Czech University of Life Sciences Prague

Faculty of Forestry and Wood Sciences

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GROWTH AND SILVICULTURE OF COMMERCIAL TREE SPECIES ON SELECTED PLANTATIONS IN COLOMBIA

Diploma Thesis

In Forestry, Water and Landscape Management

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Supervised by:

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Statutory declaration

I hereby certify that I have elaborated my thesis independently, only with the expert guidance of my thesis director Prof. Ing. Vilém Podrázský CSc. and thesis tutor from Bucaramanga - Colombia Ing. Cesar Rogelio Anaya Herrera.

I further declare that all data and information I have used in my thesis are stated in the references.

In Prague …….. ……...

Signature: Omaira Silena Gil Vides

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Abstract

Colombia is a country with high forestry potential for development of its 114 million hectares, there is an identified potential of 17 million of which are only being used in commercial forest plantations to date the equivalent 1.504% (255,759 ha.) estimates for the "ZIF" to February 2010. Of the 17 million hectares suitable for forestry, 5.1 million hectares are lands without restrictions, there are soils that do not require any adjustment to the respective plantations and development of forestry projects also have been identified in regions safety, which makes them much safer projects and a little distant or shielded by state security of internal armed conflict in the country.

Aim of the diploma thesis is the evaluation of two foreign species for the Colombian environment, *Pinus patula* and *Cupressus lusitanica*, but has shown excellent results in high yields with rotation period between 12 and 16 years. Research was established and conducted in the department of Santander, municipality of Matanza, in the trial Alto Bravo, on the farm "Nuevo Campo".

The methodology followed was to establish plots within plantations, to make two measurements in a period of six months, the first in September of 2012 and the second in March 2013, Measurements were taken overall height, diameter at breast height and population. Results of the research showed that the increases in the time period of six months are in line with the national average in the species *Pinus patula*, and that the species *Cupressus lusitanica*, was established in conditions not conducive to optimal development.

It was concluded that the region has potential, have resources and technical assistance for the establishment of forest plantations, but the community has great fear for the establishment of monocultures.

Keywords: development, potential, plantations, species, rotation periods, measurements, foreign species.

INDEX

1. INTRODUCTION

Colombia is one of the 12 (twelve) countries of South America and is the fourth largest, besides being the only one who has a privileged position between two seas, the Pacific Ocean and Caribbean Sea covering a large region of their coastal areas, also has a system of mountains with is foothill and the last part of the Andes mountains, this gives a variety of climates and altitudes; Is a tropical country located in the area of Ecuador meridian, has a great representation of taxa, flora and fauna typical of the area in addition to the varieties of wildlife migrations from different parts of the world for the variety of ecosystems. Therefore Colombia has rain forest, herbaceous shrub Amazon hills, savannah plains, deserts and xeric shrublands, alluvial forests, tropical rain forests, mangrove forests, swamp forests and vegetation, the savannas of the Caribbean, Andean forests and tropical dry or humid forests. With this variety Colombia ranks as one of 19 mega-diverse countries, has 44.25% of South Americans Paramus so, one of the countries with the highest wet areas with high flow of rivers across the country worldwide.

Reforestation in Colombia has had several cycles, which have gone from an early stage in the 50's, which was reforested for protective purposes, conservation and ornamental, which allowed initial approaches to industrial production process, very incipient for this time of the country's history. In the early 60's, Carton de Colombia, private sector company, Initiated programs of reforestation for industrial purposes but only for supply the needs of your own company, basically produced timber for manufacture of paper and paperboard starting at the same time research programs with pine, cypress and eucalyptus that have yielded important contributions to the development of this sector in the country. Therefore, in this paper refers to two species*; Pinus patula* and *Cupressus lusitanica,* in the department of Santander.

With the creation in 1968 of INDERENA and CONIF in 1974 it was started by the national government a development phase and forestry research in seed production, nursery stock and forest plantations, which have gained great momentum with the passage of time in the country, and every day more interest in the sector forestry as an economical and profitable in the medium and long term, thanks to the mild climate, light, variety of climatic zones and water supply throughout the year. In the early 80's there was the greatest boom in Colombian reforestation, an average of 27,000 ha/year due to tax and fiscal incentives were awarded for this activity to make these work attractive, profitable and important economic activities in the country. In this decade include the important and significant advances in research and technological development in partnership with neighboring countries.

Studies carried out by state agencies in conjunction with the private sector found to the Andean, Caribbean and the Orinoquia region has a potential to short, medium and long term to develop projects that achieve commercial reforestation figures for more than 17

million hectares. Which does not include or not invade native forests, forest reserves or national parks, also does not compete with land used for agriculture and cattle production that are the important activities of vocation in our country.

2. OBJETIVES

The main objective of this thesis as a degree option is the assessment of growth and development of two tree species in general conditions in the town Matanza region in the Santander Department in Colombia, considering environmental aspects, characterization of the region, the agro-ecological environment, social and economic development and inferred in plantation establishment.

The work will focus on gathering information on a specific site in the department of Santander in Colombia, and seek to determine the coupling analysis, performance, development, and disease damage which may present the selected species under normal commercial terms in this specific region.

For the future it will be reflected a proposal or recommendation concerning to the forest models that conform to the requirements of the region for periods subsequent productive forest

The following specific objectives will be pursued:

I. To see if the conditions of development and the respective increases in height, DBH, and production are favorable according to time in the specific region (years of development).
II. To take measurements of height, DBH, basal area, among others. For this analysis by distance and lack of time two measurements are taken; the first in September 2012 and the second in March 2013.
III. To determine what are the advantages of plantation development to be used for commercial purposes.
IV. To check which of the two selected species is better adapted to the conditions of the region and the environment.

3. LITERATURE REVIEW

3.1. Background to the case of study, Colombia

3.1.1. General information

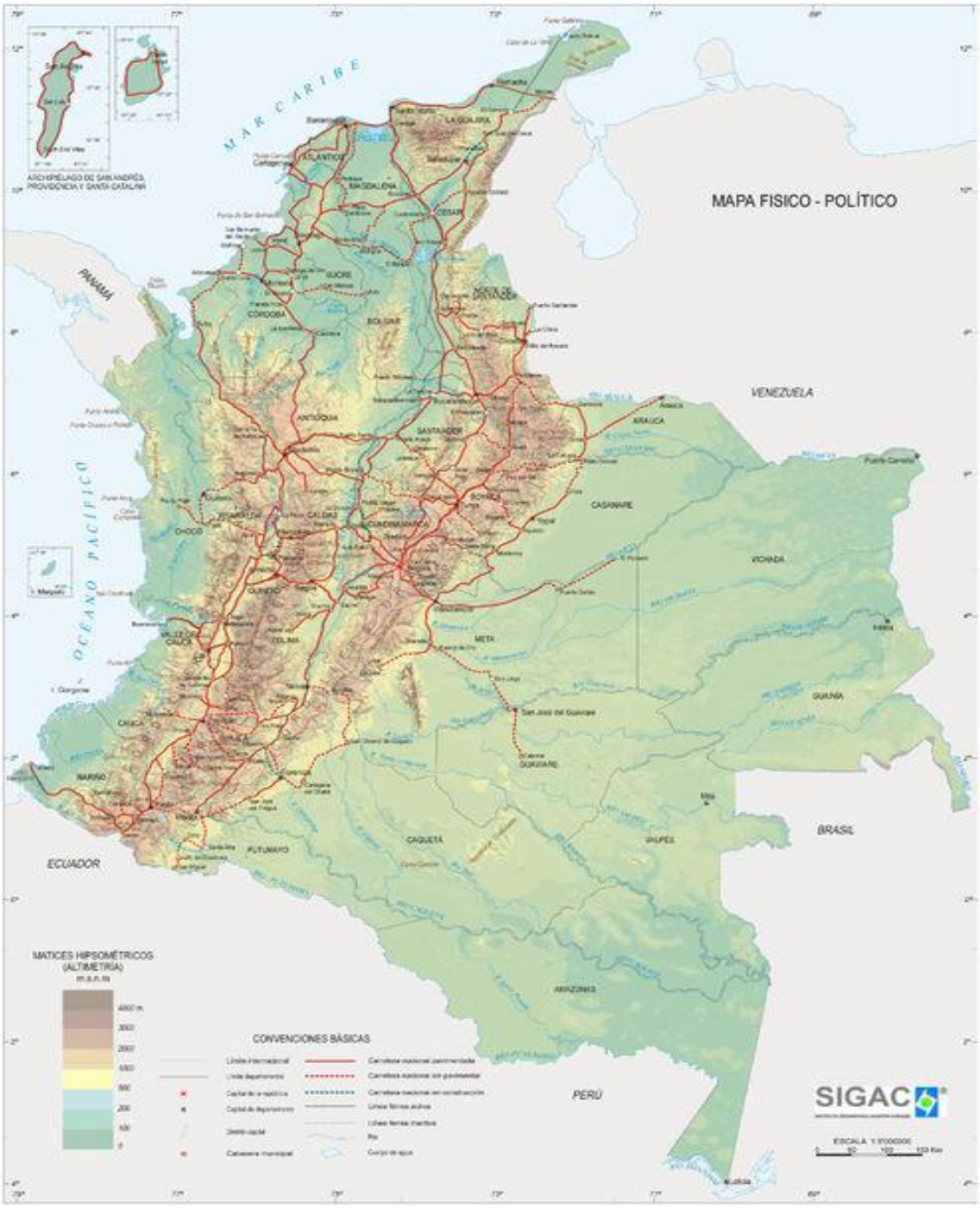


Figure 1. Physical and political division map of Colombia , Source: IGAC, Instituto Geográfico Agustin Codazzi Agustin Codazzi Geographic Institute, Colombia 2010

Official Name: Republic of Colombia
Capital: Bogotá, Capital District (D.C.)
Habitants: Approximately 46 million according to DANE 2008. (DANE is the Colombian Department of Statistics)
Area: (1.141.748 km² square kilometers), includes the San Andres and Providencia islands.
Climate: Tropical, varies according to the altitude.
Mountain Ranges: Occidental, Central, Oriental. (From the Andean mountain range)
Highest Peak: Pico Cristobal Colon, (5.800 m asl)
Colombia is divided into five natural regions according to topography: Caribbean Region, Andean Region, Pacific Region, Orinoco Region, Amazon Region; These regions are subdivided into 32 departments, legally constituted and registered in the National Constitution of 1991.

Table 1. Political Division of Colombia by departments

No.	Name of department	Capital of department	Area
1	Amazonas	Leticia	109.665 km²
2	Antioquia	Medellín	63.612 km²
3	Arauca	Arauca	23.818 km²
4	Atlántico	Barranquilla	3.388 km²
5	Bolívar	Cartagena	25.978 km²
6	Boyacá	Tunja	23.189 km²
7	Caldas	Manizales	7.888 km²
8	Caquetá	Florencia	88.965 km²
9	Casanare	Yopal	44.640 km²
10	Cauca	Popayán	29.308 km²
11	Cesar	Valledupar	22.905 km²
12	Chocó	Quibdó	46.530 km²
13	Córdoba	Montería	25.020 km²
14	Cundinamarca	Bogotá	22.653 km²
15	Guainía	Puerto Inírida	72.238 km²
16	Guaviare	San José del Guaviare	53.460 km²
17	Huila	Neiva	19.890 km²
18	La Guajira	Riohacha	20.848 km²
19	Magdalena	Santa Marta	23.188 km²
20	Meta	Villavicencio	85.635 km²
21	Nariño	San Juan de Pasto	33.268 km²
22	Norte de Santander	Cúcuta	21.658 km²
23	Putumayo	Mocoa	24.885 km²
24	Quindío	Armenia	1.845 km²
25	Risaralda	Pereira	4.140 km²
26	San Andrés y Providencia	San Andrés	52 km²
27	**Santander**	**Bucaramanga**	**30.537 km²**
28	Sucre	Sincelejo	10.917 km²
29	Tolima	Ibagué	23.562 km²
30	Valle del Cauca	Cali	22.140 km²
31	Vaupés	Mitú	54.135 km²
32	Vichada	Puerto Carreño	100.242 km²

Source DANE (Colombian Department of Statistics) 2011.

3.1.2. Geographical Location

The Republic of Colombia is located at the northwestern tip of South America, between 4 degrees south latitude and 12 degrees north latitude, and between 67 ° and 79 ° west longitude. Thanks to its geographical position, Colombia has coasts on the Atlantic and Pacific oceans. It also has jurisdiction over a stretch of the Amazon River in the Amazon trapeze, so it has been called "Homeland of Three Seas". The territorial limits: continentally limits with Venezuela to the east, southeast Brazil, Peru and Ecuador to the south and northwest Panama. Similarly, the Colombian government officially recognizes those neighboring countries with which it has agreements and underwater maritime delimitation, such as Jamaica, Honduras, Nicaragua, Costa Rica, Dominican Republic and Haiti. Additionally, parts of the country do the islands of San Andres and Providencia, the Rosario and San Bernardo, in the Caribbean (Atlantic) and the islands of Gorgona, Malpelo and Gorgonilla in the Pacific.

Colombia is an equatorial country whose climate is determined by the trade winds, humidity and altitude above sea level: the higher the altitude the temperature is lower. The regime of the seasons are bimodal, in most of the territory are two rainy seasons, from April to June and from August to November, and two of summer; the country enjoys a constant brightness throughout the year, with an equal amount of hours day and night.

Figure 2. Situation of Colombia in the world

Figure 3. Continentally limits of Colombia

3.1.3. Climate

Weather in Colombia is studied by the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM). The Colombian climate is characteristic of the equator meridian, has a tropical climate that maintains a uniform temperature most of the year. The climate is determined by the geographical and weather including: rainfall, solar intensity radiation, temperature, wind systems, altitude and humidity and continentally atmospheric. These factors develop a broad mosaic of climates and microclimates in Colombia.

Ranging from the hottest at 36°C on the coast and the plains to cooler temperatures below 0°C on the mountain peaks of the Andes Mountains and the Sierra Nevada of Santa Marta, the Andean mountain system has the greatest variety of climate determined by altitude and climate levels classified in warm weather (below 1,000 m altitude, temperatures exceeding 24°C and further, covering 80% of the size of the country), mild (between 1,000 and 2,000 meters, temperature between 17 and 24°C, corresponding to 10% of the country) cold (2,000 to 3,000 meters, temperatures between 12 and 17°C, covering 8%), wasteland (land over 3,000 m with temperatures below 12°C) and perpetual snow. In general, the habited area of the country has a warm and temperate climate; Bogotá the capital city is one of the highest cities in the world (2.600 m asl) and presents an atypical cold climate of equatorial latitude. Source «La atmósfera, el tiempo y el clima» IDEAM 2012.

In figure 4, the Colombian temperature behavior depending on the geographic and altitude of the region is demonstrated. On the right side of the figure shows the range of values given in degrees Celsius.

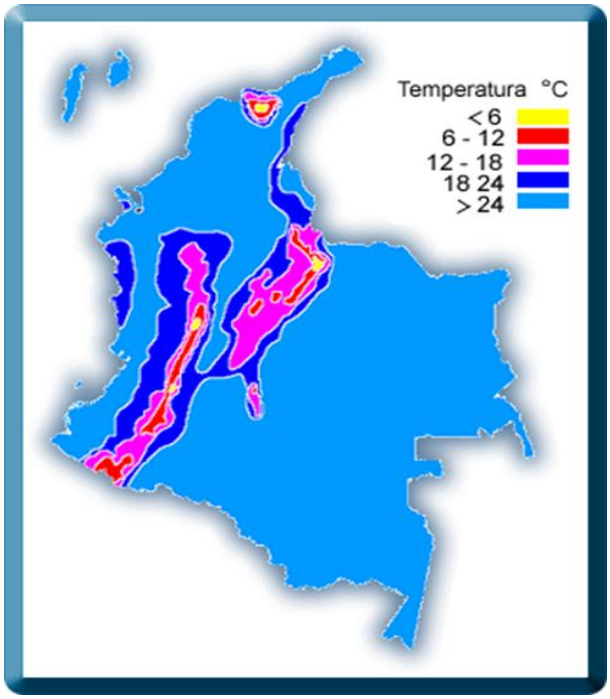


Figure 4. Map of temperature behavior in Colombia, Source Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) Colombia 2011.

Colombia temperature behavior

- **Types of climate**

The country present savannah type climate characterized by a dry and the rainy season with vegetation of grasses in the Orinoco, Bolivar, northern of Huila and center of the Cauca Valley. Super humid jungle climate, with abundant rainfall, little variation in temperature and lush jungle vegetation in the Colombian Pacific region, Amazonas and the basins of the Magdalena and Catatumbo rivers. Rainy humid climate with lower rainfall, high temperatures and a variation of forest vegetation low density

characteristic of Caquetá, Vaupes, Antioquia and Cordoba. And desert climate: high temperatures and low rainfall, with a little vegetation, is presented in La Guajira, Tatacoa desert and the desert of the Candelaria in Boyacá. The climate in the country is hot and humid. Source «La atmósfera, el tiempo y el clima» IDEAM 2012.

- **Elements of climate, rainfall**

The highest levels of rainfall occur in Colombia in the department of Chocó, the large volume of moist air masses that originate in the Pacific Ocean and enter the country on the west accumulate on the western flank of the Western Cordillera receiving between 3,000 and 12,000 mm per year, in contrast to the 500 mm annual average receives the department of La Guajira. Source «La atmósfera, el tiempo y el clima» IDEAM 2012.

