FRRs of 15-22 percent, and good FRRs for exotic pines of 11-12 percent (Frey 2007; Monges 2017; Cubas-Báez 2020; Cubbage et al. 2022);
- Exceptional growth rates for commercial tree species, at 25-38 m^3 ha^{-1} yr^{-1} for *Eucalyptus spp.* and 20-32 m^3 $ha^{-1}year^{-1}$ for exotic pines (Frey 2007; Monges 2017; Silvipar AB n.d.; Vargas 2021; Cubas-Báez 2020);
- Costs for forestry land of US $1,000-$3,000 per ha (Segovia 2024; Osuna 2024; Yanosky 2024);
- Plantation establishment costs of US $1,600-$2,609 per ha, comparable to costs in other countries in the Southern Cone (INFONA 2022, Ortíz & Molinas 2022; Cubas-Báez 2020; Cubbage et al. 2022);
- No restrictions on foreign citizens repatriating profits or owning land (US Department of State 2023; República de Paraguay 1991);

- Low risk of disease and pests in commercial plantations, except for leafcutter ants (*Atta* and *Acromyrmex spp.*) (Frey 2007; Ramírez 2017).

Investors must still contend with certain issues, including time-consuming bureaucratic processes, a complex regulatory framework, sector risks, and governance concerns (US Department of State 2022; US Department of State 2023; Transparency International 2023; Forest Trends 2022). Routes to overseas markets can be costly and complex, and investors need to be particularly diligent when acquiring property to avoid problematic land-titling issues and tenure conflicts (US Department of State 2021; IntlReg Admin 2023; Durand-Morat 2019; Camara Vial Paraguaya 2023). Additionally, the threat of wildfires is considered high (INFONA 2024). Despite the prospect of having to manage these risks and complexities, the lure of high profits continues to bring investments in plantation forestry to the highly productive Región Oriental. In this respect, it follows a path similar to that of the agricultural sector. In other respects, their paths are very different.

One important difference is that investments in agriculture led to the conversion of a staggering 95 percent of the region's forests to cropland and pasture (FAO 2018: INFONA 2023a). Among other consequences of this deforestation, natural habitats were decimated; critical watersheds made vulnerable to erosion and increased runoff; and fuelwood, the most important source of energy for Paraguayan households and many industries, left in short supply (World Bank 2020; IMF 2023). Unlike tree planting for timber and fiber, habitat restoration and conservation planting have made little headway, and plantation establishment for fuelwood production continues to lag. Approaches to break this stalemate are needed and might include, for example, public-private partnerships and payment for environmental services programs.

The extent to which trees can be reestablished in the landscape, for both production and conservation, will help determine the direction of the country's economy and impact the welfare of its citizens. Implementing the government's new plan for restoring tree cover for conservation remains a challenge, as is finding the right mechanisms and incentives to step up planting for fuelwood production. Commercial plantation forestry for timber and fiber, in contrast, is moving ahead swiftly with multimillion-dollar investments and an unprecedented surge in tree planting, which are bringing new jobs and industries along with them. Bolstering this expansion with environmental and social best practices and forest certification will help underpin its sustainability,

bring plantation forestry to the forefront of the national economy, and springboard Paraguay's forest products into international markets.

CONFLICTS OF INTEREST

The authors confirm there are no conflicts of interest.

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