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Diversity and regeneration status of native woody plants species under Eucalyptus and Cupressus plantation forests around Jimma town, Oromia Regional State, Southwest Ethiopia

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Acronym/Abbreviation

AFR	African Forest Landscape Restoration
AEs	Area Enclosures
CRGE	Climate Resilient Green Economy
CSA	Central Statistics Agency
EFAP	Ethiopian Forestry Action program Commission
FAO	Food and Agriculture Organization
FDRE	Federal democratic republic of Ethiopia
FRA	Forest Resources Assessment
GLI	Green Legacy Initiative
GTP	Growth and Transformation Plan
IPBES	Intergovernmental Platform for Biodiversity and Ecosystem Services
MOA	Ministry of Agriculture
MoFECC	Ministry of Environment, Forest and Climate Change
SLM	Sustainable Land Management
SWC	Soil and Water Conservation
WANRMO	Woreda Agricultural and Natural Resource Management Offices
WCMC	World Conservation Monitoring Centre
UN	United Nation

Abstract

Plantation forests are man-made forest ecosystems, established by planting or seeding, which helps in the process of afforestation and reforestation. Native plants are plants that have been growing in a particular habitat and region, typically for thousands of years or longer. The main aim of this research was to assess the effects of Eucalyptus and Cupressus plantations on native woody plants species diversity and compare natural regeneration status under those plantation forests. The study was conducted around Jimma town. A plot sampling method was used to gather vegetation data from quadrats measuring 20 m × 20 m at intervals along a 100 m transect line. The collected plant specimens' identification was carried out both in the field and later in the Herbarium. The Shannon diversity (H') and evenness (E') indices were calculated as a measure to incorporate species richness and diversity. The regeneration status of the two forest stands was also assessed by computing density ratios between seedlings and saplings and trees individuals. The height classes for seedlings (< 0.5 m), saplings (0.5 m – 2 m) and trees (> 2 m) was used to categorize plants height structure. Those Species which possess high number of individuals in the lower height classes, particularly in the first class, were considered to have good regeneration potential. In total, 42 species of native trees and shrubs representing 21 families, 38 species of native woody plants in the Eucalyptus plantation and 36 species under Cupressus plantation were recorded. 20 species of trees, 15 species of shrubs and 7 species of shrubs / or small trees were recorded. Based on values from Shannon – Wiener's diversity index, the diversity of species was higher in Eucalyptus vegetation (1.3) than Cupressus (1.2). The evenness value for plants under Cupressus forest was similar with Eucalyptus. A two-sample t-test was used to compare the means of native wood plants under Eucalyptus and Cupressus plantations, to determine if they are significantly different from each other. Since the p-value is less than the typical significance level, the result indicated that the type of plantation exerts an influence on the presence or abundance of native plants. The vegetation structure of native woody plants in both plantations showed that the seedling and sapling classes were relatively dominant. In general, under Eucalyptus plantations 24 species of and under Cupressus plantations 25 species of native woody plants were regenerated naturally. Exotic trees hinder native plant regrowth by outcompeting them for resources, producing chemicals that inhibit growth, altering soil and microclimate conditions, displacing native vegetation, disrupting mutualistic relationships. The study therefore suggests that introducing diverse native trees, optimizing light, managing plantation density, promoting natural regeneration, and fostering stakeholder collaboration to enhance biodiversity and ecosystem resilience in plantations, supporting native plants and broader conservation aims.

Key Words: Exotic plants; Native woody plants; Regeneration; Diversity; Plantations forest.

1. INTRODUCTION

1.1. Background of the study

A Plantation forest is a cultivated forest ecosystem grown by planting and/or seeding, which realizes the effort of afforestation and reforestation (FRA, 2012). Plantation is a forest mostly composed of trees, where the planted trees constitute more than half of the growing stock when matured (FRA, 2015). According to Grotta (2019), plantation forest is a type of managed forest in which, usually trees are planted, of the same age and generally of the same species. The main shared characteristics of these definitions point to forested areas that are artificially established by planting or seeding. The two main approaches or strategies of forest plantations are Afforestation and Reforestation. Afforestation means planting trees on sites not planted in recent history, (half a century or longer) on the other hand reforestation deals with planting of trees in more recently deforested areas (Hamilton et al., 2010) usually indigenous plants are used in reforestation.

It is well known that tree plantation helps fight many Ecological problems like deforestation, erosion of soils, desertification, global warming and thus improving the beauty and balance of the environment. Restoring forests can fight climate change, uplift communities and rehabilitate biodiversity. Most planted forests around the world are monocultures with exotic species, but mixed-planted forests are increasingly established (Paula, et al. 2020). In comparison, exotic plants can be invasive; introducing them into a new location can't be predicted and is sometimes dangerous. Additionally, exotic species can sometimes be vulnerable to large outbreaks of insect pests and diseases (Carn et al. 2009)

In other hand Native plants are plants that have been growing in a particular habitat and region for a long period of time. Native plants are also known as indigenous; they are highly adapted to the physical conditions of their particular ecosystem (Leopold and Donald, 2005). They form favorable habitats for wildlife in the area and support the food web by supplying food for wildlife. To encourage the growth of native ecosystems, many environmentalists recommend only local native trees to be planted. Regeneration of native woody species under the canopy of exotic tree plantations could be reduced. This is mainly of plants competing for natural resources, and this could in turn create nutrient and water shortages in communities that are particularly native species (Bernhard-Reversat, 2001).

1.2. Statement of the problem

Indigenous species have evolved in their place of origin over millennia and have built up a resistance to current diseases. Beyond their usefulness as sources of timber, fiber and fuel, they play critical and multiple roles in Creating biodiversity, regenerating basic natural resources such as water and soil, and providing ecosystem services.

There are many reasons why, Ethiopia's native trees are at risk of extinction. They have been dismantled without reforestation, which could lead to the disappearance of some species, while other threatened tree species suffer from deforestation. Historically, the country is engaged in various re-vegetation projects and plans to disseminate best practices. Tree afforestation attempts in Ethiopia were usually monocultures of exotic plants species such as *Eucalyptus camaldulensis, Eucalyptus globulus, Cupressus lusitanica, Pinus patula, Casuarina cunninghamiana, Pinus radiata* and the native plants *Juniperus procera.*

Several researchers have contrasted plantations of exotic species with natural forests in their studies to evaluate their impacts in naturally regenerated native species. Few studies have been conducted to compare native species diversity and regeneration capacity under different exotic species plantation forests. Consequently, there exists a knowledge gap and clear understanding regarding the issue. Therefore, the main aim of this research was to study and compare the effects of Eucalyptus and Cupressus plantation species on the regeneration and diversity of native woody plant species.

1.3. Research question

1. What is the diversity of native woody plant species under Eucalyptus and Cupressus plantation forests?
2. What is the natural regeneration status of native woody plants under Eucalyptus and Cupressus plantation forests?
3. What is the relationship between the type of plantation species and native plant biodiversity regeneration under both plantation forest types?