In figure 5, the description of annual precipitation, by area, depending on altitude and spatial location in the country is resented. The intensity of rain is described by color and amount of millimeters per year.

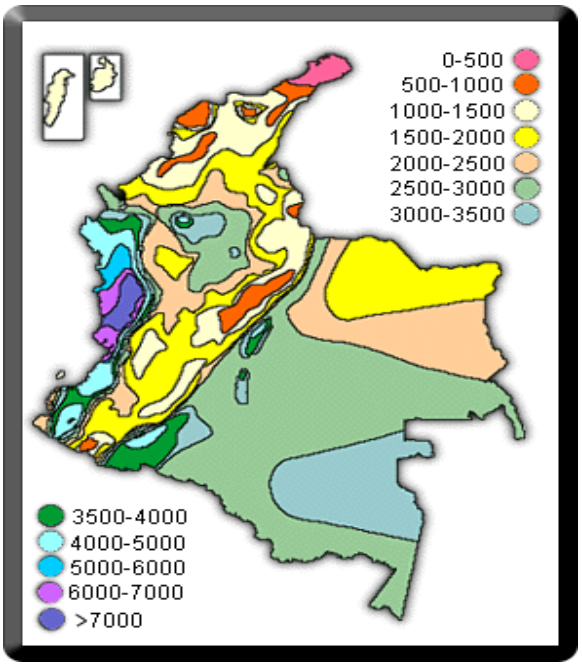


Figure 5. Map of annual rainfall trend in Colombia, Source Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) Colombia 2011.

Colombia Annual Precipitation

- **Solar radiation**

The areas receiving greater global solar radiation in Colombia in excess of 5,0 kWh/m² per day are: the Caribbean Region, northeast of the Orinoco, large sections of Meta and Casanare and small areas of the departments of Cauca, Huila, Valle del Cauca, Tolima, Cundinamarca, Boyaca, Los Santanderes, Antioquia and the islands of San Andres and Providencia. Higher values (between 5,5 and 6,0 kWh/m² per day and in places with higher values) are presented in the department of La Guajira, north and

south of Magdalena, Cesar and reduced North Atlantic sector, Bolivar, Sucre and Valle del Cauca. Source «La atmósfera, el tiempo y el clima» IDEAM 2012.

3.1.4. Type of soils

Colombia for the geographic location, presents special climatic conditions in most of its territory: tropical climate, which is characterized by high humidity and high temperature throughout the year, 82,88% of the territory is located below the 1000 m (hot weather) and has an average temperature higher than 27°C. In addition, the Agustin Codazzi Geographic Institute IGAC (2008) has estimated that approximately 80% of the territory has a wet-weather, wet or rain. Such climatic conditions have generated intense alteration processes of primary minerals and parent material of organic matter mineralization, as well as washing (leaching) of intense all that is soluble in water. These processes produce a colloidal inorganic complex exchange of low activity (LAC), dominated by kaolinitic clays, low colloidal organic matter accumulation of low quality soil impoverishment bases, which implies a decrease in pH and an intense acidification, all of which combine to produce a low fertility soils, the effect of plant nutrition. Source IGAC, Instituto Geográfico Agustin Codazzi, Agustin Codazzi Geographic Institute, 2008. Levantamiento de suelos. http://www:igac.gov.co/levansuelos.htm

In the Table 2, shows the distribution of soil orders, according to the respective natural regions where Colombia is divided.

Table2. Distribution of soil orders of Colombia by natural regions.

Natural Region	Dominant soil orders
Amazonia	Oxisol (36.9%), Inceptisol (20.8%), Ultisol (18.9%), Entisol (16.1%), Espodosol (2.9%)
Andina	Inceptisol (35%), Entisol (33%), Andisol (18%), Alfisol (3%), Ultisol (3%), Mollisol (2%)
Orinoquia	Oxisol (39%), Inceptisol (28%), Entisol (21%), Ultisol (6%)
Llanura Caribe*	Inceptisol (38%), Entisol (31%), Mollisol (6%), Vertisol (6%), Aridisol (5%), Alfisol (4%), Oxisol (1%)
Andén Pacífico	Inceptisol (50%), Entisol (26%), Oxisol (8%), Ultisol (8%), Histosol (4%)
Valles interandinos**	Inceptisol (44.4%), Entisol (40.1%), Alfisol (3.7%), Mollisol (3.7%), Vertisol (1.4%), Andisol (0.8%)
Caribean Islands	Inceptisol (30%), Entisol (22%), Vertisol (15%), Histosol (13%), Mollisol -12%

* Include La Guajira.

** Includes high and mid Magdalena valley and Cauca river valley.

Source: IGAC, Instituto Geográfico Agustin Codazzi, Agustin Codazzi Geographic Institute, Colombia 2008

According to the Agustin Codazzi Geographic Institute IGAC (2008), approximately 75% of the country's soils have pH values less than 5,5 and 47,6% have pH < 5. Furthermore, in the Amazon, the Orinoco, the Pacific Platform, the Magdalena Valley

and the Caribbean islands contained predominantly low organic matter (between 1 and 1,5% organic carbon) in the Caribbean region organic carbon content is between 0,5 and 1% and in Guajira is less than 0,5%, that is, 63,11% in the country of soils have deficient in organic matter content, the behavior of this characteristic in the Andes is very variable due to the large number of environmental conditions that occur in it. In soils of 88% of the country, they are deficient in phosphorus for plants.

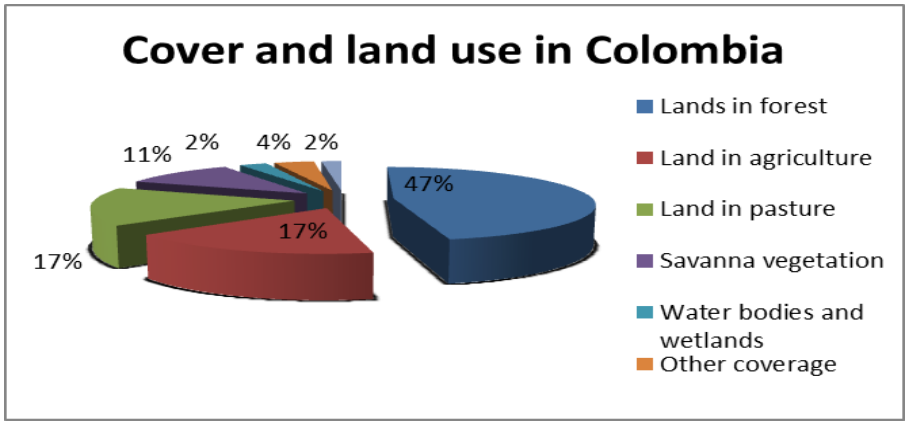
The overall distribution of soil orders in the country corresponds to the following proportions:

Table 3. General distribution of soil orders in Colombia

Orders of soil	%
Inseptisol	31,4
Entisol	26,6
Oxisol	20
Ultisol	10,1
Andisol	4,5
Mollisol	4,2
Espodosol	0,9
Alfisol	0,8
Vertisol	0,6
Histosol	0,5
Aridosol	0,4

Source: IGAC, Instituto Geográfico Agustin Codazzi, Agustin Codazzi Geographic Institute, Colombia 2008

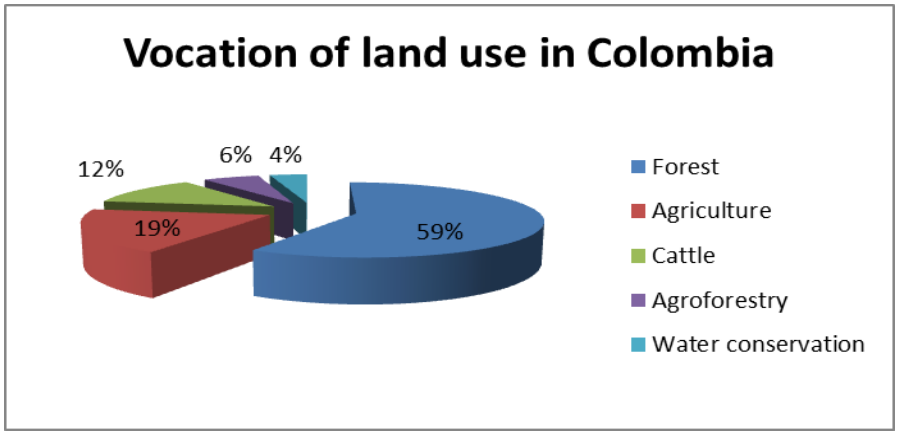
In the graph 1 can be observed the percentage distribution coverage and current land use in Colombia this information corresponding to the Colombian Institute for Rural Development (INCODER) 2010.



Source: Colombian Institute for Rural Development (INCODER). Colombia 2010.

Graph 1. Cover and land use in Colombia

In the graph 2 it can be observed the percentage distribution to the historical vocation of the land use in Colombia, when the forest activity has a big portion. This information corresponds to the Colombian Institute for Rural Development (INCODER) 2010.



Source: Colombian Institute for Rural Development (INCODER). Colombia 2010.

Graph 2. Vocation of land use in Colombia

3.1.5. Vegetation and flora in Colombia

Colombia is a country located in the tropics of Ecuador, has a large representation of taxonomic groups of flora and fauna typical of the area in addition to the varieties of wildlife migrations from different parts of the world for the variety of ecosystems; owns 44.25% of the South American paramos, making it one of the countries with the highest wet areas with high fluidity and rivers across the world. It presents rain forest, herbaceous shrub Amazon hills, savannah plains, deserts and xeric shrublands, alluvial forests, tropical rain forests, mangrove forests, swamp forests and vegetation, the savannas of the Caribbean, Andean forests and tropical dry forests or humid. With this variety Colombia ranks as one of 20 mega-diverse countries.

Colombia has between 40,000 and 45,000 species of plants, equivalent to 10 or 20% of total plant species worldwide, considered very high for a country of intermediate size. Since all South Africa contains about 30,000 species, and Brazil, which covers an area 6.5 times that of Colombia, has 55,000. It has the third highest number of endemic vascular plants; It hosts over 50,000 species of flowers, first variety of orchids. In carnivorous plants has some of the genus *Drosera*, *Pinguicula*, *Utricularia*, among others.

Colombia is a country rich in plant varieties, the variety of climates, soils and landforms that exist make the country will present a wide range of vegetation, hard to find elsewhere. Along, with the width and height of the country, we find plant species as dissimilar. Since mangroves, these curious trees that abound

in the media burning and brackish coastal; and the rare species that cling to the bare ground and the sandy frost desert next to the snowy peaks.

- **The Amazon rainforest:** Is a largest nature reserve in the world, has the vast vegetation, with over 3,000 different plant species per square kilometer, has more developed trees upright thanks to its climate and Colombia has a part in the department called Amazonas.

- **The Pacific Forest:** It is characterized as one of the world's rainiest, the vegetation is not as high as that of the Amazon, but it is also rich in varieties.
- **The forests of the Middle Magdalena and Catatumbo:** Formations are extensive but with characteristics similar to the above, the vegetation does not reach great heights.
- **The Andean vegetation:** In the Andean region decreases as a function of vegetation height, which determines the temperature, so: find in the high humid paramo, characterized by frailejón and moss: follows immediately the cloud forest, characterized by bamboo, ferns, boba palm and aliso.
- **The savanna vegetation:** This vegetation type is characterized by large associations of grass, interspersed with gallery forests, characteristic of regions of the eastern plains and savannahs of Bolívar, Córdoba, Magdalena and Cesar.
- **The desert vegetation:** In the Guajira Peninsula is found great dry semi desert vegetation, determined by cactus and tree species typical of the region. Source: Amazon Institute of Scientific SINCHI 2009 and Research Institute of Biological Resources Alexander von Humboldt 2010 – Colombia

Table 4. Current coverage of ecosystem types in Colombia

Biome	Current Area (Km²)
Paramo	18.000
Amazonian forests	14.000
Herbaceous shrubby hills Amazon	7.500
Amazonian lowland forests and catingales	36.000
savannah plains	106.500
Deserts and xeric shrublands	9.500
Alluvial forests (vegas)	95.000
Tropical rainforests	378.000
Mangrove Forests	3.300
Forests and other marsh vegetation	6.500
Caribbean Savannas	1.000
Andean forests	45.000
Dry forests, tropical subhumid	1.200
Areas intervened moderately	70.000
Areas heavily intervened	350.000
Total	**1.140.000**

Source: Colombian Institute for Rural Development (INCODER). Colombia 2010.

3.1.6. Some native forest species in Colombia

Below is a short description of the situation of Colombian native forest species and their problems. Currently it is estimated that over 40% of timber production in Colombia comes from illegal sources in the amount of natural forests that exist in the country and the lack of control of them. This reality, coupled with intensive use of precious woods, generates a lot of pressure on the weak forest ecosystems in the country and especially on some of the commercially valuable species, many of which already have some degree of threat.

This pressure effects, in many cases, lead to depletion and scarcity of the species, such as mahogany (*Swietenia macrophylla*) highly commercialized in Amazonia and Chocó, today is very scarce and has been replaced by other species of lower quality and other species are being marketed in higher proportions: Cedar (*Cedrela odorata*): 17%, Oak (*Tabebuia rosea*): 14% Cativo (*Prioria copaifera*): 10%, Espavé (*Anacardium excelsum*): 9%, Canalete (*Jacaranda copaia* 9%), Sande (*Brosimum utile*): 9%

In this sense, it can be noted that almost 70% of traded timber belongs only six species, worrying factor considering the vast diversity of forest timber species in Colombia. Therefore the use of lesser-known species with commercial potential, represent a great way to deflect the pressure on endangered species and increase the profitability of sustainable forest management. Source: www.revista-mm.com "Conservación y valorización participativa del bosque y sus servicios ambientales"- Amazonia Colombiana Junio 2012.

Table 5. Species with the highest degree of threat

Common Name	Species	Family
Cedro	*Cedrela Odorata*	Meliaceae
Abarco	*Cariniana Pyriformis*	Lecythidaceae
Roble	*Quercus Humboldtii*	Fagaceae
Caoba	*Swietenia Macrophylla*	Meliaceae
Comino	*Aniba Perutilis*	Lauraceae
Chaquiro	*Retrophyllum Rospigliosii*	Podocarpaceae
Nogal	*Juglans Neotiopica*	Juglandaceae
Caracolí	*Anacardium Excelsum*	Anacardiaceae
Carreto	*Aspidosperma Polyneuron*	Apocynaceae
Pino Colombiano	*Podocarpus Oleifolias*	Podocarpaceae

Source: List published by Ministry of Environment and Sustainable Development in the official website – Colombia

It is important to note that 50% of the country, maintaining forest cover and in this area, 50% is concentrated in collective lands of indigenous and Afro communities, in the region of Darién, Chocó and Amazon basin primarily. The extraction and trade in illegal timber, generates a negative impact in the environmental and socio-economic development in the country, affecting the security and control of these communities on their territory. Here is a list of some of the native species that can be used, but because of ignorance, importance not given the real value, according to the qualities and characteristics of the species. Source: www.revista-mm.com "Conservación y valorización participativa del bosque y sus servicios ambientales"- Amazonia Colombiana Junio 2012.

Table 6. Some Colombian native forest species

No.	COMMON NAME	SPECIES
1	Abarco del Amazonas	*Cariniana decandra*
2	Aceite Maria	*Calophyllum mariae*
3	Aceituno	*Simarouba Amara*
4	Achapo	*Cedrelinga catanaeformis*
5	Algarrobo	*Hymenaea courbaril*
6	Algarrobo-Roble	*Hymenea oblongifolia*
7	Almendro	*Goupia glabra*
8	Andiroba	*Carapa guianensis*
9	Arenillo	*Erisma uncinatum*
10	Bálsamo	*Myroxylon balsamum*
11	Bilibil	*Brosimum alicastrum*
12	Caimito	*Chrysophylum caimito*
13	Camajon	*Sterculia apetala*
14	Canalete	*Jacaranda copaia*
15	Capirón	*Calycophyllum spruceanum*
16	Capitancillo	*Pentaclethra macroloba*
17	Carrá	*Huberodendron patinoi*
18	Castaño Blanco	*Scleronema micranthum*
19	Castaño Rojo	*Scleronema praecox*
20	Ceibo	*Pachira quinata*
21	Chanul	*Humiriastrum procerum*
22	Chonta	*Iriartea deltoidea*
23	Creolino	*Monopterix uaucu*
24	Cuangare	*Otoba gracilipes*
25	Cumala	*Virola sebifera*
26	Gomo	*Vochysia vismiifolia*
27	Granadillo	*Platymiscium pinnatum*
28	Guayacán	*Buchenavia capitata*
29	Hobo	*Spondias mombin*
30	Lechero amarillo	*Brosimum potabile*
31	Ojé	*Ficus insipida*
32	Palo sangre	*Brosimum rubescens*
33	Peinemono	*Apeiba aspera*
34	Perillo	*Couma macrocarpa*
35	Quinilla	*Manilkara bidentata*
36	Sajo	*Campnosperma panamensis*
37	Sande	*Brosimum utile*
38	Soroga	*Vochysia ferruginea*
39	Tometo	*Symphonia globulifera*
40	Yanchama roja	*Poulsenia armata*

Source: www.revista-mm.com "Conservación y valorización participativa del bosque y sus servicios ambientales"- Amazonia Colombiana Junio 2012.

