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FLORISTIC COMPOSITION, DIVERSITY, VEGETATION STRIUCTURE AND REGENERATION STATUS OF WOODY PLANT SPECIES IN GAREMBA NATURAL FOREST, ARBEGONA WOREDA, SIDAMA REGION, ETHIOPIA

MSc THESIS

BY: LEMA LEGESE

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A THESIS SUBMITTED TO DILLA UNIVERSITY, SCHOOL OF GRAGUATE STUDIES, DEPARTMENT OF BIOLOGY IN PARTIAL FULFILLMENT OF THE REQUIRMENT FOR THE DEGREE OF MASTERS OF SCIENCE IN BOTANICAL SCIENCE

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As a research advisor, I hereby certify that I have read and evaluated this Thesis prepared under my guidance by **Lema Legese** entitled "**FLORISTIC COMPOSITION, DIVERSITY, VEGETATION STRIUCTURE AND REGENERATION STATUS OF WOODY PLANT SPECIES IN GAREMBA NATURAL FOREST, ARBEGONA WOREDA, SIDAMA REGION, ETHIOPIA**". I recommended that it be submitted as fulfilling the Thesis requirement.

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As a member of the board of examiners of the masters of Science. Thesis Open Defense Examination, we certify that we have read, evaluated the Thesis prepared by Lema Legese and examined the candidate. We recommended that the Thesis be accepted as fulfilling the Thesis requirement for the degree of Masters of Science in Biology.

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BIOGRAPHICAL SKETCH

He was born on October 8, 1988 E.C, now a day it called Sidama Region, Yirgalem zone, Shafamo woreda, Shako Urje Kebele special village called Faficho. He attended elementary school Shafamo and secondary school education in Arbegona. He completed first degree at Wolkite University since 2009 E.C. He joined then Dilla University of school of graduate studies in Biology (Botanical Science) In 2013 E.C.

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ABSTRACT

The natural forest of Garemba was studied to determine the floristic composition, diversity, and analysis of vegetation structure and regeneration status of woody plant species. Systematic sampling method was used to collect data for woody plant species. Accordingly, 60 sample plots of 20m×20m (400m²) were established systematically at every 100m interval along eight (8) transect lines which are 400m apart to sample woody species. Total of 35 plant species belong 32 genera and 24 families of vascular plants were recorded, in which Family Rosaceae represented by 4 species followed by Asteraceae and Rubiaceae each represented by 3 species, Cupressaceae, Fabaceae, Myrsinaceae and Solanaceae (2 species each) and 17 other families were each represented by 1 species. The collected specimens were composed of 20 (57.1%) of trees, 13 (37.1%) shrubs and 2 (6.02%) lianas. Out of 35 plant species 2 were, Erythrina brucei and solanecio gigas are endemic to Ethiopia and 2 plant species, Dombeya torrida and Maesa lanceolata are indicator. Three plant community types were recognized, community type one (1) had higher species diversity and evenness, 3.54 and 0.87 respectively. Total density and basal area calculated for all plant species were 618 individuals/ha and 15.1 m²/ha, respectively. Arindinaria alpine and Erica arborea were found the densest and most frequent species. The five most dominant tree species of Garemba forest occupied 53.2% of total important value index. Phytogeographical comparisons with other similar forests in Ethiopia showed that Garemba forest is more similarity to Dry evergreen montane forests. Most of the tree densities were distributed in lower diameter (DBH) and height class and proceeding with decreasing degree of individuals towards the higher DBH classes and height classes. It shows an inverted J-shape distribution, which shows that this vegetation is in good regeneration status. Analysis of regeneration status of all plant species in study forest showed that seedling> sapling> mature trees implying the forest is at good regeneration status. By recognizing the significance of Garemba forest, recommendation is made to improve the protection and conservation status of the forest through forest management approaches and sustainable utilization.

Key words: composition, Diversity, Garemba Natural Forest, population structure, Woody Species.

1. INTRODUCTION

1.1Background of the study

Globally forests are known to be critically important habitats for the biodiversity they contain and for the ecological functions they serve. Totally in the worldwide forests covered 30% of the land and which account about 3952 million hectare (FAO, 2007). Tropical montane forests are well known among the hottest spot ecosystems on earth. This diversified ecosystem is under severe Condition because they are highly suitable for agricultural purposes (Rodrigues *et al*., 2004). However, gradually the coverage of forest is declining due to deforestation, which is taking place at a rate of 12.9 million ha/year mainly as a result of conversion of forests to expansion of agricultural land, rapid growth of human population, habitat loss and fragmentation, and unwise utilization of forests for various purposes (FAO, 2007).

Ethiopia is one of the biodiversity reach areas in the world. The country is extremely heterogeneous in ecology with diversity species (Sisay Alemu *et al.*, 2021). In the Horn of Africa region, Ethiopia is regarded as a major center of diversity and endemism for several plant species (Abreham *et al*., 2013). This results from the wide variations in climate, geology and terrain working on different time scales. Furthermore, the vegetation is extremely complex due to great variations in altitude implying equally great spatial differences in moisture regimes as well as temperatures within very short horizontal distances (Genene Bekele, 2014). Forest cover in Ethiopia declined from 15.11 million hectare in 1990 to 12.9 million hectares in 2010, during which 18.66% of the forest cover was deforested within those 20 years. As a result, nearly 141,000 hectares was destroyed every year (Tamiru *et al*., 2021).

Currently, Ethiopia has about 17.35 million hectares of forests (15.7% of the country's area), which include bamboo, dense woodland, natural forests, and planted forests.) is estimation includes a land spanning more than 0.5 hectare covered by trees attaining a height of >2 m and a canopy cover of >20% or trees with potential to reach these thresholds insitu in due course (Girma Boz and Melesse Maryo, 2020). The declining of vegetation resources in all areas of the country in general and fragmented areas in forests in particular is mainly due to increased population growth followed by deforestation and land degradation (Z. Mekonnen and A. Nigatu, 2013). These consequences reduce ecosystem services like carbon stocks, soil properties, and the hydrological cycle (Lal, 2012) and the vegetation dynamics and tree density at the local and regional scales which are important in structuring plant communities (Hubbell *et al*., 1999).

According to Ensermu Kelbessa *et al*. (1992), 120 threatened endemic plant species are known from Ethiopia, thirty five of these species were from the Dry Afromontane forests of the country. In the face of these problems ecologists and conservation biologists have required to protect forest vegetation using different strategies from strict protection in the national parks to suitable management and other integrated conservation and development programs. The destruction of vegetation and environmental degradation has become issues of national and global concern in recent years. This is because of the fact that declining the vegetation cover and depletion of natural resources are closely associated with drought and food shortages that have become major threat affecting the life of millions of people. The diversity, regeneration status, floristic composition and vegetation structure are crucial elements to clearly visualize the anthropogenic activities as well as environmental factors affecting the vegetation of an area. Hence, for forest management accurate data on forest resource is considered to be an essential requirement (FAO, 2010).

Mountain Garemba natural forest is one of the forest of Arbegona District victimized by these anthropogenic activities as well as environmental factors. However, the problems are more intensified and the woody plant population has gradually declined from time to time. Some of the major problems that contribute to the destruction of natural habitats, and hence woody plants in mount Garemba natural forest are temporary and permanent settlement, charcoal making, firewood collection, overgrazing, and selective tree cutting for construction were the main threats in the Mount Garemba natural forest (Samson *et al*., 2010) Such factors mentioned in the above are responsible for the declining of woody plants in their habitat and population density (Workneh *et al*., 2016). Hence, for effective management and conservation of the ecosystem of the country, there is an urgent need to develop a sound management and conservation plan, and this, in turn, require detail baseline information on the ecology and status of the area. However, the assessment of floristic composition and structure of woody plants and other attributes has not been studied so far in the study area. Therefore, the main objective of this study is to present the results of the study of floristic composition, diversity, vegetation structure and regeneration status of woody plant species in Garemba natural forest, Sidama Region, Ethiopia. And provide reliable information for the development of appropriate management plan for effective conservation.

1.2 Statement of the Problem

The availability of accurate data on forest resources is an essential requirement for forest management and planning within the context of sustainable development (FAO, 2007). Botanical assessments such as floristic composition and structure studies are essential in view of their value in understanding the extent of plant diversity in forest ecosystem (WCMC, 1992). Knowledge of floristic composition and structure of forest resources is also useful in identifying important elements of plant diversity, protecting threatened and economic species, and monitoring the state of refers, among others (Ssegawa and Nkuutu, 2006). The study of floristic composition and structure of tropical forest becomes more imperative in the face of ever increasing threat to the forest ecosystem. Reduction in forest cover has a number of consequences including soil erosion and reduction capacity for carbon sequestration, loss of biodiversity and instability of ecosystems and reduced availability of various wood and non-wood forest products and services (Alemu Mekonnen and Bluffstone, 2007).

The assessment of vegetation composition of woody and other attributes has not been studied so far on the Mountain Garemba Natural Forest though it renders significant ecological services and socio-economic values to the local communities. Though Mountain Garemba forest is one of the protected forest areas, currently it is under server anthropogenic impacts. Hence, there is a need of sound conservation and sustainable use of this forest. This necessitates perceiving the nature of its plant community, species diversity and its linkage to the local communities. The lack of such basic information is one of the serious problems that hampered the conservation management and rational utilization of the forest resources of the area. Thus, species documentation, community identification and description of this forest are important and this study will initiated to provide primary information about the floristic composition, diversity, and vegetation structure and regeneration status of woody plant species in mount Garemba natural forest, Sidama Region, Ethiopia.

1.3 Objectives of the study

1.3.1 General objective

To assess floristic composition, diversity, vegetation structure and regeneration status of woody plant species in Garemba natural forest, Sidama Region, Ethiopia.

1.3.2 Specific Objectives

- ✓ To provide a list of plant species documented in the study forest
- ✓ To assess the species diversity of woody plant species among community types of the study forest
- ✓ To determine and identify plant community types in the study forest
- ✓ To describe the structural pattern of the vegetation in the study forest
- ✓ To make phytogeographic comparisons of the study forest with any other related forest in the country
- ✓ To determine the regeneration status of some selected species in the study area
- ✓ To generate baseline information that would help in the future management and conservation of the study forest

1.4 Research Questions

- ➢ What floristic composition of plant species does exist in the study forest?
- ➢ What species diversity, evenness and richness of woody plant species does exist in the study forest?
- ➢ What type of vegetation community does exist in the study forest?
- ➢ What does vegetation structure of the study forest depict?
- ➢ How much is the degree of similarity (sorensen's) as compared to forest at different geographical locations of the country?
- ➢ What pattern of regeneration status is derived from some selected species of forest?
- ➢ What kind conservation status need to woody plant species of study area?

1.5. Significance of the Study

This study will have great significances for many development programs. The results of the study will provide the information to policy makers, planners, administrators, forest conservation organizations and institutions, to review their strategies and ensure their participations in forest conservation action planning and implementation program and know the critically factors that can accelerate their uses. This can facilitate allocation of many resources for researchers and other forests conservation programs. Hence this study will attempt to find out the floristic composition, diversity, and vegetation structure and regeneration status of woody plant species in mountain Garemba natural forest, Sidama Region, Ethiopia.

1.6. Scope and limitations of the study

This study was restricted only regarding on woody plant species. Due to various reasons survey on herbs and detail soil physical and chemical analysis of the study area is not conducted. During this study, the researcher has faced a resource limitation (budget and time), material limitations during field work (measurement instruments and other equipment), non-availability of organized secondary data and previously conducted related work in the area to support the achievement of the current work were the main constraints**.** The study was limited both in scope and depth to manageable size based on the researcher`s time availability, budget and other factors. On the basis of these situations the scope of the study was delimited to mount garemba natural forest.

2. LITERATURE REVIEW

2.1 Mountain Ecosystems

Mountain ecosystems are landscapes characterized by distinctive abiotic, biotic, social, cultural, economic and spiritual values (Martinelli, 2007). Mountains embody fragile, topographically highly variable, often difficult environments. Mountains serve as source of water, energy and biological diversity and source of key resources such as minerals, forest, and agricultural products. Billions of people, not only living within and immediately adjacent to mountains, but also downstream and further afield, exploit the diversity of resources available in and around mountain regions. Perhaps the greatest global value of mountain areas derives from the fact that almost all of the world's major rivers rise within them (Price, 2004; Gurung, 2006).

