



**Jimma University**

**College of Natural Sciences**

**Department of Biology**

Woody Species Diversity and Population structure in Solloka Natural Forest,  
Nonno Benja District, Jimma Zone, Southwest Ethiopia

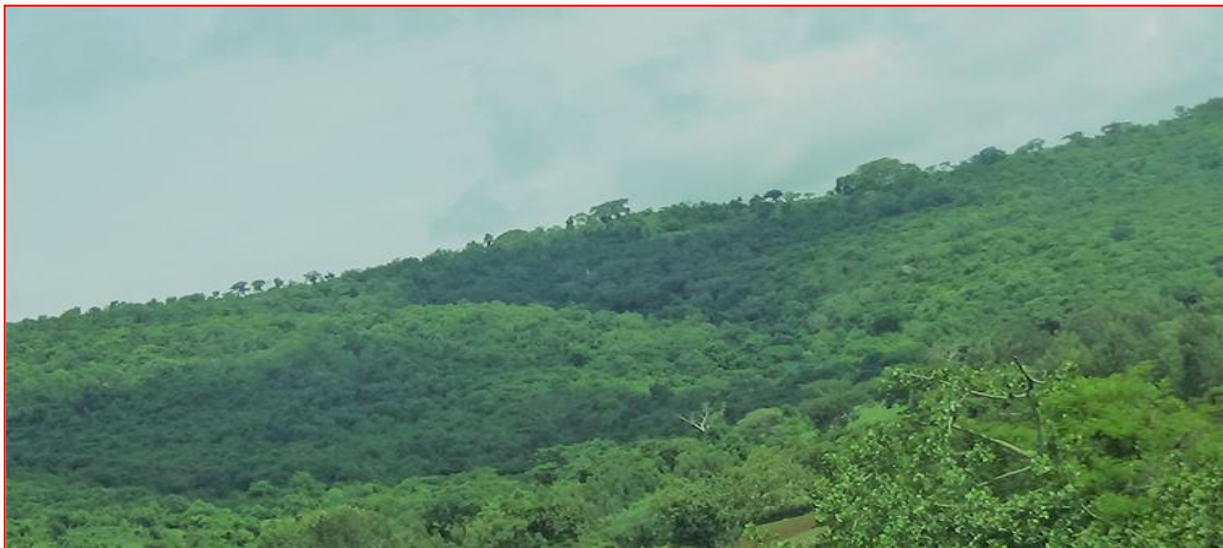
By

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## **List of Acronyms**

SCBD: Secretariat of the Conservation on Biologic Diversity

SNF: Solloka Natural Forest.

UNCED: United Nations Conference on Environment and Development

WCMC: World Conservation Monitoring Center

WWF: World Wide Fund

## Abstract

*Assessments of woody species diversity and structural analysis studies are crucial for providing information on species richness of the forest and regenerating status which enable developing management strategies for long term resource security. Hence, the study was conducted in Solloka Natural Forest, Nonno Benja District, Jimma zone, Oromia Regional State, South West Ethiopia to investigate the woody species composition of the forest, richness and Diversity, structure and natural regenerating status from May to June 2022. Systematic sampling design was used in the study forest to collect vegetation data from 32 sample quadrats of 20mx20m, 5mx5m for woody species, seedling and sapling respectively at every 50m altitudinal variation. DBH  $\geq$  2.5cm and height  $\geq$ 2m were measured using Tape meter and hypsometer respectively. A total of 71 woody species belonging to 59 genera and 38 families were identified from the studied forest. 40 (56.3%) of the species were trees, 27 (38%) were shrubs and the remaining 4 (5.6%) were climbers. *Euclea schimperi* was found to be the most frequent (90.6%) species in the Forest. The Shannon diversity index ( $H'$ ) and evenness ( $J$ ) of Solloka Forest was 3.6 and 0.84 respectively. The density of mature tree, seedling and sapling was 2785/ha, 2673/ha and 1372/ha respectively. The study realized that the presence of much more small sized woody species in Solloka Natural Forest. The overall basal area of the forest was 54m<sup>2</sup>/ha. Analysis of IVI showed that *Olea europea* had the highest value (28.7) followed by *Euclea schimperi* and *Syzgium guineense* which had 25.15 and 19.05 respectively. Four general pattern of population structure was identified which showed different variations in different DBH and Height class distributions. As analysis indicated 26 (36.6%) woody species showed “good” regenerating whereas 32 (45%), 11 (15.5%), and 2 (2.8%) showed “fair”, “none” and “poor: regenerating respectively but “new” regenerating status of the woody species was not observed in the study quadrats. Complete clearance of the forest, illegal settlement, agriculture and grazing land expansions are the critical problems faced the forest which the concerned bodies should create continuous awareness, using the full knowledge of indigenous people for the sustainable use of forest resources.*