1.4. Objective of the study

1.4.1. General Objective

The general objective of the study was to study the native woody plant species diversity and regeneration status under Eucalyptus and Cupressus plantation forests

1.4.2. Specific objectives

- To study the diversity of native woody plant species under Eucalyptus and Cupressus plantation forests.
- To study naturally regenerated native woody plant species composition and density in Eucalyptus and Cupressus plantation forest
- To compare the naturally regenerated native species plants under both plantation forests.

1.5. Significance of the study

This study offers crucial insights for informing conservation and management strategies aimed at bolstering biodiversity and ecosystem resilience within plantation landscapes. Efforts to optimize light conditions, manage species density, and promote diverse vegetation communities are essential for fostering healthier and more sustainable plantation ecosystems in the future

It can help for trees-based sustainable forest management. Baseline information on the practice, attitude and perception of the importance of prioritizing native trees in the national tree plantation programs of Ethiopia. It will also provide necessary information for authorities to work on forest plantation management program. Finally, it can be referenced by other researchers interested in carrying-out studies on the current community perception, attitude and practice of forest conservation.

2. LITERATURE REVIEW

Sometimes the only alternative in restoring forest landscapes is planting trees, especially on very badly degraded landscapes. Depending on whether it is both productive and ecologically desirable a tree species can be selected, and in some cases one function, either productivity or environmental functionality, may be desired. The extent of forest plantations has increased by more than half over the last 25 years (Mac Dicken, 2015). Because of their economic role, there are indications that the area of forest plantations will continue to increase. The establishment of forest plantations was often based on exotic species. In 2010, 117 nations, representing 67% of the total global forest area, reported using exotic economic species in planted forests (FAO, 2010). However, exotic species can be difficult to control (Niskanen and Saastamoinen, 1996) and their impacts on biodiversity conservation and recovery have been viewed negatively (Makino et al., 2007).

As the area of degraded lands expands, there is a greater need for the restoration of forests to get benefits from the tree products (fuel wood, timber, leaf mulches, etc.), and for their ecological effects, for example, nutrient recycling, or attracting birds and other wildlife to the landscape. Loss of soil fertility, soil compaction, colonizing grasses and other vegetation can be serious obstacles to natural plant regeneration. Within a forest landscape, the preferred choice for restoration would be natural regeneration. Planting would only be a secondary option, to be used in cases where natural regeneration cannot proceed due to obstacles such as poor soil conditions, seed sources being far away, habitat isolation, and colonization by aggressive grasses (Montagnini, 2005).

Plantations trees use for the production of wood and fiber, and also could provide several other ecosystem services, such as clean water production, carbon sequestration, regulation of the hydrological cycle and improvement in the connectivity of landscape features for biodiversity conservation and the prevention of desertification (Bauhus, et al., 2010). Globally in 2012, 46.3% of industrial round-wood comes from planted forests (Jürgensen et al., 2014).

2.1. Ethiopian forest plantation past and present

Ethiopia, renowned for its rich biodiversity and diverse ecosystems, struggles with formidable ecological challenges, major ones among them being widespread land degradation. According to research findings, more than 85% of Ethiopia's land area suffers from varying degrees of degradation, presenting a critical threat to the country's environmental sustainability and socio-economic development (Gebreselassie et al., 2016). In response to this pressing issue, Ethiopia has embarked on ambitious afforestation endeavors dating back to the late 19th century. These initiatives, aimed at combating deforestation and addressing the acute shortage of firewood and lumber, have seen the widespread establishment of monoculture plantations, notably featuring Eucalyptus species, which collectively span over 12 million hectares worldwide (Békélé, 2003).

However, despite the scale of these afforestation efforts, monoculture Eucalyptus plantations have attracted significant criticism from environmental experts and researchers. Concerns primarily revolve around their potential to suppress native vegetation and adversely impact biodiversity conservation efforts. This criticism underscores the need for a nuanced approach to afforestation, one that balances economic imperatives with ecological sustainability (Evans, 1992; FAO, 2001). In the Ethiopian context, the popularity of Eucalyptus as a plantation species is driven by its rapid growth rate and economic viability. Farmers often opt to cultivate Eucalyptus trees due to their ability to generate income, which serves to cover various expenses, including government taxes, school fees, and donations to social organizations (Zerga and Berta, 2016). Consequently, the cultivation of Eucalyptus has expanded beyond state-owned enterprises to encompass community forests and agricultural lands, contributing to both economic livelihoods and environmental transformations (Aramde et al., 2013).

Beyond Eucalyptus, Ethiopia also hosts plantations of other exotic species, such as Cupressus, which find applications in construction, furniture making, and various other industries. However, the proliferation of Cupressus plantations has not been immune to criticism, particularly regarding issues of high shading conditions and slower litter decomposition, which impede the natural regeneration of native vegetation. These challenges highlight the complexities inherent in balancing the economic benefits of plantation forestry with the imperative of preserving native biodiversity (Tesfaye et al., 2020).

Research studies indicate that Eucalyptus plantations may offer a higher level of woody species diversity compared to Cupressus plantations. Despite this, concerns persist regarding the broader ecological impacts of monoculture plantations and their potential long-term ramifications for ecosystem resilience and sustainability (Bekele, 2018).

In combination with afforestation efforts, Ethiopia has also implemented initiatives aimed at addressing deforestation and land degradation, including participatory forest management and community-driven soil conservation and tree planting programs. Notably, recent endeavors like the Green Legacy Initiative have garnered significant public participation, signaling a collective determination to confront environmental challenges head-on (Ali, 2022).

Nevertheless, the continued degradation of Ethiopia's natural forests, which harbor a wealth of biodiversity, remains a pressing concern. Historical trends indicate a substantial decline in forest cover over the years, posing existential threats to endemic species and ecological stability (EFAP, 1994). As such, there is an urgent need for holistic strategies that prioritize both conservation and sustainable land management practices.

While afforestation efforts represent a critical step towards mitigating land degradation and combating deforestation in Ethiopia, the journey towards environmental stewardship is multifaceted and complex. Balancing economic development with ecological sustainability necessitates a nuanced approach that acknowledges the interconnectedness of socio-economic and environmental dynamics.

2.2. Why exotic trees?

The vast majority of plantations worldwide are monocultures, in which only a few tree species (*Eucalyptus, Conifers and Tectona*) are widespread (FAO, 2001; Evans and Turnbull, 2004). However, monocultures have been subject to critic for their unpleasant impact on the local ecology and services (Lamb et al., 2005) and for their poor ability to provide many of the common forestry goods used by local populations (Evans, 1999).