2.2 Mountain Forests as Biodiversity Reservoir

Melkania *et al*. (2006) pointed out that mountains have significant relief features of the second order on the earth's surface. Globally, a considerable portion of mountains are covered by various vegetation types as natural high forests, plantations, wood and scrublands, and herbaceous vegetation. According to Price *et al*., (2004), mountain forests account for 26.5% of the global forest area. These forests, apart from the other uses, are essential to protect fragile mountain slopes from erosion and leaching processes and as reservoirs of species for resettlement of deforested, fragmented, or newly created habitats after being affected by anthropogenic or natural disturbances (Körner and Ohsawa, 2005).

Mountain vegetation often shows marked zonation due to environmental gradients like moisture and temperature linked with elevation. Elevation is the one and most important topographic factor apart from the aspect and slope controlling vegetation growth (Jin *et al.,* 2008). As the result of compression of the climatic zones along an elevation gradient, exposure effects and large habitat diversity, species richness in mountains commonly exceeds that in the lowlands at the same scale (Gurung, 2006).

2.3 Vegetation of Ethiopia

Ethiopia is one of the countries in the world endowed with rich biological resources. One of these resources is natural vegetation where floristic and faunistic life forms dynamic ecosystems (Girma Balcha, 2004).According to van der Maarel (1979), vegetation is defined as a system of spontaneously growing plants in a particular region. However, cultivated plants such as crops and weeds surrounding them are not considered as vegetation. Some experts define vegetation as a concrete stand of plants occurring in a uniform environment with relatively uniform floristic composition and structure (vander Maarel, 1979). The composition and structure makes it distinct from the surrounding environment (vander Maarel, 1979).The vegetation cover of a given area has a definite structure and composition, which is developed because of the long term interaction between biotic and abiotic factors. The pattern of distribution and vertical stratification of vegetation fluctuate due to different climatic zones, soil types, latitude and topography of the area. These in turn influence the distribution and type of plants and animals in the forest.

The Ethiopian highlands contribute to more than 50% of the land area with Afromontane vegetation, of which dry mountain forests form the largest part (Tamrat Bekele, 1994). Vegetation formation is influenced by many factors, such as climate, geology, edaphic factors and biotic factors including interference by humans in ecological succession. Vegetation is dynamic, that is constantly changing. Reasons for the changes can be ecological or evolutionary processes, climatic changes human land uses, and interaction between factors (Skarpe, 1991). As stated by Grossman *et al*., (1998), vegetation is dynamic, and often requires a high degree of variability. It is also measured for both inventory and monitoring purposes, and can be used as a strong indicator of the ecological functioning. Thus, classification of vegetation can serve as an important component of a larger strategy to understand and conserve this natural resource. The evergreen scrubland vegetation occurs in the highlands of Ethiopia either as an intact scrub, i.e. in association with the dry evergreen mountain forest or usually as secondary growth after deforestation of the dry evergreen mountain forest. Ethiopia, because of its geographical position, ranges of altitude, rainfall pattern and soil variability has an immense ecological diversity and a huge wealth of biological resources. This complex topography attributed from its geological formation coupled with environmental heterogeneity offers suitable environments for a wide range of life forms both flora and fauna (Gete Zeleke, 2003).

The vegetation of Ethiopia has been classified into twelve vegetation types (Friis *et al*., 2010). These are: 1) Desert and semi-desert scrubland, 2) Acacia-Commiphora woodland and bushland, 3) Wooded grassland of the western Gambela region, 4) Combretum-Terminaliawoodland and wooded grassland, 5) Dry evergreen Afromontane forest and grassland complex, 6) Moist evergreen Afromontane forest, 7) Transitional rain forest, 8) Ericaceous belt, 9) Afroalpine belt, 10) Riverine vegetation, 11) Salt lakes, salt-lake shores, marsh and pan vegetation and 12) Freshwater lakes, lake shores, marsh and floodplain vegetations.

Desert and semi desertscrubland ecosystem: It is found in the low land area with an altitude of 500 meters above sea level.Drought tolerant vegetation scarcely covers the area. Trees like Acacia species, *Boswellia ogadenenesis*, *commiphora staphyleifolia* and other shrubs are growing in the range (FAO, 2014). The semi desert scrubland is mainly found in the north-western part of the nation.

Acacia commiphora woodland ecosystem; It is found in the altitudinal ranges of 900 to 1900 meters above sea level. Trees and shrubs are evergreen, and some are deciduous type. Different acacia and commiphora tree species as well as shrubs like Acalypha, Barleria, Aerva, and Aloe species are common. It consists of Zebra, Wild Ass, Black Rhinoceros mammals. Abundant birds such as Golden-breasted Bunting, Salvadori's Seedeater,Yellow throated serin, Ruppells weaver, white headed Buffalo weaver and Abyssinian bush crow are found in the ecology (FAO, 2014).

Moist Evergreen Montane forest; The moist evergreen montane forest consists of high forests of the country mainly the southwest forests, wettest and also humid forest in the south eastern plateau known as the Harenna forest (Ermias Lulekal, 2005). This forest occurs mainly in the southwestern part of the country (Wollega, Illubabor and Kafa) with altitudinal ranges of 1500-2500 m.a.s.l., average annual temperature of 18-20^{0}C and annual rainfall between 1500-2000 mm sometimes even higher than 2000 mm, with rain all the year round, but a maximum in April-October (Tadesse Woldemariam *et al*., 2003). The characteristic plant species in this vegetation type include the largest and commercially most important trees found in Ethiopia: Aningeria adolfi-friedericii, *Podo carpusfalcatus*, *Trilepisium madagascariense*, *Albizia gummifera*, *Celtisa Africana*, *Polyscias fulva, Schefflera abyssinica*, *Bersama abyssinica*. The under-storey contains coffee plants (*Coffea arabica*), some of which are known to be wild populations (Temesgen Gashaw, 2015)

Lowland semi-evergreen forest ecosystem: It is found in the altitudinal range of 450 to 650 meters above sea level. Most trees are deciduous type with, 15-20-meters tall and the tree canopy is continuous. *Baphia abyssinica* is dominant vegetation followed by *Celtis toka*, *Diospyros abyssinica*, *Trichilia zanha*, *Golungensis lecaniodiscus*, and Malacantha alnifolia Zanthoxylum. Wild mammals such as Lesser Cane rat, Nile Lechwe and White-eared Kob, are found in the jungle. Some Leopard and Bush Elephants population are decreased from time to time and they are under threat. Different types of birds are also found in the ecosystem. Particularly Yellow fronted canary, Red tailed Buzzard and Red throated Bee eater birds are common (Skarpe, 1991).

Dry evergreen montane forest of Ethiopia: Dry Evergreen Montane Forest is a very complex vegetation type occurring roughly above 1500m and below 3200m in altitude, with average annual temperature and rainfall of 14-250C and 700-1100mm, respectively(Zerihun,1999). It is inhabited by the majority of the Ethiopian population and represents a zone of sedentary cereal-based mixed agriculture for centuries. This type of forest develops in areas of relatively high humidity, but not much rain, and where there is a prolonged dry season. Dry evergreen montane forests experience long dry seasons (4-8 months) and the rainy period is 8 somewhat unreliable. During the dry season, not only moisture stress but also temperature increases and daytime humidity drops and water courses either dry up or greatly diminish inflow (Demel, 1996). The shrubs occurring in this vegetation type include; *Carissa spinarum* and *Dodonaea angustifolia* (Zerihun, 1999). The characteristic plant species in this vegetation type include *Olea europaea*, *Juniperus procera*, *Celtis africana*, *Euphorbiaampliphylla*, Dracaena spp, *Carrisa edulis*, *Rosa abyssinica*, *Mimusopskummel*, *Ekebergia capensis*, etc. The vegetation type is associated with highland bamboo (*Arundinaria alpina*) and extensive areas of grassland rich in species including legumes. The most important genera are Hyparrhenia, Eragrostis, Panicm, Sporobolus, Eleusine, Pennisetum, Trifolium, Eriosaema, Crotalaria (Temesgen Gashaw, 2015).

Afroalpine and sub- afroalpine ecosystem: The vegetation type consists of areas which are, higher than 3200m a.s.l in highly rugged and dissected mountain peaks of the country. The lower limit of the afroalpine falls at about 3500m, while sub afroalpine areas range between 3200-3500m. The characteristic plant species in this vegetation type include small trees, giant herbs, shrubs and herbs: Erica arborea, Philipphia trimera, Kniphofia spp., Helichrysum spp., Bartsia petitiana, Alchemilla spp., Crassula spp., and giant Lobelia spp.; grasses are mainly species of

Festuca, Poa and Agrostis (Temesgen Gashaw, 2015). Two of the most famous parks of Ethiopia Semien Mountain National Park (SMNP) in the north and Bale Mountains National Park (BMNP) in the south are located here.

Livestock grazing and barely cultivation, usually involving fire, are the major human activities, threatening existence of this vegetation. Afroalpine area has cold temperature throughout the year with frequent snow. Community which resides in this area cultivates crops like barley, oat, potato and flax. It grows variety of grasses and shrub flora and succulent stem weeds which are grouped in Crassulaceae family. Anthropological interference and free grazing in the niches are the major causes of the reduction of flora and fauna biodiversity. Soil fertility depletion is observed due to continuous farming and high leaching. This condition needs due attention to restore and conserve the remaining resources (Temesgen Gashaw, 2015).

Montane grassland ecosystem: This ecosystem has physiognomy which comprises different floristic arrangement and bionetwork. Montane grass land is mostly found within the range of 1500 to 3200 meters above sea level. Several species of grass like Eragrostis, Hyparrhenia, Pennisetum, Panicum, Cymbopogon, Cynodn and trifolium are commonly found in the system (Skarpe, 1991). Shrubs occurring in this vegetation type include *Acokanthera schimperi*, *Carissa edulis*, *Euclea schimperi*, *Rhamnus staddo*, *Myrsine africana*, *Dodonaea angustifolia*, Rhus spp., *Calpurnia aurea*, *Jasminum abyssinicum*, *Osyris quartipartita*, *Ximenia americana*, *Protea gaguedi*. The trees include *Teclea nobilis*, *Croton macrostachyus*, *Bersama abyssinica*, *Olea europaea* sub-spp. cuspidata, *Juniperus procera*, Ficus spp., *Euphorbia abyssinica*, E.candelabrum, Dracaena spp. The dominant liana is *Pterolobium stellatum*. The scrub differs from the thicket in having more and larger trees usually occurring in small clumps. The vegetation type has been expanding at the expense of others. However, it is disappearing from vicinities of towns due to high demand for firewood (Temesgen Gashaw, 2015).

Combretum-Terminalia or Broad Leaved Deciduous Woodland: The characteristic plant species in this vegetation type include small trees with fairly large deciduous leaves often with the lowland bamboo (Oxythenatera abyssinica): species of Combretum and Terminalia, Oxythenanthera abyssinica, Boswellia papyrifera, Lannea schimperi, Anogeissus leiocarpa, Stereospermum kunthianum, etc. The understory is a combination of herbs and grasses while in some of the shallow valleys extensive areas of very tall grasses dominated by species of

Cymbopogon, Hyparrhenia, Echinochloa, Sorghum, Pennisetum, etc. are found. This vegetation type occurs in the north-western, western and south-western parts of the country with altitudinal range of 500 and 1900m (Temesgen Gashaw, 2015). The vegetation has developed under the influence of fire.

2.5 Regeneration of vegetation

Plants maintain and expand their populations in time and space by the process of regeneration. Regeneration is a complex ecosystem process involving asexual and sexual reproduction, dispersal and establishment in relation to environmental factors (Barnes *et al*., 1998). It is an ecological process that ensures the development of successive generations of plants. The strategies by which plants regenerate are soil seed banks, seedling banks and vegetative parts (Habtam, 2012). According to Petrie (1999), natural regeneration refers to the natural process by which plants replace or reestablish themselves by means of self-sown seed or vegetative recovery (sprouting from stumps, rhizomes or roots).

2.6 The threats to Ethiopian vegetation

The Ethiopia vegetation's, particularly the forest resources are under severe pressure as a consequence of inhabitants' need for farmlands and grazing lands. There is a severe and increasing fuel wood gap in the country; which leads to depletion of the standing stock and, hence, further degradation of the remaining forest stands (EPA, 1997). The loss of forest resource is severe in the Ethiopian highlands where most of the vast mountain massifs in the heart of the country lie above 1500 m elevation (Deriba Geleti, 2006).