**Key words:** Population structure, richness and Diversity, Vegetation structure

# 1. INTRODUCTION

## 1.1. Background of the study

Woody plant species is very important and a key to forest biodiversity due to the fact that it provides resource and habitats for other living organisms (Mace *et al.*, 2012 cited in Sileshi *et al.*, 2022). The basic knowledge of woody plant species composition and population structure is very critical to manage forest resources in a sustainable way (Pappoe *et al.*, 2010 cited in Sileshi *et al.*, 2022).

Forests are basic natural resources for human existence and wellbeing (Murthy *et al.*, 2002; World Bank, 2004; SCBD, 2009). They provide food, oxygen, shelter, recreation, and spiritual sustenance for human, and they are the source for over 5,000 commercially-traded products, extending from pharmaceuticals to timber and clothing. In addition, these assets help to maintain the fertility of soil, used as home for wild life, protect water resources and diminish the risk of natural disasters such as land slide and flooding.

Africa possesses 675 million hectares of forest and 350 million hectares of wooded land which together cover 35 percent of its total land area (UNEP, 2015). This incorporates tropical moist forests essentially in Central and West Africa, tropical dry forest, mostly in East and Southern Africa. Globally, 40% of tropical forest areas and 14% of total African surface have been secured by woodland (Ereso, 2021 cited in P. Mayaux *et al.*, 1990).

East Africa is well endowed with diverse ecosystems that provide different services and habitats for a wide range of species. It also encompasses a wide variety of forests that support a wealth of biological diversity. The major forest sorts of this region incorporate tropical and sub-tropical forests, forests plantations, Savannah, Acacia woodlands and mangroves. The forests are exceptionally critical to people's livelihoods and regional socio-economic development through provision of goods and services. Separated from providing fuel wood for energy, timber and poles for construction, medicine and food, they also contribute in ensuring soil conservation, harbor valuable biodiversity and are water catchment areas and offer recreational opportunities. As the report of FAO (2010) shown in 2010 there were almost 73 million hectares of forest in East Africa and the annual loss of forests was around 0.7 million hectares. East Africa is moderately dry area highly influenced by the Sahara Desert (Bekele, 2000). Desert covers more

than 1 million square kilometers. The climate is characterized by high temperature low precipitation (less than 200mm). It presents a great geographical difference with high and rugged mountains, flat-topped plateaus, deep gorges, river valleys and plains.

Ethiopia is biggest landlocked country in Africa with an area of 1.13 million square kilometers, located in the northeast of Africa. It is well known and included among the top 25 biological-wealth countries in the world, and possess two of the world's 34 biodiversity hotspots. The altitudinal variations with the highest peak at Ras Dashen (4,620 m above sea level) and the lowest 126 m below sea level in the Afar depression is the most significant reason that makes Ethiopia one of the very few countries that is rich in a wide range of biological heterogeneity (Fekensa et al., 2016). The climatic conditions of Ethiopia are very diverse that varies from hot and dry desert in the lowland areas to cold and humid alpine habitats in the highlands. Furthermore, the natural vegetation is highly complex due to the fact that it has great variations in altitude suggesting equally great spatial differences in humidity regimes such as temperatures within very short horizontal distances (Didita *et al.*, 2010).As a result, Ethiopia has the maximum forest land resources in the Horn of Africa which is estimated as a total of 12.5 million hectare (Sisay and Gitima, 2020).

