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Prospects for commercial tree farming in Colombia

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ABSTRACT

Over the next few decades, the area of planted forests required to satisfy worldwide demand for fiber, timber, and environmental services will need to increase by tens of millions of hectares (Mha). As no single nation can accommodate this expansion, planting sites in multiple countries must be identified. One prospective location is Colombia, which boasts nearly 26 Mha of land suitable for commercial tree planting, fair-to-excellent growth rates for major industrial species, good professional expertise, seaports on the Pacific and Caribbean coasts, and low-to-moderate land prices. Yet, despite these outstanding assets, tree plantations in Colombia cover only 542 thousand hectares (ha), with almost 90 percent located in three distinct regions: the Andean, Orinoco, and Caribbean. Constraints to commercial tree farming in Colombia include cultural preferences for non-wood products in construction and domestic applications, low capacity for processing industrial roundwood, and lack of reliable wood supplies needed for firms to scale up operations. While land prices are attractive in the remote Orinoco Region, they are considerably higher in more accessible regions, such as the Andean and Caribbean, which are closer to markets, mills, and ports. These factors along with security problems, low levels of formal land titling, and property rights issues in rural areas can complicate operations and add risk to investments in plantation forestry. With land for tree planting at a premium and increasing global demand for wood, fiber, and carbon sequestration, Colombia's plantation sector stands to profit, provided it can successfully address the barriers to its growth.

INTRODUCTION

Global demand for forest products and services is expected to increase dramatically over the next few decades. Korhonen et al. (2021) and Nepal et al. (2019) estimate that by 2070, between 379 to 475 Mha of planted forests may be required to satisfy worldwide needs for fiber, timber, and carbon sequestration, an increase of 31-64 percent over 2020 levels of 290 Mha (FAO 2020). Moreover, the Trillion Trees Initiative being promoted for climate change mitigation could require as much as one billion ha of land for tree planting, assuming an average planting rate of 1,000 trees per ha (Korhonen et al. 2021).

Identifying suitable planting sites around the world for such a vast area is complex and entails an assessment of many factors in multiple countries. Such variables include the biophysical conditions required for tree growth; investment returns; the governance and regulatory setting; land availability, cost, and tract size; pressure from competing land uses; property rights; transportation, wood industry, and energy infrastructure; and social and environmental impacts. This article explores many of these key attributes in the context of evaluating Colombia's potential for expanding its area of planted forests to meet future demand.

Located in the northern tip of South America, with over 114 Mha of land, Colombia is situated north of Ecuador and Brazil, south of Panama, and west of Venezuela (The United Nations Statistics Department 2014). The country has as many as 25.9 Mha considered suitable for commercial tree planting (La Unidad de Planificación de Desarrollo Rural Agropecuario [UPRA] 2023). Yet it only has about 542 thousand ha of plantations, consisting mainly of exotic eucalypts, pines, and acacias (MADR 2023). Factors contributing to the relatively small planted forest area include the country's highly diverse climatic conditions, the broken landscape and rugged topography of the Andean Mountain Region, a small domestic market, the uncertainty of wood supplies needed to support wood industries, a limited capacity for processing roundwood and manufacturing wood products, and cultural preferences, including a preference for non-wood products in construction and other domestic applications (Toro 2017; Office National des Forets–Andina 2018; MADR 2020). Production and investments in rural Colombia have also been constrained for decades due to violence associated with drug cartels, conflicts over land and

property rights, and armed struggles with guerilla groups (Segovia 2017; Ariza et al. 2022).[1] Because forestry investments require many years to mature, most investors will seek stable low-risk settings with good governance for their operations and avoid high-risk situations.

Of Colombia's five major geographic regions, three stand out as being particularly promising for forestry investments: the Andean, the Orinoco, and the Caribbean (refer to Table 1, Figures 1 and 2). Each has unique characteristics that favor commercial forestry as well as its own peculiarities and tradeoffs. Most planting has historically been carried out in the Andean Region, which has reasonably good access to transportation infrastructure and hosts the country's largest forest industries (MADR 2023). The nearest seaport, however, is about 450 km away from the main planting areas (Google Maps n.d.). Not surprisingly, level high-quality terrain for farming in this mountainous region can fetch high prices, though costs for forestry land run lower (Guadua Bamboo 2023; Castaño 2023).

The Orinoco Region has an abundance of large tracts of land at very low prices in the sprawling Llanos grasslands. The region has good growing conditions for trees and is the focus of much of the country's recent planting efforts. The Orinoco's remote setting and limited transportation infrastructure connecting it with the rest of the country, however, increase the costs of shipping raw materials to distant markets and mills, which can impact profits substantially.

[1] Although the effects of violence and land tenure insecurity on plantation forestry in Colombia have not been well studied, there is extensive literature on their impacts on agricultural production and investment in rural areas.

Table 1. Suitability of land for tree planting and area planted by regions.

Major geographic regions	Area planted 2022 (Ha)	Total area suitable for planting (Mha)	Percentage of suitable area already planted
Andean	220,206	8.61	2.56
Orinoco	183,341	8.17	2.24
Caribbean	81,122	4.63	1.75
Pacific	56,022	2.29	2.45
Amazon	1,207	2.23	0.05
Total	**541,898.00**	**25.93**	**9.06**

Sources: Suitability data from UPRA (2023). Planted area figures from MADR (2023).

Although the Caribbean Region is not as well established as the other two major regions for forestry, it has a combination of attributes that may make it highly advantageous for commercial-scale tree planting. On one hand, the region is mostly flat with few altitudinal changes; has favorable temperature and rainfall regimes; good access to roads, markets, and population centers; and is relatively close to major ports. On the other hand, prices for forestry land in general run higher in the Caribbean compared to the Andean and Orinoco Regions.

Figure 1. Major regions of non-insular Colombia. Adapted from Florida Institute of Human and Machine Cognition (n.d.).

While security in some areas of the country is more problematic than in others, overall conditions have improved following the 2016 peace agreement between the government and the Revolutionary Armed Forces of Colombia (FARC), and the country is considered to be a favorable location for foreign investment (US Department of State 2021). Investors interested in Colombia's plantation sector willing to take risks and able to manage its tradeoffs may be able to capitalize on the vast potential of the country for plantation forestry.

Figure 2. Departments of Colombia (Travel Guide of Colombia 2016).

MATERIALS AND METHODS

This article summarizes a review of over 90 sources concerning Colombia and its potential for industrial-scale tree farming. It focuses on the three main planting areas: the Andean and Orinoco Regions, which are strikingly different from each other, as well as the less established Caribbean Region, which also has high potential for plantation development.

Sources include information from journals; websites from government, industry, international institutions, and non-governmental organizations; grey literature; and personal communications from experts in the field. The authors made an effort to identify and utilize only the most recent and best available information. Screening and evaluating information constituted a major part of the work, with primary source documents favored over secondary references. Statistics found to be outside expected ranges were checked and verified, or discarded if they could not be supported with corroborating evidence. In general, more recent statistics were used instead of older ones.