These highlands cover about 44% of Ethiopian land area; accommodate 88% of the total population because of their agricultural potential and low prevalence of diseases. They also contain about 95% cultivated land and more than 67% of the livestock (EFAP, 1993). The location of Ethiopian high forests on the zone of these densely populated highlands and their unique ecology make them endangered. According to FAO (1985), the major threats to the conservation of the Ethiopian vegetation are increasingly intensive use of forestlands for agriculture and livestock, need of fuel wood and construction materials, forest fires and human settlement. These major causes of forest destruction are very much interrelated and most are ultimately initiated by the rapid population growth in the country (Getachew Eshete, 2002).

2.7 The Value of Forests

In Ethiopia the contribution of forests to local livelihoods and the national economy as a whole is the values, but is largely unrecorded and hence unrecognized. Forest resources are among natural resources that have substantial socio-economic, cultural and ecological importance in Ethiopia. There is a growing awareness of the significance of forest resources and the link between biodiversity, ecosystem service and human well-being (EFS, 2014). Forests are also source of timber and non- timber forest products (NTFPs). The economic value of Ethiopian forest is not given the proper attention, even if they are sources of ecosystem services, including NTFPs that sustain rural livelihoods.

The most important NTFPs that generate substantial income for rural households and foreign currency earnings in Ethiopia are coffee, honey and natural gums and resins. A study conducted on a participatory forest management concession in a southeastern city called Dodola, indicates that forest products are the most important sources of income, contributing to 34% and 53% of household per capita income and per capita cash income respectively (EFS, 2014).

2.7.1 Ecological services of forests

Ecosystem services are the outcome from ecosystem functions that benefit human being (FAO, 2007). The services provided by forests cover a wide range of ecological, economic, social and cultural considerations and processes. This diversity means that there are no easy management is not a technical or mechanical process but one that must necessarily in crepitate a variety of competing interest groups and views (Bingham *et al.*, 1995). There are a number of components to broad range of services that forests provide in addition to their values of basic goods. They contribute more than other terrestrial biomass to climate relevant cycles and biodiversity related processes (FAO, 2007). According to Daily (1997), The major services provided by forests includes: Regulation of water regimes, modulating climate, maintenance of soil quality, carbon sequestration, maintenance of biodiversity in themselves and being a habitat for other species air pollution, biological control, cultural, astatic and amenity services.

2.7.2 Socio-economic services of forests

Forests provide a wide range of products and services catering to a variety of man's socio-economic needs. The economic values of the forest are inherently anthropocentric by nature forests form the basis of a variety of industries including timber, processed wood and paper, rubber, and fruits. They also contain products that are necessary to the viability of rural communities. These products include fuel, fodder, game, construction materials, and medicines (FAO, 2010).

In Ethiopia forest resource play a vital role as source of energy. The energy consumption of rural Ethiopia is mainly based on biomass sources for which fuel wood being the highest component. Almost, all rural Ethiopian households entirely depend on biomass fuel to meet their energy requirements for cooking, heating and lighting. Biomass based fuel accounts for 85% and 95% of the total energy and household consumptions respectively. In the share of different biomass based fuels in the total domestic energy, fuel wood and tree residues take 70%, animal dung 8%, agricultural residues 7% and the rest comes from other sources (EARO, 2000).Fuel wood and tree residue represent the bulk of the domestic energy supply. Fuel woods are derived mainly from various forest vegetation's such as high forests, woodlands, bush lands, etc. This extra ordinary dependence on biomass-based fuel persisted in the country for a long period of time and is one of the highest in Africa (Mulugeta Limeneh, 2007).

The forest resource in Ethiopia also provide non-timber forest products (NTFPs), which cover a wide range of product naturally produced by certain forest species (Anonymous, 2001).According to Demel Teketay (2002), The most important NTFPs in Ethiopia include Gum Arabic, resin, coffee, species, incense, edible plant products (fruit, seeds, oil, fodder, etc.), fibers, essential oils, tannin and dyes. Traditional Medicine has an important place in the health care of Ethiopian population. It is estimated that 80% of the people in Ethiopia rely on some form of traditional medicines that are obtained from plants for their primary health care needs.

2.8 Plant community and vegetation structure

Vegetation structure is the organization in space of the individuals that form a community and by extension a vegetation type or plant association (Muller-Dombois and Ellenberg, 1974). It is the spatial pattern of growth forms in a plant community, especially with regard to their height, abundance or coverage within the individual layer (Jennings *et al*., 2003).

2.9 Species Diversity, Richness, evenness and Similarity

Species diversity can be viewed from different perspectives: alpha, beta and gamma diversity. Alpha diversity refers to the diversity of species within a particular habitat or community. Beta diversity is a measure of the rate and extent of change in species along a gradient from one habitat to another. It is between habitat diversity that measures turnover rates. Beta diversity is sometimes called habitat diversity (Kent and Coker, 1992). Gamma diversity is the diversity of species in comparable habitats along geographical transect and it depends on the alpha and beta diversity (Kent and Coker, 1992).

Species diversity indices provide information about community composition. Measures of species diversity are usually seen to be key indicators for the wellbeing of ecological systems. Among many of the species diversity indices, diversity and evenness are often calculated using Shannon diversity index (Kent and Coker, 1992). It is the most widely used index that combines species richness with evenness. Species richness refers to the total number of species in a community while evenness is the relative abundance of species within the sample or community (Kent and Coker, 1992). Diversity is, thus, measured by recording the number of species and their relative abundances.

The two components may be examined separately or combined in some form of index like the Shannon diversity index. Patterns of plant species diversity have often been noted for prioritizing conservation activities because they reflect the underlying ecological processes such as soil moisture, disturbance and succession are important for management (Lovett *et al*., 2000). Similarity indices measure the degree to which the species composition of quadrants or samples is alike. Sorenson's coefficient which is expressed as $Ss = 2a/ (2a+b+c)$ is the most common binary similarity coefficients because it relies on presence or absence data (Kent and Coker, 1992).

3. MATERIALS AND METHODS

3.1. Description of Study Area

3.1.1. Location and topography of the study area

This study was conducted at mount Garemba natural forest in Sidama Region, Ethiopia particularly at Arbegona Woreda. Arbegona district is characterized by mountainous landscape having an altitude ranges from 2200 to 3340 m asl. Arbegona district is located between $6^0$35'0" – $6^0$45'0" N and $38^0$40'0" - $38^0$50'0" E. It is located 261 km south from Addis Ababa and 77 km southeast from Hawassa town. It is bordered by Gorche district in North West, Kokosa district on the North, Bensa district on the East and Shafamo district on West (Feleke Assefa *et al*., 2015). Garemba mount forest covers 148 ha at elevation ranging from 3073 to 3340 m.asl.

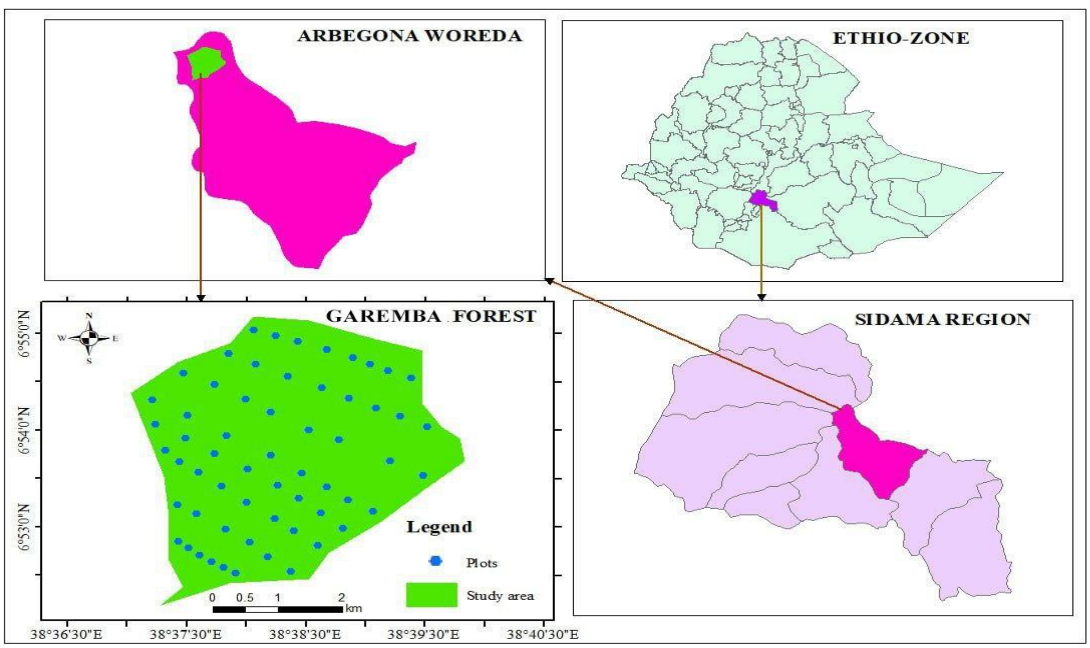


Figure 1.Locational Map of the study area

3.1.2 Geology and soil

The geology of the area is characterized by tertiary intrusive and extrusive rock and thus a trap series of lava deposit, which was (further) uplifted during the formation of the Rift Valley in the Tertiary(AWAO, 2022). The study area comprised mostly chromic Luvisols followed by Humic Nitosols, which is highly eroded and not suitable for cultivation. Soil acidity was stated as a constraint in the study area affecting the productivity of crops. As reported by Ashenafi Mekonnen *et al*. (2017), there was limited practice of liming the acidic soil due to shortage of lime in the area. Due to this low productivity of crops in the area, farmers started shifting from crop production to livestock production.

3.2.3 Relief and drainage

The relief Arbegons Wereda is characterized by undulating high plateau dissected by streams and rivers flowing from these plateau towards the rift valley. Its altitude ranges from approximately 2200 to 3340 m asl. Garemba maintain is the highest peak (3340 m a.s.l.) in this Wereda. The major perennial Gadicha, Taare and Goronte. These rivers are mainly used for irrigation because of their network formed around the Arbegona Town (AWAO, 2022). The stream that originate and flow down from around Mount Garemba join together to form the Genale River which provides hydroelectric power and is currently generating 254 MW of power.

3.1.4 Climate

The climate data was collected from Arbegona Woreda Agricultural Office, obtained from National Meteorological Agency. Ten years data (2012-2022) were taken. Due to its altitudinal location, the Woreda is divided into three agro-climatic zones. Dega which covers 20% of the total area of the Woreda, Woina Dega which is 50% and Kolla covers about 30% (AWAO, 2022). The mean annual rainfall of the study area is 764mm AWAO, 2022). The distribution of rain fall in the area is characterized by wet season from April to September. The big rain is from July to September. The mean annual temperature of the study area is 17.1^0c ranging from the mean annual minimum temperature of 10.0^0c to the mean annual maximum temperature of 25.8^0c. The study falls in to Dega.

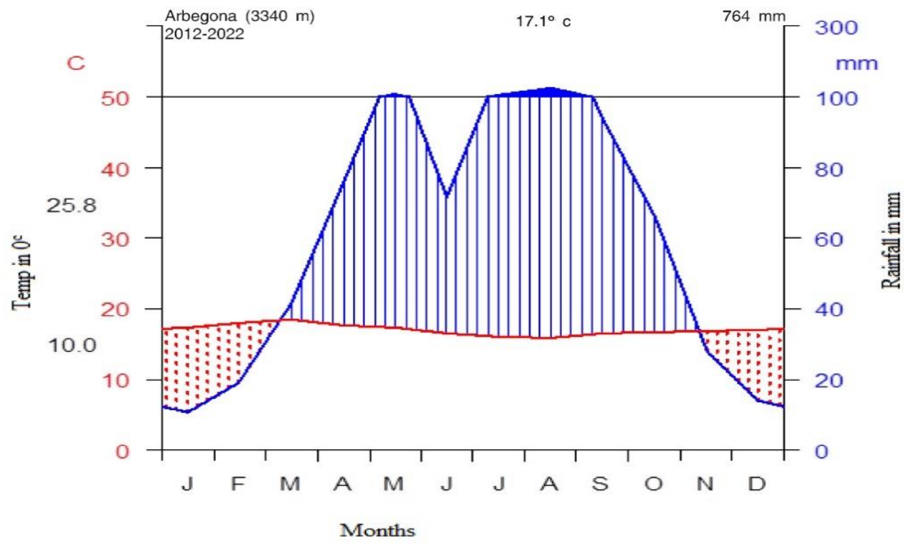


Fig.2. Climate- diagram of Arbegona

3.1.5 Land use pattern

The classification of land of an area under different type of socio-economic uses is important for socio-economic purposes. Patterns of land use changes from time to time depending up on socio-economic change. According to AWAO (2022), a survey of land in this Woreda shows 25124.8 ha (73.7%) of its land is cultivated, 2170.2 ha (6.4%) forest, 5102 ha (15%) woodland and bushland, 39.1ha (1.49%) land for investment and the remaining and 1302 ha (3.8%) includes non-cultivated, water bodies, swampy and rocky mountain areas and others.