Similar figure was reported by Babiso *et al* (2020) that Ethiopian forest cover was estimated to be 12.5 million hectares. Before many decades ago, forest cover of Ethiopia was found to be about 40% of the overall landmass of the country (Sisay and Gitima, 2020) .The flora of Ethiopia could be very heterogeneous and has a wealthy endemic element. It is far expected to include 6000 species of higher plants, of which about 10 percent are endemic (Waktole *et al.*, 2019; Temesgen and Warkineh, 2020).

Unfortunately, now a days, several researchers and investigators realized that natural vegetations in Ethiopia are dramatically destructed by a number of factors. The possible factors which are responsible for the declining of forest cover of Ethiopia are population growth, farmland expansion, the demand for increasing amounts of construction material, for timber, fuel wood and charcoal have a strong influence on the natural vegetations both in terms of quality and quantity (Getnet,2018 cited in Reusing ,2000).

A Number of authors are also detailed that in Ethiopia, environmental degradation and deforestation have been taking place for centuries and agree on forests in the entire country declined from the original 35% to 16% in 1952, 3.6% by 1980, 2.6% by 1987, and an estimated 2.4% in 1992 (Berhanu, *et al.*, 2019; Hundera and Gadissa, 2008; FAO, 2003; Tegegn and Workneh, 2017) are among the authors who demonstrated that Ethiopian forest is declining at the fastest rate.

## **1.2 Statement of the problem**

According to IBC (2010) Ethiopia is a country of diverse plant species forming the lion share flora of 6,200 species out of the total flora species of 7,850 in East Africa. As Kelbessa *et al.*, (1992) the country is a critical regional center for biological diversity due to its wide ranges of altitude, great geographical diversity with high and rugged mountains, flat-topped plateaus and deep gorges, incised river valleys and rolling plains.

Because of Ethiopia's topography, range of altitude, rain fall patterns, and soil changeability it has an immense ecological diversity and a huge wealth of biological resources (IBC, 2007). This topographic and altitudinal variation made the emergence of wide ranges of living spaces that are reasonable for advancement and survival of different plant and animal species (Zelege, 2003). The flora of Ethiopia and Eritrea harbors about 6,000 higher plant species with 10% endemism (Waktole *et al.*, 2019; Temesgen and Warkineh 2020; Kelbesa *et al.*, 1992). Besides, woody plant species in the Flora of Ethiopia and Eritrea was assessed to be 1100; out of these about 300 are tree species (Teketay *et al.*, 2000).

Botanical assessments such as woody species heterogeneity and structural analysis studies are crucial for providing information on species richness of the forest, practicable forest management purpose and useful in understanding forest ecology and ecosystem function (Pappoe *et al.*, 2010 cited in Burju *et al.*, 2013).

Nowadays, more woody species are imperiled (endangered) than ever before due to human activities (Reusing, 2000). As a result, diverse wild animals misplaced their homes and began to migrate and many native woody species are destructed. The farmlands are exposed to erosion and agricultural productivity is also diminishing (Fekadu *et al.*, 2019). Lemenih and Teketay

(2006); Didita *et al.*, 2010) studies also strengthens the above notion that the biologically rich resources of Ethiopia are rapidly diminishing due to broad deforestation. IUCN (2006) explained on its hand showed that vegetation resources in all areas of the country in general and in fragmented landscapes in particular are drastically declined due to expanded population followed by deforestation and land degradation. The loss of such forest resources would have an - incredible impact on the environment, biological diversity and socio-economic setup of the communities (SCB, 2001). It also has challenges on Ecological and environmental related factors such as soil degradation, soil erosion, and alteration of natural resources resulting from the destruction of habitats (Hundera *et al.*, 2007).

Solloka Natural forest of Nonno Benja district, Jimma zone, Southwest Ethiopia is one of the remnant forest patches in Southwest Ethiopia where no study was conducted yet. Therefore, studies on woody species diversity of this forest is essential for providing satisfactory information required for concerned bodies to enable them for guiding decision making on forest management and conservation , monitoring vegetation and land use changes in order to control their impacts through conservation practices. Such studies are moreover very crucial for understanding forest ecology and ecosystem functions, in identifying economically important plants and securing threatened plant species. The study will also use to recognize the overall regeneration status of the forest to take measure on the factors that primarily cause declining of the forest.