The lead author is a former Senior Forestry Specialist for the World Bank with over 30 years of forestry experience in Latin America and Asia. The second coauthor is a Colombian forest economist and forester with decades of experience in his home country. The other coauthors, both foresters and forest economists, have extensive experience in academic and applied research in forest economics in Latin America and globally with educational institutions, government, international organizations, and private industry. Some of the insights are based on the principal author's and co-authors' on-the-ground experiences in forestry in Colombia, neighboring Ecuador and Venezuela, and other countries in Latin America.

RESULTS AND DISCUSSION

Plantation resources

Of the estimated 542 thousand ha of plantations in Colombia, the major species being planted are *Acacia mangium* (12.5 percent), *Pinus patula* (10.9 percent), *Pinus caribaea* (9.4 percent), *Eucalyptus grandis* (7.8 percent), *Tectona grandis* (7.4 percent), *Eucalyptus pellita* (6.9 percent), *Hevea brasiliensis* (6.8 percent), and *Pinus tecunumanii* (6.0 percent) (MADR 2023). *Eucalyptus*

urophylla, Eucalyptus tereticornis, Eucalyptus globulus, Pinus oocarpa, Pinus maximinoi, Pinus radiata, Pinus kesiiya, Pinus ayacahuite, Pinus caribeae, Pinus chiapensis, Pinus greggii, and *Pinus jaliscana*, among others, are known to be planted in lesser quantities, as is *Gmelina arborea* (MADR 2023; Bartholomäus et al. 1998; Traffic n.d.; Wright and Isaza 1997; SGS South Africa 2018). The Forest Stewardship Council (FSC 2023) reports that the country has 31 chain of custody certificates and 14 forest management certificates corresponding to 212,494 ha.

Growth rates for the species studied were overall fair-to-excellent, establishment costs moderate, and financial returns highly variable, though good-to-excellent returns were found in some situations. Statistics gathered show rotation lengths for major commercial species ranging from 6 to 18 years while mean annual increments (MAI) fluctuated from 7 to 40 cubic meters per ha per year (m3/ha/yr) depending mainly on location and species (Lopera 2020; FinAgro 2018; Castaño 2023; MADR 2006) (Table 2). Plantation establishment costs in Colombia were near the international cost averages calculated by Cubbage et al. (2022), varying from $1,273 to $2,200 depending on the species, region, and number of years of management included in the estimates (Castaño 2023; Braun and Held 2017; Lopera 2020) (Table 3)[2]. Investment returns showed financial rates of return (FRR) from a low of 0.23 percent for *P. patula* to a high of 14.23 percent for *P. tecunumanii* (Lopera 2020) (table 4).

[2] Cubbage et al. (2022) found that the average establishment cost was $1,534 per ha and the median cost was $1,355 per ha in 16 countries and 47 planted species/management regimes.

Table 2. Growth rates of major commercial tree species in Colombia.

Species	Growth (MAI) (m3/ha/yr)	Rotation (Years)	Location	Source
E. grandis	25 to 40	8	n.a.	FinAgro 2018
	35	7	Antioquia Province	Lopera 2020
E. pellita	15 to 20	12	n.a.	FinAgro 2018
	30 to 40	7	Vichada Province	Castaño 2023
E. tereticornis	20	8	n.a.	MADR 2006
	22 to 30	7	Caribbean Region	Castaño 2023
P. patula	18	12 to 18	Antioquia Province	Lopera 2020
	18 to 22	8	Antioquia Province	Castaño 2023
	20 to 26	8	Andean Region	Castaño 2023
P. tecunumanii	28	16	Antioquia Province	Lopera 2020
	30 to 34	6	Meta and Vichada Provinces	Castaño 2023
	35 to 38	6	Antioquia and Andean Region	Castaño 2023
P. maximinoi	28 to 30	14 to 16	Antioquia and Andean Region	Castaño 2023
E. urograndis	35 to 40	7	Andean and Caribbean Regions and Antioquia, Meta, and Vichada Provinces	Castaño 2023
A. mangium	26 to 30	12	n.a.	MADR 2006
E. globulus	15 to 35	15 to 35	n.a.	MADR 2006
G. arborea	20 to 25	10	n.a.	MADR 2006
Tectona grandis	7 to 10	7 to 10	n.a.	MADR 2006

Sources: Data from FinAgro (2018); Lopera (2020); Castaño (2023); MADR (2006).

Table 3. Plantation establishment costs (planting and early management).

Region/Department	Type	Cost (US$)	Years of management	Source
Andean	Softwood/Hardwood	$1,339	3	Castaño 2023
Caribbean	Hardwood	$1,273	3	Castaño 2023
Orinoco	Softwood/Hardwood	$1,390	3	Castaño 2023
Not specified	Eucalyptus	$1,420	5	Braun and Held 2017
Not specified	Pines	$2,200	5	Braun and Held 2017
Antioquia (Andean)	*Eucalyptus grandis*	$1,805	5	Lopera 2020
Antioquia (Andean)	*Pinus patula*	$1,557	5	Lopera 2020
Antioquia (Andean)	*Pinus patula*	$1,441	5	Lopera 2020
Antioquia (Andean)	*Pinus tecunumanii*	$1,813	5	Lopera 2020

Sources: Data from Castaño (2023); Braun and Held (2017); Lopera (2020).

Table 4. Investment returns for major commercial tree species in the Department of Antioquia (Andean Region).

Species	Growth (m3/ha/yr)	Rotation length (Years)	Establishment costs US $	FRR (Percent)	NPV (US $)	LEV (US$)
E. grandis	35	7	1,805	2.22	-594	-1426
P. patula	18	12	1,557	0.23	-976	-1619
P. patula	18	18	1,441	10.98	933	1244
P. tecunumanii	28	16	1,813	14.23	3362	3362

Sources: Data from Lopera (2020); Cubbage et al (2022). Note: Returns were calculated using an eight percent discount rate. Costs include site preparation, planting, and five years of management expenses. Negative NPVs are associated with plantations dedicated to fiber production. Financial results are positive when trees are grown for multiple wood products.

A systematic strategic-level evaluation of land suitability for commercial tree planting was conducted by Colombia's Ministry of Agriculture Rural Agricultural Planning Unit (UPRA) and is accessible on its Rural Agricultural Planning Information System website (Sistema de Planificación Rural Agropecuario or SIPRA). SIPRA uses multiple variables to assess suitability, including those for biophysical attributes, social and ecosystem concerns, and socioeconomic factors. In 2023, the results of our query of SIPRA showed a total of 25.93 Mha of land as appropriate for commercial tree planting, of which 7.51 Mha are classified as having high potential, 6.59 Mha with moderate potential, and 11.83 million with low potential (UPRA 2023)

(Table 5 and Figure 3). Even if only the sites with the highest potential are appropriate for tree planting, the potential planting area in Colombia is still enormous.

Table 5. Suitability classes for tree planting and area planted.

Regions	Area planted 2022 (Ha)	Total area suitable for tree planting (Mha)	High suitability for tree planting (Mha)	Moderate suitability for tree planting (Mha)	Low suitability for tree planting (Mha)
Andean	220,206	8.61	3.74	2.55	2.32
Orinoco	183,341	8.17	0.62	1.43	6.12
Caribbean	81,122	4.63	2.41	1.30	0.92
Pacific	56,022	2.29	0.71	0.85	0.73
Amazon	1,207	2.23	0.04	0.46	1.74
Total	**541,898**	**25.93**	**7.51**	**6.59**	**11.83**

Sources: Data from UPRA (2023); MADR (2023).