Nowadays, smallholder farmers have the largest area of Eucalyptus plantations which is more than 0.5 million ha in East Africa (Getahun, 2010). It is often much more profitable to plant fast-growing species, such as Eucalyptus and Cupressus trees because of the growing demand for construction material and fuelwood, due to the growing population and decline in agricultural farmland high productivity plants as a crop leads to the increased plantation of Eucalyptus trees by smallholder farmers (Bekele, 2015). Major reasons of supporting Eucalyptus production include: they grow fast; they need minimum care; they grow in varied ecological regions and degraded environments; they coppice after harvest; are resistant to environmental stress and diseases; their seeds are easy to harvest, store and no extra treatment treatment is needed (FAO 1979; Zerfu 2002; Mekonnen et al. 2007; Nduwamung et al).

2.3. Benefits of planting native trees

Using native rather than exotic species has numerous advantages, including: 1) better adaptation to environmental conditions and helps improve soil; 2) Propagules are locally available; 3) protect genetic diversity and 4) provide resources for local wildlife (Montagnini, 2005). As indicated in some studies, species diversity and species richness increased with the decreasing in Eucalyptus stands and vice versa. The densities of naturally regenerated woody species showed a decreasing trend with the increase in the density of Eucalyptus plantation and vice versa. Therefore, the density of Eucalyptus plantations was negatively correlated with the density of naturally regenerated woody species (Homma, 2008).

2.4. Regeneration of native woody plants

Regeneration is an essential part of the dynamics of any forest ecosystem and also regulates the existence of species and the restoration of degraded forest areas (Malik and Bhatt, 2016). Sustainable management and use of forests would be possible if sufficient knowledge about. Regeneration dynamics and factors affecting important forest cover types were available (Tesfaye et al., 2010). Consequently, an assessment of population structure and regeneration status is required to establish an effective forest resource base for protection and conservation management (Teketay et al., 2018) but a small number of seedlings and seedlings of this species exhibit poor health and regeneration (Tripathi and Khan, 2007). The population structure can show whether there is a sustained recovery and a stable population. Studying the population structure patterns of species can provide important information about recruitment status and sustainable population management. It provides evidence for other planning and conservation strategies and helps to recognize forest ecosystems and biodiversity (Wadt et al., 2008).

Even though natural resources in Ethiopia have great contribution to development, most of natural resources are highly exposed to degradation (Teketay, 2001). Over the last 3,000 years, there has been progressive deforestation, Rapid population growth, extensive forest clearing for cultivation, overgrazing, movement of political centers, and exploitation of forests for fuel wood and construction materials drastically reduced the forest area to 16 percent in the 1950s to 3.1 percent by 1982 (FAO, 2001).

In contrast, some studies showed that (Lugo, 1997; Moges, 1998; Engelmark, 2001; Yirdaw, 2002; Senbeta et al., 2002; Lemenih and Teketay, 2004; Lemenih et al., 2004) Plantations can have a catalytic effect on the regeneration of some species and can be used as a management tool for restoration of degraded lands. Recent research on tropical forest plantations indicates that plantations may enhance the recruitment, establishment and succession of native woody species by functioning as foster ecosystems (Lugo et al., 1993; Otsamo, 2000). Usually, high valued native trees used in local tree planting programs are late-successional plants. However, late-successional species usually cannot survive the environmental stress associated with open-field plantation such as high insolation, dry and degraded soil conditions (uhl et al., 1988).

3. MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted in a plantation forest around Jimma town, southwest Ethiopia. The area is found 352 km Southwest of Addis Ababa, with an average elevation of between 1718 and 2000 meters above sea level has an average temperature that ranges from 12.32 to 28.54°C and an annual rainfall that ranges from 800 to 2000 mm Average annual precipitation of 91.72m (CSA, 2015).

The study site is part of a government-owned plantation forest, which extends from around Beda-Buna (Merewa) to Jiren area, covering an area of approximately 7.5 km^2 to the east of the town. The study site is a mountainous plantation area, which had diverse landscape features, extending from gently sloping to very steep gradient. Based on observed facts, the study region is characterized by diverse landscape features ranging from steep slopes to plain fields. The plantation forests include trees of different ages.

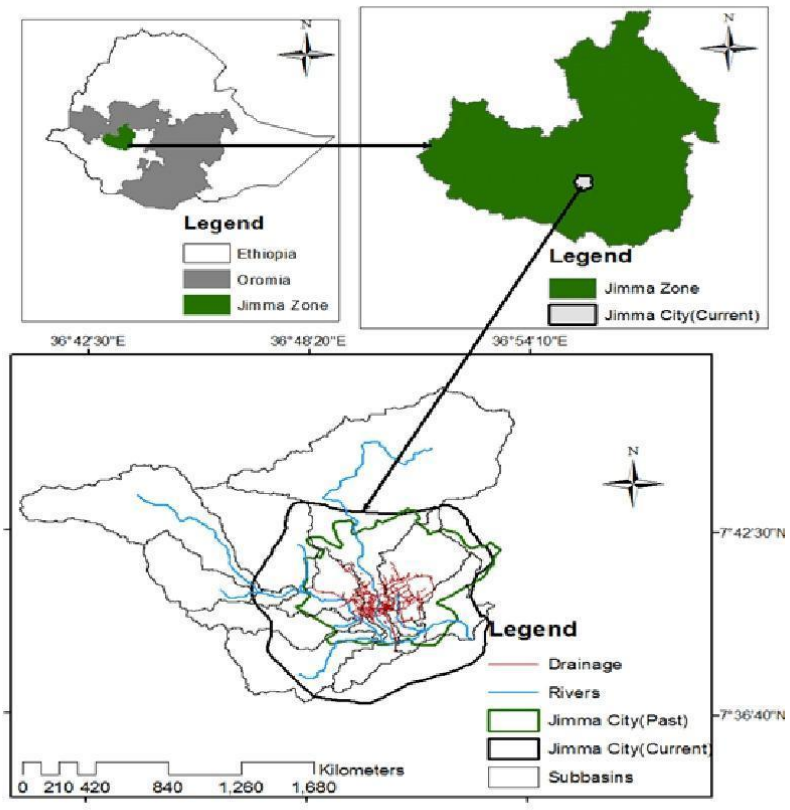

Figure 1 Location map of study area from Oromia region to Jimma town

(Image source: www.researchgate.net)