Solloka natural forest plays a primary role in ecological service and provides economic importance for nearby communities. As far as we know, any study has not been conducted on Solloka natural forest of Nonno Benja district in Jimma zone. This study aims to identify the woody species composition, diversity, structure, and the overall regeneration status of the central forest of the study area. The expectation of this study was surveying the richness, diversity and abundance of woody plant species that contributes to the conservation efforts by different stakeholders.

### **1.3 Research Questions**

The following research questions were forwarded and answered during the study.

1. What type and number of wood species are found Solloka natural forest?
2. What do the species diversity looks like in Solloka natural forest?
3. What do the vegetation structure of woody species seems in Solloka Natural forest the forest?

### **1.4 Objectives of the Study**

#### **1.4.1 General Objective**

The general objective of the study was to assess the woody species diversity and vegetation structure of Solloka natural forest.

#### **1.4.2 Specific Objectives**

The specific objectives of the study were the following:-

1. To assess the woody species composition and richness in the study area
2. To determine the diversity of woody species.
3. To investigate the population structure of woody species.

### **1.5 Significance of the Study**

This study will be used to provide useful information for concerned bodies so as to manage biological resources and the way in which biological resources will be conserved. It will also be used to identify those species which are highly threatened and those that need great attention for conservation. The study will be also very crucial for all stakeholders to use the forest and forest products in a sustainable way. The regeneration status of the forest will be determined so as to take any necessary measures for the rapid loss of woody plant species. The information obtained from this study will also be used for further ecological studies.

## 2. Literature Review

### 2.1 Vegetation Types of Ethiopia

Vegetation is defined as a collection of plants that grow together in a particular area and is characterized either by its constituent species or by the combination of structural and functional characteristics that determine the general appearance of the vegetation (Goldsmith *et al.*, 1986 cited in Tegegn and Workineh, 2017). As this report has shown, a system of plants with largely sudden growth is called a vegetation. The vegetation of Ethiopia is extremely complex. There is a variety of vegetation from one region of the country to another; some regions of countries (southern and southwestern parts of countries) are relatively richer in biological heterogeneity than other parts of countries. (Woldu ,1999) report also indicated that the complexities of vegetation emerge from the great variation in altitude employing equally great spatial difference in moisture regime as well as temperature and also depend on rainfall and altitude variation.

Ethiopia is recognized as one of the top twenty-five biodiversity wealthiest countries in the world and hosts the Eastern Afromontane and the Horn of Africa hotspots (Temesgen and Workineh, 2020 cited in WCMC, 1994). The diverse topography integrated with the variation of climatic factors have created diverse vegetation types in the country. Because of its large elevational range, it has become the source for variation in topography and climate, and has resulted in a heterogenous landscape with high habitat diversity, species diversity, and centers of species endemism, particularly in the highlands. As Asefa *et al* (2020) indicated, phytogeographically, Ethiopia hosts different vegetation types, including the tropical lowland rainforest in the southwest, arid and semi-arid dry forests within the East, and the Afroalpine forests in the north and southeast. (Mesfin and Tamiru, 2020) on their part also justified that the vegetation types of Ethiopia are extremely diverse, ranging from afro-alpine to desert and this is due to a great geographical diversity with high and rugged mountains, flat-topped plateaus, deep gorges, river valleys, and plains which ranges from 116 m below sea level at Dallol Depression (Afar) to the highest mountain, Ras Dashaen (Gondar), 4,620 meters above sea level.

In similar manner, Friis and Demissew (2001) illustrated the vegetation types in Ethiopia are also fantastically diverse, varying from Afroalpine and Sub Afroalpine to riparian and swamp vegetation. According to this report, these vegetation types encompass Afroalpine and Sub Afroalpine plant life, dry evergreen montane forest and grassland, Moist evergreen montane forest, evergreen scrub, Combretum terminalia (broad-leaved) deciduous woodland, acacia-commiphora (small-leaved) deciduous woodland, lowland semi-ever green forest, the desert and semi-desert scrubland, and riparian and swamp vegetation.