3.2. History of forest management in Colombia

3.2.1. Forestry in Colombia

The history of forestry and forest management programs in Colombia had several cycles, which have gone from an early stage in the 50's where lands were reforested for protective purposes, conservation and ornamental initiating the introduction of foreign species, which allowed initial approximations to the process of industrial production. In the early 60's "Carton de Colombia", one of the largest companies in the private sector and dedicated to paper and cardboard industry, start their own industrial reforestation

programs in order to supply their own needs as well as pioneering programs research with pine, cypress and eucalyptus, which have yielded important and significant for the development of this sector in the country.

The national government processes start into environmental regulations, protection and conservation areas, considered as elements of environmental protection, preservation of ecosystems and renewable natural resources, among which are referenced chronologically the most important or relevant issues in the last 100 years.

- **Historical forestry policy and laws**

The Colombian government began to legislate on issues of environmental laws and regulations and forest nearly a century ago. Below the most relevant laws and regulations involving the country's forest.

- 1919 Law 119, National Forests.
- 1954 Creation first Regional Corporation.
- 1959 Law 2, the National forestry and conservation of renewable natural resources in Colombia; creation of seven important RF (Forest Reserve). Pacific RF; Central RF; Magdalena River RF; RF of the Sierra Nevada de Santa Marta; RF Serranía de los Motilones; Cocuy RF; Amazon RF.
- 1968 Decree law 2420, Creation of the Institute of Natural Resources Development (INDERENA).
- 1969 First statute by agreement of forest law (logging permits).
- 1971 Agreement 42, National Parks Regulations.
- 1973 Law 23/73 Expedition Natural Resources Code and environmental protection.
- 1974 Decree law 2811, Changes regarding water sources in the Law 23/73.
- 1978 Decree 1541, 1608, 1681, Concerning the protection of wildlife, hydro biological resources and environmental protection.
- 1986 Creation of 18 entities attached to the Department of National Planning, to promote protection and reforestation programs, covering 35% of the country.
- 1991 New Colombian Constitution, 80 items concerning. Environmental protection; Forest reserve and National Parks.
- 1993 In response and active participation of Colombia in the Rio Convention on environment and development: Law 99 of 1993, creation of the Ministry of the environment and the creation of the National Environmental System (SINA) in effect on the date.
- 2010 National Development Plan 2010-2014. Concept of Colombia Green Desert. Important aspects in this plan; Law 1377, 2010. Regulating the activity of commercial reforestation and the National Plan of Forest Development 2025.

With the creation of "INDERENA" in 1968 and "CONIF" in 1974 started by the national government a stage or phase of research and development of forestry in the seed production technologies in raid formation and establishment of nurseries and the first tree plantations not only for programs of conservation and protection, if not

directed to forestry use. Following this, the Ministry of Economic Development in accompaniment with the private sector made in 1976 "The indicative plan of pulp, paper and cardboard" that allowed at the time that the industrial reforestation advance, reaching figures at the time of 1.100 ha/year to supply the paper industry was launched. In this time this information is not significant, but that once meant so much, as this meant they were less than 1.100 ha/year have not be deforested or cut down for this purpose.

In early 80's it had the greatest boom in Colombian reforestation started, an average of 27,000 ha/year due to tax and fiscal incentives were awarded for this activity to make this work attractive, profitable and important economic activities in the country. In this decade include the important and significant advances in research and technological development in partnership with neighboring countries. Unfortunately for the forest industry in this decade, Colombia initiated economic liberalization processes and the resources that were available for program purposes of forest support were diverted and the rulers of the time had its eye on the development of other activities such as agriculture, industry and international trade.

Colombia has important advances in story to rules and laws have been well worth noting also important that these processes have been advanced that unfortunately most of these areas of protection and laces and Colombian forestry development corridors are to be far from population centers, this is excellent opportunity situation for many of the illegal groups outside the law to increase logging of native forests for the proliferation of illicit crops.

3.3. Current situation of Colombian forestry

Studies carried out by state agencies in conjunction with the private sector found to the Andean, Caribbean and the Orinoquia region has a potential to short, medium and long term to develop projects that achieve commercial reforestation figures for more than 17 million hectares. Which are not included or not invade native forests, forest reserves or national parks, also does not compete with land used for agriculture and cattle that are the important activities of vocation in our country.

The national government in its effort to establish high forest cores by constructing highly competitive forest culture in time and according to studies developed previously it been found necessary to obtain high yields, use in identifying the best soils in terms of slope, water availability, nutrient content and have good accessibility, his means that within the zoning criteria should dispense with certain concepts like that forest lands are those of steep slopes or erosion process; as was the criterion that was driving in the country for the last years. Of the 32 departments nationwide have been identified 20 qualities and skills development projects and processes with a demarcation of forest soils. Source CONIF, National Research Corporation and forestry development – 2010.

In the table below it can seen the list of departments and the area that are available according to the agro-climatic and soil conditions.

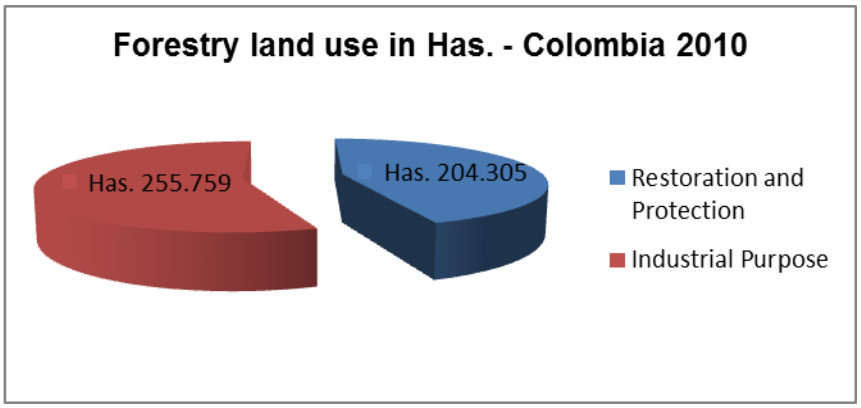
Table 7. Zoning by forest aptitude by departments

Departments	Unrestricted soil Has.	Soil with minor restrictions Has.
Antioquia	1.477.221	2.137.309
Arauca		930.025
Atlántico(*)	35.820	40.152
Bolívar(*)	355.475	94.177
Boyaca	2.892	2.877
Caldas	22.420	146.284
Casanare	24.295	1.705.973
Cauca (Cuenca alta río)	90.227	182.036
Cesar	376.935	392.104
Córdoba	189.753	233.770
Cundinamarca	150.116	150.887
Huila	50.022	163.283
Magdalena(*)	500.166	194.942
Meta	339.403	2.604.763
Nariño	365.621	295.872
Santander	281.353	451.824
Sucre	136.263	167.934
Tolima	229.705	145.193
Quindío	32.130	17.846
Vichada	467.834	2.128.105
	5.127.651	12.185.356
Total Has.	**17.313.007**	

(*) Towns riverine of the Magdalena River

Source: ZIF, Establishment and implementation of a forest statistical information system – February 2010, Bogota D.C. Colombia.

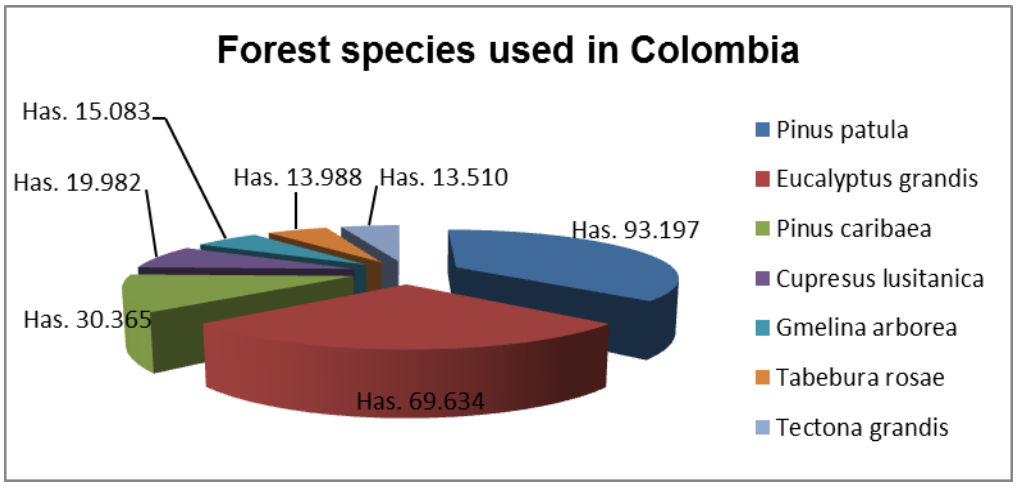
With the last forestry census conducted by the ZIF (Establishment and implementation of a forest statistical information system) there have been identified to February 2010, only 460,064 hectares. Of which 204,305 have been developed under restoration and protection schemes developed by the different regional autonomous corporations that are state agencies in support of NGOs (non-governmental organizations), indigenes and afro-descendant communities especially. And only 255,759 have industrial purposes.



Source: ZIF, Establishment and implementation of a forest statistical information system – February 2010, Bogota D.C. Colombia.

Graph 3. Forestry land use in Colombia 2010, according last forestry census conducted by ZIF

Research and technological development in forestry has led to identify several species depending on activity and use among which stand out; Pines (*Pine maximinoi*, *Pine tecunumanii*) and Eucalyptus for pulp production, sawmilling industries, construction, activated carbon and boards, Teca (*Tectona grandis*), Nogal Cafetero (*Cordia alliodora*), Acacias (*Acacia mangium*), Melina (*Gmelina arborea*), sawmilling industries, plywood, furniture and other uses. Among the latter the most used species are*: Pinus patula* with an area of 93,197 ha., *Eucalyptus grandis* with 69,634 ha., *Pinus caribaea* with 30,365 ha., *Cupresus lusitanica* with 19,982 ha., *Gmelina arborea* with 15,083 ha., *Tabebuia rosae* with 13,988 ha., *Tectona grandis* with 13,510 ha. Source CONIF, National Research Corporation and forestry development – 2010.



Source: ZIF, Establishment and implementation of a forest statistical information system – February 2010, Bogota D.C. Colombia.

Graph 4. The increased use of forest species in Colombia

Current developments in forestry, commercial plantations of private companies and research programs developed by government and private enterprise point to the genetic improvement of trees in order to achieve better yields, higher growth, better quality wood, resistant to pests and diseases, and greater adaptability among species and their origin in different areas, depending on which floor heat, the agricultural conditions of the areas of reforestation.

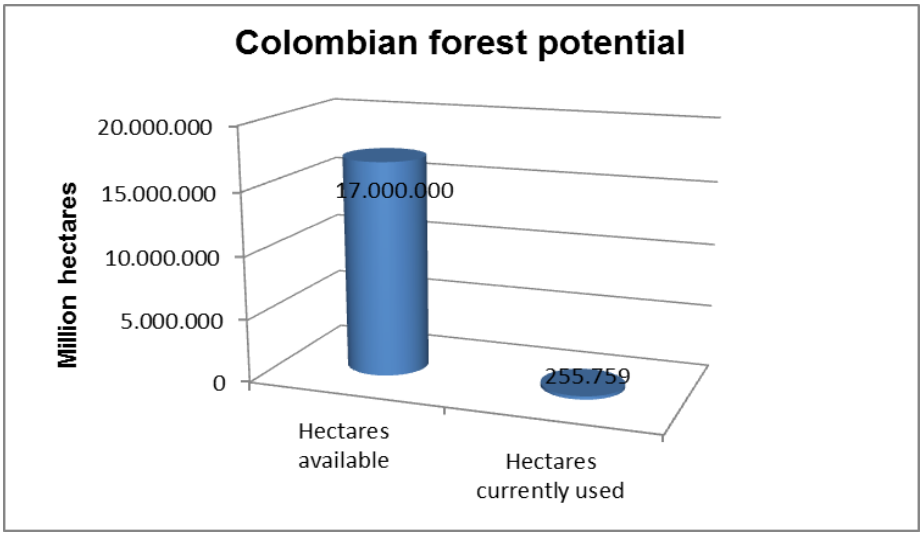
3.3.1. Some guidelines of national forest management plan.

Global management guidelines refer to do within the process of integrated management of natural resources in the area of influence of the plans, programs and forest projects, in order to facilitate the structuring of investment plans, objectives that the national government has set, will be oriented towards the following topics:

- The preservation and protection of native forest species.
- The prevention of illegal and indiscriminate logging.
- The adequacy and forestry step production.

- The recovery of forest areas affected by illicit crops.
- The forest production by silvicultural programs.

Of the 17 million of hectares available for forestry projects in Colombia there are only using 255.759 this amounts more or less 1.5% of total potential designed for this type of project.



Source CONIF, National Research Corporation and forestry development and Proexport Colombia 2010

Graph 5. Colombian Forest Potential

4. MATERIALS AND METHODS

To start the description of the methodology of this study it requires the characterization and description of the general area to reach the specified area.

4.1. Santander department

Figure 6. Map of location of Santander department in Colombia, Source IGAC, Instituto Geográfico Agustin Codazzi Agustin Codazzi Geographic Institute, Colombia 2008

Location of Santander department in Colombia

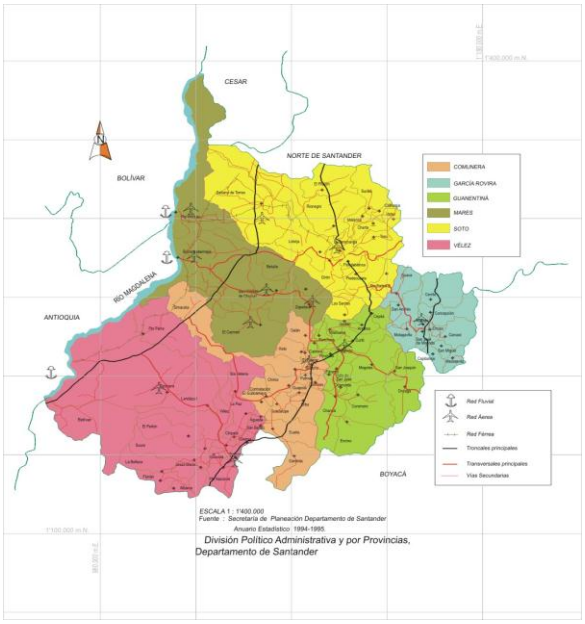


Figure 7. Map division by provinces of Santander department. Source: Secretary of planning – Santander department. Statistical yearbook 2004- 2005

Division by provinces of Santander department

The Department of Santander is located northeast of the country in the Andean region, between 05º42'34'' and 08º07'58'' N and 72º26' and 74°32' west longitude. It has an area of 30.537 km2 which represents 2,7% of the national territory. Bordered on the north by the departments of Cesar and Norte de Santander on the east and on the south by the department of Boyacá and on the west by the Magdalena River which separates it from the departments of Antioquia and Bolivar; the department of Santander has 87 municipalities, which have been grouped into provinces, provincial development centers and a metropolitan area.

Table 8. Political and administrative division of Santander department

No.	Name of province	Municipalities
1	Comunera province	Chima, Confines, Contratación, El Guacamayo, El Palmar, Galán, Gámbita, Guadalupe, Guapotá, Hato, Oiba, Palmas del Socorro, Santa Helena del Opón, Simacota, Socorro, Suaita.
2	García-Rovira province	Capitanejo, Carcasí, Cepitá, Cerrito, Concepción, Enciso, Guaca, Macaravita, Málaga, Molagavita, San Andrés, San José de Miranda, San Miguel.
3	Guanentá province	Aratoca, Barichara, Cabrera, Coromoro, Curití, Charalá, Encino, Jordán, Mogotes, Ocamonte, Onzaga, Páramo, Pinchote, San Joaquín, San Gil, Valle de San José, Villanueva.
4	Soto province	Bucaramanga, California, Charta, El Playón, Floridablanca, Girón, Lebrija, Los Santos, **Matanza,** Piedecuesta, Rionegro, Santa Bárbara, Suratá,Tona, Vetas
5	Mares province	Barrancabermeja, Betulia, El Carmen de Chucurí, Puerto Wilches, Sabana de Torres, San Vicente de Chucurí, Zapatoca.
6	Velez province	Aguada, Albania, Barbosa, Bolívar, Cimitarra, El Peñón, Chipatá, Florián, Guavatá, Güepsa, Jesús María, La Belleza, La Paz, Landázuri, Puente Nacional, Puerto Parra, San Benito, Sucre, Vélez.

Source: Secretary of planning – Santander department. Statistical yearbook 1994- 1995

4.1.1. Physiography of Santander

The relief in the territory of the Santander department distinguishes two major physiographic units called Middle Magdalena Valley and the Cordillera Oriental. The Magdalena Valley, west of the department, is characterized by flat and gently rolling valleys; on the banks of the Magdalena River the most predominates are jungle vegetation and east of these, there is an equatorial forest belt. Meanwhile, the Eastern Cordillera occupies most of the department in general direction southwest – northeast. The terrain is broken and steep slopes with heights greater than 3.000 m asl, and in the mountains of the Lloriquíes or Cobardes. Furthermore, on the western flank of the ridge, is a series of terraces with very dry environment, the largest and most important is the Mesa de los Santos or Jéridas; all these plateaus are in a staggered manner, highly eroded and cut sharply to the canyon Chicamocha. The latter is one of the most remarkable morphological Santander relief found in eastern – west direction.

4.1.2. General climate of Santander

The climate of the department of Santander is affected by the diversity of altitude, which provides different climatic zones and landscapes. In the lower Magdalena Valley, average temperatures are around 29°C and abundant rainfall, recording up to 3.800 millimeters annually, on the flank of the Cordillera decreasing temperature, rainfall of 1.500 – 2.000 millimeters of annual average, with the exception of the south and especially Chicamocha canyon where precipitation is less than 500 millimeters and high temperatures reaching values up to 32°C, the area of the paramos recorded temperatures below 7°C and low rainfall. Their lands are distributed in warm climatic zones, temperate and bioclimatic paramos.