The Convention on Biodiversity (n.d.) identified 134 distinct ecosystems in Colombia, underscoring the wide range of conditions and locations potentially appropriate for tree planting throughout the country. This article, however, concentrates on the three main planting areas, as previously mentioned, with the highest potential for industrial tree plantations: the Andean and the Orinoco Regions, where planting programs are well underway, and the Caribbean Region, where large-scale tree planting is still in its early stages but seems to hold good promise.

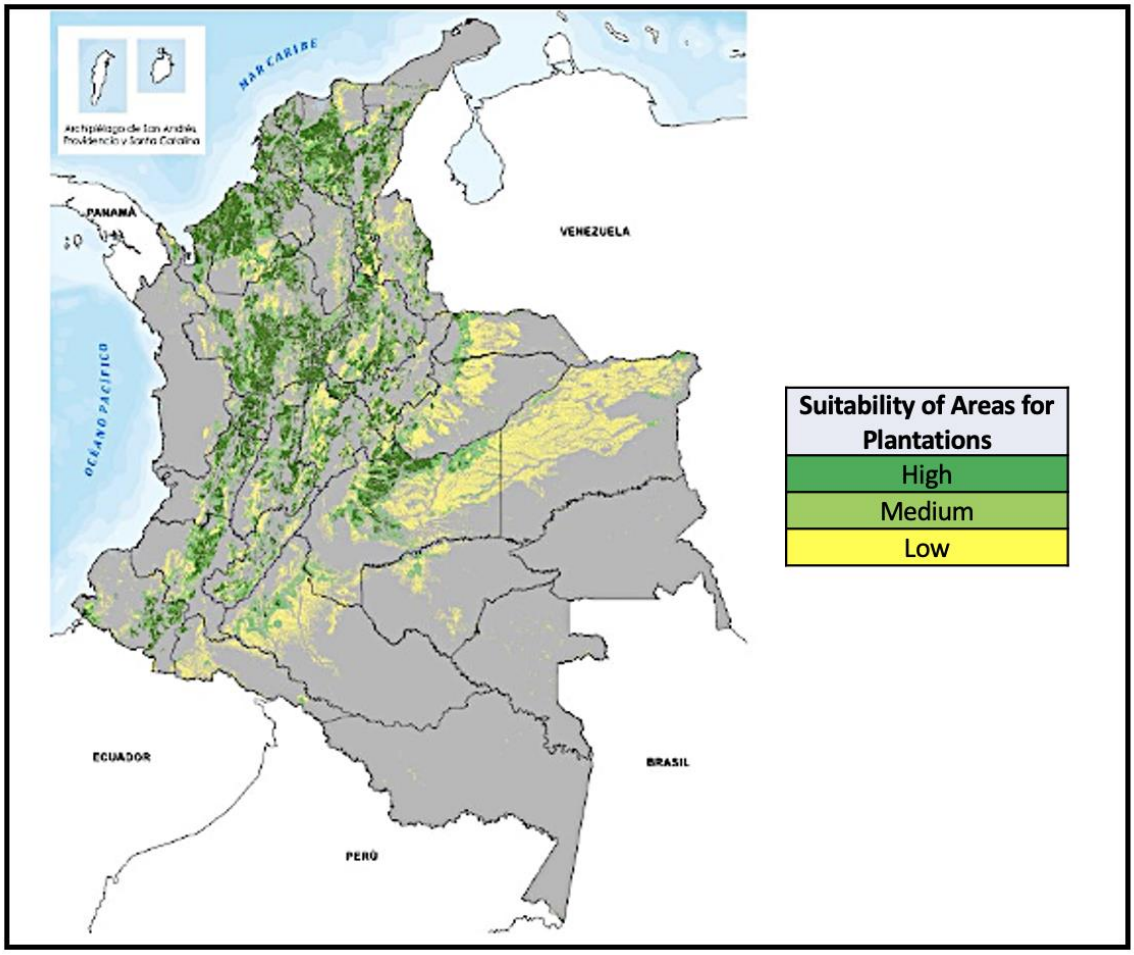

Figure 3. Areas suitable for commercial tree planting in Colombia. Adapted from MADR (2023).

Andean Region

In 2022, the Andean Region had approximately 220,206 ha of commercial plantations, or about 41 percent of the entire plantation area of the country, and 8.6 million ha of land suitable for plantations (MADR 2023; UPRA 2023). About 3.7 million ha in the region have high potential for tree plantations, 2.6 Mha have moderate potential, and 2.3 Mha have low potential (UPRA 2023) (Table 6). Within the region, the Department of Antioquia had 115,942 ha of plantations and is a bellwether for commercial forestry in the Colombian Andes (MADR 2023). The department's topography is highly diverse, rugged in some areas, and largely mountainous, although with still substantial areas of only moderately sloped or nearly level lands in the basins. Altitudes in the department vary from 1,756 m to over 2,450 m. Rainfall in Antioquia ranges from 750 to 2,800 mm annually and the province's annual average temperature ranges from 12º to 29º C (FinAgro 2020a). The predominant Köppen climate regime in the department is tropical rainforest, with

smaller areas of tropical monsoon, tropical savanna, and oceanic climate regions (Medina et al. 2021).

Table 6. Suitability for tree planting in the Andean Region by Departments.

Andean Region Departments	High suitability for tree planting (Ha)	Moderate suitability for tree planting (Ha)	Low suitability for tree planting (Ha)	Total area suitable for tree planting (Ha)
Antioquia	1,507,453	764,671	479,591	2,751,715
Boyacá	342,758	179,383	246,342	768,483
Caldas	176,777	83,591	44,338	304,706
Cundinamarca	315,357	325,001	372,120	1,012,478
Huila	138,838	240,694	218,664	598,196
Norte de Santander	140,926	199,346	374,297	714,569
Quindío	40,856	44,079	12,286	97,221
Risaralda	80,547	39,297	18,524	138,368
Santander	632,083	395,498	320,593	1,348,174
Tolima	364,605	281,358	231,489	877,452
TOTAL	**3,740,200**	**2,552,918**	**2,318,244**	**8,611,362**

Source: Data from UPRA (2023).

Examples of some of the largest plantation holdings in Antioquia and the wider Andean Region include Cipreses de Colombia S.A, Reforestadora Integral De Antioquia, and Smurfit Kappa Colombia. Cipreses de Colombia S.A (currently Núcleos de Madera) has 5,620 ha of *P. patula, P. tecunumanii,* and *C. lusitánica*; Reforestadora Integral De Antioquia has 9,511 of *A. mangium, Tectona grandis, G. arborea, P. patula, P. tecunumanii,* and *P. oocarpa* (Cipreses de Colombia S.A. 2017; Reforestadora Integral De Antioquia n.d.). Smurfit Kappa Colombia is the largest single owner of commercial plantations in the country with 41,722 ha of FSC-certified pine and eucalypts dispersed throughout six departments, half of which fall into the Andean Region including Antioquia and the other half in the Pacific Region (Smurfit Kappa 2022). Smurfit Kappa's softwood plantations include *P. patula, P. tecunumanii, P. oocarpa, P. kesiiya, P. maximinoi, P. ayacahuite, P. caribeae, P. chiapensis, P. greggii,* and *P. jaliscana.* Hardwoods planted by the firm are *E. grandis, E. urograndis, E. globulus, E. urophylla,* and *G. spp* (SGS South Africa 2018).