A number of authors have contributed to the classification of the vegetation sorts in Ethiopia. Among these (Soromessa and Woldu, 1999; Demissew and Friis, 2009; Didita, 2007; Abebe & Denu, 2007; Hundera *et al.*, 2007; Yineger *et al.*, 2008; Kelbessa and Soromessa, 2008; Unbushe and Tekle, 2016; Bekele and Abebe, 2016) have been contributed in classifying Ethiopian vegetation sorts. Eventhough some authors classify Ethiopian vegetation types into 8 groups (Asefa *et al.*, 2020), the other again (Soromessa *et al.*, 2004) categorize Ethiopia vegetations types into 9 for the purpose of developing the conservation strategy of Ethiopia, the above scholars grouped Ethiopian vegetation types into 12 ecosystems. From 12 types of Ethiopian vegetations some are presented below.

### **2.1.1 Afroalpine and sub- afroalpine vegetation types**

As IBC (2009) detailed this biological system is found on a mountain between 3,200 and 4,600m asl. It is one of the broadly distributed vegetation sorts in Ethiopia unlike, in other African habitats (Asefa *et al.*, 2020 and IBC, 2005). These vegetation types have broadly been designated as the national protected areas due to the presence of several endemic plant and animal species. .

The characteristic species of this vegetation type includes giant lobelia (*Lobelia rhynchopetalum*), the evergreen tree heather (*Erica arborea*), and shrubby and herbaceous everlasting flowers (*Helichrysum spp.*) are few of the species that inhabit this vegetation area (Asefa *et al.*, 2020)

### **2.1.2 Dry Evergreen Afromontane Forest**

This vegetation sorts are situated on highlands and mountains located at altitudinal changes between 1,500 to 3,200 masl. The forests in this ecosystem have been greatly declined due to transformation of forest lands to agricultural lands and other interference by people and livestock and finally replaced by bushland and scrub in most areas (IBC, 2009). On the other hand, (Friis *et al.*, 2010) clarified in their report that dry evergreen montane is generally found between 1800 and 3000 m a.s.l, where human settlements and movement dominate. This vegetation sort is characterized by a complex set of successions with wide-ranging grasslands rich in legumes, shrubs, and small to large-sized trees to closed forest with vertical canopy stratification. These forests cover most of the mountainous topography of the Ethiopian highlands. As (IBC, 2005; IBC, 2009 and Friis *et al.*, 2010) detailed, the foremost common species generally exist in this vegetation sort are *Juniperus procera*, *Podocarpus falcatus*, *Olea europaea subsp. Cuspidata*, and. On the other hand (Asefa *et al.*, 2020) expressed in his report that eucalyptus has rarely becomes naturalized as its presence in this vegetation is due to direct human interference.

### **2.1.3. Moist evergreen montane forest vegetation**

The moist evergreen vegetation sorts (ecosystems) of the country found with altitudinal range between 800 to 2,500 masl (IBC, 2009). In other way, (Asefa *et al.*, 2020) clarified the altitudinal range in which the moist evergreen montane forest is found as between 1,500 to 2,600 masl. The Ethiopian montane forests are portion of the global biodiversity conservation priority areas as well as centers for plant diversity and endemic bird areas basically because of uncommonly high endemism of species and habitat degradation (Asefa *et al.*, 2020). According to this report, moist evergreen montane forest is primarily distributed to the southwest escarpment of Ethiopia between elevations of 1500 and 2600 m and the transitional rainforest, which is distributed from 500 to 1500 m in elevation. The transitional rainforest is composed of species from both the Afromontane rainforest and the lowland forests (Friis, 1992, Gole *et al.*, 2008), proposing that it links the forest from highlands with lowlands. This forest is the location of the famous wild population of *Coffea arabica* (Senbeta and Denich, 2006). However, moist evergreen montane forest is threatened by tea and coffee plantations, human settlement, and agriculture (Gole *et al.*, 2008). As IBC (2009) demonstrated the moist evergreen montane forest is characterized by the

species such as *Galuniera saxifraga*, *Teclea nobilis*, *Ocotea kenyensis*, *Clausena anisata*, *Maesa lanceolata* and *Maytenus spp.*