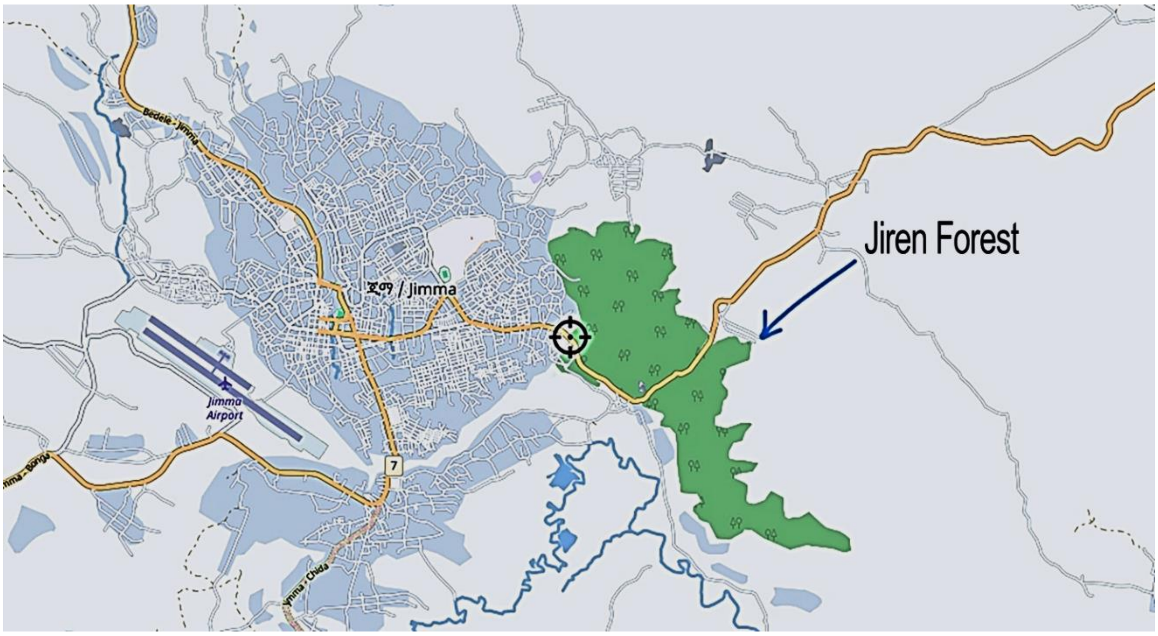

Figure 2 Location map of the study area around Jimma town

(Image source: GloVis)

3.2. Study Design

Reconnaissance survey of the study area was conducted prior to the actual data collection. Ground and topography survey was conducted to obtain information on the general pattern of plantation forest and decide where to place the transect lines for the actual field data collection. The ground survey involved physically exploring and mapping out the terrain, while the topography survey focused on understanding the natural features and elevation variations within the study area. A quadrat sampling method using a measuring tape was employed. Vegetation data was collected from 42 plots of size 20 m X 20 m, which were established at 20m intervals along 100 m transect line. Each transect line was a 1 – 3 kms apart from each other.

The reconnaissance survey conducted prior to the data collection was essential for understanding the study area's characteristics and planning the fieldwork effectively. Ground and topography surveys provided crucial information about the terrain, vegetation distribution, and elevation changes, which helped in determining suitable locations for transect lines and sampling sites.

During the ground survey, researchers physically explored the area, mapping out various features such as slopes, soil types, and vegetation cover. This hands-on approach allowed them to gain firsthand knowledge of the study area's landscape, which informed decisions about where to place transect lines for later data collection.

Simultaneously, the topography survey focused on gathering data related to natural features and elevation variations. This involved using specialized equipment to measure elevation levels at different points across the study area. Understanding these variations was essential for selecting representative sampling sites and ensuring that data collected would accurately reflect the area's diversity.

The quadrat sampling method, using a measuring tape, was selected for its efficacy in systematically gathering vegetation data by measuring the plot area and plant height. Transect lines were established at intervals, and quadrats were placed along these lines to divide the study area into manageable plots for data collection. This approach allowed researchers to gather detailed information about vegetation composition, density, and distribution patterns within the study area.

Overall, the reconnaissance survey, ground survey, topography survey, and quadrat sampling method were integral components of the data collection process, enabling researchers to obtain accurate and representative data for their study of the plantation forest ecosystem.

3.3. Data collection and identification

All native woody plants species on native woody plants under Eucalyptus and Cupressus plantations were collected and recorded. A quadrat sampling method with the help of a measuring tape was used to gather vegetation data from quadrats measuring 20 m × 20 m at intervals along a 100 m transect line. Plots arranged sequentially to show the progression of changes, allowing for easy comparison and identification of patterns or trends. Collected specimens were identified both in the field and later in the herbarium. Height of native woody species was measured from 20 m × 20 m. Regeneration of native woody plant density was assessed in contrasting quadrats the main quadrat, sub quadrat and mini quadrat; plants were categorized as seedling, sapling and trees.

- For seedling class data, subplots (2 m × 2 m) containing individual woody plant species ≤ 0.5 m in height were collected (Chauhan et al., 2008)
- For sapling class data, the sub-plot of (5 m × 5 m) which had individual woody plants of height 0.5 m – 2 m and DBH of < 10 cm (about 3.94 in) were recorded.
- For trees class data, native woody plants were collected from a height of > 2 m and a 20 m x 20 m with a diameter at breast height of 10 cm (3.94 in).

Keys and descriptions of taxa in the Flora of Ethiopia were used to verify the identification. Voucher specimens were collected, numbered, pressed and taken to Jimma University Herbarium, for drying, identification and storage.

3.4. Data analysis

Analysis of native trees species diversity was determined by calculating Shannon diversity and evenness index. The population structure pattern of height class for native plants species was computed. Subsequently, the results of the analysis were interpreted, discussed and conclusions were drawn accordingly.

3.4.1. Native Species diversity

Species diversity is typically evaluated using Shannon diversity index, which takes into account both species richness and evenness. The Shannon diversity index (H') and evenness index (E') were commonly used measures to incorporate both aspects of diversity (Magurran, 1988).

The formula for calculating the Shannon diversity index is

$$H' = -\sum_{ci=1}^{n} pi\ lnpi$$

Equation 1 Shannon's diversity index

Where H' = Shannon diversity index

Pi = the proportion of the valid value of the i^{th} species (p_i = $(n_i)/N$), n_i, the valid value indicator of the i^{th} species and N is the important value indicator for all Species).

ln = natural logarithm to base e (loge)

Evenness value was calculated using the following formula.

$$J = H/H_{max},$$

Equation 2 Evenness index

Where J = the species evenness; H_{max} = lnS, where "S" stands for the number of species

For comparison, the regeneration status of the native plants species sampled under both plantation forests was analyzed from seedlings to saplings and from saplings to mature trees

(Shankar, 2001). The height classes for seedlings (< 0.5 m), saplings (0.5 m – 2 m) and trees (> 2 m) were used to classify the mentioned growth levels. Composition and density of seedlings saplings and trees indicate the status of regeneration. The total seedling, sapling and mature tree/shrub species densities data in both plantation forests were analyzed.

Species which are abundant in the lower growth classes were considered to have good regeneration potential whereas, those which possess either no or few numbers of individuals in the lower growth classes were considered be poor in regeneration status. From the analysis, all the species which showed good as well as poor regeneration were categorically described in the chart.

3.4.2. Vegetation structure

By carefully collecting and studying data, native woody plants in the study area were sorted into three groups based on their height: seedlings, saplings, and trees. This helped us understand the types of native plants growing in the Eucalyptus and Cupressus forests.

Seedlings are the youngest plants, identified by their small size and delicate growth. They give us insights into how the ecosystem is regenerating, showing us where seeds are growing and sprouting.