Orinoco Region

According to MADR (2023), the Orinoco Region had 183,341 ha of commercial plantations by the end of 2022, or 34 percent of the total area planted. The region comprises four relatively large departments covering an area of over 25 Mha with about 8.2 Mha (31 percent) suitable for commercial tree planting. Some 616 thousand ha in the Orinoco are considered to have high potential for plantations, 1.4 Mha have moderate potential, and another 6.1 Mha have low potential (UPRA 2023) (Table 7). These rankings, however, can be deceptive, as the overall biophysical conditions in the area are mostly favorable for tree planting and growth. The limiting factor for conventional forestry in the Orinoco is the long distances required to transport wood to markets, mills, and ports combined with an inadequate transportation infrastructure servicing the region (MADR 2023; Google Maps n.d.). Major capital investments from the government such as improved roads and railways would be needed to resolve the long-standing transportation issue. There may be workarounds, however, such as transporting products by river, including through Venezuela, or milling wood directly in the region to manufacture higher-value products which could offset the high transportation costs.

Table 7. Suitability for tree planting in the Orinoco Region by Departments.

Orinoco Region Departments	High suitability for tree planting (Ha)	Moderate suitability for tree planting (Ha)	Low suitability for tree planting (Ha)	Total area suitable for tree planting (Ha)
Arauca	20,880	157,756	433,056	611,692
Casanare	61,424	195,484	908,008	1,164,916
Meta	533,128	958,222	1,920,899	3,412,249
Vichada	422	120,020	2,857,485	2,977,927
Total	**615,854**	**1,431,482**	**6,119,448**	**8,166,784**

Source: Data from UPRA (2023).

The landlocked Department of Vichada is currently the most important in the Orinoco Region for commercial forestry, though Meta Department runs a close second, is more centrally located, has more highly suitable areas for planting, and thus may have better long-term potential. Located in the sprawling and sparsely populated low-altitude grasslands, or Llanos, Vichada borders

Venezuela to its east. The undulating 570,000 km^2 (57 Mha) Llanos grasslands are flanked by the Andes to the north and west, the Guaviare and Amazon Rivers to the south, and the Orinoco River and Guiana Highlands to the east (Britannica 2023). UPRA (2023) estimates that Vichada has 422 ha of land with highly favorable conditions for commercial forestry, 120 thousand ha with moderate potential, and a staggering 2.86 Mha with low potential. The small area of 422 ha classified as having high potential is largely a result of the department's remote setting and limited transportation infrastructure connecting it with the rest of the country – not its biophysical potential for tree growth (De la Torre 2023). While the potential planting area in the Llanos is substantial, it is still only a small fraction of the grasslands overall 57 Mha, part of which extends into Venezuela. Large areas of tree crops, therefore, could be planted without competing with current land uses or negatively impacting sensitive environmental or cultural areas[3].

The Llanos is divided into the high and low plains (Alto Llanos or "altillanura" and the Llanos Bajos). Altitudes in general do not exceed 300 meters, with sweeping plateaus at altitudes of 30 to 60 meters common (Britannica 2023). The average annual precipitation varies from 2,300 mm to 2,500 mm per year and the mean daily temperature is between 26.5º and 28.9º C in Meta and Vichada Provinces, the two main planting areas in the Colombian Llanos (FinAgro 2020b). Vichada Department has two Köppen Climate Regions, tropical monsoon and tropical savanna (Medina et al. 2021). While the Llanos in general has favorable climates for tree planting and growth, soil conditions are reportedly poor in many areas and may require extensive mechanical and chemical preparation prior to planting (MADR 2015). The largest forestry firm in Vichada Department, Forest First S.A.S., holds 15,178 ha of *A. mangium* and *E. pellita* and plans to plant 150,000 ha by the end of the decade (Preferred by Nature 2021; Forest First S.A.S. 2020). Also located in Vichada, Inverbosques (2020) has 6,515 ha of *A. mangium*; Reforestadora La Paz (2022) has 6,049 ha of *A. mangium, P. caribeae,* and *E pellita*; and Aldea Forestal has 3,286 ha of A. *mangium, P. caribaea,* and *E pellita* (Calderón 2021).

[3] Colombia has 1,552 protected areas in seven different categories. Over 19 Mha of these are terrestrial protected areas, equivalent to 16.72 percent of the land area of Colombia. (Registro Único Nacional de Áreas Protegidas 2023). Investors and operators need to take into account the proximity of plantations to protected areas to avoid disturbing natural areas and carry out rigorous environmental and social impact assessments and implement mitigation programs to avoid harm to natural ecosystems and the surrounding populations.

Caribbean Region

Located at the northern extreme of the country, the Caribbean Region has about 15 percent (81 thousand ha) of Colombia's commercial plantations and covers about 142,000 km^2 of land (MADR 2023). Its proximity to the coast provides close access to major ports. Overall, the region is characterized by flat lowlands and a tropical monsoon climate, resulting in favorable conditions for both tree planting and growth (Medina et al. 2021; Aldana-Domínguez et al. 2017). Despite being almost uniformly flat with only minor fluctuations in elevation, the region supports a range of ecosystems, from dry forests in the La Guajira Department to rainforests in the Gulf of Urabá Region (The Colombian Information Site 2015). UPRA (2023) estimates there are about 4.63 Mha suitable for tree planting with about 2.40 Mha having high potential, 1.30 Mha with moderate potential, and 924 thousand ha with low potential (Table 8). The main commercial species being planted in the Caribbean Region include *T. grandis, G. arborea, E. tereticornis, E. urophylla, E. camaldulensis, B. quinate,* and *A. mangium* (ProColombia n.d.).

Table 8. Suitability for tree planting in the Caribbean Region by Departments.

Caribbean Region Departments	High suitability for tree planting (Ha)	Moderate suitability for tree planting (Ha)	Low suitability for tree planting (Ha)	Total area suitable for tree planting (Ha)
Córdoba	730,284	360,226	215,304	1,305,814
Magdalena	565,594	365,728	188,062	1,119,384
Cesár	522,371	238,787	245,461	1,006,619
Bolivar	238,418	186,181	178,454	603,053
Sucre	210,299	78,874	43,414	332,587
Guajira	66,708	45,776	52,166	164,650
Atlántico	74,367	23,916	1,330	99,613
San Andres	0	0	0	0
Providencia	0	0	0	0
Total	**2,408,041**	**1,299,488**	**924,191**	**4,631,720**

Source: Data are from UPRA (2023).

Wood industries

According to MADR (2020), Colombia has one of the lowest levels of domestic wood use in Latin America and, consequently, limited forest industries. There are a mere 273 wood processing

facilities in the country, located mainly in the Andean Region. These employ most of the 22,835 people working in wood products, pulp, and paper manufacturing (MADR 2022) (Figure 4). Some 65 percent of Colombia's industrial wood supply comes from planted forests, about 61 percent of which is used for solid wood products, and 39 percent goes to the production of pulp. Virtually all of the pulp produced in Colombia comes from plantation-grown fiber. Wood from the country's native forests is primarily used for cooking, heating, fence posts, and construction in rural areas (MADR 2023). While estimates vary, the most realistic approximation of the forest sector's contribution to Colombia's GDP seems to be a low 0.69 percent (Sociedad de Agricultores de Colombia 2022).