4.2. Municipality of Matanza

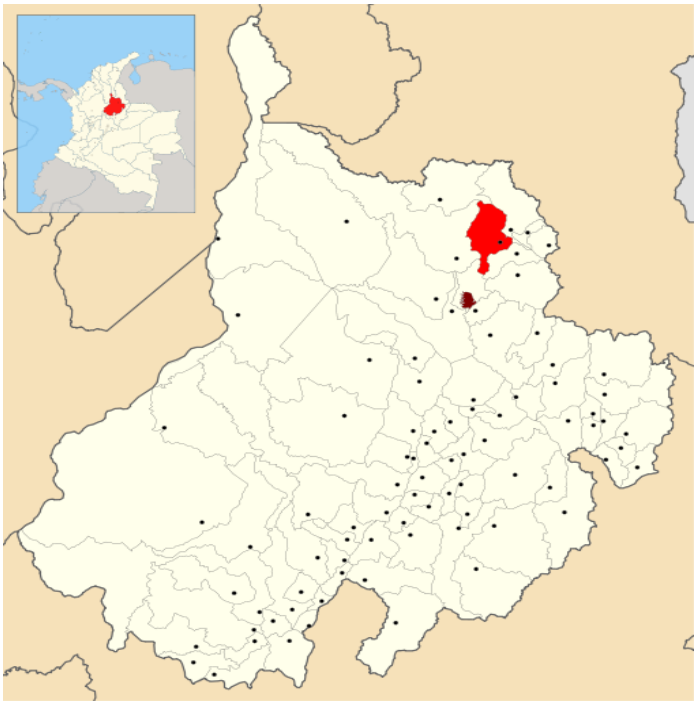


Figure 8. Map division by province of Santander department. Source: Secretary of planning – Santander department. Statistical yearbook 2004- 2005

Location of Matanza municipality in Santander

Matanza is located towards the north of the province of Soto, commonly known as cold zone, just from 35 km of Bucaramanga and 494 Km of Bogota the capital city. Bordered with Bucaramanga, Charta, Playon, Rionegro, Surata all of this municipalities in the province of Soto. Georeferencing coordinates Latitude: 7,32528 and Longitude: -73,0194. In the planar coordinate system is located between coordinates 1.289.000 to 1.314.000 meters north and 1.099.700 to 1.119.100 meters east.

Total area: 243,24 km², extension urban area: 0,24 km², extension rural area: 243 km², average altitude between 900 m asl and 1.700 m asl; average temperature ranges between 5°C and 20°C.

The analysis of precipitation in the study area was based on information reported by the historical reports of Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) – Colombia, whose annual values vary between 660 and 2.550 millimeters approximately, the rainfall for this region is bimodal with winter periods between the months of March to May or in some years of April to June and September to November.

The stations analyzed present in average between 7 and 16 days with precipitation per month and maximum daily rainfall up 167 millimeters. The normal average daily rainfall in this region is estimated at 36 millimeters. The relative humidity is estimated of 80% annual average, the estimated annual sunshine at 1.900 hours, the months with the highest wind speed are March, the months that have lower wind speed are June and July (2,5m/s), November (1,7m/s) and June (0,5m/s) respectively, average annual evaporation varies between 800 and 1.100 millimeters, the months of increased evapotranspiration are from January to March with values between 86 and 125 millimeters and the lowest is November with values between 72 and 108 millimeters.

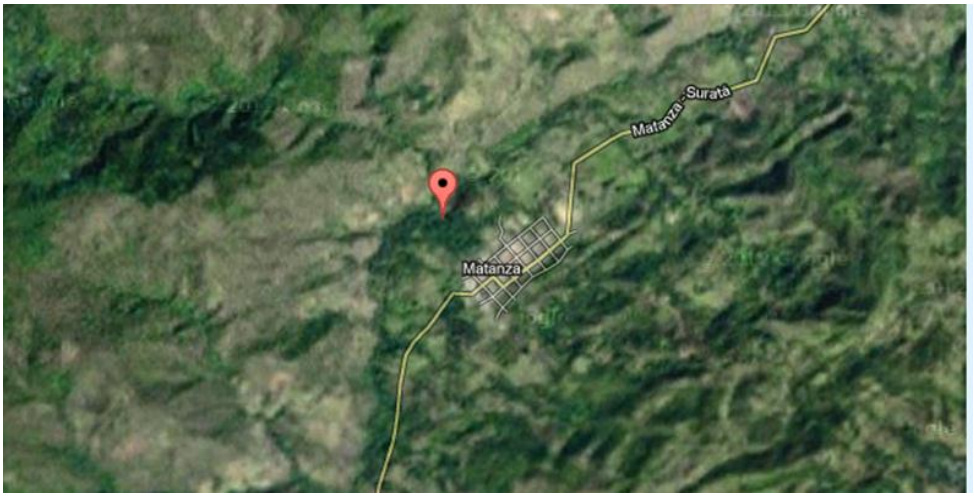


Figure 9. Source: Google images 2013 – Digital globe, GeoEye U.S., Geological survey

Satellite image of the Matanza municipality

4.3. Selection of locality of interest

The plantations were established in the municipality of Matanza, in the trial Alto Bravo, on the farm "Nuevo Campo". It is region in which since year 2007 have been established afforestation programs with conifers species, for industrial and commercial purposes and which meets the characteristics that are sought for the study of the analysis target. The farm "Nuevo Campo" is owned by the association of producers of wood "MADECHARTA". The location is represented with the coordinates 07º12'07,55'' N and 73º08'19,24'' E. Elevation is 999 m asl, it has a total area of 55, 3 hectares and areas are divided into different plots with coniferous species of various age ranges.

4.3.1. Selection of species

On the farm studied are found the following introduced species, *Pinus patula*, *Cupressus lusitanica* and *Eucalyptus grandis.* The purpose of the study is the comparison between two similar species, under the same edapho-climatic conditions and environmental characteristics for development.

4.3.1.1. *Pinus patula*

Table 9. Scientific classification of *Pinus patula*

Scientific classification	
Kingdom	Plantae
Division	Pinophyta
Class	Pinopsida
Order	Pinales
Family	Pinaceae
Genus	Pinus
Subgenus	Pinus
Species	***Pinus patula***

Source: Eguiluz T.1982. Clima y Distribución del género pinus en México. Distrito Federal. Mexico.

- **Geographical distribution:** It is found naturally forming pure stands in Mexico and South - Western U.S. It has been introduced in the South Africa, Southern Rhodesia, Madagascar, New Zealand and Argentina among others. In Colombia it has produced excellent results in the Valle del Cauca, Cauca, Antioquia, Cundinamarca and Santander.

- **Main features of the tree:** The tree grows to 40 m tall and 120 cm dbh, usually with a single, straight, slender trunk; in closed canopy stands, the depth of the conical or domed crown is ca. 33%. The bark on young trees is thin, scaly, red-brown, with age becoming thick, dark grey-brown, rough and scaly with large elongated plates and deep longitudinal fissures. First-order branches are long, slender, spreading or slightly ascending; higher order branches are slender, drooping, the ultimate branches pendent.

4.3.1.2. *Cupressus lusitanica*

Table 10. Scientific classification of *Cupressus lusitanica*

Scientific classification	
Kingdom	Plantae
Division	Pinophyta
Class	Pinopsida
Order	Pinales
Family	Cupressaceae
Genus	Cupressus
Species	***C. lusitanica***

Source: Conifer Specialist Group (1998). *Cupressus lusitanica*. 2006.

- **Geographical distribution:** It's original in eastern Mediterranean regions, major areas exist in northern Libya, southern Greece (Crete and Rhodes), southern Turkey and Cyprus, western Syria, Lebanon, Jordan West and parts of Iran. It has been planted widely for commercial production: at high altitudes in Colombia (3.300 m), Bolivia and South Africa, and near sea level in New Zealand where is fully naturalized. In Colombia trees are planted to form windbreak curtains. With major developments as native species it has been introduced in Belize, Costa Rica, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, United States of America

- **Main features of the tree:** *Cupressus lusitanica* is an evergreen conifer tree with a conic to ovoid-conic crown, growing to 40 m tall. The foliage grows in dense sprays, dark green to somewhat yellow-green in colour. The leaves are scale-like, 2–5 mm long. This species supports basic and acidic soils, tolerates arid or compacted soils and rejects too wet or sandy sites. This tree needs sun, enduring great heat and drought, but not severe cold temperatures below -10°C.

4.4. Experimental plots

Having selected species we are proceeded to do a reconnaissance of the area where be performed and establish their respective plots and make a minimum two replications per species, with minimum of 50 individuals.

- **Parcel 1:** Introduced Species *Pinus patula,* total area of the parcel 4,78 hectares, planting 1.100 trees per hectare with a distance between trees 3 m x 3 m. and 5.258 initially established trees.

- **Parcel 2:** Introduced Species *Cupressus lusitanica,* total area of the parcel 3,50 hectares, planting 1.100 trees per hectare with a distance between trees 3 m x 3 m. and 3.850 initially established trees.

Two experimental plots where some of the sampling are located on the same property and have a distance from each other of 985 meters, the size of each rectangular is 30 x 15 meters, with an area of 450 m² that equals to 0,045 hectares. There were four replicates in each parcel at random; covering 1.800 m² that equals to 0, 18 hectares, repetitions each covers 50 trees.

In total, there were established two plots for each species at two locations, together representing 8 particular research plots.

4.5. Measurements of total heights and diameter at breast height (dbh)

Measurements of the diameter at breast height and total height were performed on each of the four plots for each species, the total number of plot eight for the two different species, the plots were numbered for easier and simpler identifications, parcel of *Pinus patula,* plot number 1, plot number 2, plot number 3 and plot number 4, parcel of *Cupressus lusitanica,* plot number 5, plot number 6, plot number 7 and plot number 8.

In each plot it was proceeded to take the diameter at breast height (dbh), to a height of 1.30 meters with a tape measure, at each of the trees in the experimental plots. The planting layout facilitates the count and mobility within the plots, as seen in the photographs that are part of the registration.

The next step was to take the measure of total height in each of the eight plots, it had an estimated take 200 trees by species, but the measurement was found that the plots are not complete; some trees are absent, which served to determiner another indicator and new mortality measurement in this process. The height of the trees was taken with a measuring instrument telescopic pole divided into several sections and graduated in mm, standard length ranges from 3 to 10 meters; this instrument was used because the sample trees are below10 meters high. Together with diameter at breast height (dbh) and height measurements was performed marking of the trees with a corresponding number from one to two hundred per species in each plot, thus facilitate future measurements and to establish the comparative data.

Parcel *Pinus patula,* plots rightful number 1, with their respective number dialing since one to fifty; plot number 2 since fifty-one to one-hundred; plot number 3 since one-hundred and one to one-hundred and fifty; plot number 4 since one-hundred and fifty-one to two-hundred.

Parcel *Cupressus lusitanica,* plots rightful number 1, with their respective number dialing since one to fifty; plot number 2 since fifty-one to one-hundred; plot number 3 since one-hundred and one to one-hundred and fifty; plot number 4 since one-hundred and fifty-one to two-hundred. The numbering was individually by parcel by plots.

With the respective calculations of height and the diameter at breast height (dbh); it was calculated basal area and total volume for each plot and for each species of tree. To determinate stem volume was used one of the local formula described below.

$$\text{Stem volume} = V = \frac{3{,}1416*(Dap/100)^2* h*f}{4}$$

V= Volume m^3

Π= 3,1416

Dap= Diameter at breast height

h= Height

f= Form factor (in this case 0,5 for coniferous species)

With the data collected in each of the plots was selected one of the tallest tree, one of half height and one of the lowest height for applied the Smalian formula, this local formula is used to calculate measurements for harvested timber, will use this to give an

estimate of volume in the three different ranges, because the plantation is very young and was not allowed felling a tree for measurement by 1 meter of section.

Smalian formula = $Vm^3 = \frac{(D1/100)^2+(D2/100)^2}{2} * 0,7854 * Hc$

V=Volume in cubic meters (m^3)

D1= Larger diameter in meters

D2= Minor diameter in meters

0,7854= Factor resulting from the relationship $\pi/4$, being $\pi=3,1416$

Hc= Commercial height, in this case the H, is the total height.

The Smalian formula was used in twelve trees per species for the four plots, the first measurements were made on September 5 of 2012, and the second to establish the comparative was made on March 9 of 2013.

4.6. Statistical processes

The statistical analysis is made for each species of tree in this case *Pinus patula* and *Cupressus lusitanica,* It consists in a simple and fundamental description of statistical explications with: Mean; Median, Standard deviation and Variance values for the parameters of height, diameter at breast height (dbh), basal area and estimated the standing volume from a sample trees.

The parameters of diameter at breast height (dbh) and height are used in order to fulfill the correlation analysis. The correlation analysis is used to choose the best approaching equation (lineal or not lineal) of diameter at breast height (dbh) and height values, in order to guess the height of the trees not measured.

4.7. Purpose of the analysis of variance

The variance analysis we will use to verify statistically significant between there, when we have more than two samples or groups in the same approach.

Formula= $\sigma^2 = \sum(X-M)^2 / N$

σ^2= Will be the symbol that represents the standard deviation of the sample

X= Individual sample

M= Arithmetic mean

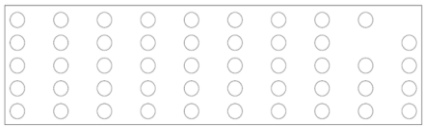
N= Total sample number

5. RESULTS

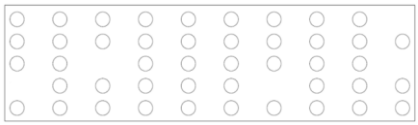
5.1. General evaluation

Layout and design of the plots analyzed¸ it starts with *Pinus patula,* plots number 1, 2, 3, 4 and *Cupressus lusitanica* plots number 5, 6, 7 and 8.

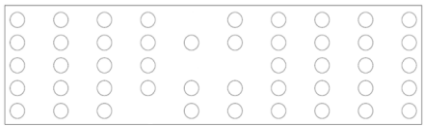
Plot 1 = 48 trees



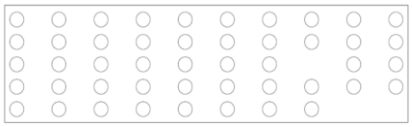
Plot 2 = 45 trees



Plot 3 = 46 trees

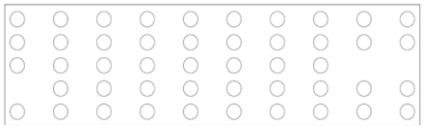


Plot 4 = 47 tress

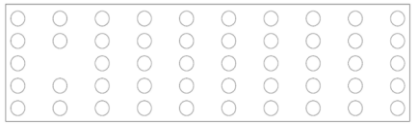


Cupressus lusitanica,

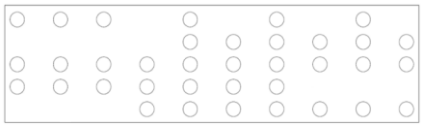
Plot 5 = 47 trees



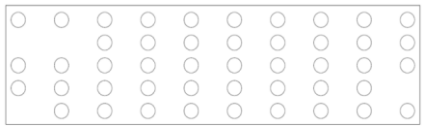
Plot 6 = 49 trees



Plot 7 = 36 trees



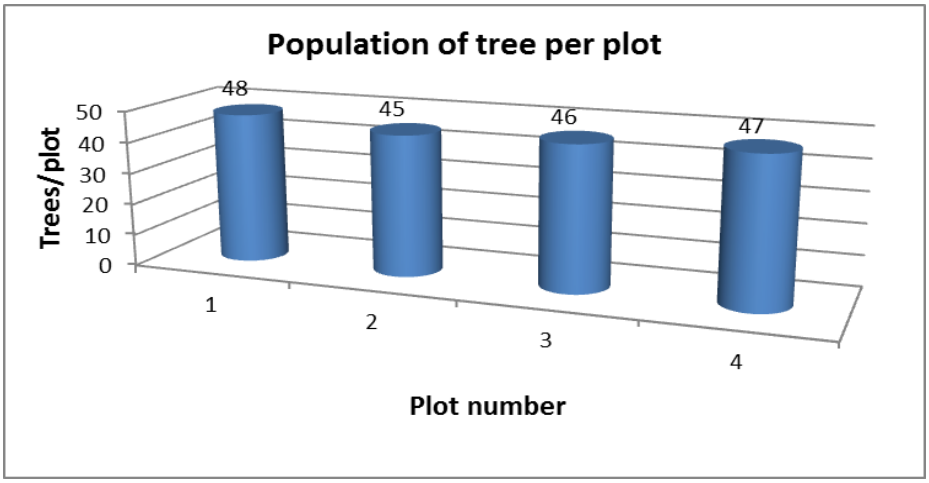
Plot 8 = 46 trees



In the plot graphs numbered from 1 to 8 shows the distribution and the number of trees in the plots analyzed, this count also established a population estimate per hectare five years after the establishment of the plantation. Each plot has an area of 15 x 30 meters and each circle represents a tree, whitespace are the trees were not found in field; the information collected of the planting data was 1.100 trees per one hectare but in the real situation was totally different, the two- hundred trees that are expected to measure in the parcel of *Pinus patula,* in four different replications, only found one hundred eighty-six trees, equivalent to 93% of the initial population. In the parcel of *Cupressus lusitanica,* was the same only found one hundred seventy-eight trees, equivalent to 89% of the initial population.