Saplings are in the middle stage of growth and are stronger than seedlings, with thicker stems and more developed leaves. Their presence shows us that the forest is growing well and progressing towards maturity.

The trees are the tallest and most mature plants in the forest. They are the backbone of the ecosystem, providing habitat, shelter, and important ecological services.

By putting the plants into these groups, we learned a lot about the vegetation structure and distribution of native plant in the plantation forests.

3.4.3. T-Test

An independent group t-test, also known as a two-sample t-test, is a statistical method used to compare the means of two independent groups to determine if they are significantly different from each other. I used this test to test whether there is a significant difference between groups of native woody plants collected under Eucalyptus and Cupressus plantation.

- The Null hypothesis (N_0) was that the difference between the two groups is 0 and the Alternative hypothesis (N_1) was that the difference between the two sample means is not zero.

- t-test groups = native woody plants under Eucalyptus and Cupressus plantations
- variables = number of native woody plants collected

$$t = \frac{(x_1 - x_2)}{\sqrt{\frac{(s_1)^2}{n_1} + \frac{(s_2)^2}{n_2}}}$$

Equation 3 T-Test

$\bar{\mathbf{x}}_1$: sample mean for population 1

$\bar{\mathbf{x}}_2$: sample mean for population 2

μ_1: mean for population 1

μ_2: mean for population 2

$\mathbf{n}_1$: sample size for sample mean from population 1.

$\mathbf{n}_2$: sample size for sample mean from population 2.

$\mathbf{s}^2{}_1$: variance for sample 1

$\mathbf{s}^2{}_2$: variance for sample 2

df: degree of freedom

4. RESULT

4.1. Floristic composition

Table 1 displays the identification and recording of 42 species of native woody plants. Among the native woody plants 38 species were recorded under Eucalyptus plantation and 36 species under Cupressus plantations. Based on their growth habit, 27 species were trees, 15 species were shrubs. Of the 42 woody species identified in the plantation understories, 32 were found in all forest stands.

The results of the native woody plant species found within the plantation forest were listed in a table, which provided a comprehensive overview of the vegetation stand in the plantation forests. Furthermore, the native woody plants in the area appeared to be predominantly characterized by smaller trees and shrubs.

Table 1 List of identified native plant species under plantation forests

No	Species	Vernacular name (oro)	Family name	Habit	Abundance	
					Eucalyptus	***Cupressus***
1	*Albizia schimperiana*	Ambabessa	Mimosaceae	T	63	61
2	*Bersama abyssinica*	Lolchiisa	Melianthaceae	T	47	8
3	*Brucea antidysenterica*	Qomonyoo	Simaroubaceae	S/T	25	42
4	*Calpurnia aurea*	Ceekaa	Fabaceae	T	274	36
5	*Catha edulis*	Caatii	Celasteraceae	S	29	
6	*Clausena anisata*	Ulmayee	Rutaceae	S/T	68	23
7	*Croton macrostachyus*	Bakkanniisa	Euphorbiaceae	T	267	33
8	*Coffea arabica*	Buna	Rubiaceae	S	8	16
9	*Combretum molle*	Rukeensa	Combretaceae	T	13	29
10	*Cordia africana*	Waddeessa	Boraginaceae	T	8	
11	*Dodonaea viscosa*	Iticha	Sapindaceae	S	49	28
12	*Ehretia cymossa*	Ulaagaa	Boraginaceae	S	29	44
13	*Ekebergia capensis*	Somboo	Meliaceae	T	50	31
14	*Erythrina abyssinica*	Waleensuu	Leguminosae	T	58	29
15	*Erythrina brucei*	Beeroo	Euphorbiaceae	T	30	42
16	*Euphorbia tirucali*	Cadaa	Euphorbiaceae	T	13	
17	*Ficus exasperata*	Baalansoofii	Moraceae	T	46	21
18	*Ficus sur*	Harbuu	Moraceae	T		17
19	*Ficus vasta*	Qilxuu	Moraceae	T	5	
20	*Grewia bicolor*	Harooressa	Malvaceae	S/T	59	30
21	*Maesa lanceolata*	Abbayyii	Myrsinaceae	T	145	126

22	*Manilkara butugi*	Buttujjii	Sapotaceae	T		22
23	*Millettia ferruginea*	Askirra	Fabaceae	T	86	17
24	*Maytenus arbutifolia*	Kombolcha	Celasteraceae	S	312	129
25	*Maytenus senegalensis*	Acaacii	Celasteraceae	S/T	609	276
26	*Ricinus communis*	Qobboo	Euphorbiaceae	S	30	
27	*Rubus steudneri*	Goraa	Rosaceae	S	402	77
28	*Rytigynia neglecta*	Mixoo	Rubiaceae	S/T		17
29	*Sapium ellipticum*	Bosoqa	Euphorbiaceae	T	71	40
30	*Sesbania sesban*	Sasbaaniyaa	Fabaceae	S/T	22	36
31	*Senna didymobotrya*	Asen meka	Fabaceae	S	368	90
32	*Senna longiracemosa*		Fabaceae	S	667	124
33	*Sida rhombifolia*		Malvaceae	S	685	198
34	*Sida schimperiana*		Malvaceae	S	321	146
35	*Solanum incanum*	Hiddii	Solanaceae	S	273	147
36	*Solanum macranthum*		Solanaceae	S	99	159
37	*Solanum marginatum*	Hiddii	Solanaceae	S/T	76	155
38	*Syzygium guineense*	Baddeessa	Myrtaceae	T	28	11
39	*Vachelia abyssinica*	Laaftoo	Fabaceae	T	51	20
40	*Vachelia seyal*	Doddota	Fabaceae	T		5
41	*Verbascum sinaiticum*	Reejjii	Scrophulariaceae	S	57	
42	*Vernonia amygdalina*	Eebicha	Scrophulariaceae	S	22	46
	SUM				5465	2331

4.2. Plantation types and landscape features

Most of the Eucalyptus plantation forest site was an area of coppice forest trees dominated by Eucalyptus species. Rotations of coppice trees were cultivated for timber and fuel wood production. The ecology of the coppice-rotation stands of Eucalyptus comprised of different species of plants, both exotic and native woody species. Cupressus plantation forest which was dominated by Cupressus species had also been harvested mainly for timber production.

Table 2 Types and landscape features of plantation forests

Forest stand	Order of data collection	No of plots	Slope (%)	Native plants/ha	Diversity (H’)	Evenness (E)
Eucalyptus	1	4	35%	743.24	0.8916	0.086
	2	5	30%	1258.1	0.3803	0.034
	3	5	22%	900	0.4667	0.0438
	4	5	20%	791.22	0.4851	0.0464
Cupressus	1	4	15%	313.513	0.4913	0.0541
	2	5	40%	335.135	0.5567	0.0606
	3	4	20%	357.43	0.37415	0.0403
	4	5	20%	569.595	0.369	0.037

Table 2 presents an overview of the key characteristics of plantation forests, including measures of overall richness and diversity.