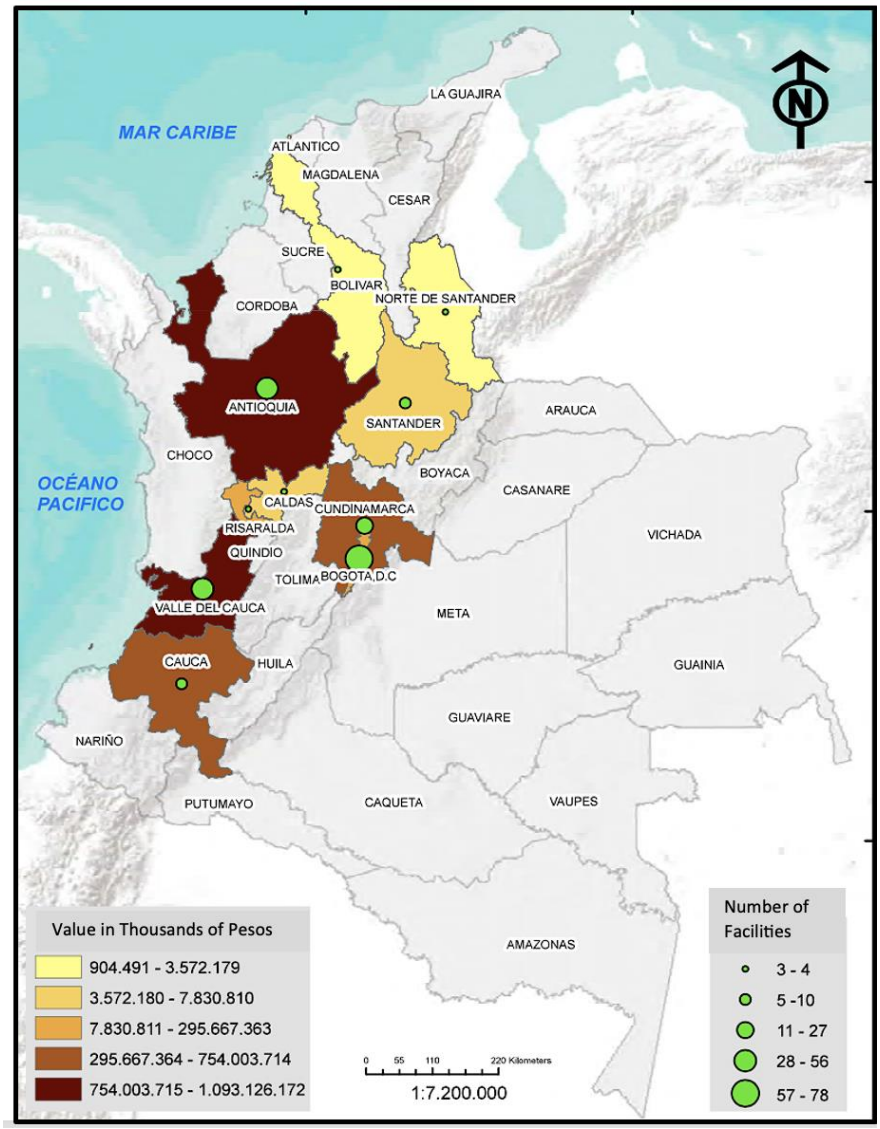

Figure 4. Location of wood processing facilities (MADR 2022).

Despite its potential to produce high volumes of wood and fiber, the country has a significant trade deficit for pulp, paper, and solid wood products. In 2022, Colombia exported US $53.5 million in wood and wood products while importing US $383.3 million (MADR 2023). Previously, in 2020, the country exported US $3 million in pulp and US $243 million in paper products, while importing US $130 million in pulp and US $508 million in paper products. About half of the pulp and paper imports to Colombia originated in the United States, and the other half from Brazil and Chile according to the International Tropical Timber Technical Association (ATIBT 2023). The main importers of Colombian pulp and paper were Mexico, Ecuador, Peru, Brazil, and Costa Rica (Observatory of Economic Complexity 2020).

Carbon sequestration

The prospect of planting trees exclusively or partially for carbon sequestration might someday be an attractive investment option in Colombia. Verra (2023), the largest voluntary carbon standard, reports there are already nine afforestation, reforestation, and revegetation projects, usually referred to as ARR projects, registered for the country, covering 171,630 ha. They are expected to sequester 360,782 tons of CO_2e, excluding buffer amounts. Some carbon standards allow the combining of carbon sequestration with wood and fiber production and harvesting for generating carbon credits, which could help dovetail industrial needs with climate change mitigation within the same plantation (Verra 2022).

According to Forest Trend's Ecosystem Marketplace (2022), the average price for one ton of CO_2e sequestered from forestry and land use projects was about US $5.80, although the prices dropped significantly in 2023 to less than half this amount (CarbonCredits.com 2023; World Bank 2023). While the historical price of carbon for forestry projects in the Voluntary Carbon Market is not high enough in itself to incentivize and sustain large-scale tree planting, international efforts are underway to promote higher prices and stabilize carbon markets (Bloomberg 2022). The World Bank (2023) suggests a target price range of US $61 to $122 per ton of CO_2e is needed to provide sufficient incentives for investors and project developers, which is consistent with an analysis made by Shell plc (2021). Higher market prices for carbon sequestered through plantation forestry are critical due to significant upfront investments needed for 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 registered and traded.

Land

Colombia has a total land area of 114 Mha (The United Nations Statistics Department 2014). Land ownership in the rural areas of the country is considered to be the most unequal in Latin America and the Caribbean, with 78 percent of the agricultural land owned by only one percent of the population (Departamento Administrativo Nacional de Estadística 2014; OXFAM 2017; Departamento Administrativo Nacional de Estadística 2022). Some 22 percent of rural lands are state-owned, 52 percent are privately owned, 3 percent are held by Afro-Colombian communities, and 23 percent are held by indigenous communities (USAID 2017). About 38 Mha of rural lands fall under some form of collective ownership (Arango 2018). An estimated 51 percent of all tree plantations are owned by small landholders in areas of less than 100 ha (Braun and Held 2017). This finding is illustrated in Figure 5 showing the detailed distribution of tree plantations by tract size from over 500 hundred participants in the government's forest subsidy program, the Certificado de Incentivo Forestal (CIF) or Forestry Investment Certificate (FinAgro 2016).