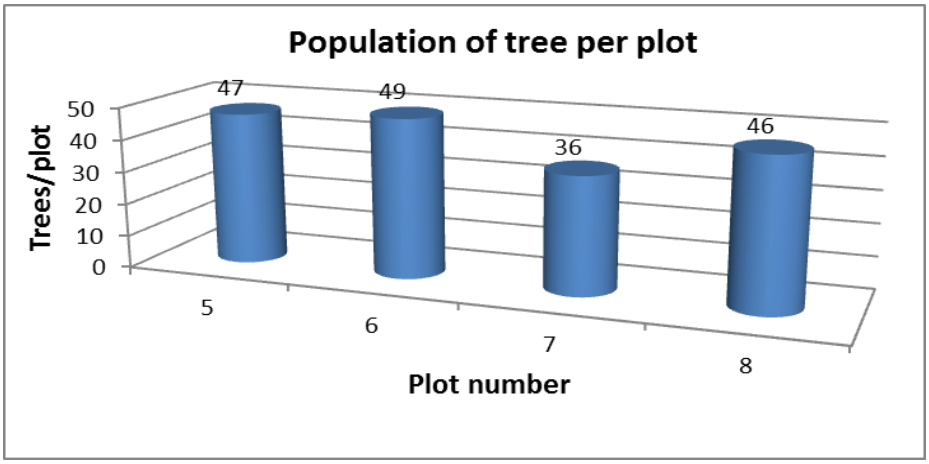
To set the 8 plots, proceeded to divide the parcels into 4 parts and sampling plots were located equidistant from the center. You can see the shape of the lots in the annex drawings number 2 and 3 in the annex part.

The next two graphs show the quantity of trees per species in the study plots.



Source: Ing. Cesar Rogelio Anaya and Omaira Silena Gil Vides, Colombia September of 2012

Graph 6. Population of tree per plot, *Pinus patula*



Source: Ing. Cesar Rogelio Anaya and Omaira Silena Gil Vides, Colombia September of 2012

Graph 7. Population of tree per plot, *Cupressus lusitanica*

5.2. Statistical analysis and results for species in each plot

Measurements were made for height, diameter at breast height in two different periods with a difference of six months; the first measurements were performed on 5th of September 2012 and the second on 9th of March 2013, with the following results.

Basic statistical variables were calculated for each species in each plot were basal area in m², total volume in m³ and for all the statistical part with arithmetic mean, quadratic mean, variance and standard deviation. The summary of the tabulated data on the first measurement are presented in the following Tables, from the Table 11 to Table 26 for the both species.

Table 11. Statistical analysis for *Pinus patula* plot 1

Plot 1				
Measurement 5-Sep-2012				
Pinus patula	n° of trees per plot		48	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	28,03	4,77	0,00044	0,1592
Quadratic mean	28,56	4,84	0,00048	0,1788
Variance	37,95	5,58	0,00160	0,5619
Standar deviation	6,16	2,36	0,04003	0,7496

Source: Omaira Silena Gil Vides, Colombia September of 2012

Table 12. Statistical analysis for *Pinus patula* plot 2

Plot 2				
Measurement 5-Sep-2012				
Pinus patula	n° of trees per plot		45	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	28,16	5,21	0,00046	0,1960
Quadratic mean	29,13	5,38	0,00052	0,2525
Variance	49,77	8,84	0,00160	1,0520
Standar deviation	7,06	2,97	0,04003	1,0257

Source: Omaira Silena Gil Vides, Colombia September of 2012

Table 13. Statistical analysis for *Pinus patula* plot 3

Plot 3				
Measurement 5-Sep-2012				
Pinus patula	n° of trees per plot		46	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	33,21	6,22	0,00063	0,3042
Quadratic mean	34,02	6,35	0,00068	0,3492
Variance	49,34	8,2	0,00172	1,1232
Standar deviation	7,02	2,86	0,04149	1,0598

Source: Omaira Silena Gil Vides, Colombia September of 2012

Table 14. Statistical analysis for *Pinus patula* plot 4

Plot 4				
Measurement 5-Sep-2012				
Pinus patula	n° of trees per plot		47	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	35,44	6,75	0,00070	0,3597
Quadratic mean	35,92	6,84	0,00074	0,3911
Variance	39,38	7,09	0,00140	1,0239
Standar deviation	6,28	2,66	0,03746	1,0119

Source: Omaira Silena Gil Vides, Colombia September of 2012

Table 15. Statistical analysis for *Cupressus lusitanica* plot 5

Plot 5				
Measurement 5-Sep-2012				
Cupressus lusitanica	**n° of trees per plot**		47	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	15,71	3,19	0,00014	0,0350
Quadratic mean	16,06	3,29	0,00015	0,0406
Variance	22,42	5,22	0,00038	0,1378
Standar deviation	4,74	2,28	0,01961	0,3712

Source: Omaira Silena Gil Vides, Colombia September of 2012

Table 16. Statistical analysis for *Cupressus lusitanica* plot 6

Plot 6				
Measurement 5-Sep-2012				
Cupressus lusitanica	**n° of trees per plot**		49	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	20,38	3,67	0,00025	0,0753
Quadratic mean	21,33	3,83	0,00029	0,0945
Variance	44,07	7,18	0,00097	0,3936
Standar deviation	6,64	2,68	0,03110	0,6274

Source: Omaira Silena Gil Vides, Colombia September of 2012

Table 17. Statistical analysis for *Cupressus lusitanica* plot 7

Plot 7				
Measurement 5-Sep-2012				
Cupressus lusitanica	**n° of trees per plot**		36	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	22,39	4,19	0,00030	0,1036
Quadratic mean	23,58	4,34	0,00035	0,1247
Variance	43,81	6,46	0,00098	0,3999
Standar deviation	6,62	2,54	0,03127	0,6323

Source: Omaira Silena Gil Vides, Colombia September of 2012

Table 18. Statistical analysis for *Cupressus lusitanica* plot 8

Plot 8				
Measurement 5-Sep-2012				
Cupressus lusitanica	**n° of trees per plot**		46	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	21,04	3,81	0,00026	0,0801
Quadratic mean	21,83	3,94	0,00029	0,0946
Variance	38,58	6,4	0,00083	0,3270
Standar deviation	6,21	2,53	0,02875	0,5718

Source: Omaira Silena Gil Vides, Colombia September of 2012

In this first sample will be appreciated that the development of the *Pinus patula*, is relatively better than that of the other species in this case i.e. *Cupressus lusitanica*, from Tables 11 to Table 18, shows the final statistical results of the first sampling on September of 2012. The arithmetic mean gives a value of a set of numbers; there is not a representative result of the reality of the state of the plantation, but serves to locate in the standard range that can be found in the specific lot.

The summary of the tabulated data on the second measurement on 9th of March 2013; *Pinus patula* and *Cupressus lusitanica.* Since the Table 19 to Table 26.

Table 19. Statistical analysis for *Pinus patula* plot 1, second measurement

Plot 1				
Measurement 9-Mar-2013				
Pinus patula	**n° of trees per plot**		48	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	28,88	5,09	0,00045	0,1730
Quadratic mean	28,36	5,15	0,00049	0,1928
Variance	38,05	5,64	0,00118	0,5888
Standar deviation	6,17	2,38	0,03431	0,7674

Source: Omaira Silena Gil Vides, Colombia March of 2013

Table 20. Statistical analysis for *Pinus patula* plot 2, second measurement

Plot 2				
Measurement 9-Mar-2013				
Pinus patula	**n° of trees per plot**		45	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	28,5	5,51	0,00047	0,2107
Quadratic mean	29,47	5,67	0,00053	0,2692
Variance	49,86	8,96	0,00163	1,1075
Standar deviation	7,06	2,99	0,04033	1,0524

Source: Omaira Silena Gil Vides, Colombia March of 2013

Table 21. Statistical analysis for *Pinus patula* plot 3, second measurement

Plot 3				
Measurement 9-Mar-2013				
Pinus patula	**n° of trees per plot**		46	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	33,54	6,53	0,00064	0,3240
Quadratic mean	34,34	6,65	0,00070	0,3706
Variance	49,44	8,23	0,00174	1,1787
Standar deviation	7,03	2,87	0,04174	1,0857

Source: Omaira Silena Gil Vides, Colombia March of 2013

Table 22. Statistical analysis for *Pinus patula* plot 4, second measurement

Plot 4				
Measurement 9-Mar-2013				
Pinus patula	**n° of trees per plot**		47	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	35,78	7,06	0,00072	0,3802
Quadratic mean	36,24	7,15	0,00075	0,4144
Variance	39,38	7,18	0,00142	1,0715
Standar deviation	6,28	2,68	0,03764	1,0352

Source: Omaira Silena Gil Vides, Colombia March of 2013

Table 23. Statistical analysis for *Cupressus lusitanica* plot 5, second measurement

Plot 5				
Measurement 9-Mar-2013				
Cupressus lusitanica	**n° of trees per plot**		47	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	16	3,43	0,00015	0,0387
Quadratic mean	16,34	3,52	0,00016	0,0445
Variance	22,49	5,22	0,00039	0,1485
Standar deviation	4,74	2,28	0,01986	0,3853

Source: Omaira Silena Gil Vides, Colombia March of 2013

Table 24. Statistical analysis for *Cupressus lusitanica* plot 6, second measurement

Plot 6				
Measurement 9-Mar-2013				
Cupressus lusitanica	**n° of trees per plot**		49	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	20,77	3,93	0,00026	0,0828
Quadratic mean	21,71	4,08	0,00029	0,1032
Variance	44,14	7,29	0,00099	0,4242
Standar deviation	6,64	2,7	0,03142	0,6513

Source: Omaira Silena Gil Vides, Colombia March of 2013

Table 25. Statistical analysis for *Cupressus lusitanica* plot 7, second measurement

Plot 7				
Measurement 9-Mar-2013				
Cupressus lusitanica	**n° of trees per plot**		36	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	22,73	4,43	0,00031	0,1117
Quadratic mean	23,89	4,57	0,00036	0,1337
Variance	43,66	6,56	0,00099	0,4236
Standar deviation	6,61	2,56	0,03147	0,6509

Source: Omaira Silena Gil Vides, Colombia March of 2013

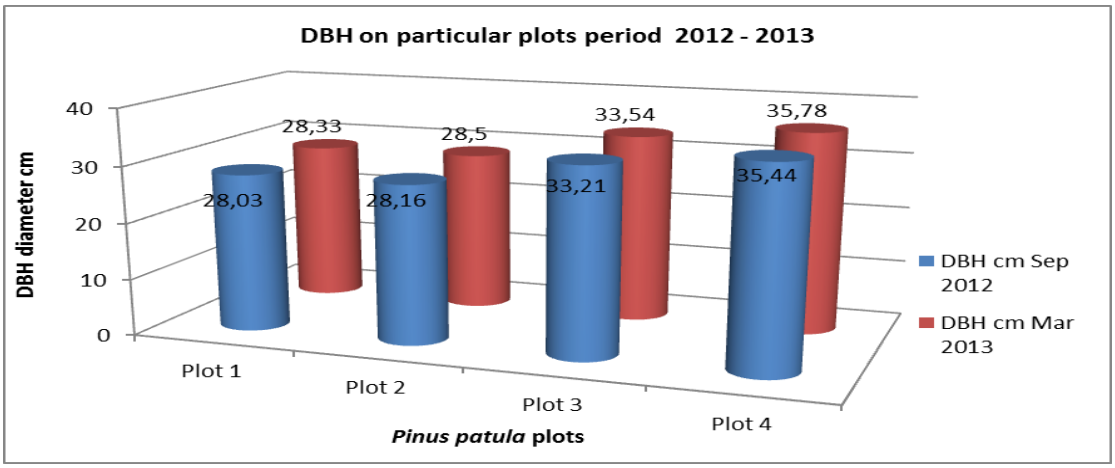
Table 26. Statistical analysis for *Cupressus lusitanica* plot 8, second measurement

Plot 8				
Measurement 9-Mar-2013				
Cupressus lusitanica	**n° of trees per plot**		46	
Parameters analyzed	**DBH cm**	**Height m**	**Basal area m²**	**Volumen m³**
Aritmetic mean	21,44	4,07	0,00027	0,0883
Quadratic mean	22,22	4,2	0,00030	0,0108
Variance	38,64	6,73	0,00084	0,3575
Standar deviation	6,22	2,59	0,02905	0,5979

Source: Omaira Silena Gil Vides, Colombia March of 2013

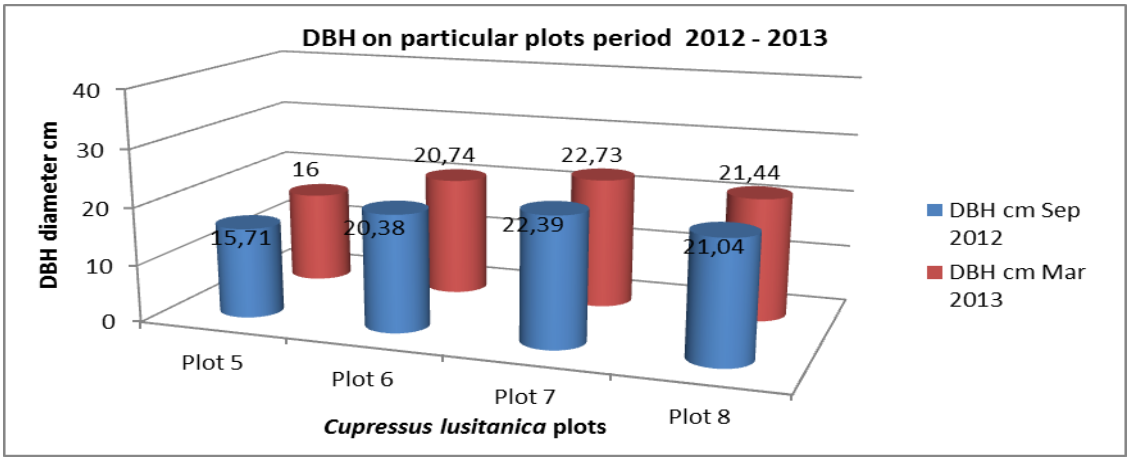
5.2.1. DBH and Height structure in the plots

In the following graphs this represented an average increase in the time period of six months between of the two samplings in the particular plots.



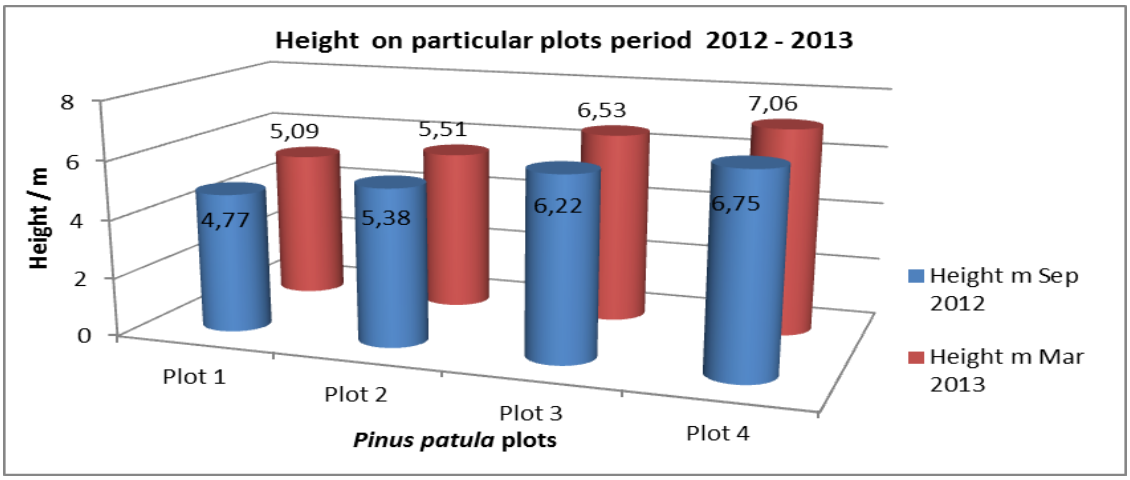
Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 8. DBH on particular plots, *Pinus patula* period 2012 - 2013



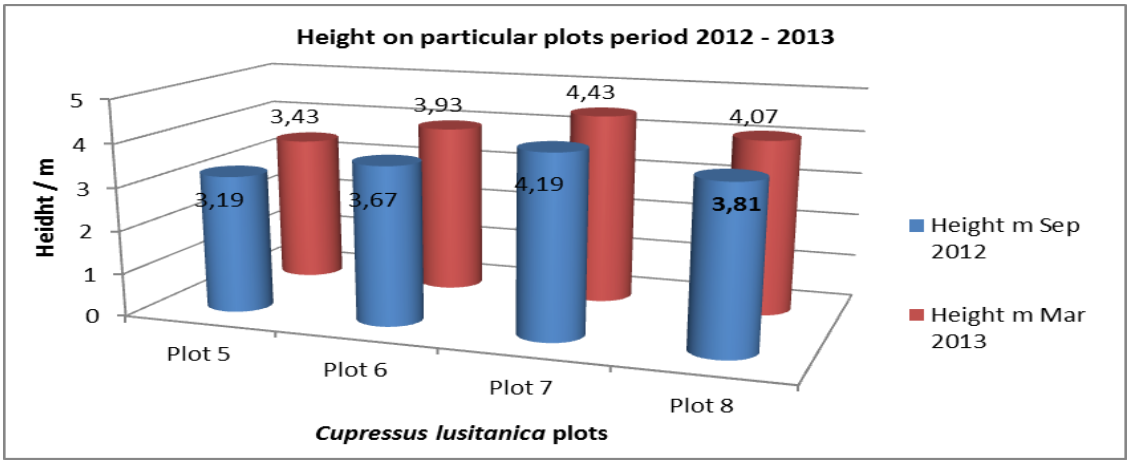
Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 9. DBH on particular plots, *Cupressus lusitanica* period 2012 – 2013



Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 10. Height on particular plots, *Pinus patula* period 2012 – 2013



Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 11. Height on particular plots, *Cupressus lusitanica* period 2012 – 2013

In the previous graphs are represented the results of the measurements conducted at two plantations with equal edapho-climatic terms (soil conditions, climate as temperature, relative humidity, rains, slope of the terrain between other).