3.1.6 Human population

Based on the data obtained from Arbegona Woreda Agricultural Office (AWAO, 2022) in the year 2022, the Woreda had a total population of 163645 of which female population accounts about 81710 and about 81935 are males. Out of these 75906 of females are found in rural areas and 7198 of females are reside in urban areas. Male population in rural areas accounts about 74736 and at urban 5805.

3.1.7 Natural vegetation

Sidama highlands are part of the eastern Dry evergreen montane Biodiversity Hotspot, and is thus of significant global importance (Burgess *et al*., 2004). The vegetation of the study area with important tree species. At the elevation between 3244-3340 m.a.s.l., The *Arundinaria alpine* and *Erica arborea* are dominant in association with *Bersema abyssinica, Buddleja polystacha, Brucea antidysentrica, Canthium ololigocarpum, Cupressus lusitanica, Discopodium penninervum, Dombeya torrida, Ilex mitis and Prunus africana.*

At the middle zone between 3172-3237 m.a.s.l. The *Commiphera schimperi* and *Dovyalis abyssinica* are dominant associated with *Erythrina brucei, Hagenia abyssinica, Hypericum revoltum, Myrsine melanophyleoes, phytolocca dodecandria, Solanecio gigas and Urera hypselodendron.*

At lower zone between 3073-3175 m.a.s.l. The *Ekebergia capensis* and *Solanum incanum* are dominant in associated with *Galiniera saxifraga, Juniperus procera, Measa lanceolata, Ocotea kenyensis, Olea europea, Pittosporum abyssinica, Rubus apetalus, Rubus steudnrii, Vernonia amygladina and Vernonia auriculifera*

Plate 1. Partial view of Garamba vegetation

3.1.8 Wildlife

There are various wild animals in Garemba Forest including mammals, Fan-tailed raven (*Streptopelia lugens*), Thick billed raven (*Galerida theklae)*, Mountain thrush (*Turdusoli vaceus*), Wattled ibis (*Cinnyris venustus*), Alpine swift (Tachymarptis *melba*), hyena, tiger and cheetah. The endemic mammals such as Menelik'sbush buck and red fox are also found the Arbegona Garemba forest (AWAO, 2022).

3.1.9 Socio Economic Activity

The study area is located in a region which is one of the highly dense populated parts of country and the forests and settlement place is connected without gap between them. Cutting of trees and grazing is forbidden by the local government but the local people are still use the forest for grazing and use selective cutting of bamboo for different purposes. The economic activity in the district is predominantly agriculture. Most of people depend on agricultural products (animals herding, bee keeping, and cash/non-cash crop products). The major food is Enset and the annual cereal crops in the area are maize, barely, teff, bean and wheat. Livestock rearing is also another major activity in the district. The major livestock reared in the Arbegona district were cattle, sheep, goats, mules, beekeeping, donkeys, horses and poultry (AWAO, 2022). Most areas of the district are highly degraded due to deforestation through expansion of marginal land to farmland and unwise land using practices. This leads to depletion of natural resources, low land productivity and loss of wild animals. The major problems of the highlands are: deforestation, land degradation, soil erosion, loss of biodiversity, loss of crop productivity, loss of soil fertility and food insecurity.

Plate.2 Socio-economic conditions of study area

3.2 Methods

3.2.1. Reconnaissance survey

A reconnaissance survey was conducted across the Garemba forest on Oct. 12-16/2021 in order to obtain an impression of the site conditions and variation in physiognomy of the vegetation and to identify sampling site.

Data collection was made from December18 through February 17, 2022

3.2.2 Sampling design

Systematic sampling design was used to collect vegetation data from the study site. The transect lines and sampling plots were made based on the total area of study site for vegetation data collection. The sampling plots were placed at every 100 m intervals along the 8 transect lines laid at 400m interval. Each of the 6 transects contains 8 plots and remain 2 transects contain 6 plots respectively with equal size of 20 m x 20 m (400 m^2) and five subplots 5m*5m (25m2), four at corners and one in the middle established to collect data for seedling and sapling for regeneration analysis. A total of 60 sampling plots were considered to trees and shrubs. The first transect was laid starting from the lowest altitude of the study area by entering about 200m from edge of the forest to avoid the "edge effect".

3.2.3. Vegetation data collection

3.2.3.1 Floristic data

The data were collected between March and end of April 2022. Each individual of the woody species in the plots were counted, the breast height of all trees and shrubs at height >2.5 m and DBH >2.5 cm were measure. Those woody plant species with DBH ≤ 2.5 cm but with height > 1.5 m and ≤2.5 m will recorded as sampling and those ≤ 1.5 m height as seedling. The diameters at breast height (DBH) of all the woody plant at 1.3 meter above the ground were measured using a meter tape. Height of trees was measured using calibrated bamboo stick. When the crown or canopy structure made height difficult to measure, it was visually estimated. If the tree branched at breast height, the diameter was measured separately for the branches and averaged. Woody plant species outside the study plots were also recorded to prepare a complete list of plants in the study area. DBH values were calculated from circumference measurements. Physiographic variables such as altitude, latitude and longitude was measured for each plots using GPs. Canopy cover data defined here as the proportion of area in a quadrat covered by tree and shrub species recorded and gathered from each quadrat were converted to the 1-9 Braun- Blanquette scale, which was later modified by Van der Maarel (1979) as follows:

1: Rare, generally one individual;

2: Occasional, with less than 5% cover of the total;

3: Abundant, with less than 5% cover of the total;

4: Very abundant, with less than 5% cover of the total;

5: 5-12% covers of the total area;

6: 12-25% covers of the total area;

7: 25-50% covers of the total area;

8: 50-75% covers of the total area;

9: 75-100% covers of the total area;

3.2.3.2 Structural data

All woody plant species greater than 2.5 m in each plot were estimated. The DBH (diameter at breast height) value were calculated by using the following formula C= πd where C=Circumference, π=3.14 and d=diameter (Kent and Coker, 1992). Density, frequencies, basal area, and IVI of trees and shrubs were calculated after individual woody plant species were measured and counted.

3.2.4 Identification of voucher specimen

The equipment's such as plastic bags, plant press, tape measurement, scissors, and note books were used during vegetation data collection in the field. Their local names were recorded and Specimens were collected, pressed, dried. Then after Species were identify using Ethiopia and Eretria flora books, especially Azene (2007) and confirmed by a researcher advisor.

3.2.5 Data analysis

3.2.5.1 Floristic data analysis

Microsoft Excel was employed to organize data and describe floristic composition and growth forms. Hierarchical cluster analysis was used for identifying groups of community types of plant species using R computer program version 2.15.2 (The R core Team, 2015). Species abundance data in each quadrant were used as input. The plant community types were named after two / or three characteristic and /or dominant species selected using the relative magnitude of their mean cover-abundance value.

3.2.5.2 Species diversity analysis

The evenness and diversity of plant species was analyzed using the Shannon Evenness Index (E) and Shannon-Wiener Diversity Index (H') (Jayarman, 2000). Shannon and Wiener (1949) index of species diversity was applied to quantify species diversity and richness. This method is one of the most widely used approaches in measuring the diversity of species. The diversity of each cluster was calculated using Shannon-Weiner diversity index, based on cover/abundance value of the species as input source. The relative equitability (evenness) of the species in each cluster also calculated. The indices of species diversity, richness and evenness were measured using different indices. Species diversity indices widely used was: Shannon-Weiner index and Sorenson index of similarity (Mueller-Dombois and Ellenberg, 1974). For this study the Shannon Weiner diversity index was used to calculate as follows (Krebs, 1999; Kent and Cocker, 1992 and Jayarman, 2000).

$$\text{Shannon Index } (H') = -\sum_{i}^{s} p_i \ln p_i$$

Where: H′ = the Shannon diversity index, pi is the proportion of the total community abundance and ln (pi) is the natural log of pi, S = numbers of species encountered and Σ = sum from species 1 to species S. The minimum value of H' is 0, for a plot with a single species and H`=1 indicates that the plot with complete Evenness. The different value of H` for each plot indicates that the difference in species richness and evenness (Whittaker, 1975). The value of H` increases as species richness and evenness increase and vice versa (Manuel and Molles, 2007). Equitability or evenness index was calculated from the ratio of observed diversity to maximum diversity using the equation.

$$E = H'/\ln(S)$$

Where: E = Evenness; H' = Shannon-Wiener Diversity Index. The value of evenness index falls between 0 and 1.

3.2.5.3 Structural data analysis

Structural analysis of the vegetation was described based on the analysis of species density, DBH, height, basal area, frequency, and Important Value Index (IVI) for those individual species having DBH greater than 2.5 cm and height greater than 2.5 m. All individuals of woody plant species record in all plots were using in the analysis of vegetation structure. Parameters like tree density, frequency, tree height, diameter at breast height (DBH) and basal area (Kent & Coker, 1992) were used to describe vegetation structure and calculated as follows:

$$\text{Density (D)} = \frac{\text{the number of above ground stems of species}}{\text{Sampled area in hectare}}$$

Basal Area (B.A) = (DBH/2)2 * 3.14

$$\text{Frequency (F)} = \frac{\text{(Number of plots in which a species occurs)}}{\text{Total number of plots}}$$

$$\text{Relative Frequency (R.F)} = \frac{\text{Frequency of a species x 100}}{\text{Total frequency of all species.}}$$

Important Value Indices (IVI) = Dominance + Relative Frequency + Relative Density

Where,

$$\text{Relative basal area} = \frac{\text{(Basal area of the species) x 100}}{\text{Total basal area}}$$

$$\text{Relative abundance} = \frac{\text{(Number of all individual of species) x 100}}{\text{Total occurrence of the species in all the plots}}$$

3.2.5.4 Phytogeographical comparison

Sorensen's similarity index was employed to compare Garamba forest woody plant species composition to forests located at different parts of the country. Sorensen's similarity index is used to evaluate woody plant species and species distribution among plant communities and mathematically expressed with the following formula (Kent and Coker, 1992).

$$Ss= 2a/2a+b+c$$

Where Ss = Sorensen's similarity coefficient

a = number of woody species common to Garemba Forest and other forests in comparison;

b = Number of woody species found only in Garemba Forest;

c = Number of woody species found only in the forest in comparison with Garemba forest.

3.2.5.5 Population structure

Population structure is the distribution of the individuals of each species in arbitrarily DBH size classes to provide the overall profile of species under study (Peter, 1996). The population structure of all woody species in the study site were analyzed using the data of stems having DBH>2.5 cm. The population structure diagrams used to discuss the different patterns of population structures (Peter, 1996).

4. RESULTS AND DISCUSSIONS

4.1 Floristic Composition of Woody Plant species

4.1.1 Floristic Composition

A total of 35 woody plant species belong to 32 genera and 24 families were recorded in the study area. The most diverse families were Rosaceae (4 species), Asteraceae and Rubiaceae (3 species each), Cupressaceae, Fabaceae, Myrsinaceae and Solanaceae (2 species each), and 17 other families were represented by 1 species. A total of 1483 individuals of woody plants were counted.

Table1. List of plant Families with their number of genera and species encountered in Garemba Natural Forest.