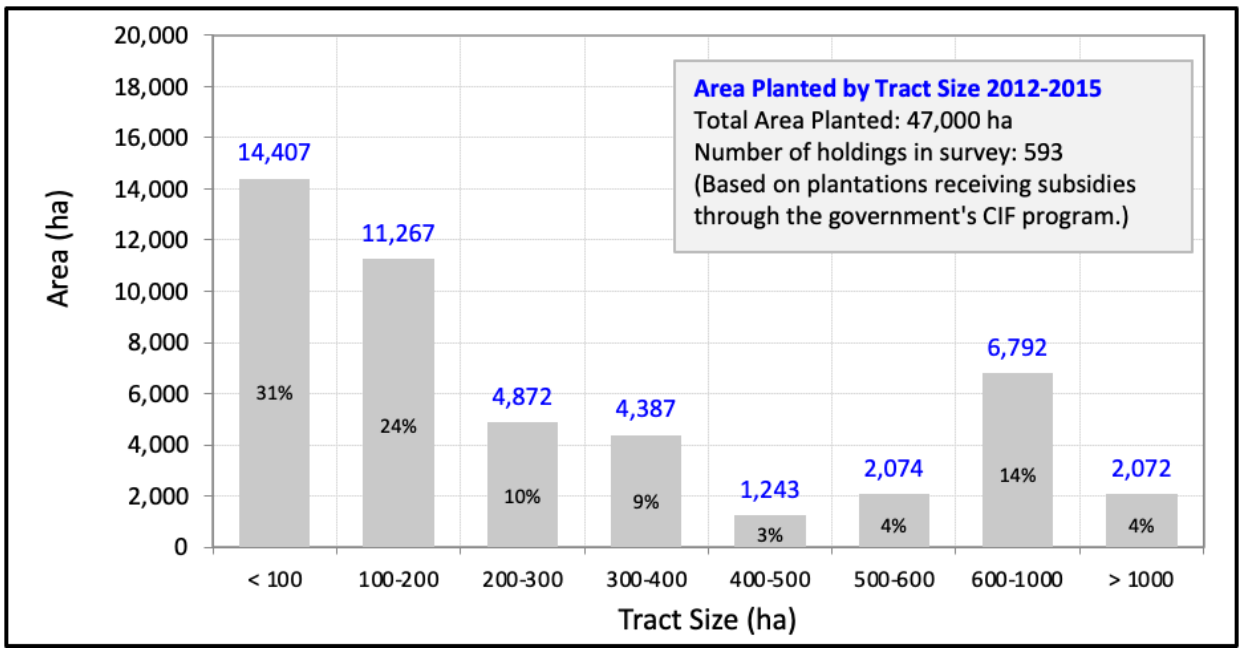

Figure 5. Area planted by tract size from 2012 to 2015 (FinAgro 2016).

Rural land prices vary considerably according to the location and quality for agricultural purposes, the possession of a legal title, the presence and condition of buildings and infrastructure, the inclusion of livestock, access to roads, distances to markets, and the particular motivation of sellers, among others. Because forest land has less stringent requirements for soil quality and slope

gradients compared to most agricultural lands, it is difficult to determine the suitability of land advertised without rigorous on-site inspections, which were not a part of this study.

Prices for the highest-quality agricultural holdings with a clean title and good access to roads and markets can be expensive in Colombia (Guadua Bamboo 2023). The average price for agricultural (non-forest) land in Antioquia (Andean Region), for example, was found to be about US $7,642 per ha with the highest price US $14,939 per ha (Puntopropiedad 2023; Mitula 2023). Carlos Castaño (2023), manager of the forestry firm Silvotecnia, reports, however, that prices of land suitable for forestry and tree planting in Antioquia run closer to US $2,350 per ha and US $ 1,900 per ha for other departments in the Andean Region. Clearly, costs for the best quality land in the Andean Region are high, but less expensive land where commercial tree crops can be cultivated may be available at lower prices. Castaño (2023) provides a benchmark price of US $3,700 her ha for land suitable for tree planting in the Caribbean Region. For the Orinoco, Castano's reference price for forestry land is US $470 per ha (Castaño 2023). Large tracts of land (in excess of 30,000 ha) are still available in the Orinoco at very reasonable prices (Mitula 2023)[4].

Land tenure security varies depending on the profile of the owner or landholder. Small farmers, indigenous people, Afro-Colombians, and women are particularly vulnerable and may be susceptible to intimidation, coercion, and forced removal from their lands. Rates of formal land titling are low for these groups, as well, with only 48 percent of 3.7 million rural parcels overall having registered titles and 1.7 million rural holdings having no formal records of ownership (USAID 2017). Foreign investors may want to consider teaming up with a reliable and knowledgeable Colombian firm for land purchases given the many complexities and risks involved.

Risks to investors

Risks to investors in Colombia's plantation forest sector are considered moderately high to high. The interest rate for loans in Colombia as of November 2023 was 11.4 percent, which is a reflection of a moderately risky investment climate. In comparison, the interest rate in the US was 4.8

[4] A review of 15 properties was made on the internet from which five were selected in Vichada on the basis of their size and suitability for tree planting. The five holdings ranged in size from 2,000 to 34,294 ha. The lowest-priced holding in Vichada had an asking price of US $391 equivalent per ha, while the largest and highest-priced holding was advertised at US $1,042 equivalent per ha and included substantial infrastructure and 600 head of cattle (Puntopropiedad 2023; Mitula 2023).

percent, in Chile 6.7 percent, and in Brazil 11.7 percent (The Economist 2023). Sewall, in its 2022 Annual Investor Survey, reports that the discount rate applicable for investments in hardwood plantations in Colombia is 500 basis points above the US timberland base rate of 4.87 percent, categorizing them as "higher risk" (Vicary 2023).

The World Bank (2021) ranked Colombia 67 out of 190 in terms of ease of doing business and reports an average of 1,280 days for establishing contracts. Standard and Poor's rated the country as investment grade at BBB- in 2023 (CBonds 2023). Transparency International (2022) gives Colombia a low score of 39 out of 100 and ranks the country as 92nd out of 180 countries in terms of corruption[5,6]. The government has no controls on remittances of profits or capital by foreign investors and no restrictions on foreign investments in the forest sector.

The US Department of State (2023) considers travel to Colombia in general a level 3 ("reconsider travel" advisory) due to crime, terrorism, civil unrest, and kidnapping. There are also level 4 advisories ("do not travel" warnings) for the Departments of Arauca, Cauca, and Norte de Santander and for all areas along the Venezuelan border, which are reported to be poorly demarcated leading to inadvertent trespassing. Even accidental entry into Venezuela is illegal and non-citizens may be subject to imprisonment. The US Department of State (2023) further advises that the National Liberation Army, FARC, and Segunda Marquetalia terrorist groups are still launching attacks in the country. Overall conditions for security have, nevertheless, improved following the 2016 peace agreement between the government and the FARC, and the country is considered a favorable location for foreign investment by the US Government (US Department of State 2021).

With only about one percent of Colombia's commercial plantations affected, forest pests have not been a major problem so far (FAO 2007). Infestations are reportedly rising, however, and could pose more significant problems as plantations expand across the country. As the distance between planted areas decreases, the likelihood of transmitting pests and pathogens will likely increase. Carlos Rodas (2023), one of the foremost experts on forest pests in Colombia, contends that the

[5] For comparative purposes, the World Bank ranks the United States of America as sixth in ease of doing business (World Bank 2021).
[6] A score of 0 indicates high corruption, whereas a score of 100 is the lowest level of corruption. (Transparency International 2022).

future of plantation forestry in the country will hinge on implementing a comprehensive pest management program to accompany the growth of the sector.