It clearly shows the increase in the *Pinus patula*, plantation established in the year 2007; and which has been increased by the height is recorded between 80 cm and 1 meter and diameter between 1 and 1,5 cm per year. The Graph 8 and the Graph 10 evidenced by the increase in a period of six months than 30 cm of height and 0,31 mm of diameter in overall average for the plots but it is seen that there are trees that are more developed of better force.

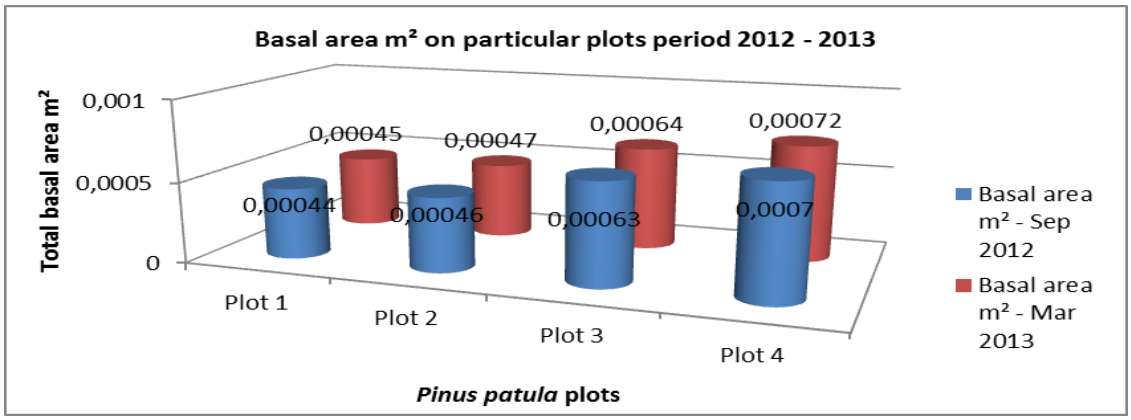
The Graph 9 and Graph 11 evidenced developing the species *Cupressus lusitanica*, with lower yields in height and diameter with average annual increases between 50 and 80 cm in height and diameter between 1 and 1,5 cm per year. The plantation in generally

has smaller increments, the registration of samples recorded an average increase in height of 24-26 cm and in diameters between 0,29 and 0,40 mm in the period from 5th of September 2012 to 9th of March 2013.

5.2.2. Structure of Basal area m² and Total volume m³ in the particular plots

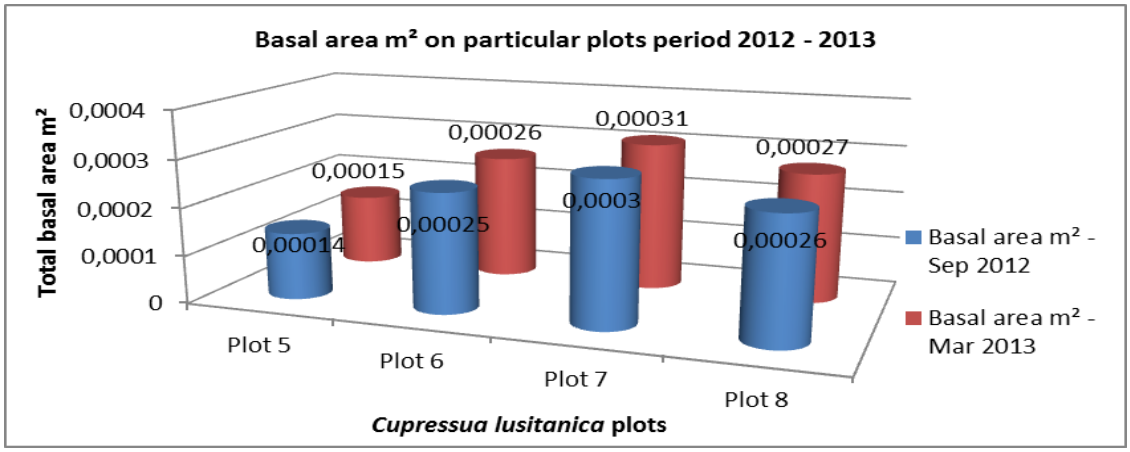
The data recorded in the pre-sample height and diameter at breast height it allows us to obtain results for other important measurements and give for us an idea of volumetric increases in the studied plantations. With data of DBH and height was calculated the basal area and total volume per tree in each particular plot per species in the period between September 2012 and March 2013.

The graphs below are representing the basal area and total volume in the two species tested, *Pinus patula* and *cupressus lusitanica*, per average tree in each plots, in the period between September of 2012 and March of 2013.



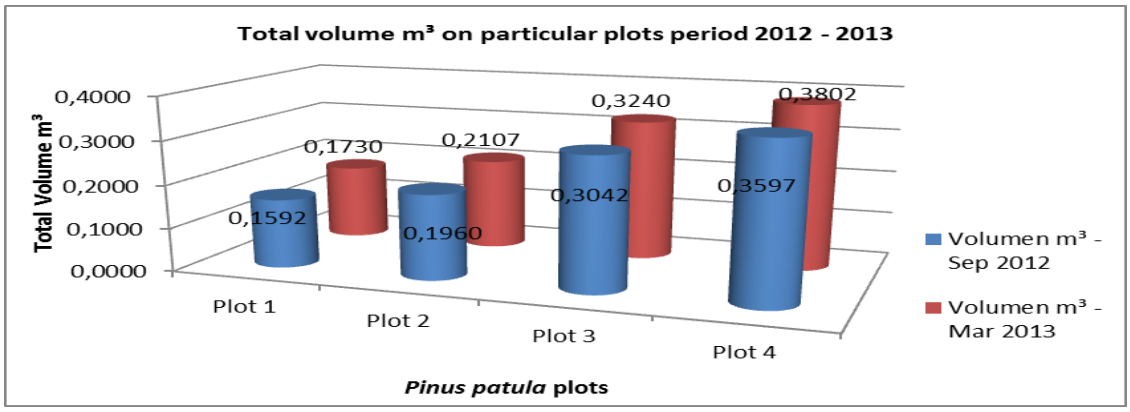
Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 12. Basal area m² on particular plots per tree, *Pinus patula* period 2012 – 2013



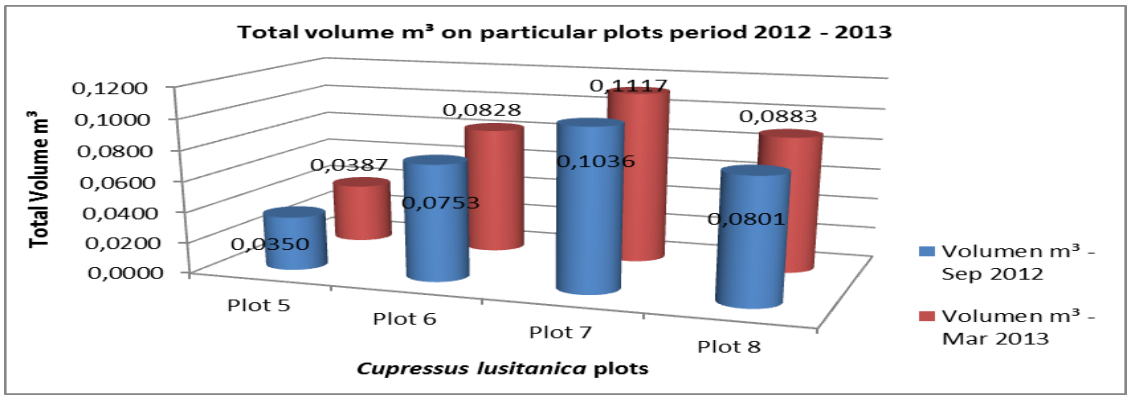
Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 13. Basal area m² on particular plots per tree, *Cupressus lusitanica* period 2012 – 2013



Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 14. Total volume m³ on particular plots per tree, *Pinus patula* period 2012 – 2013



Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 15. Total volume m³ on particular plots per tree, *Cupressus lusitanica* period 2012 – 2013

It is very clear evidence of the better development and adaptation of the species *Pinus patula* above of the development and adaptation of *Cupressus lusitanica*, the growing trend in height and diameter is greater, which leads to the result indicating that the increment in basal area and total volume is also greater. Regarding the population was the same of numbers of trees at the first measurement in each plot, as losses in population apparently occur in the establishment of plantations and planting distance is handled are crops that usually have no thinning before 7 or 9 years or depending on the final propose. Basal area yields and volume are significant and directly proportional to the height and diameter measurements.

The Graph 12 and Graph 13 illustrate the basal area increments of the *Pinus patula* and *Cupressus lusitanica*. Where increases in the period of six months according to the measurements were at 3,3% in *Pinus patula* and 3,6% in *Cupressus lusitanica;* the relative increases are greater in the species *Cupressus lusitanica;* since the plantation looks much better, but overall has a better force and development the *Pinus patula* plantation. The Graph 14 and Graph 15 illustrate the total volume increments in the two plantations, the increase compared to the previous measurement and directly

proportional to the result of basal area is expressed in the following form, *Pinus patula* 8% and *Cupressus lusitanica* 10%

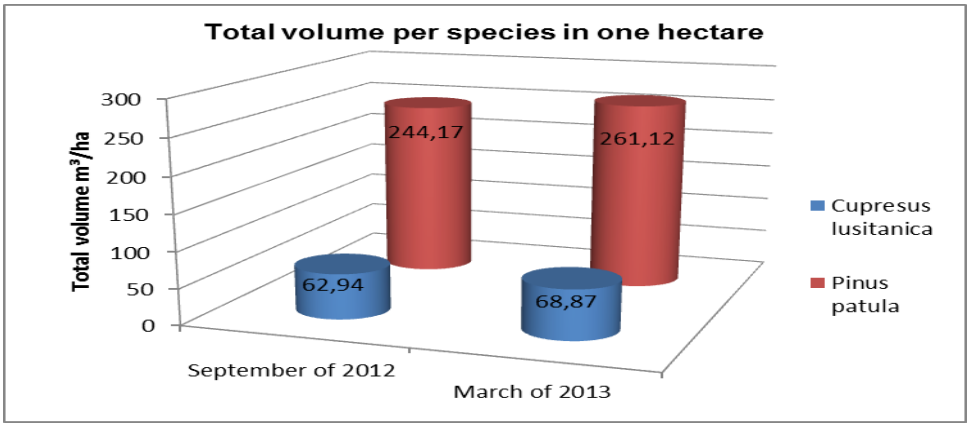
5.2.3. Comparative increase per one hectare in a period of six months

It is very important to establish the comparative development between the species objective of the study, with all the information gathered from the analyzed period of six months we proceeded to perform the respective calculations of increases in one hectare. In the next Table 27, is the description of the volume increases for plots and estimated a increases total volume in one hectare for the two species.

Table 27. Comparative increase of total volume per species in one hectare

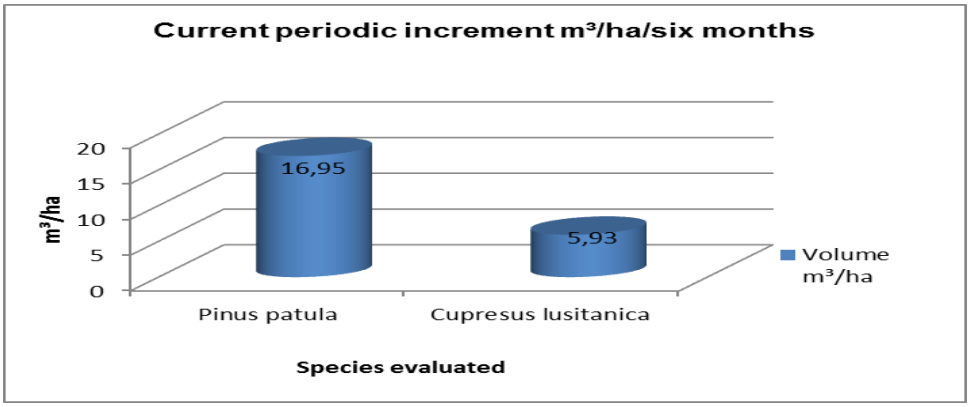
	Species	Total volume m³ ∑ Plots	Total volume m³/ha	Current periodic volume increment (Six months)	Percentage (%) of CPI/six months
05-sep-12	*Cupresus lusitanica*	12,73	62,94		
	Pinus patula	47,26	244,17		
09-mar-13	*Cupresus lusitanica*	13,93	68,87	5,93	8,61
	Pinus patula	50,54	261,12	16,95	6,19

Source: Omaira Silena Gil Vides, Colombia March of 2013



Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 16. Total volume m³/ha per species, in a period of six months



Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 17. Current periodic increment m³/ha/six months per species

In the previous graphs, Graph 16 and Graph 17, are reflected the total volume per one hectare in the both species evaluated, where the development of the *Pinus patula,* is significantly higher than the *Cupressus lusitanica,* starting from the point that the species were established in April of 2007. In the Graph 17 the comparison is made of the respective increments in a period between 5th of September 2012 and 9th of March 2013 in one hectare, where the *Pinus patula* showed an increase of 16,95 m³/ha and *Cupresus lusitanica* showed an increase of 5,93 m³/ha in a respective period of the six months according with the evaluation.

5.2.4. Results of volume calculations Smalian Formula

In the methodological part was referenced the use of this formula for a real volume of sampling trees on each plots per species.

Table 28. Calculations of volume by Smalian formula, *Pinus patula* Sep- 2012

Pinus patula - September - 2012				
No. Tree	Height m	D 1	D2	Total Volume m³
7	6,5	51,6	5	0,6860
43	3,3	22,3	5	0,0677
50	4,9	34,1	5	0,2286
93	8,6	53,1	5	0,9607
85	2,5	15,8	5	0,0270
88	5,5	33,7	5	0,2507
147	8	53,4	5	0,9037
133	4	25,7	5	0,1077
146	6	36,8	5	0,3250
179	9	52,9	5	0,9979
192	4	30,2	5	0,1472
185	6,5	38,1	5	0,3769

Source: Omaira Silena Gil Vides, Colombia March of 2013

Table 29. Calculations of volume by Smalian formula, *Pinus patula* Mar- 2013

Pinus patula - March - 2013				
No. Tree	Height m	D 1	D2	Total Volume m³
7	7	51,6	5	0,7388
43	3,5	22,3	5	0,0718
50	5,3	34,1	5	0,2472
93	9,3	53,1	5	1,0389
85	2,8	15,8	5	0,0302
88	5,9	33,7	5	0,2689
147	8,3	53,4	5	0,9376
133	4,3	25,7	5	0,1158
146	6,2	36,8	5	0,3358
179	9,6	52,9	5	1,0644
192	4,4	30,2	5	0,1619
185	6,9	38,1	5	0,4001

Source: Omaira Silena Gil Vides, Colombia March of 2013

Table 30. Calculations of volume by Smalian formula, *Cupressus lusitanica* Sep-2012

Cupressus lusitanica - September - 2012				
No. Tree	Height m	D 1	D2	Total Volume m³
3	4,5	27,1	5	0,1342
38	1,8	14,8	5	0,0173
21	3	21,6	5	0,0579
80	5,6	37,3	5	0,3115
96	1,6	16,4	5	0,0185
62	3,5	25,3	5	0,0914
115	5,8	37,2	5	0,3209
147	1,8	15,3	5	0,0183
137	3,8	25,3	5	0,0992
180	5	37,3	5	0,2781
199	1,7	16,2	5	0,0192
160	3,1	21,4	5	0,0588

Source: Omaira Silena Gil Vides, Colombia March of 2013

Table 31. Calculations of volume by Smalian formula, Cupressus lusitanica Mar - 2013

Cupressus lusitanica - March 2013				
No. Tree	Height m	D 1	D2	Total Volume m³
3	4,7	27,1	5	0,1402
38	2	14,8	5	0,0192
21	3,3	21,6	5	0,0637
80	5,8	37,3	5	0,3226
96	1,8	16,4	5	0,0208
62	3,8	25,3	5	0,0992
115	6	37,2	5	0,3320
147	2	15,3	5	0,0203
137	4,1	25,3	5	0,1071
180	5,4	37,3	5	0,3003
199	1,9	16,2	5	0,0214
160	3,3	21,4	5	0,0626

Source: Omaira Silena Gil Vides, Colombia March of 2013

In the above Tables 28, 29, 30 and 31, it is the description of the trees chosen with respective measure the samples are observed and the application of the Smalian formula, D1 is diameter at ground level and D2 is in this case the diameter in the top of the trees. Was estimated 5 cm of the smaller diameter in all samples; this formula is used in the locality for measurements of harvested timber, but is that used in the region to give estimates of real volume.