Family	Genera	Species	Family	Genera	Species
Aquifoliaceae	1	1	Oleaceae	1	1
Asteraceae	2	3	Phytolaccaceae	1	1
Burseraceae	1	1	Pittosporaceae	1	1
Celestraceae	1	1	Poaceae	1	1
Cupressaceae	2	2	Rosaceae	2	4
Ericaceae	1	1	Rubiaceae	2	3
Fabaceae	2	2	Simaroubaceae	1	1
Flacounticaceae	1	1	Solanaceae	2	2
Francoaceae	1	1	Scrophulariaceae	1	1
Hypericaceae	1	1	Stericulaceae	1	1
Lauraceae	1	1	Urticaceae	1	1
Meliaceae	1	1			
Myrsinaceae	2	2			

Floristically, Garemba natural forest had fewer number of woody plant species (35) when compared to some other Dry evergreen forests in Ethiopia like Assabila forest in West Gojjam (Mengistu Agegnehu, 2020) with 44 species, Angeda forest located in southeast (Shambel Alemu, 2011) with 87 species, Wurg forest in southwest (Girma and Melesse, 2020) with 76 species and Ylat forest (Sisay Tegegne, 2016) with 60 species. This might be due to logging, clearing vegetation for arable land expansion and grazing and lack of sufficient conservation as well as lack of community based forest management.

4.1.2 Habit

The analysis of the habit of woody species recorded from Garemba natural forest revealed that trees contributed the highest species number 19 (57.6%) followed by shrubs with 12(36.4%) and lianas comprised of 2 (6.02%) species (Figure 3). Based on the endemic flora of Ethiopia available in the published volumes of Flora of Ethiopia and Eritrea, from the 35 species, collected 2 were endemic. This endemic species are *Ertythrina brucei* in the family fabaceae and *Solanecio gigas* in the family of asteraceae. Endemic plant species of Ethiopia and their level of threat have been given in Ensermu Kelbessa *et al*., (1992) and Vivero *et al*., (2005). The two indicator plant species were recorded from Garemba forest are *Dombeya torrida* and *Maesa lanceolate*.

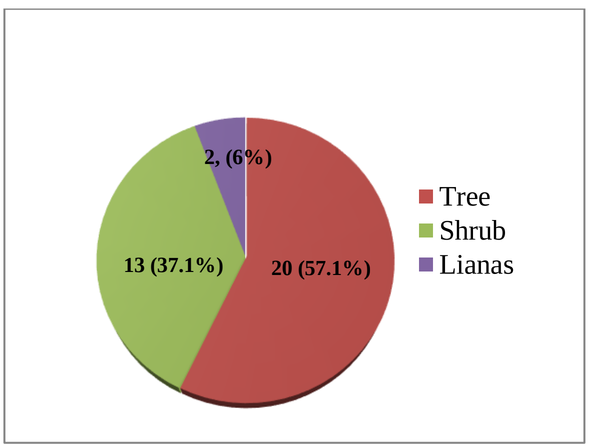


Fig 3. Growth forms of collected plant species in Mountain Garemba

4.2 Vegetation Community Types

The cluster numbers in the dendrogram correspond to the community types. The description of the plant community types is based on the frequency and characteristic species. A total of three communities were derived at dissimilarity level. These clusters were designated as local plant community level. Usually trees and shrubs were with higher value. The description of the plant community types based on the frequency and related structural characteristic of species with their altitudinal distribution is as follows. The cluster numbers in the dendrogram corresponds to numbers of the community types in the subsequent discussion.

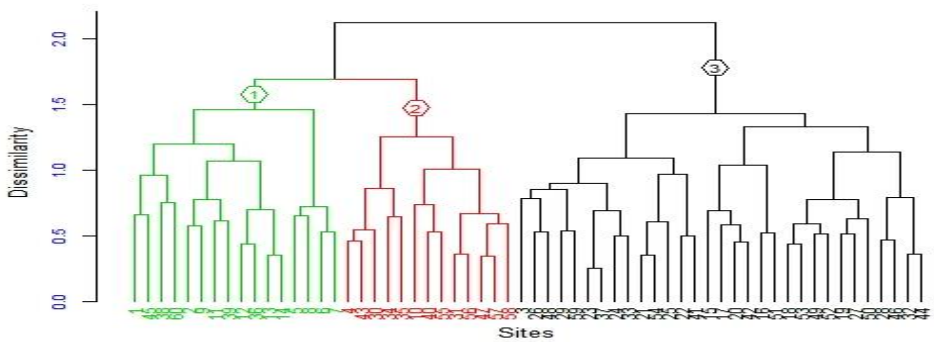


Figure. 4. Dendrogram showing the woody plants community types of the study area

Table.2 Communities and the distribution of sample plots in the communities

Community type	Plots in the community	Total plots	Altitude (m)
I	1, 45, 38, 60, 2, 9, 11, 39, 12, 36, 13, 14, 5, 8, 6 and 7	16	3244—3340 M.a.s.l
II	4, 43, 30, 34, 35, 10, 40, 55, 31, 56, 47, 57 and 58	13	3172 — 3237 m.a.s.l.
III	3, 26, 48, 29, 59, 23, 37, 24, 33, 21, 54, 25, 22, 41, 15, 17, 20, 42, 16, 51, 18, 53, 49, 52, 19, 27, 50, 28, 46, 32 and 44	31	3073 — 3175 m.a.s.l

Community 1 *Arundinaria alpine -Erica arborea* community type

This community type was distributed between the altitudinal ranges of 3244-3340 M.a.s.l and contains 16 plots and 11 plant species. The *Arundinaria alpine* and *Erica arborea* were dominant species of this community. The other woody species associated with this community type include: *Bersema abyssinica, Buddleja polystacha, Brucea antidysentrica, Canthium ololigocarpum, Cupressus lusitanica, Discopodium penninervum, Dombeya torrida, Ilex mitis* and *Prunus africana.*

Community 2 *Commiphera schimperi -Dovyalis abyssinica* community type

This community type was found at the altitudinal ranging between 3172-3237 m.a.s.l. This community resulted from 13 plots and 9 plant species. The *Commiphera schimperi* and *Dovyalis abyssinica* were dominated species of this community. The other woody species associated with this community type include: *Erythrina brucei, Hagenia abyssinica, Hypericum revoltum, Myrsine melanophyleoes, phytolocca dodecandria, Solanecio gigas* and *Urera hypselodendron.*

Community 3 *Ekebergia capensis -Solanum incanum* community type

This community type was distributed between the altitudinal ranges of 3073-3175 m.a.s.l and contains 31 plots and 13 plant species. The *Ekebergia capensis* and *Solanum incanum* were dominant species of this community. The other woody species associated with this community type include: *Galiniera saxifraga, Juniperus procera, Measa lanceolata, Ocotea kenyensis, Olea europea, Pittosporum abyssinica, Rubus apetalus, Rubus steudnrii, Vernonia amygladina* and *Vernonia auriculifera*

4.3 Measure of species diversity analysis

Diversity to be high if the species distributed evenly and, only a few species dominate the area, the diversity will be low (Rosenzweig, M.1995). In Garemba natural forest, 35 plant species and 24 families' were recorded. Shannon-Wiener diversity index and Evenness were computed for the three communities for the vegetation data of Garemba Forest. Of the three community types, community 1 has the high species richness and diversity and followed by community 3 with the highest evenness. Community 3 has the low species richness and diversity which may be due to the dominance of the environment by few species but, community 2 has an intermediate evenness value compared to communities 1 and 3. Also, the low species evenness can be attributed to excessive disturbance, variable conditions for regenerations and exploitation of some species (Wassie and Demel, 2006). There was no a big difference in Shannon diversity index and evenness among the three communities. The reason for closeness of diversity and evenness of these three communities could be attributed to relatively comparable altitudinal ranges.

Table 3: Species richness, evenness and Shannon-Weiner diversity index of the plant community types in Garemba forest

Communities	Richness	H	Shannon Evenness
1.	31	3.54	0.87
2.	29	3.42	0.84
3.	24	3.33	0.85

4.4 Vegetation Structure

4.4.1 Density

The number of plants per unit area is expressed as density and it is critical measure for long term for management. According to the data analysis the density of tree and shrub individuals of Garemba forest with DBH greater than 2.5cm was 262.9 stems per hectare. *Arundinaria alpine* had 78.7 stems per ha (29.9%), *Erica arborea* 77.9 stems per ha (29.6%), *Hypericum revoltum* 61.7 stems per ha (23.5%) and *Galiniera saxifraga* 8.7 per ha (3.3%) and DBH greater than 10cm are 165.4 stems per hectare. When the total density 618 stems per ha of Garemba natural forest was compared with that of three other Dry evergreen forest in Ethiopia, it is lower than that of Gole forest, 626 individuals ha^{-1} (Etalem Geresu, 2016), Gatira Goere's, 1156 stems per ha (Andualem Ayalew, 2020), and Menagesha suba, 2016 individuals ha^{-1} (Dinkissa Bechet, 2011).

Table.4. Density of tree with DBH greater than 2.5cm and 10cm per hectare.

Type species	Density of individuals per hectare	
	DBH>2.5cm	DBH>10cm
Arundinaria alpine	79	32
Bersema abyssinica	4.6	4.2
Commiphera schimperi	2	5
Cupressus lusitanica	0.8	1.7
Dombeya torrida	6.25	1.25
Ekebergia capensis	2.5	6.7
Erica arbora	78	11.25
Erythrina brucei	1.25	8
Galiniera saxifrage	8.75	3.3
Hagenia abyssinica	0.83	36.25
Hypericum revoltum	61.7	7.2
Ilex mitis	5	11.7
Juniperus procera	0.83	0.83
Maesa lanceolata	0.83	2.9
Myrsine melanophleoes	4.2	11.7
Ocotea kenyensis	2.1	3.3
Olea europaea	0.83	2.9
Pittosporum abyssinium	3.75	6.7
Prunus Africana	0.42	9.2
Total density/hectare	262.9	165.4

4.4.2 Diameter at breast height (DBH) Class distribution

A total of 1483 individuals whose DBH >2.5cm were recorded and six DBH classes were established for DBH analysis. DBH class 1(2.5-10cm), 2(10-20cm), 3(20-30cm), 4(30-40cm), 5(40-50cm), 6(>50cm). The distribution of trees in different DBH class is shown in (fig. 5). It is shown that 938 of the individuals have DBH between 2.5 and 10 cm, 304 of the individuals have DBH class between 10 and 20; and 241 of the individuals have DBH greater than 20 cm.

This show inverted— J shape population distribution. This pattern shows as good regeneration potential of the forest in area.

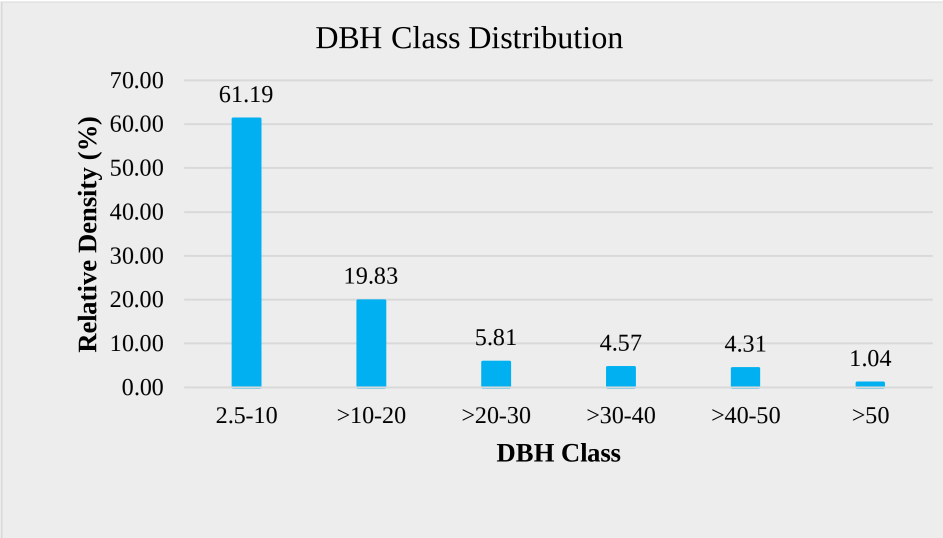


Figure.5. DBH classes distribution of woody species in Garemba natural forest.

The density of woody species of Garemba forest was compared with others forests in Ethiopia regarding the ratio of the diversity of woody species with DBH>2.5 to DBH>10 cm given (Table. 5) The ratio of the density of individuals with DBH greater than 2.5 cm to individuals with DBH greater than in 10 cm in the Garemba natural forest was greater than that of Gole forest (Etalem Geresu, 2016). High total density, but low density of trees greater than 10 cm DBH, low basal area and short trees with small diameters are the main structural characteristics typifying secondary forest (Genene Berkele, 2014). Therefore, the very large proportion of small sized individuals and small number of big trees indicate that the Garemba natural forest is in the stage of secondary development. On other hand the ratio in Garemba forest was more or less similar with that of Gelesha (Bilew, 2022).