The full list of plantation species and their abundance are recorded in each plantation forests were given in Appendix 1

4.3. Native plants species diversity

The diversity of native woody species under Eucalyptus and Cupressus plantations is shown in Table 3. The diversity value was notably higher in Eucalyptus vegetation compared to Cupressus, as evidenced by Shannon's diversity index, pointing to a richer array of native woody plant species within Eucalyptus environments. In contrast, Cupressus plantations displayed relatively lower species richness. The evenness values for native woody plants under Eucalyptus plantation was found to be nearly identical to that observed under Cupressus plantations, suggesting a similar distribution pattern of species abundance within these two distinct forest types.

Table 3 Native plants species diversity

Plantation forest stand	Shannon - wiener diversity index (H')	H_{max}	Evenness (E)
Eucalyptus	1.322	3.63	0.154
Cupressus	1.207	3.61	0.155

4.4. T-Test

In the test, it was assumed that the variances for the two populations groups were unequal.

- t-test groups = native woody plants under Eucalyptus and Cupressus plantations
- variables= number of native plants collected
- Null hypothesis (H_0) is that the difference between the two groups is 0.
- Alternative hypothesis (H_1) the difference between the two sample means is not zero.
- Significance level (α) = 0.05
- critical t-value (for two-tail) ≈ 2

Table 4 T-Test Result

T-Test: Two-Sample Assuming Unequal Variances		
	Eucalyptus	***Cupressus***
Mean	129.9048	54.3

Variance	32720.53	4025
Observations	42	42
df	51	
t Stat	2.56	
p-value	0.0136	
t Critical	2	

After conducting an independent t-test between native woody plants under Eucalyptus and Cupressus plantations, result found: p-value = 0.0136. Therefore, the outcome of this independent group t-test (p-value = 0.0136) is less than a chosen significance level (0.05) and the t-statistic value (2.56) exceeds the critical t-value 2.

4.5. Vegetation structure

The chart below illustrates the vegetation structure of native woody plants by height, revealing a notable absence of trees and dominance of seedlings and saplings. The height class distribution categorizes the range of heights for seedlings (0 - 0.5 m), saplings (0.5 – 2 m), and trees (> 2 m). In Eucalyptus plantations, the density of native plant seedlings was 57%, saplings 38%, and trees 5%. Conversely, in Cupressus plantations, the density of seedlings was 55%, saplings 41%, and trees 4%.

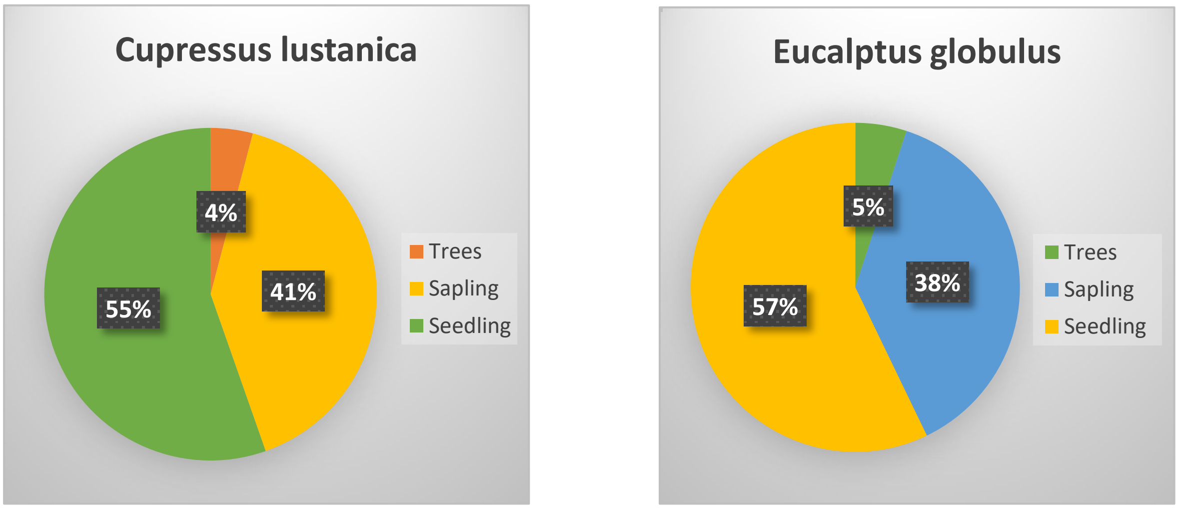

Figure 3 Population structure of native woody plants

4.6. Regeneration of native woody plants

Under Eucalyptus canopy, 22 species were observed to regenerate spontaneously. Meanwhile, Cupressus plantation forests exhibited 23 species of native plants regenerating naturally. In each plantation forest type's different values of population densities were observed. Shrub species exhibited regeneration within Eucalyptus plantations, featuring native plants like *Sida rhombifolia, Sena longiceracemosa, Mytenus senegalensis*, and *Rubus steudneri*. Conversely, beneath Cupressus plantations, native species such as *Mytenus senegalensis, Sena rhombifolia*, and *Solanum marginatum* displayed notable regeneration, all belonging to the shrub category. Few trees species were lacking seedlings such as, *Cordia africana* and *Euphorbia tirucali*, while having mature trees.

Table 6 Native woody plants regeneration recorded in each plantation forest

No	Species	Eucalyptus			Cupressus		
		Seedling	Sapling	Trees	Seedling	Sapling	Trees
1	*Albizia schimperiana*	35	22	5	33	18	16
2	*Bersama abyssinica*	18	29		5	3	
3	*Brucea antidysenterica*	12		13	17	9	16
4	*Calpurnea aurea*	142	132	23	15	21	
5	*Catha edulis*	16	13				
6	*Clausena anisata*	44	24		7	16	
7	*Croton macrostachyus*	172	94		24	9	
8	*Coffea arabica*		14	68	4	5	7
9	*Combretum molle*	8	5		13	16	
10	*Cordia africana*		4	4			
11	*Dodonaea viscosa*	27	22		7	21	
12	*Ehretia cymossa*	10	19		29	15	
13	*Ekebergia capeosis*	26	24		26	5	
14	*Erythrina abyssinica*	23	35	11	17	12	
15	*Erythrina brucei*	14	7	9	14	11	17
16	*Euphorbia tirucali*	5	8				
17	*Ficus palmata*	12	22	12	12	9	
18	*Ficus sur*				4	7	6
19	*Ficus vasta*		2	8			
20	*Grewia bicolor*	43	16	17	18	12	
21	*Maesa lanceolata*	54	91		97	29	
22	*Manilkara butugi*				10	12	
23	*Milletia ferruginea*	73	13		11	6	
24	*Mytenus arbutifolia*	128	178		77	52	
25	*Mytenus senegalensis*	348	261		187	87	34
26	*Ricinus communis*	6	24		1		
27	*Rubus steudneri*	246	156		35	42	
28	*Rytigynia neglecta*				11	6	