5.2.5. Results of volume increment in each plots per period

In the next Table 32 and Table 33, we can find the results of Stock Volume in each experimental plot in the period of six months between 5th of September 2012 and 9th of March 2013. The table also contains some basic statistical analysis and the differences between maximum and minimum volume values of all plots and percentage of different per six months period.

Table 32. Stock Volume and statistical results for each plot *Pinus patula*

Pinus patula		
Plots	**2012 Volume m³/plot**	**2013 Volume m³/plot**
Plot 1	7,64	8,3
Plot 2	8,81	9,47
Plot 3	13,99	14,9
Plot 4	16,82	17,87
Aritmetic mean	11,82	12,64
Standar deviatio	2,47	2,53
Variance	6,12	6,39
Maximun	16,82	17,87
Minimun	7,64	8,30
Difference	9,18	9,57
% of difference	54,57	53,64

Source: Omaira Silena Gil Vides, Colombia March of 2013

Table 33. Stock Volume and statistical results for each plot *Cupressus lusitanica*

Cupressus lusitanica		
Plots	**2012 Volume m³/plot**	**2013 Volume m³/plot**
Plot 5	1,64	1,81
Plot 6	3,69	4,05
Plot 7	3,72	4,01
Plot 8	3,68	4,06
Aritmetic mean	3,18	3,48
Standar deviatio	1,31	1,37
Variance	1,73	1,87
Maximun	3,72	4,06
Minimun	1,64	1,81
Difference	2,08	2,25
% of difference	55,91	55,41

Source: Omaira Silena Gil Vides, Colombia March of 2013

In the above Tables 32 and 33, it can be appreciated the increased volume in the studied plots, where is notorious a showing the better developing of *Pinus patula*, the increase is not equal in all areas, but in increase percentage per plots was between 7% and 10% for the studied period of six months not much difference between both species. Also the *Cupressus lusitanica,* has a greater increase 10% over the previous period, the stock of volume is in general higher but volumes and force of the plantation are lower than the *Pinus patula.*

5.3. Analysis of variance the statistical results between *Pinus patula* and *Cupressus lusitanica.*

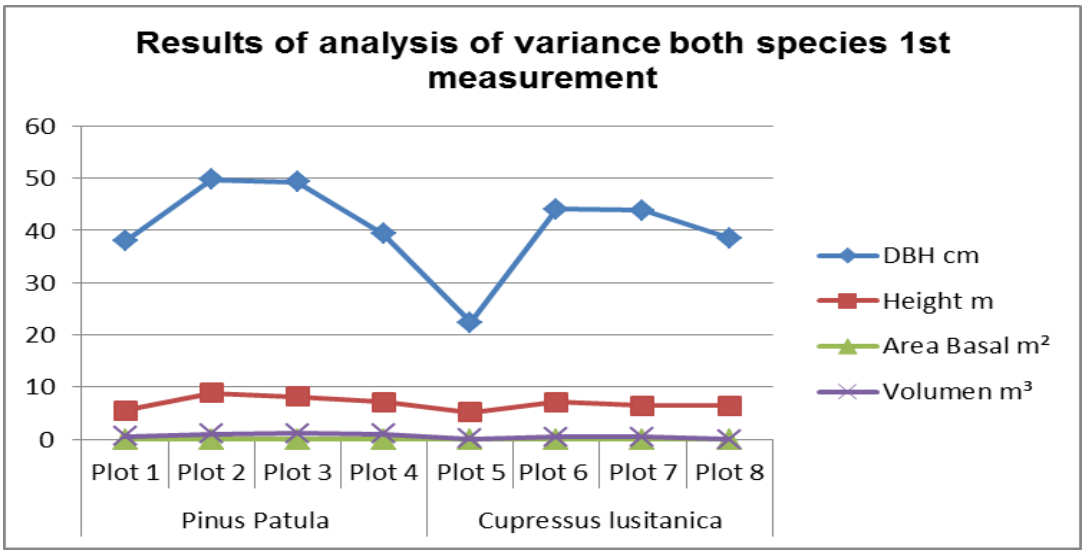
A large variance indicates that there is much variation between subjects, that there are greater individual differences than average; small variance indicates little variability between subjects, minor differences between subjects. The variance quantifies all that's

different between subjects or observations. The results of the two analyzed species are described below in the Table 34, Graph 18 for the first measurement 5th of September 2012 and the Table 35, Graph 19 for the second measurement on 9th of March 2013.

Table 34. Results of analysis of variance both species 1st measurement

		Measurement 5-Sep-2012			
		DBH cm	Height m	Area Basal m²	Volumen m³
Pinus Patula	Plot 1	37,95	5,58	0,00116	0,5619
	Plot 2	49,77	8,84	0,0016	1,0257
	Plot 3	49,34	8,2	0,00172	1,1232
	Plot 4	39,38	7,09	0,0014	1,0239
Cupressus lusitanica	Plot 5	22,42	5,22	0,00038	0,1378
	Plot 6	44,07	7,18	0,00097	0,3936
	Plot 7	43,81	6,46	0,00098	0,3999
	Plot 8	38,58	6,4	0,00083	0,0327

Source: Omaira Silena Gil Vides, Colombia April of 2013



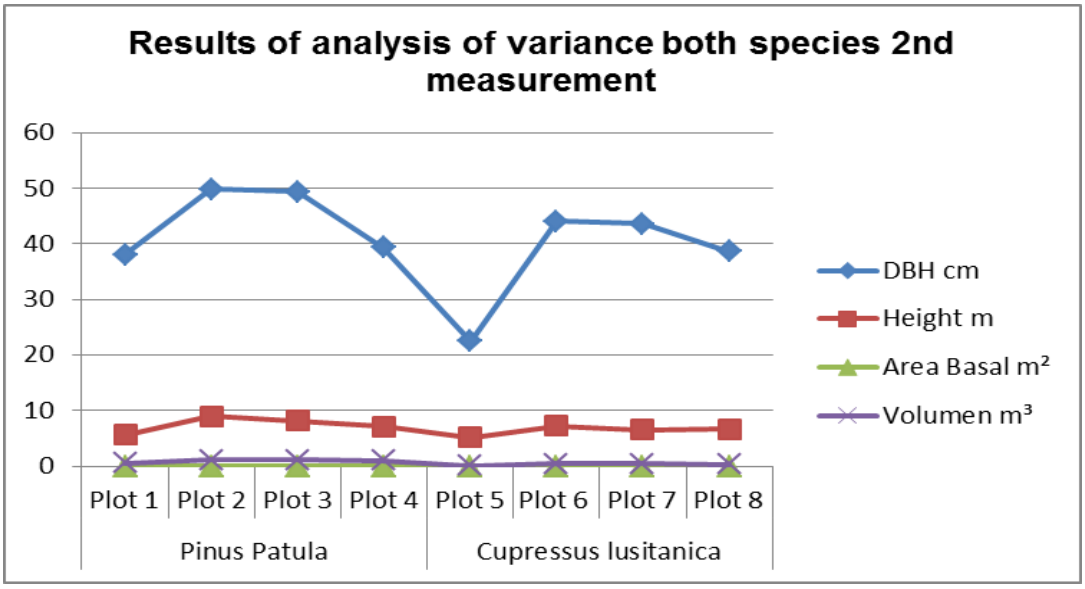
Source: Omaira Silena Gil Vides, Colombia April of 2013

Graph 18. Results of analysis of variance both species 1st measurement

Table 35. Results of analysis of variance both species 2nd measurement

		Measurement 9-Mar-2013			
		DBH cm	Height m	Area Basal m²	Volumen m³
Pinus Patula	Plot 1	38,05	5,64	0,00118	0,5888
	Plot 2	49,86	8,96	0,00163	1,1075
	Plot 3	49,44	8,23	0,00174	1,1787
	Plot 4	39,38	7,18	0,00142	1,0715
Cupressus lusitanica	Plot 5	22,49	5,22	0,00039	0,1485
	Plot 6	44,14	7,29	0,00099	0,4242
	Plot 7	43,66	6,56	0,00099	0,4236
	Plot 8	38,64	6,73	0,00084	0,3575

Source: Omaira Silena Gil Vides, Colombia April of 2013



Source: Omaira Silena Gil Vides, Colombia April of 2013

Graph 19. Results of analysis of variance both species 2nd measurement

It was found that the results of analysis of variance, expressed variation in the DBH and height, because the differences of diameters and sizes of the trees of the respective samples are significant, it is observed that there is no homogeneity in the growth and development of the parcels; in this case the differences are no differences between individual plots with identical media, but that the trees in each group are very different. The results found in basal area, total volume are directly proportional with the respective height and diameter of breast height.

With the analysis of variance found that if there were significant differences between the two species tested, as shown numerically in Table 33 and Table 34 and graphically in the graph 16 and 17. The biggest difference is in the plot 5 of the *Cupressus lusitanica*, With respect to that found in the other plots analyzed.

6. DISCUSSION

6.1. Comparative exotic species analyzed, *Pinus patula* and *Cupressus lusitanica*

The two species in this analysis are introduced or exotic in Colombia, but have been used in the last 50 years with purposes of industrialization of the forestry. Below the results of research and statistics data show the fate of these species in the country.

6.1.1. *Pinus patula*

It is one of the most widely introduced conifers that have spread across the Colombian Andes. The massive planting of the species that has been done in Colombia and elsewhere in the world is due mainly to industrial and commercial interest, since trees are uniform, grow quickly and wood has good quality, it is used for making paper pulp mainly. Estimated rotation period is between 10 – 20 years, average growth in Colombian plantations represents 30 m of height and 120 cm of diameter in sites that promote optimal development, the growth of this species is fast and in the early stages development can achieve annual growth of 1,5 m. of height. Increases in parcels established with good silvicultural practices and programs between 0,80 – 1,50 m. in high during the first 10 years and volume yields between 10 and 35 m³/ha/year. Typical species of monoculture practices with planting distances 2,5 x 2,5 m. or 3 x 3 m. These results are obtained from the company "EL SEMILLERO", dedicated to the sale and marketing of forest species in Colombia, exclusive representatives of "Seed Export", Forest Seed Bank "BSF" and "CATLE"

Table 36. Time performance of some forest species in Colombia and other countries

Coniferous	Country	Rotation period/years	Average annual increase (m³/ha/year)
Pinus tecunumannii	Colombia	16	30 - 40
Pinus radiata	Chile	20 - 25	10 - 25
Pinus spp.	Uruguay	20	16 - 23
Pinus patula	Colombia	16	16 - 30
Pinus spp.	Brasil	15 - 20	16
Pinus spp.	E.U.A. (southeast)	25	10 - 15

Source: CONIF 2002, CENPAPEL 2003

In the Table 36 is represented a comparison of coniferous species in some countries with forest tradition, where the principal emphasis is in the general standard about rotation periods and average in annual volume increase. Colombia in annual volumetric increase are between 16 – 40m³/ha/year, this increments with a rotation period of 16 years; figuring in this Table *Pinus patula*,this species have a national average between 16 -30m³/ha/year in a turn of rotation period of 16 years, as a competitive material. Estimates of the plots analyzed in the municipality of Matanza, in the trial Alto Bravo,

are not far from the national averages, in the Graph 17 represented the volumetric increase in the objective plantation when was 16,95 m³/ha in a period of six months.

Figure 10. Measurement in *Pinus patula* plots September of 2012. Source: Photo Archives Omaira Silena Gil Vides

Figure 11. Current status of the *Pinus patula* plantation on March of 2013. Source: Photo Archives Omaira Silena Gil Vides

Figure 12. Average growth of trees in the plantation March of 2013. Source: Photo archives Omaira Silena Gil Vides

Figure 13. Record measurement of soil conditions September of 2012. Source: Photo archives Omaira Silena Gil Visdes

The photographic record are seen the figure 10, 11, 12 and 13 where we can appreciate the development of the plantation status in September 2012 and the status in March of 2013, characteristics of health status and good management practices. When performing comparative yields tested and published for the company "EL SEMILLERO", it is noted that the yield for the species *Pinus patula*, is in the range of development and national average.

6.1.2. *Cupressus lusitanica*

Being considered as one of the most beautiful exotic woods in the international market and considering its ability to grow in the right conditions, which favors the permanent supply of raw material and thus the marketing of timber and end products at low prices, the *Cupressus lusitanica* is one of the most important forest resources in different economic countries and Colombia is not exception, having a small margin of this species. Thanks to the experiences worldwide for sustainable use of the species, it has been established that the *Cupressus lusitanica* offers a high potential for use in a diverse fields, such as industry, the ornamental designs and landscape management. This species also has the ability to help restore soil in which they have extreme alterations in their physical and chemical properties.

The species has an estimated rotation period between 18–25 years, growth of up to 30 m. of height and diameter between 50–80 cm in optimal sites for cultivation, with appropriate soil conditions yields were achieved between 15 and 30 m^3/ha/year. Does not compete well with weeds, especially grasses which is why it is recommended to perform cleaning duties on the plantation to prevent competition of the development of the trees. Typical species of monoculture practices with planting distances 2,5 x 2,5 m. or 3 x 3 m. But the amplitude of the tree crown for this plantations, it was concluded that the optimum planting distance is 4 x 4 m., slow development and growth in the first 5 years, beginning in pruning when the tree reaches between 5 and 6 meters. Results are obtained from the company "CIPRESES DE COLOMBIA S.A." Agribusiness Company belonging to the Organization Ardila Lulle dedicated to forestry and timber harvesting.

Table 37. Official registration of *Cupressus lusitanica* plantations in Colombia

Department	Hectares
Antioquia	6.612
Caldas	1.146
Cauca	216
Huila	186
Quindio	341
Risaralda	601
Santander	327
Total	**9.429**

Source: Cipreses de Colombia S.A - 2005

The Table 37 shows the national inventory of the species, Santander in the general location of the study has 327 hectares, is not too much because the most important development of this type of species is in Antioquia department. Values are far from national production and annual volumetric average increases in the Graph 17 represented the volumetric increase in the objective plantation when was 5,93 m^3/ha in a period of six months.

Figure 14. Image of soil structure in the plot 7 September of 2012. Source: Photo Archives Omaira Silena Gil Vides

Figure 15. Measurements in March of 2013. Source: Photo Archives Omaira Silena Gil Vides

Figure 16. Current status of the *Cupressus lusitanica* plantation on March of 2013. Source: Photo Archives Omaira Silena Gil Vides

In the previous photographs figure number 14, 15 and 16 shows some images of the real situation and current status of the plantation, it is a young plantation, established in sandy soil and in an area with a high degree of slope, factors that may negatively influence in the optimal development of the plantation. The company "CIPRESES DE COLOMBIA S.A." it is a private Colombian forestry sector company and its main objective was to study the establishment and development of the species *Cupressus lusitanica*, in their records the national average of volumetric increases are between 15 and 30m³/ha/year. By observing the data obtained from the measurements on the corresponding period of six months the plantation object of study is a little below the minimum range of national annual increments, as for the six-month period was 5,93m³/ha from September of 2012 to March of 2013.

7. RECOMMENDATIONS

7.1. Generalities

The introduced species conifers compared with native species have the ability to grow in adverse conditions or specific climate, thus in tropical countries as in the case of Colombia with having environmental conditions, brightness and variety of climatic zones, the development of these species is favorable and profitability with relation to the shift rotation is high. Usually the rotation periods in commercial forest species depending on the final use with the range between 8 years in the species like *Eucalyptus grandis* for production of paper and cardboard and between 12 – 18 years in coniferous species in which is located the *Pinus patula* and *Cupressus lusitanica*, for use in construction, production of furniture among many uses. While a native species as *Cedrela odorata*, *Quercus humboldtii*, *Swietenia macrophylla*, *Juglans neotiopica*, *Cariniana pyriformis*, between other have rotation periods in the Colombian framework development of approximately from 25 and 35 years, depending on the conditions and establishment region.

In the measurements made on the plantations under investigation in the municipality of Matanza, in the trial Alto Bravo, on the farm "Nuevo Campo" we found a standard average development for the *Pinus patula* species, agroforestry conditions have been planned, the plantation generally has a good health status. But there are conditions that can be improved in establishing plantations in the future in the region. The species established on the farm have a pivot root system; therefore the caution is not to establish such plantations near of the water sources. The plantation under study is a community project and has common interests and particular target by investors, because depending on the development and outcome of these first plantings is the possibility to establish in the region a significant numbers of hectares in the near future.

7.1.1. Suggestions for future plantations

Thanks to the cooperation and partnership between KFW (Kreditanstalt für Wiederaufbau) Germany´s Bank, Ministry of Colombian Environmental, the National Federation of Coffee in Colombia and monitoring by the Regional Autonomous Corporation of Santander, in the year 2007, in the Santander department was established a series of forest plantations in order to supply in the future the raw material, for the company of wood processing "MADECHARTA". Were established 334,5 hectares in 5 municipalities neighboring and all for the same purpose because they are located equidistantly from the processing plant.

The Matanza municipality has in the program 55,4 hectares, that's where it was conducted a comparative study of the species. In the Table 38 you can appreciate the inventory for the established plantations in the region in the year 2007.