Table.5. Comparison of tree densities with DBH>2.5 and> 10 cm from Garemba natural forest with other forests.

DBH class in cm Ratio			
Forest	DBH>2.5 (a)	DBH>10 (b)	a/b
Gole forest[1]	260	270	0.96
Gatira George's [2]	305	57	5.35
Menegesha[3]	484	208	2.30
Gelesha[4]	315	244.58	1.29
Garamba[5]	262.3	165.4	1.59

Source: [1]Etalem (2016), [2]Andualem (2020), [3]Dinkissa (2011), [4]Bilew (2022), [5]Lema (present study).

4.4.3 Height of woody species

For the description of the structure of Garemba natural forest height is greater than 2.5 m were selected. The woody species in the study area are categorized into seven height classes; 1(2.5-5 m), 2(>5-8 m), 3(>8-11 m), 4(>11-14 m), 5(>14-17 m), 6(>17-20 m) and 7(>20 m). The height distribution of trees is shown in (fig.6). Although there is selective cutting trees at certain height (8-11 m and 11-14 m). The seven height class distribution of trees and shrubs in the forest indicated that high proportion of (44.1%) of individuals in the lower height class (2.5-8 m). The height shows similar trend as that of DBH class distribution. This indicates that the forest contains large proportion of small to medium sized individuals, which in turn indicating that the forest is in secondary stage development.

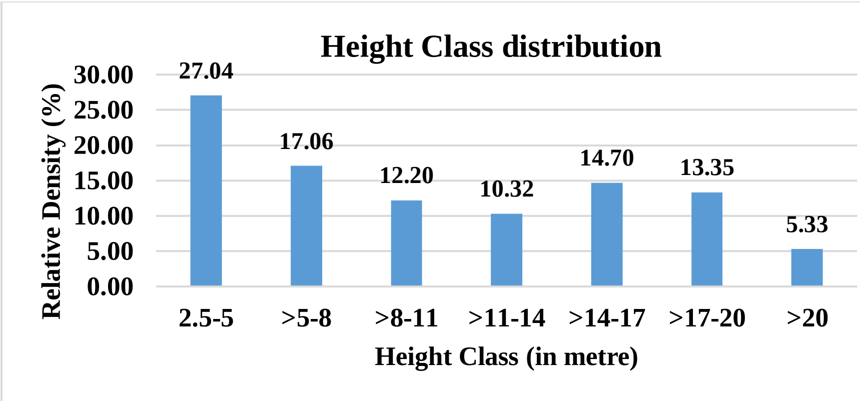


Figure.6 Height class distributions of woody species in Garemba natural forest.

4.4.4 Basal area

The cross-sectional area of all the stems in a stand at breast height is known as the basal area (BA) (1.3 m above ground level). For woody species with DBH>2.5 cm, the total basal area in Garemba natural vegetation was 15.1 m²/ha. About 12.56 m²/ha (83.2%) of the total basal area was contributed by six woody species like: *Arundinaria alpine* (25.4%), *Hagenia abyssinica* (35.2%), *Erica arborea* (7.5%), Ilex mitis (6.3 %), *Hypericum revoltum* (5.5%) and Erythrina brucei (3.3%) were found with the highest basal area in the study forest. Comparison of the basal area of this forest with other Dry evergreen forests in Ethiopia shows that it is greater than Gatira George's (7.84 m²/ha) (Andualem, 2020) and lower than Megada (68.5 m²/ha) (Genene, 2014) and Menegesha (158.68 m²/ha) (Dinkissa, 2011). This may be due to variations in the conservation of the forests, exposure to deforestation and geographical location of the forest.

Table.6. the seven top basal area of selected woody species in Garemba forest

No	Species name	Basal area in m²/ha	%
1	*Arundinaria alpine*	3.83	25.3
2	*Erica arborea*	1.13	7.5
3	*Erythrina brucei*	0.5	3.3
4	*Hagenia abyssinica*	5.32	35.2
5	*Hyperricum revoltum*	0.83	5.5
6	*Ilex mitis*	0.95	6.3
7	*Maesa lanceolata*	0.48	3.2

4.4.5 Frequency

Frequency is defined as the number of quadrats (expressed as percentage) in which a specific species was discovered in the research area. It gives an appropriate indication for homogeneity and heterogeneity of vegetation. *Erica arborea* was found to be the most frequent species in Garemba forest occurring in 6.3% of all plots sampled followed by *Arundinaria alpine* 5.6%, *Hypericum revoltum* 5.3%, *Hagenia abyssinica* 5.1%, *Vernonia auriculifera* 5%, *lex mitis* 4.6% and *Brucea antidysentrica* 4.5%. The least frequent species include among others *Solanum incunum, Olea europaea* and *Jumperus procera* each constituning 0.15%, 1.1% and 0.65% respectively. Conversely high percentage of number of species in the lower frequency classes and lower percentage number of species in the higher frequency classes indicates high degree of heterogeneity (Simon Shibru and Girma Balcha, 2004).

Table.7. the six top frequented plants species in Garemba natural forest

No	Species name	Family	Relative frequency	%
1	*Arundinaria alpine*	poaceae	5.62	5.5
2	*Erica arborea*	Ericaceae	6.3	6.3
3	*Hagenia abyssinica*	Rosaceae	5.2	5.1
4	*Hypericum revoltum*	Hypericaceae	5.4	5.3
5	*Ilex mitis*	Aquifoliaceae	4.75	4.6
6	*Vernonia auriculifera*	Asteraceae	5.1	5

4.4.6 Importance Value Indix (IVI)

The IVI values have aided in recognizing species structural relevance in community organization (Premaveni *et al.*, 2014). It's also used to compare the ecological significance of species, with a high IVI score indicating high sociological structure in the community. According to show Shibru and Balcha (2004), species with the greatest IVI are dominants species a given vegetation. The IVI of the vegetation's woody species was determinate using three structural characteristics (Relative basal area, Relative frequency and Relative density). In this respect, the results of IVI in Garemba natural forest revealed that for *Arundinaria alpine* (58.6), *Hagenia abyssinica* (46.3), *Erica arborea* (28.2) and *Hypericum revoltum* (22.04) were the four species with higher important value index. These woody plants could be ecologically essential in the natural vegetation of Garemba natural forest. Whereas, woody species like, *Solanum incanum* (2.33), *Mytenus arbutifolia* (3.1) and *Juniperus procera* (0.94) found with lower (Table. 8). This indicates that these species are the least ecologically significant species in the site.

Table.8. the eight top ecologically important woody species with highest important value index (IVI), RD, RBA and RF.

No	Species	Do	RF	RBA	IVI
1	*Arundinaria alpine*	17.9	6.3	35.15	58.6
2	*Erica arborea*	14.4	6.3	7.5	28.2
3	*Erythrina brucei*	1.48	3.2	3.3	8.1
4	*Hagenia abyssinica*	6	5.2	35.15	46.3
5	*Hypericum revoltum*	11.1	5.4	5.5	22.04
6	*Ilex mitis*	3	4.75	6.3	14.01
7	*Maesa lanceolata*	3.7	4.3	3.2	11.2
8	*Myrisene melanophleoes*	2.3	3.4	3.3	9.3

Note: Do = Dominancy, RF = Relative Frequency, RBA =Relative Basal Area and IVI = Important Value Index

4.4.7 Phytogeographical comparison

The floristic element approach has been used widely; geographical position of a flora plays a more important role in determining the composition of floristic elements than climate. This may be in part because floristic elements are defined by their geographical, rather than ecological distributions (Qian *et al.*, 2006).

The direct comparison of the species diversity of one forest with other forests is not feasible due to variations in size, survey methods used, and objective of the study among forests (Tadesse Woldemariam, 2003). However, the overall species richness of the forest can give more or less a general impression of their diversity and phytogeographical similarity. In this regard Garemba Forest is compared with eight Dry evergreen montane forests in the country to see the distribution pattern of woody species in the study area and to know the relative similarity in its woody species composition (Table 9). These are Angeda, Borana, Garadura, Gurumo woide, Menagesha Suba, Telet, Ylat and Zijje maryam church forests.

Table 9. Phytogeographical comparisons between Garemba and other forests.

Forest	Altitudinal range	a	b	C	Ss	Sources
Angeda forest	2145-2562	19	16	68	0.31	Shambel Alemu, 2011
Borena forest	1000-3700	16	19	41	0.35	Tsehaynew Getnet, 2020
Gara duro forest	2339-2900	15	20	19	0.43	Kedir Beno, 2020
Gurumo woide forest	2170-2429	9	16	37	0.25	Haron Matalo, 2016
Menagesha suba forest	2404-2951	25	10	87	0.34	Dinkissa Beche, 2020
Telet forest	2201-2539	10	25	38	0.24	Mengistu Agegnehu, 2020
Ylat forest	1699-3202	14	21	46	0.29	Sissy Tegegne, 2016
Zijje maryam church forest	700-3200	28	7	42	0.53	Berhane Gebreslassie *et al.*, 2022

Sorensen's similarity index which is dependent on the number of common species shared by the forests being compared indicated that Garemba and Zijje maryam church forest show the highest similarity (53%). This was followed by Gara duro and Borena forest with similarity of 43% and 35% respectively. The Garemba and Telet forests had the lowest similarity of 24%.

The distribution range of a species is controlled by environmental factors for which the organism has the narrowest range of adaptability or control. Other important factors controlling species distribution a part from changes in the environmental conditions include evolutionary changes that greatly influence the potential range of species (Shambel Bantiwalu, 2010). This explains high dissimilarity between species confined to Garemba and Telet forests and the two forests differ in their woody species probably due to different levels of precipitation as well as the nature of the soils.

4.5 Population structure of selected Woody species in Garemba forest

4.5.1 DBH class distribution of structural patterns of selected woody species

Analysis of the DBH class distribution of six woody species interims of their density in Garemba forest revealed 6 general distribution patterns.

The first population pattern was represented by *Mysine melanophyleoes.* In this population pattern, higher number of individuals in the middle diameter class and low number of individuals in lower and higher diameter (DBH) class (Fig. a). *Ekebergia capensis, Dovyalis abyssinica,* *Commiphera schimperi* and *Canthium oligocarpum* had Bell-shaped population structure. The second population pattern was represented by *Erica arborea*. In this population pattern, high number of individuals in first diameter class followed by very low number of individual in the second diameter and absence of individuals in the successive higher diameter classes. Species like *Arundinaria alpina, Hypericum revoltum* and *Galiniera saxifraga* had this type of population pattern. This type of population structure suggests good reproduction and bad recruitment status (fig. b).

The third structure (Fig. c) included *pittosporum abyssinium.* This pattern was represented by high number of individual in first two DBH class, gradual decrease in the number of individuals towards the medium classes, and then a subsequent increase in towards high DBH classes. Such structure does not actually occur in nature. It probably indicates selective cutting and removal of medium sized individuals of these species. Species like *Olea europaea* and *Prunus african* showed 'U' shaped pattern. The fourth pattern was represented by *Maesa lanceloata*. In this pattern, high number of individuals in the lower diameter classes and decreasing the number of individuals towards higher diameter (DBH) classes (fig. d). *Cupressus lusitanca, Juniperus procera* and *Dombeya torrida* had inverted J- shape population pattern. This type of population structure suggests good regeneration status.