Numerous insects and fungi are known to attack exotic species of pine, ciprés (*Cupressus*), and eucalypts in Colombia. The most prevalent plantation pests are indigenous and include defoliating moth caterpillars (Geometridae), leaf-cutting ants (Formicidae), and stem-infesting "stick" insects (Phasmatodea) (Madrigal 1993; Pinzón-Florian 2020; Rodas 2023). In addition, Rodas (2023) reports a rise in exotic insect pests including certain species of *Gonipterus, Pineus, Ophelimus,* and *Glysaspis.* According to Rodas (1998) there are 30 species of defoliating insects in the Andean Region that affect trees. The genera *Atta* and *Acromyrmex* (leafcutter ants) are the most common in Colombia (Forest First S.A.S. 2020; Pinzón-Florian 2020). Infestations by the genus *Atta* frequently appear in plantations below altitudes of 2000 m (Pinzón-Florian 2020). Leafcutter ants frequently attack newly planted seedlings, particularly eucalypts, for which control is required (FAO 2007; Forest First S.A.S. 2020).

Pathogenic fungi may attack the trunks, stems, leaves or needles, and shoots of commercially important pines and eucalypts in Colombia. One of the most widespread fungal pests in Colombia's plantations is *Dothistroma septosporum* (Rodas 2023; Pinzón-Florian 2020). *D. septosporum* is a needle blight, mainly affecting young and mature plantations of *Pinus tecunumanii* (provenance LE), *P. kesiya*, and *P. oocarpa* in Western Colombia, while *P. maximinoi* has demonstrated good resistance (Rodas et al. 2015; Pinzón-Florian 2020). Severe infestations can be fatal, but less serious infections can still affect growth and yield (Pinzón-Florian 2020). Rodas (2023) reports that *Lecanosticta pharomachri*, another needle blight, may be an emerging problem in Colombia. The fungus *Chrysoporthe cubensis* is widespread in the country and infects commercial plantations of *Eucalyptus spp*. The fungus causes cankers which can damage limbs and trunks and eventually result in tree mortality. Surviving trees may be stunted or have poor form (FAO 2007). *C. cubensis* is also known to cause fatal infections in eucalypts, particularly in young plantations (Wingfield et al. 2001). Other pathogenic fungi found in Colombia include *Phialophora spp*., *Pestalotia spp*., and *Dothirella spp*. (FAO 2007).

Forest fires are pervasive in Colombia's natural forests despite the tropical setting. In 2020, for example, there were 21,500 forest fires recorded, and from 2001 to 2021 an estimated 331,000 ha of natural forest were affected by fires, an average of 16,550 ha of forest burned annually (Global

Forest Watch 2023). Fires are used by farmers to clear standing forests and burn windrowed trees, which may escape control and transform into wildfires. Farmers also burn cropland during the dry season to remove agricultural residue and set fires to encourage the green-up of pastures and rangelands. The extent to which commercial plantations are being affected by fires is not well documented, but the risk of fires is considered high, especially in the sweeping grasslands of the Llanos. Paradoxically, while the risk of wildfires is high, actual losses due to fires in forest plantations are reported to be low to modest (De la Torre 2023). Investors and plantation owners should, nevertheless, include adequate wildfire detection and suppression measures in their budgets and plantation management (including fire breaks) to avoid catastrophic losses.

While there is no comprehensive data on the theft of trees from Colombia's plantations, according to the Federación Nacional de Industriales de la Madera (FEDEMADERAS 2023a), tree theft in native forests is a major problem. The lack of clear property boundaries and ownership rights compounds the difficulty in controlling theft in natural forests, which could also extend to plantations. As the plantation area in the country continues to expand and deforestation reduces the native forest cover in close proximity to population centers, the likelihood of theft will probably increase for the country's plantations. Even today, common practice is to first attend to security by establishing a guard post and hiring full-time guards before planting trees.

Institutional setting

The Ministry of Agriculture and Rural Development (MADR), the Ministry of Environment and Sustainable Development (MADS), and the Regional Autonomous Corporation for Sustainable Development (CAR) are the principal government institutions regulating the forestry sector. Within MADR, the key units are the Committee on Forestry Policy, the National Chamber of Forestry Value Chains, and the Coordination Unit for National Reforestation. Within MADS, the main units affiliated with forestry are The National Environmental Council, the Intersectoral Commission on Climate Change, The Intersectoral Commission on Controlling Deforestation and Forest Protection, the National Forestry Roundtable, and the Regional Forestry Roundtables (Merle et al. 2018; ATIBT 2023). CARs are regional development entities that aim to provide integrated oversight of MADS laws and policies in specific natural regions, such as watersheds or ecosystems (Schneider 2021). FEDEMADERAS is a nonprofit consortium of Colombian forestry,

wood, and furniture companies that brings together a wide range of suppliers of goods and services in the value chain (FEDEMADERAS 2023b).

Policy and regulatory setting

The principal regulatory guidance for the forest sector is covered by Forest Law No. 1310 (2010), Decree 2811 (1974), General Environmental Law No. 99, and Decree 1791 (1996). The 2010 forest law, which replaces the antiquated forest law from 1959, allows plantations that were originally planted for protection to be used for production. Decree 2811 sets out the National Code for Renewable Natural Resources, and General Environmental Law 99 provides the legal framework for a national environmental system. Decree 1791 specifies harvesting regimes for forests (ATIBT 2023).

Colombia's forest policy is presented in the following documents: the Forest Policy (1996); National Forestry Development Plan (2006); National Strategy for Prevention, Pursuit, Control and Oversight (2010); Action Plan for Commercial Reforestation (2011); Agreement for Competition in the Forest Products Value Chain for Wood, Lumber, and Furniture (2011); Management Policy on Biodiversity and Ecosystem Services (2012); Intersectoral Agreement for Legal Wood in Colombia (2015-2018); National Policy to Combat Deforestation (Law 1753, 2015); Integrated Strategy for Controlling Deforestation and Forest Management (MADS); and Policy Guidelines for Commercial Forestry Plantations for Wood Supply and Its Value Chain (2016-2038) (Merle et al. 2018).

The economic reforms of the 1990s allowed for the treatment of foreign investors as nationals and lifted controls on remittances of profits and capital. There are no restrictions noted for investments in forestry or agriculture for foreign firms and investors (US Department of State 2021). The government's forest subsidy program, CIF, pays 50 percent of the costs of planting and five years of management up to a ceiling amount for major commercial species (MADR 2013). Colombia's Guía de Exportación e Importación de Productos Maderables is a user friendly guide that lays out the process for exporting and importing wood products (MADS 2016). Another useful resource is the Legal Guide to do Business in Colombia, which contains specific information on commercial issues in the forest sector, including taxation (Herrera 2021).

Transportation infrastructure

Colombia's major ocean ports in the Caribbean are in Barranquilla, Cartagena de Indias, and Santa Marta. The largest ports in the Pacific are in Tumaco and Buenaventura (iContainers n.d.). Table 9 shows the distances to these ports from the main planting areas of Antioquia, Vichada, and Cordoba Departments. Distances from Vichada (Orinoco Region) and Antioquia (Andean Region) are extremely long, with steep and winding roads through the Andes and its foothills, slowing transport and increasing costs for forest products. Distances from the major planting areas in central Cordoba (Caribbean Region) to ports in the Caribbean are considerably shorter than those from the Andean and Orinoco Regions, lowering costs.