Table 38. Inventory of plantations established in Santander 2007

Year of establishment	Municipality	Types of system				Total (HAS)	Number of Members
		Forest plantation	Agroforestry system	Establishment of degraded forest	Natural forest conservation		
2007	Tona	17	7		10	34	18
	Charta	25	29		20	74	18
	Matanza	**35,4**	**10**		**10**	**55,4**	**8**
	Surata	88,5	56	7	10	161,5	20
	California	10				10	3
	Total (HAS)	**175,9**	**102**	**7**	**50**	**334,9**	**68**

Source: CDMB - Regional Autonomous Corporation of Santander 2007

These programs were directed especially to forest protection and conservation of watersheds, recovery of degraded forest areas and to strengthen the conformation of forest cores in areas of influence for the program, contributing to the consolidation of productive forest use and employment generation to improve the living conditions of the rural population.

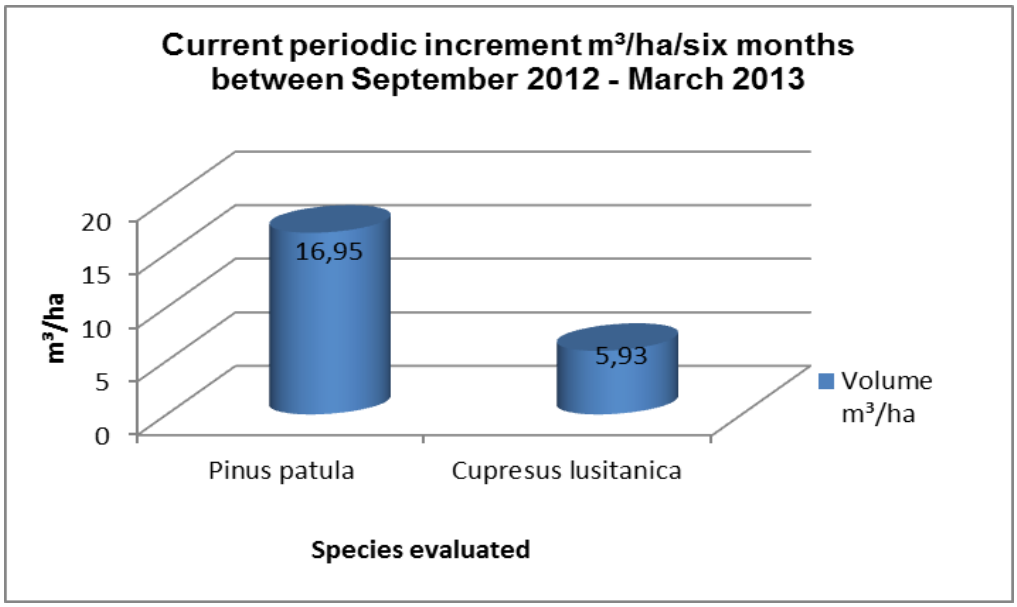
With the results obtained in our case of study it was found that *Pinus patula* is an interesting option for trading and with good management practices but the results can be much better. The establishment and silvicultural management of forest plantations in Colombia, it is an activity that involves a process of monitoring and cultural change in rural communities, beginning by changing thinking of rural users when the programs target them and have added a strategic plan of economic incentives as was this particular case. The Colombian forestry regulations at this time have strategic and economic plants incentives for farmers wishing to implement reforestation activities on their farms.

Many programs to establish forest plantations with exotic species as *Pinus patula* and *Cupressus lusitanica* for countries like Colombia are profitable for the environmental conditions, variety of thermal floors and hydric supply among many other factors. Starting from the point of view concerning by environmental management in the region where we carry out comparative studied of species, the conservation of natural resources and the imbalance that the introduction of these species can cause in to natural ecosystems is the main concern of farmers and the wider community. Therefore, the accompanying of technical assistance is vital to the establishment and development of future plantings, which should be handled factors ranging from selection of specifies site to plant, the characteristics of the relief which should take into account the slopes and primary care of water resources. The silvicultural management of plantations established includes all activities guaranteeing optimum establishment and seedling growth in a given time and ranging from seed collection until final harvest, for this case

includes all activities from the time of planting as one of the main indicators of survival percentage of the plantation, followed by appropriate management to clean, cultural practices, fertilization, phyto-sanitary control and others.

In the field it was observed that planting corresponding to the species *Pinus patula*, with a total of 4,78 hectares it has better performance in terms of average 30 cm of heights and development and increasing the diameter of the trunk with 0,31 mm of average in a period of six months; a difference to the plantation established with *Cupressus lusitanica*, with a total of 3,5 hectares present average heights between 24 – 26 cm and increasing the diameter of the trunk between 0,29 – 0,40 mm in the same time period and finally represented by a difference of volume between of the both species the 11,03m³/ha in the period of six months. What finally represents a significant difference in economic resources over a period of time because the increase in *Pinus patula* was 16,95 m³/ha and in *Cupressus lusitanica* was 5,93 m³/ha

In the Graph 20 Seen the different in total volume of cubic meters for the both species in the same time period of six months between September of 2012 and March of 2103, when the *Pinus patula*, present better development and increase.



Source: Omaira Silena Gil Vides, Colombia March of 2013

Graph 20. Increment of total volume m³/ha in six months between September 2012 and March 2013.

The suggestions made are based on the results obtained in the analyzed zones for improvement of future forests development, considering legal and development aspects of the region where the research was conducted.

So are taken into account the following issues: The source of information of the following programs is suggested by Ministry of Agriculture and Rural Development in Colombia, for the program "Sector forestal en Colombia". 2010

- **Conservation of natural forests**

The incentive program in Colombia consists into keep and protects areas of natural forest that people own on their properties, this program makes five annual payments to the owners, the values are estimated per hectares and involved lots from 5 to 40 hectares. Payments are made per hectare per year are estimated in €120.

- **Establishment of forest on degraded areas**

The program seeks to establish native trees species in areas where forests have been fragmented by indiscriminate logging and flooding in order to maintain and preserve sources of water supply for urban and rural population and also to the agroindustrial production systems.

Only is allowed to plant native species, due to those are to sites where the main objective is the preservation of diversity, it should be planted with a density of at least 120 trees per hectare where distances between trees cannot be less than five meters. During the five years program, the payments will be: for the first two years every six months which will be for the establishment and maintenance of the plantation and from the third year the payments will be annually. To obtain to these payments is necessary an inspection from the government who certifies the work is done within the plantations purpose.

- **Establishment of agroforestry systems**

Silvopasture system, mixed between trees and grass, it improves pasture, establishes edge for paddocks division, proteins banks, among others purposes. This forestry program requires to plant species suitable on forage production, providing shade to the cattle, fixing nitrogen in the soil and that at the end of productive cycle it could be cut to obtain wood. System also used in combination with agricultural crops, the most notorious example in Colombia, is the establishing timber trees in cocoa and coffee crops, species are selected according to site conditions and compatibility with the crop.

- **Forest plantations**

The National Government with it insignia program, is aimed to incentive the planting, established and maintenance of forest plantations during the first five years but producers must ensure the purpose of planting, which is to produce wood for the continuous supply of the country's timber sector. The program has a five years period, the first two years are paid every six months, to establishment and maintenance of the plantation, for the next three years the payments will be annually. To obtain to these payments is necessary an inspection from the government who certifies the work is done within the plantations purpose. The establishments of these programs works mainly with coniferous species, considering that are foreign species but with a quick and easy adaptation to the climatic and topographic conditions of the region; besides giving better yields in shorter rotation periods, the rotation and capital income is higher for the volumes that can be obtained in less time than with native species.

7.1.2. Suggestions for healthy status and damages

Overall health status of the plantation is very good, until now neither of the two species has been affected by disease, insects or fungi attacks, but must take into account in the region under study there are indications to isolated attacks of *Fusarium spp.* and *Pythium spp.* These kinds of fungi attack in ascending form the trees to kill the whole tree; from the root system to the top of the tree.
Some causes for this are present is excess moisture and lack of management in the plantation. The symptoms are yellowing of the tree foliage until you feel its full drying; the suggestion by technicians and specialists is to take corrective and preventive measures at the right time because these fungi are easily expanded throughout the plantation.

In the following photographs are seen attacks of these pathogens.

Figure 17. Appearance of wood affected for fungus. Source: Photo Archives Ing. Cesar Rogelio Anaya Herrera

8. CONCLUSION

According to FAO projections, it is anticipated that in the future the demand for wood will be met by forest plantations due to environmental pressures that have made efforts worldwide which are seriously aimed at reducing of the logging of natural forests, improve logging practices, reduce illegal forest activities and strengthen ordination community forestry.

The objectives outlined in the beginning of the study were met.

1. It was determined that the region has favorable conditions for the development of forestry projects but the owners have some misgivings for this kind of plantations because the environmental impacts of monocultures, which are harmful to biodiversity, water cycle and native species, are very evident in foreign pine plantations.

2. The respective measurements were performed, one in the month of September 2012 and the second in March of 2013 with the collaboration of the Forestry Engineer Cesar Rogelio Anaya Herrera. With measurements it was established the increase for make the comparative performance of the two species tested.

3. One observation is that plantations are established should have the ideal conditions for development, in the case of *Cupressus lusitanica*, it was established on land with a slope greater than 30% and in a sandy soil. Conditions that significantly disadvantage the ideal development of this species; otherwise than that seen in the establishment of the *Pinus patula.*

4. The species with greater adaptation and development was *Pinus patula*, with yields that are commensurate the national annual average in increase of volume and height.

5. One conclusion that could be established is that the owners of farms and farmers in the region have a clearer idea of timber production in a short time and to form and organize a production centers for the wood processing center “MADECHARTA”.

6. To date there are no large forests established to ensure the continuity of industrial timber processes in the region, therefore there is a great business opportunity by increases that can be obtained over a period since 8 to 16 years depending on the ultimate purpose of wood use.

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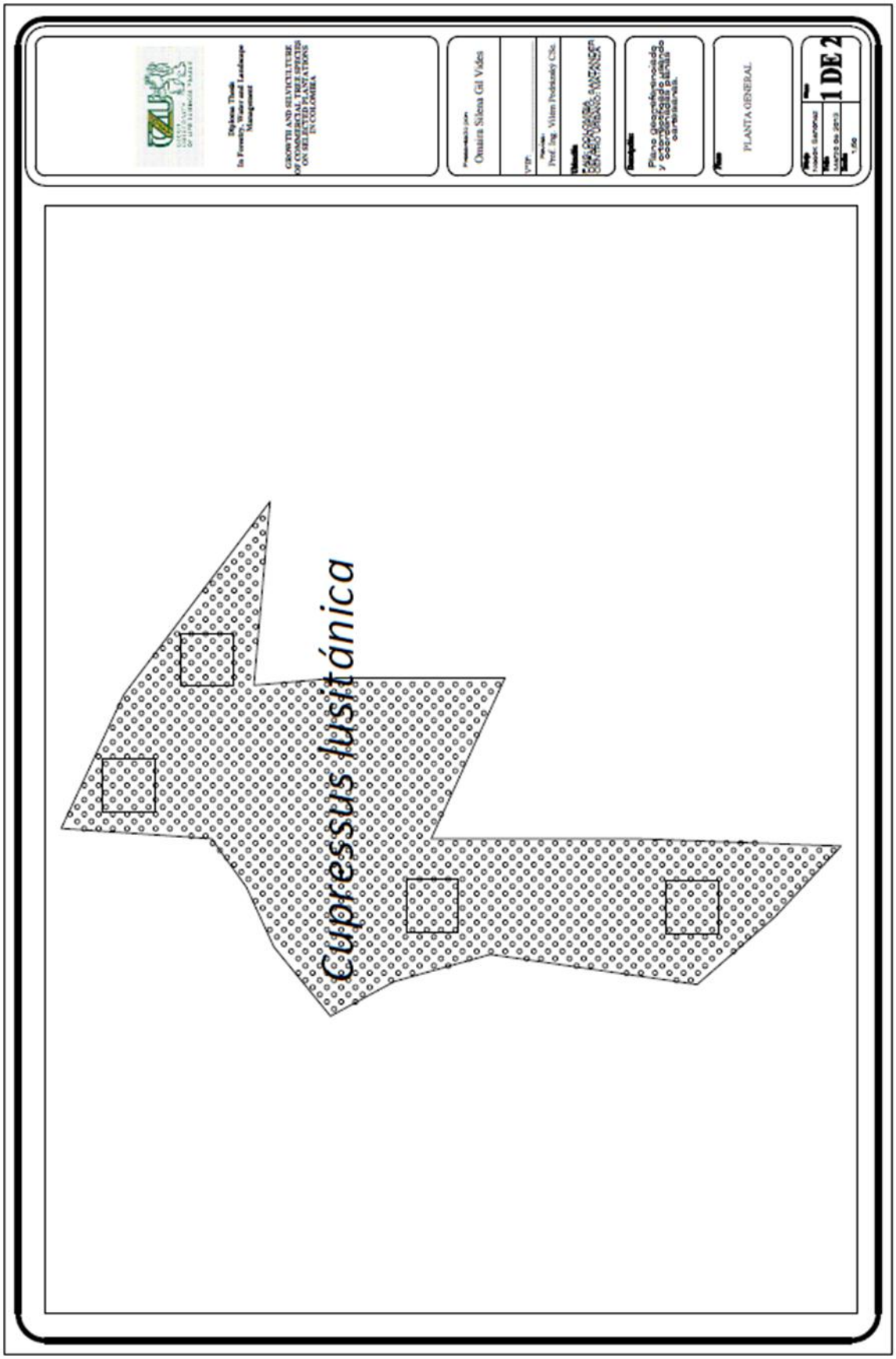
10. ANNEXES

Annex 1. General map of the location of the farm Nuevo Campo, municipally of Matanza, department of Santander, Colombia.

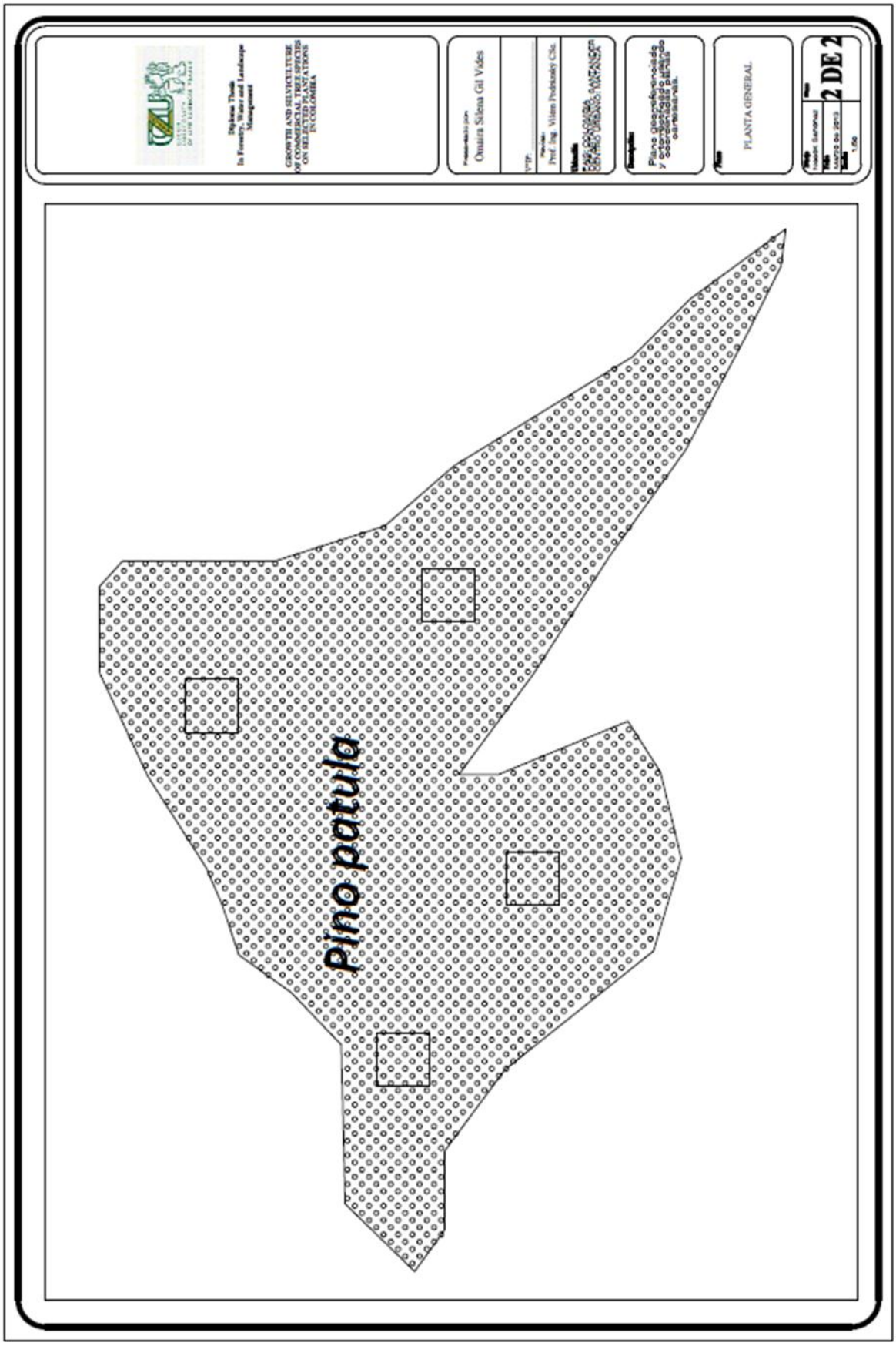
Annex 2. Map of plot planted with *Pinus patula,* highlighted experimental plots.

Annex 3. Map of plot planted with *Cupressus lusitanica,* highlighted experimental plots.

Annex 4. Map of planting initial design in the parcel of *Cupressus lusitanica*



Annex 5. Map of planting initial design in the parcel of *Pinus patula*



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