The fifth pattern included *Ocotea kenyensis* represented by the broken up inverted 'J' curve structure also show good regeneration but discontinuous recruitment in to large size classes (Fig. e). This pattern includes other species like *Vernonia amygdalina*, *Bersema abyssinica* and *Vernonia auriculifera*. Once of this possible reason for the discontinuity in this type of structure could be the anthropogenic disturbance. The six pattern was represented by *Hagenia abyssinica.* In this pattern, high number of individuals in the higher DBH classes and decreasing the number of individuals toward lower DBH classes (Fig. f). Species such as *Ilex mitis*, *Erythrina brucei* and *Acacia albida* had 'J'- shaped population distribution

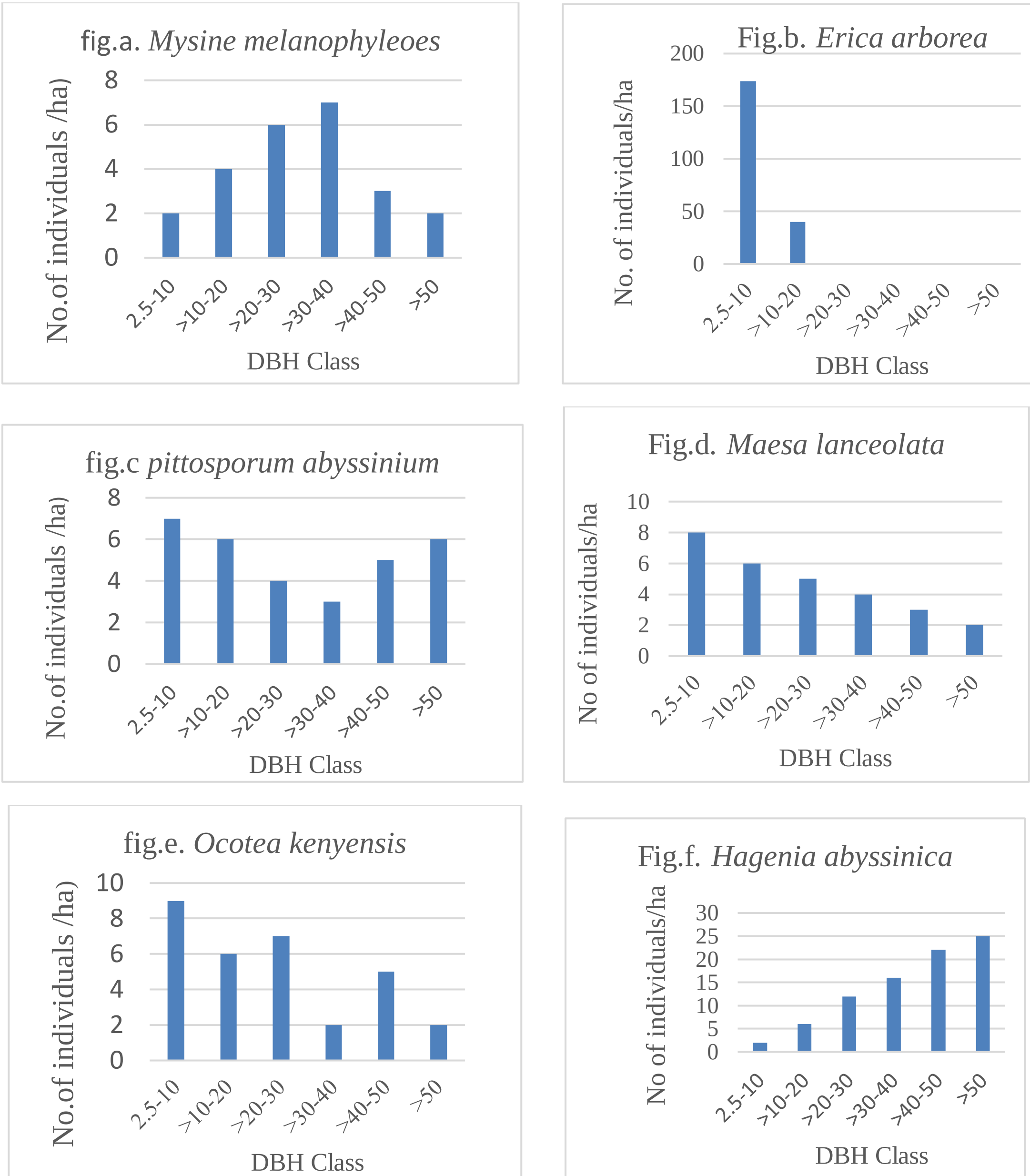
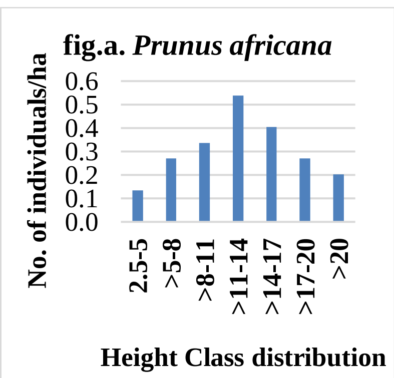
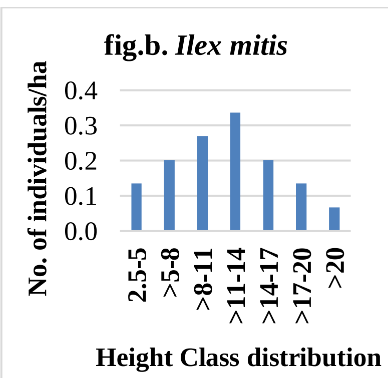


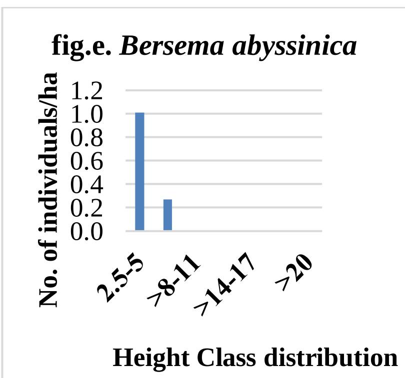
Figure.7 DBH class distribution of structural patterns of selected woody species in Garemba natural forest.

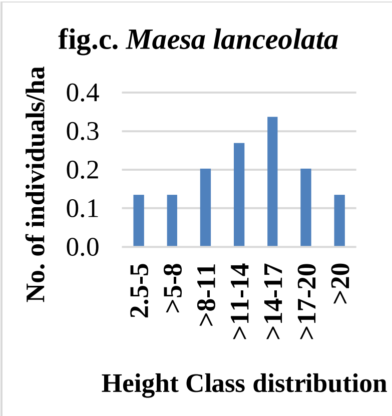
4.5.2 Height class distribution of structural patterns of selected woody species

Analysis of the height class distribution of five selected woody species in terms of their density in Garemba forest revealed two general distribution patterns. The first pattern was represented by *Prunus africana, Ilex mitis, Maesa lanceolata, Hagenia abyssinica, Juniperus procera, Dombeya torrida, Commiphera schimperi, Ocotea kenyensis, Myrsine melanophleoes, Ekebergia capensis* and *Cupressus lusitanica*. In this pattern, high number of individuals in the middle height classes and low number of individuals in lower and higher height classes (Fig.a,b and c). It depicted in the Bell-shape population pattern. This type of population structure suggests poor reproduction and recruitment status. The second population pattern was represented by higher number of individuals in first height class followed by very low number of individual in the second height class and absence of individuals in the other higher height classes (fig.d and e). It depicted in the L- shaped population pattern. This type of population structure suggests good reproduction and bad recruitment status. This pattern was represented by the species *Hypericum revoltum* and *Bersema abyssinica*. And also species like, *Canthium oligocarpum, Galiniera saxifrage, Dovyalis abyssinica,* Vernonia spps, *Discopodium penninervum* and *Mytenus arbutifolia* show this kind of population pattern.









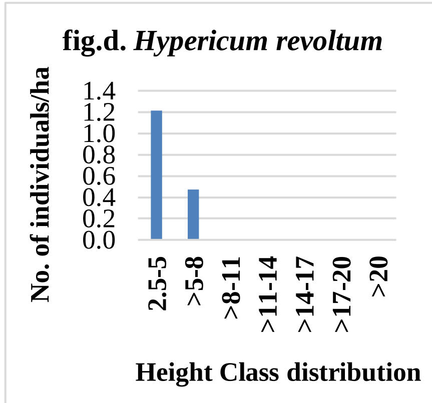


Figure 8: Height class distribution of structural patterns of selected woody species in Garemba

4.6 Regeneration status of Garemba forest

Comparing seedlings and saplings with mature trees shows the regeneration status of the forest. Analysis of regeneration status of forest has a very importance for sustainable conservation and management plan (Kitessa Hundera and Tsegaye Gadissa, 2008). Description of number of individuals of seedlings and saplings would help to indicate the status of regeneration of the forest. The composition and density of seedlings and saplings of woody species in Garemba forest were counted. Total density of seedlings, saplings and mature tree species were 481.3 ha^{-1}, 329.2 ha^{-1} and 280.8 ha^{-1} respectively. The forest is dominated by small sized woody species. This indicates that the large sized forest was affected by human disturbance. The findings of present study showed that presence of more seedlings than saplings and mature woody species in Garemba forest, it indicates that the vegetation has a good regeneration potential.

Table 10. List of woody species with their seedlings, saplings and matures/ha used to determine the regeneration status of Garemba Forest.

No.	Name of species	No. of seedling	No. of sapling	No. of mature
1	*Arundinaria alpine*	350	94	0
2	*Bersema abyssinica*	0	5	7
3	*Buddleja polystachya*	42	35	17
4	*Canthium oligocarpum*	0	0	6
5	*Commiphera schimperi*	6	47	10
6	*Cupressus lusitanica*	14	0	9
7	*Dovylis abyssinica*	17	26	12
8	*Ekebergia capensis*	20	30	35
9	*Erica arbora*	110	100	80
10	*Erythrina brucei*	13	27	11
11	*Galiniera saxifraga*	0	10	33
12	*Hagenia abyssinica*	50	20	70
13	*Hypericum revoltum*	82	54	94
14	*Ilex mitis*	72	63	28
15	*Juniperus proera*	16	4	0
16	*Maesa lanceolata*	9	66	10
17	*Myrsine melanophleoes*	30	20	22
18	*Mytenus arbutifolia*	0	0	10
19	*Ocotea kenyensis*	67	45	38
20	*Olea europaea*	0	0	6
21	*Pittosporum abyssinium*	10	16	20
22	*Prunus africana*	11	15	16
23	*Rubus apetalus*	150	70	115
24	*Solanecio gigas*	86	43	27
Total		1155	790	674
/ha		481.3	329.2	280.8

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The study has resulted in documentation of 35 woody plant species all belong to 32 genera and 24 families were recorded. The species were composed of 57.1 % tree 37.1% shrubs and 6.02% lianas. Family Rosaceae was found to be the most dominant followed by Asteraceae and Rubiaceae. Out of 35 plant species registered from the study site, 2 were, *Erythbrucei* and *solanecio gigas* are endemic to Ethiopia and 2 plant species, *Dombeya torrida* and *Maesa lanceolata* are indicator. The vegetation of the Garemba natural forest was grouped in to three community types that had varying degrees of species richness, diversity and evenness. The variation among communities could be due to different factors (anthropogenic, altitude, soil moisture and other factors), of which anthropogenic is expected to be greater. Analysis of the woody composition of Garemba forest indicated that the composition was lower than that of Wurg forest (Girma. B and Melesse. M, 2020), Aba sena forest (Fekadu *et al*., 2019), Oda forest (Markos. K and Simon. S, 2015) and Golan forest (Abdulbasit. H and Tasisa. T, 2021). Based on structural description of DBH and height class distribution on Garemba forest, similar trends have been shown in both diameter at breast height (DBH) and height. The density of tree species in the forest decrease with increasing DBH and height classes which implied the predominance of sized individuals in the lower classes than in the higher classes. This also implied that the forest is good state of recruitment.

The total basal area calculated for Garemba forest was about 15.1m²/ha for woody plant species >2.5cm in DBH, which lower than some forests like Gola forest (Abdulbasit. H and Tasisa. T, 2021), Wurg forest (Girma. B and Melesse. M, 2020), Aba sena forest (Fekadu *et al*., 2019) and Oda forest (Markos. K and Simon. S, 2015). The most frequent species in this study were *Erica arborea, Arundinaria alpine* and *Hapericum revoltum* and also *Arindinaria alpine, Hagenia abysdinica* and *Erica arborea* have highest IVI than all the rest. Phytogeographical description and comparisons of Garemba forest is highly similar to Zijje maryam church forests to the Dry evergreen montane forests than others. Analysis of population structure of selected woody species interims of their density revealed different patterns of population structure, indicating a high variation among species population dynamics of Garemba Forest. Accordingly, six population patterns have been observed in Garemba Forest. Analysis of the height class distribution of five selected woody species in terms of their density in Garemba forest revealed two general distribution patterns. Analysis of regeneration status of all woody species in study forest implies that there is relatively high number of seedlings and saplings than matured woody individuals indicates that the vegetation has a good regeneration status.