29	*Sapium ellipticum*	36	35		14	28	12
30	*Sesbania sesban*	15	7		13	23	
31	*Sena didymobotrya*	194	174		65	25	
32	*Sena longiceracemosa*	378	289		73	51	
33	*Sida rhombifolia*	522	163		123	75	
34	*Sida schimperiana*	186	135		86	60	
35	*Solanum incanum*	149	124		82	65	
36	*Solanum macrantalum*	38	61		74	85	
37	*Solanum marginatum*	49	27		114	41	
38	*Syzgium guineense*		12	16	3	5	11
39	*Vachelia abyssinica*		17	34	12	8	
40	*Vachelia seyal*					3	2
41	*Verbascum sinaiticum*	45	12				
42	*Vernonia amygdalina*	7	15		23	12	11

5. DISCUSSION

5.1. Floristic composition

In the study area, 42 native woody species were recorded, with a higher abundance observed for shrubs species under both plantation forests, each hosting unique species exclusive to its environment, yet the total number of native woody species collected was considered as low relative to the study area's extent.

Of the total individual species, the most abundant plant families in the landscape were species that belong to the Fabaceae family, which were represented by 6 species and the next abundant family was Euphorbiaceae which, were represented by 5 species. In other hand, of all species recorded *Maytenus senegalensis*, *Senna longiracemosa*, *Maytenus arbutifolia* and *Senna didymobotrya* were the most abundant plant species with 11.4%, 10.2% and 5.9% individuals per ha, respectively. However, the dominant trees species in terms of relative density and relative basal area were *Erythrina brucei*, and *Cordia africana*, which were identified under both Cupressus and Eucalyptus plantations respectively.

The result was compared to similar studies previously done in Ethiopia. For example, in other similar study conducted in shashemene munessa monoculture plantations of exotic species, a total of 56 naturally regenerated woody species were recorded beneath all plantation stands (Feyera et al., 2002).

5.2. Native Species Diversity

The data from Table 3 reveals that Eucalyptus plantations harbor a greater diversity of native woody species compared to Cupressus plantations, as evidenced by Shannon's diversity index. Despite this difference, both types of plantations show similar evenness values, indicating comparable patterns of species abundance distribution. Specifically, the Shannon diversity index for native woody plants was calculated at 1.3 for Eucalyptus and 1.2 for Cupressus plantations, suggesting lower diversity in both cases. However, there is a slightly higher presence of native plant diversity in Eucalyptus plantations compared to Cupressus, implying slightly higher species diversity under Eucalyptus canopy, potentially due to the impact of Cupressus litter accumulation hindering the growth of native woody species.

Nevertheless, the evenness value for native woody plants under Eucalyptus forests mirrors that of plants under Cupressus plantations, indicating an uneven distribution of individual woody species within both forest types. This suggests that the unevenness in species distribution contributes to the similarity in evenness values.

It's worth noting that both Shannon's diversity and evenness indices recorded in these exotic plantation forests are lower than those reported from other forest stands in Ethiopia. For instance, Hundera (2010) reported that *Cupressus lusitanica* plantation forests exhibited the highest values of diversity and evenness, followed by *Eucalyptus saligna*. This suggests that these exotic plantations may harbor a less diverse native woody species composition compared to native forest stands in the region, as highlighted by the findings in the current study.

5.3. Vegetation structure

Vegetation structure refers to the arrangement and characteristics of plants within a study area, which can offer insights into the development and dynamics of ecosystems. When examining native woody plant species within plantation forests, the composition and density of seedlings and saplings compared to mature trees are key indicators of vegetation structure.

Observations reveal a significant abundance of seedlings and saplings relative to mature trees, suggesting ongoing regeneration and growth within the forest ecosystem. This abundance indicates successful establishment of younger plants beneath the canopy of larger, mature trees. The findings of a study conducted by Getachew Tesfaye and Abiyot Berhanu in 2006 further support this observation. Their research emphasized that native woody species within exotic plantations demonstrated a successful establishment within the canopies.

However, the study notes that most native plants do not reach the mature tree stage, which could imply exploitation of mature trees in the area. Factors such as grazing and trampling by wild and domestic animals contribute to diminishing seedling populations before reaching maturity.

Furthermore, comparisons between different forest types show variations in the total abundance of seedlings, saplings, and mature trees. For instance, Cupressus forests exhibit lower overall densities compared to Eucalyptus plantations. These differences in vegetation structure highlight the diverse dynamics and ecological conditions within different forest ecosystems.

Plants can regenerate in several ways without necessarily reaching the tree stage of development. Major possible ways include:

Seed Dispersal: Seeds from adjacent forests can be dispersed into the area by various agents such as wind, water, animals, or birds. These seeds can lie dormant in the soil until favorable conditions for germination occur, such as sufficient moisture and sunlight.

Natural Regeneration: Dormant seeds that are dispersed into the area can germinate and establish themselves under suitable conditions. This process contributes to natural regeneration, where new plants grow without human intervention, utilizing resources available in the environment.

Edge Effects: The boundary between the adjacent forest and the area under consideration (often referred to as the forest edge) can create unique microclimatic conditions that favor seed germination and plant growth. These edge effects, characterized by increased light penetration and nutrient availability, can stimulate seedling establishment and growth.

Seed Bank: The soil in the adjacent forest may contain a seed bank consisting of dormant seeds from various plant species. Environmental disturbances such as logging, fire, or clearing may trigger the germination of these dormant seeds, leading to the establishment of new plants in the area.

Colonization: Seeds dispersed from adjacent forests can colonize disturbed or vacant areas, gradually establishing vegetation cover and contributing to the regeneration of plant communities. This colonization process helps restore biodiversity and ecosystem functioning in the area.

5.4. T-Test

An independent t-test was conducted to compare the mean number of native plants collected under Eucalyptus and Cupressus plantation environments, aiming to determine if there's a statistically significant difference between the two groups. The null hypothesis (N_0) stated that there is no difference between the mean numbers of native plants under the two types of plantations, while the alternative hypothesis (N_1) suggests that there is a difference.

After conducting the independent t-test, a p-value of 0.013 was obtained. This p-value represents the probability of observing the obtained difference in means or a more extreme difference if the null hypothesis were true. Since the p-value is less than the typical significance level of 0.05, the p-value is the probability of obtaining results as extreme as the observed results, assuming that the null hypothesis is true. A p-value of 0.013 indicates strong evidence to reject the null hypothesis, suggesting that there is only approximately a 1.3% chance of observing the results if the null hypothesis were true. Thus, I can conclude that there is a statistically significant difference in the mean number of native plants collected between the Eucalyptus and Cupressus plantation environments. This suggests that the type of plantation exerts an influence on the presence or abundance of native plants.

Overall, the total number of seedlings of the naturally regenerated woody species in the study area was higher. The composition and density of seedlings and saplings play a crucial role in providing insights into the regeneration status of native plants within the study area. When seedlings and saplings are significantly higher in number compared to mature trees, it indicates a higher level of regeneration for that particular species. Better regeneration was observed under the Eucalyptus plantation stand.