Table 9. Apx. distance to ports by road (km) from representative planting areas.

Dept./Region	Port of Baranquilla	Port of Cartegena de Indias	Port of Santa Marta	Port of Tumaco	Port of Buenaventura
Antioquia / Andean	871	755	827	1061	456
Vichada / Orinoco	1685	1728	1641	1768	1162
Cordoba / Caribbean	355	250	441	1461	855

Source: Data generated with Google Maps (n.d.)

As illustrated in table 9, distances by land to ocean ports from the Department of Vichada are as much as four times as far as those for Cordoba, which dramatically increases the transport costs of wood products aimed for overseas markets. To circumvent this problem, Forest First S.A.S. (2020), a major firm carrying out commercial tree planting in Vichada, proposes using bauxite barges to transport wood chips 184 km down the Meta River to its confluence with the Orinoco River and then another 756 km downstream to the Caribbean ports in Venezuela. The efficacy of this route at the moment, however, is unclear considering the current political and socioeconomic issues in Venezuela.

CONCLUSIONS

Covering over 114 Mha, Colombia is the fourth largest country in South America and may have as much as 25.9 Mha of land appropriate for commercial tree planting (The United Nations Statistics Department 2014; UPRA 2023). Some 7.5 Mha of this prospective planting area are

considered highly suitable for industrial tree plantations, 6.6 Mha have moderate suitability, and 11.8 Mha have low suitability (UPRA 2023). Despite this potential, the country has only 542 thousand ha of plantations, which is much less than plantation holdings in several other South American countries, including Chile with 2.39 Mha, Uruguay with 1.10 Mha, and Brazil with 9.93 Mha (Instituto Forestal 2023; MADR 2023; Ministerio de Ganaderia, Agricultura y Pesca 2022; Brazilian Tree Industry 2022).

The three regions with the highest potential for large-scale tree farming in Colombia – the Andean, Orinoco, and Caribbean – have many of the building blocks needed to advance plantation forestry, though they also have distinct disadvantages (Table 10). The Andean Region with 8.6 Mha of land suitable for forest plantations (43 percent with high potential) stands out as the current leader in commercial forestry (UPRA 2023). The region hosts the largest area of industrial tree plantations in the country (220,206 ha), benefits from fair-to-excellent growing conditions, and lies in close proximity to major mills and markets (MADR 2023). Its main tradeoffs are long distances to seaports, moderate land prices (US $1,900 to $2,350 per ha), competition from other land uses for high-quality sites, and limited contiguous areas of level land available for tree planting (Castaño 2023; Google Maps n.d.).

Table 10. Regional comparison of plantation forestry potential.

Region	Area suitable for plantation forestry (Mha)	Area highly suitable for plantation forestry (Mha)	Benchmark land prices for forest land (US $)	Apx. distance from major planting area to closest port	Benchmark establishment costs (US $)
Andean	8.61	3.74	$1,900 - $2,350	456 km (Antioquia to Buenaventura)	$1,339 (Hardwoods/Softwoods)
Caribbean	4.63	2.41	$3,700	250 km (Cordoba to Cartagena de Indias)	$1,373 (Hardwoods)
Orinoco	8.17	0.62	$470	1162 km (Vichada to Buenaventura)	$1,390 (Hardwoods/Softwoods)

Source: Data are from Castaño (2023); Google Maps (n.d.); UPRA (2023). Note: Establishment costs include site preparation, planting, and three years of management.

The second most important region for commercial forestry, the Orinoco, has 8.17 Mha of land potentially suitable for tree planting, the second largest area of tree plantations (183,341 ha), and large tracts of land suitable for forestry for sale at very low prices, about US $470 per ha (Castaño

2023; MADR 2023; UPRA 2023). Despite favorable biophysical conditions for cultivating trees, the Orinoco is remote, and the road network servicing this vast region and linking it to the rest of the country is deficient. Because the Orinoco lies many hundreds of kilometers from most major mills, markets, and seaports, transporting wood products can be costly. Consequently, only a small fraction of the area considered suitable for planting (7.5 percent) is considered to have high viability for tree farming (UPRA 2023). One alternative means of transport may be by river through Venezuela to the Caribbean, though this option needs to be evaluated carefully in the context of the long-standing political insecurity and transport risks. Investors may also consider producing higher-value wood products on-site to offset transport costs. Prospects for the region for sequestering carbon and mitigating climate change through plantation forestry could someday be an attractive investment option as well, providing the price of carbon for nature-based solutions rises to about US $61 to $122 per ton of CO_2e (World Bank 2023).

While the Caribbean Region presently ranks third in overall planting with only 81,122 ha, it may have the greatest long-term commercial potential compared to the Andean and Orinoco Regions (MADR 2023). Although the benchmark price of land at US $3,700 is significantly higher than that of other regions, the topography of the Caribbean Region is relatively flat with few altitudinal changes, and its climate and soils are good-to-excellent for tree cultivation (Castaño 2023). To test the waters before making large land purchases, investors may initially want to rent land for planting, employ out-grower schemes, or pilot small-scale investments. The Caribbean's main planting areas are relatively near mills, markets, and population centers and significantly closer to seaports than those of the Andean and Orinoco Regions. As a result, an estimated 52 percent of the Caribbean's potential areas for plantation forestry are considered highly suitable and another 28 percent have moderate potential – the highest of any region (UPRA 2023).

At the country level, the reasons for Colombia's lack of investments in industrial plantation forestry include cultural preferences for using non-wood products for construction and other domestic uses, limited capacity for processing roundwood, unpredictable wood supplies needed to support mills (which also discourages the construction of new ones), and overall small domestic wood market (Toro 2017; Office National des Forets–Andina 2018; MADR 2020; MADR 2022). In rural areas, conflicts with guerilla groups and drug cartels have likely dampened the enthusiasm of investors even with the recent improvements in the overall security situation (Segovia 2017;

Ariza et al. 2022; US Department of State 2021; US Department of State 2023). Furthermore, only 48 percent of rural holdings have a formal land title, with some 1.7 million rural parcels having no formal records of ownership at all (USAID 2017). The lack of clarity on ownership and property rights complicates buying and selling land and adds risks to transactions, thereby hindering investment opportunities in rural areas. Pests, timber theft, and especially wildfires, though posing potential threats to Colombia's plantations, can generally be controlled through good planning, prevention, and management (FAO 2007; Rodas 2023; FEDEMADERAS 2023; Global Forest Watch 2023; De la Torre 2023).

In summary, despite these drawbacks, Colombia has many of the elements needed to support more plantation forestry: nearly 26 Mha suitable for tree cultivation, low-to-moderate land prices with large tracts for sale (depending on the region), fair-to-excellent growing conditions for commercially important tree species, decades of experience with small- to medium-scale forestry enterprises, extensive species trials, good professional expertise, and access to seaports on the Pacific and Caribbean coasts (UPRA 2023; MADR 2023, Lopera 2020; FinAgro 2018; Castaño 2023; MADR 2006; iContainers n.d.; Mitula 2023). With available land for tree planting at a premium globally, including for climate-change mitigation, Colombia's plantation forestry sector appears to have unique strengths and high potential, provided it can mitigate the barriers to its growth.

CONFLICTS OF INTEREST

The authors confirm there are no conflicts of interest.

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