The major anthropogenic activities observed in the area include cutting of tree for fire wood, house construction, for farm land expansion and cattle grazing all of which have negatively influenced the vegetation dynamic and tree density of large sized woody individuals in study forest. The finding implies the need for conservation and management of economically and ecologically important plant species; particularly those plants where low regeneration was obtained.

5.2 Recommendation

Based on the results of the present study, the following statements were recommended;

- Creating participatory forest management by which human impacts can be minimized through discussion and consultation with the local communities.
- There is a need to minimize livestock grazing, tree cutting and other human disturbances in order to allow the natural regeneration of woody species in the forests.
- Raising awareness of local communities on the value of forest resources and ecological consequences of deforestation.
- Sustainable protection and management of the forests needed through the collaborative effort of the government, NGO and local community for reduction of tree cutting and production of charcoal.
- The present study was limited to composition, structure and diversity of woody plant species. Therefore future study should be conducted on distribution of plant species in relation to environmental factors, ethno botanical studies to explore proper forest management system, sustainable use of natural vegetation resource and developing proper conservation mechanism of vegetation regeneration potential is crucial option.

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APPENDICES

Appendix 1: List of plant species collected in Mountain Garemba Forest.

No	Scientific name	Family	Habit	Local name
1	*Acacia albida* Del.	Fabaceae	Tree	Kirare
2	*Arundinaria alpine* K. Schum	Poaceae	Tree	Lemicho
3	*Bersema abyssinica* Fresen.	Francoaceae	Tree	Xeberako
4	*Buddleja polystachya* Franch.	Scrophulariaceae	Shrub	Bulaancho
5	*Brucea antidysentrica* J.F.Mill.	Simaroubaceae	Shrub	Haxawicho
6	*Canthium oligocarpum* Hiern	Rubiaceae	Shrub	Kincho
7	*Commiphera schimperi*	Burseraceae	Tree	Gatame
8	*Cupressus lusitanica* Mill.	Cupressaceae	Tree	C/hooncho
9	*Discopodium penninervum* Hochst	Solanaceae	Shrub	Hamararcho
10	*Dombeya torrida* (J.f Gmel.) P.Bamps	Sterculaceae	Tree	Daanisa
11	*Dovyalis abyssinica* (A.Rich.) Warb.	Flacourtiaceae	Shrub	Korqicho
12	*Ekebergia capensis* Spam.	Meliaceae	Tree	Oloncho
13	*Erica arbora* L.	Ericaceae	Tree	Saato
14	*Erythrina bruce*i schweinf.	Fabaceae	Tree	Welako
15	*Galiniera saxifraga* (Hochst.) Bridson	Rubiaceae	Tree	Danshicho
16	*Hagenia abyssinica*(Brace) J.F. Gmel.	Rosaceae	Tree	Dadako
17	*Hypericum revoltum* Vahl	Hypericaceae	Tree	Garambicho
18	*Ilex mitis* (L.) Radlk.	Aquifoliaceae	Tree	Miqicho
19	*Juniperus procera* Hochst. Ex Endl.	Cupressaceae	Tree	S/hooncho
20	*Maesa lanceolata* Forssk.	Myrsinaceae	Tree	Gowacho
22	*Myrsine melanophleoes* (L.) R.Br.	Myrsinaceae	Tree	Gomorcho
22	*Mytenus arbutifolia*(A.Rich.) Wilczek	Celastraceae	Shrub	Cucco
23	*Ocotea kenyensis* (Chiov.) Robyns & Wilczek.	Lauraceae	Tree	Horoncho
24	*Olea europea* sub sp. cuspidata (Wall. ex G. Don) Cif	Oleaceae	Tree	Ejersa
25	*Pavetta abyssinica* Fresen.	Rubiaceae	Shrub	Shamelcho
26	*Phytolacca dodecandra* L. Herit.	Phytolaccaceae	Lianas	Haranjicho
27	*Pittosporum abyssinium*	Pittosporaceae	Tree	Boncho
28	*Prunus africana*(Hook.f.) Kalkm.	Rosaceae	Tree	Garbicho
29	*Rubus apetalus* Poir.	Rosacae	Shrub	Bowilama
30	*Rubus steudnerii* Schweinf.	Rosaceae	Shrub	Gorote
31	*Solanum incanum* L.	Solanaceae	Shrub	Borbodho
32	*Solanecio gigas* (Vatke) C.Jeffrey	Asteraceae	Shrub	Binjile

33	*Urera hypselodendron* (A.Rich.) Wedd	Urticaceae	Lianas	Halila
34	*Vernonia amygdalina* Del.	Asteraceae	Shrub	Hecho
35	*Vernonia auriculifera* Hiern.	Asteraceae	Shrub	Rejicho

Appendix 2 Synoptic table

No	Species	Cluster1 (16)	Cluster2 (13)	Cluster3 (31)
1	*Arundinaria alpine*	**2.72**	0.01	0
2	*Bersema abyssinica*	2.74	0.2	0
3	*Prunus afrucana*	0.84	0.9	0
4	*Buddleja polystachya*	1.28	0.77	0.54
5	*Canthium oligocarpum*	0.35	0.36	0.1
6	*Ilex mitis*	0.34	0.32	0
7	*Cupressus lusitanica*	1.38	0.07	0.29
8	*Discopodium penninervum*	2.17	0.43	0
9	*Dombeya torrida*	0.24	0.64	0.07
10	*Brucea antidysentrica*	1.25	0.36	0
11	*Erica arbora*	**4.2**	0	0
12	*Erythrina brucei*	0.86	0.45	0
13	*Urera hypselodendron*	0.29	3.37	0.43
14	*Hagenia abyssinica*	1.72	1.99	0.93
15	*Hypericum revoltum*	0.18	2.41	0
16	*Commiphera schimperi*	0	**4.74**	0.29
17	*Solanecio gigas*	0.51	1.81	0.43
18	*Phytolacca dodecandra*	0.14	2.08	0.26
19	*Myrsine melanophleoes*	0.17	2.76	0.11
20	*Dovyalis abyssinica*	0	**1.86**	0.1
21	*Mytenus arbutifolia*	0.55	1.89	1.25
22	*Ocotea kenyensis*	0.15	1.71	0.82
23	*Juniperus proera*	0.47	1.63	1.64
24	*Maesa lanceolata*	0.27	0.94	0.75
25	*Pittosporum abyssinium*	0.22	0.12	1.54
26	*Ekebergia capensis*	0.47	0.62	**2.11**
27	*Rubus apetalus*	0.02	0.04	2.18
28	*Rubus steudnerii*	0.2	0	1.18
29	*Olea europaea*	0.33	0.04	1.07
30	*Solanum incanum*	1.67	0	**5.96**
31	*Galiniera saxifraga*	0.74	0.11	1.29

32	*Vernonia amygdalina*	1.2	0.12	2.14
33	*Vernonia auriculifera*	0.22	0	1.07

Appendix.3. list of families and genera

No	Family	Genera	Species
1	Aquifoliaceae	1	1
2	Asteraceae	2	3
3	Burseraceaeeae	1	1
4	Celestraceae	1	1
5	Cupressaceae	2	2
6	Ericaceae	1	1
7	Fabaceae	2	2
8	Flacounticaceae	1	1
9	Francoaceae	1	1
10	Hypericaceae	1	1
11	Lauraceae	1	1
12	Meliaceae	1	1
13	Myrsinaceae	2	2
14	Oleaceae	1	1
15	Phytolaccaceae	1	1
16	Pittosporaceae	1	1
17	Poaceae	1	1
18	Rosaceae	2	4
19	Rubiaceae	2	3
20	Simaroubaceae	1	1
21	Solanaceae	2	2
22	Scrophulariaceae	1	1
23	Stericulaceae	1	1
24	Urticaceae	1	1

Appendix.4. Frequency of woody plant species of the study area

No	Species name	Frequency	RF
1	*Arundinaria alpine*	0.0562	5.616
2	*Bersema abyssinica*	0.0281	2.82
3	*Buddleja polystachya*	0.024	2.38
4	*Brucea antidysentrica*	0.0454	4.54
5	*Canthium oligocarpum*	0.022	4.54
6	*Commiphera schimperi*	0.026	2.592
7	*Cupressus lusitanica*	0.012	1.08
8	*Discopodium penninervum*	0.0346	3.46
9	*Dombeya torrida*	0.0281	2.81
10	*Dovyalis abyssinica*	0.0173	1.73
11	*Ekebergia capensis*	0.026	2.592
12	*Erica arbora*	0.063	6.26
13	*Erythrina brucei*	0.0323	3.24
14	*Galiniera saxifraga*	0.024	2.38
15	*Hagenia abyssinica*	0.052	5.184
16	*Hypericum revoltum*	0.054	5.4
17	*Ilex mitis*	0.0475	4.8
18	*Juniperus proera*	0.0065	0.65
19	*Maesa lanceolata*	0.0432	4.32
20	*Myrsine melanophleoes*	0.035	3.46
21	*Mytenus arbutifolia*	0.0173	1.73
22	*Ocotea kenyensis*	0.026	2.592
23	*Olea europaea*	0.011	1.08
24	*Phytolacca dodecandra*	0.011	1.08
25	*Pittosporum abyssinium*	0.030	3.024
26	*Prunus africana*	0.024	2.38
27	*Rubus apetalus*	0.024	2.38
28	*Rubus steudnerii*	0.022	2.16
29	*Solanum incanum*	0.015	1.512
30	*Solanecio gigas*	0.043	4.32
31	*Urera hypselodendron*	0.011	1.08
32	*Vernonia amygdalina*	0.041	4.104
33	*Vernonia auriculifera*	0.052	5.184

Appendix 5: The Important Value Index of woody plant species in Garamba Forest

No	Species Name	Do	RF	RBA	IVI
1	*Arundinaria alpine*	17.87	5.3	35.15	58.6
2	*Bersema abyssinica*	1.42	2.82	0.208	4.432
3	*Buddleja polystachya*	1.62	2.38	0.0879	4.082
4	*Brucea antidysentrica*	2.97	4.54	0.117	7.62
5	*Canthium oligocarpum*	1.42	4.54	0.468	6.4196
6	*Commiphera schimperi*	1.15	2.592	1.2998	5.038
7	*Cupressus lusitanica*	0.47	1.08	0.102	1.654
8	*Discopodium penninervum*	2.29	3.46	0.208	5.956
9	*Dombeya torrida*	1.21	2.81	0.468	4.489
10	*Dovyalis abyssinica*	1.01	1.73	0.47	3.207
11	*Ekebergia capensis*	1.35	2.592	1.872	5.812
12	*Erica arbora*	14.4	6.3	7.5	28.18
13	*Erythrina brucei*	1.48	3.24	3.32	8.1
14	*Galiniera saxifraga*	1.96	2.38	0.4679	4.799
15	*Hagenia abyssinica*	6.00	5.18	35.15	46.3
16	*Hypericum revoltum*	11.1	5.4	5.52	22.04
17	*Ilex mitis*	3.0	4.8	6.29	14.01
18	*Juniperus proera*	0.27	0.65	0.0255	0.943
19	*Maesa lanceolata*	3.7	4.3	3.16	11.19
20	*Myrsine melanophleoes*	2.3	3.4	3.32	9.34
21	*Mytenus arbutifolia*	1.35	1.73	0.0285	3.105
22	*Ocotea kenyensis*	1.15	2.592	0.468	4.206
23	*Olea europaea*	0.61	1.08	0.2995	1.986
24	*Phytolacca dodecandra*	0.41	1.08	0.0021	1.487
25	*Pittosporum abyssinium*	1.69	3.024	1.299	6.0094
26	*Prunus africana*	1.35	2.38	1.3	5.0243
27	*Rubus apetalus*	1.89	2.38	0.0213	4.285
28	*Rubus steudnerii*	3.44	2.16	0.102	5.701
29	*Solanum incanum*	0.81	1.512	0.00832	2.329
30	*Solanecio gigas*	2.63	4.32	0.088	7.037
31	*Urera hypselodendron*	0.61	1.08	0.00052	1.687
32	*Vernonia amygdalina*	3.17	4.104	0.468	7.741
33	*Vernonia auriculifera*	3.64	5.184	0.4679	9.293

Note: Do = Dominancy, RF = Relative Frequency, RBA =Relative Basal Area and IVI = Important Value Index