There are several reasons why native plants may struggle to regrow under exotic trees:

Competition for Resources: Exotic trees often have different root structures and growth habits compared to native trees. They may compete more effectively for resources such as water, nutrients, and sunlight, leaving fewer resources available for native plants to thrive.

Allelopathy: Some exotic trees produce chemicals that inhibit the growth of other plants, a phenomenon known as allelopathy. These chemicals can hinder the germination and growth of native plant species, creating unfavorable conditions for their regeneration.

Changed Microclimate: Exotic trees can alter the microclimate of an area by creating denser shade or modifying soil moisture levels. This altered microclimate may not be suitable for the germination and growth of native plants that are adapted to different environmental conditions.

Litter and Leaf Cover: Exotic trees often shed leaves and other litter at different times and in different quantities compared to native trees. This litter layer can inhibit the growth of native plants by blocking sunlight, altering soil pH, and creating barriers to seed germination and seedling establishment.

Ecological Disruption: Exotic trees may disrupt ecological processes that are important for the regeneration of native plants, such as nutrient cycling, soil microbial communities, and interactions with native pollinators and seed dispersers.

Lack of Symbiotic Relationships: Many native plants have symbiotic relationships with specific soil microbes, fungi, and insects that are not present or are less abundant under exotic trees. Without these symbiotic relationships, native plants may struggle to obtain essential nutrients or may be more susceptible to pests and diseases.

Overall, the introduction of exotic trees can significantly alter ecosystem dynamics and create challenges for the regeneration of native plant communities. Conservation efforts often focus on managing exotic species and restoring native vegetation to promote biodiversity and ecosystem resilience.

6. CONCLUSION

In conclusion, the study offers valuable insights into the floristic composition, plantation types, landscape features, and regeneration dynamics within our study area. Despite recording 42 native woody species, the overall species richness remains relatively low considering the extent of the area surveyed. Notably, the Fabaceae and Euphorbiaceae families stand out as dominant within the landscape, with *Erythrina brucei* and *Cordia africana* emerging as prominent tree species under Cupressus and Eucalyptus plantations, respectively.

One significant finding is the relatively low total basal area of trees in the study area, primarily due to the scarcity of trees exceeding 2 meters in height. However, Eucalyptus plantations exhibited the highest mean basal area, indicating a potential advantage for tree growth under such conditions.

Analysis of population structure underscores a dynamic regeneration process, with seedlings and saplings prevalent in both plantation forests. Interestingly, Eucalyptus plantations showed higher abundance across all stages of tree development compared to Cupressus, possibly attributable to light availability differences and shading conditions.

Notably, this study highlighted the predominance of shrubs among species showing good regeneration status. However, the overall growth success rate of tree species within the plantation area appears to be very low, potentially due to high plantation species density.

In light of these findings, it is imperative to consider plantation type and management practices when assessing native plant diversity and regeneration dynamics.

7. RECOMMENDATION

Based on the findings of the study, several recommendations can be made to improve the biodiversity and ecosystem resilience within plantation landscapes:

It is important to introduce a more diverse range of native tree species within plantation areas to enhance overall biodiversity. This can help mitigate the dominance of certain species and promote a healthier ecosystem structure.

Implement management practices to optimize light penetration within plantation forests, particularly in Cupressus-dominated areas where shading conditions may limit the growth of native species. This could involve selective thinning or pruning of trees to allow for greater light availability to understory vegetation.

Regularly monitor and manage plantation density to prevent overcrowding, which can inhibit the growth and regeneration of native tree species. Thinning operations may be necessary to maintain optimal tree spacing and reduce competition for resources.

Encourage natural regeneration processes by minimizing disturbance and creating favorable microhabitats for seed dispersal and germination. This could involve leaving gaps in plantation stands or establishing buffer zones to facilitate the establishment of native seedlings. Promote awareness of the importance of biodiversity conservation within plantation landscapes.

By implementing these recommendations, ecologically sustainable plantation ecosystems that support a diverse array of native plant species and contribute to broader conservation goals.

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9. ANNEX

Appendix 1 full list of the native woody plants abundance

No	Species	Abundance							
		E. globulus				C. lusitanica			
		1	2	3	4	1	2	3	4
1	*Albizia schimperiana*	14	31	10	8	24	17	9	17
2	*Bersama abyssinica*	10	8	29				8	
3	*Brucea antidysenterica*		12		13		9	18	15
4	*Calpurnea aurea*	32	142	41	59	10	2	9	15
5	*Catha edulis*			9	20				
6	*Clausena anisata*	6	40		22		9	7	7
7	*Croton macrostachyus*	124	43	56	44	4	5	10	14
8	*Coffea arabica*		5	3		4	2		10
9	*Combretum molle*	6		3	4	3	8	6	12
10	*Cordia africana*		6	1	1				
11	*Dodonaea viscosa*	23	12	8	6			7	22
12	*Ehretia cymossa*		7	13	9	11	3	8	22
13	*Ekebergia capeosis*	34	6	5	5		6	7	18
14	*Erythrina abyssinica*	22	47			4	6	8	11
15	*Erythrina brucei*	3	11	9	7		8	22	12
16	*Euphorbia tirucali*		4	6	3				
17	*Ficus exasperata*	18	5	16	7			5	16
18	*Ficus sur*					3		12	2
19	*Ficus vasta*	3	4		3				
20	*Grewia bicolor*		27	14	32	8	14		8
21	*Maesa lanceolata*	59	45	18	23	19	55	14	38
22	*Manilkara butugi*					12			10
23	*Milletia ferruginea*		64	22		2	1	2	12
24	*Mytenus arbutifolia*	91	154	13	54	21	12	64	32
25	*Mytenus senegalensis*	249	204	101	55	114	77	42	75
26	*Ricinus communis*		6	12	12	1			
27	*Rubus steudneri*	99	173	108	22	2	4	23	48
28	*Rytigynia neglecta*						6	2	9
29	*Sapium ellipticum*	12	23	36			10	27	17
30	*Sesbania sesban*	2	3	5	12		5	8	23
31	*Sena didymobotrya*	23	62	141	142	11	26	6	47
32	*Sena longiceracemosa*	106	181	135	245	46	5	32	41
33	*Sida rhombifolia*	155	144	174	212	12	66	51	69
34	*Sida schimperiana*	77		102	142	52	6		88
35	*Solanum incanum*	67		148	58	48	54	33	12
36	*Solanum macrantalum*	23	16	31	29	12	55	23	69
37	*Solanum marginatum*	27	12	15	22	25	43	64	23
38	*Syzgium guineense*	2		9	17		5	9	5

39	*Vacelia abyssinica*		44	7			9	5	6
40	*Vacelia seyal*					5			
41	*Verbascum sinaiticum*		7	38	12				
42	*Vernonia amygdalina*	2		8	12	3		11	32