Solloka natural forest of Nonno Benja district, is the moist evergreen montane Forest sort. The species in which current study were characterized would found to be *Olea europea Caspidata*, *Euclea schimperi*, *Syzgium guineense*, *Apodytes imidiata*, *Rhus glutinosa*, *Mimusops kummel*, *Combretum adenogonium*, *Sapium ellipticum (Krauss)*, *Brsema abyssinica Fresen*, *Nuxia oppositifolia (Hochst.) Benth*, *Draceina afromantana Mildbr*, *Maytenus glacialipus* and *Cordia africana Lam*

## **2.2 Plants Biodiversity and threats in Ethiopia**

According to Convention on Biological Diversity (1992) biological heterogeneity is the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are a part; this includes diversity within species, between species and of ecosystems.

Biological diversity is a comprehensive umbrella term for the extent of nature's variety or variation within the natural system; both in number and frequency. It is often understood in terms of the wide assortment of plants, animals and microorganisms, the genes they contain and the ecosystem they form. The biodiversity we see nowadays is the result of billions of a long time of evolution, formed by natural processes and, increasingly, by the impact of humans. It forms the web of life of which we are an integral part and upon which we so completely depend (Rawat and Agarwal, 2015).

Ethiopia is one of the major Vavilov centers of origin for numerous crops and their wild and weedy relatives. It is an important primary and secondary gene pool for many field crop species that are useful sources of germplasm for economic traits in general and sources of genes resistant to diseases and pests in particular (IBC, 2009). As Mebrat and Gashw (2013) clarified, Ethiopia is a mountainous country with great geographic diversity like rugged mountains, flat topped plateaus and deep gorges incised river valleys and rolling. As this report demonstrated, these diversified topographic features made the country to be covered by the highest forest cover in tropical Africa. As a result, Ethiopia still has a rich diversity important to the world in both

domesticated and wild plant and animal species that occur in variable and unique micro and macro-ecosystems. In similar manner, (Waktole *et al.*,2019 ; Temesgen and Warkineh 2020) detailed in their report that the flora of Ethiopia is very diverse with an estimated number between 6000 species of higher plants, of which about 10 per cent are endemic. It has been said that Ethiopia is the fifth largest floral country in tropical Africa.

Forests are fundamental for human existence and wellbeing. They provide us with nourishment, oxygen, shelter, recreation, and spiritual sustenance, and they are the source for over 5,000 commercially-traded products, extending from pharmaceuticals to timber and clothing (Murthy *et al.*, 2002; World Bank, 2004; SCBD, 2009). In addition, these resources help to maintain the fertility of agricultural land, utilized as living space for wild life, protect water resources and reduce the risk of natural disasters such as land slide and flooding (World Bank, 2004).

Forests are utilized for keeping up oxygen and carbon dioxide in the atmosphere, provide good climatic condition on earth, avoid soil erosion by reducing surface runoff and attract tourism to increase national economy. They are moreover home for a wide variety of wild biodiversity (Fekadu *et al.*, 2019). Woody species are also very important for environmental and cultural services, including the provision of shade to crops and people, soil enhancement, erosion control and heritage values (Fekadu *et al.*, 2019). They also provide traditional medicine, fodder for livestock, spices, gums, resins fuelwood, construction wood and wood for making farm implements for a large number of people in rural area (Merga, unpub).

The forest cover change in Ethiopia is basically due to the transformation of natural high forests to agricultural land and grassland, particularly in the more densely populated northern and north eastern parts of the country. Nowadays, remaining blocks of forests exist only in the south and southwest of the country. There have been distinctive estimations of forest cover change in Ethiopia. For illustration (FAO, 1999) evaluated forest cover change in Ethiopia to be almost 62 000 hectares per year; (EFAP, 1994) on its way assessed cover change of Ethiopian forest to 150 000-200, 000 hectares of forest loss per annum and (WBISPP, 2000) estimated 59, 000 hectares annually.

The most cause of deforestation in Ethiopia is cutting trees with the aim of expanding agriculture land to feed the rapidly growing population. Deforestation is estimated to take place at the rate of

200,000 ha/year (Hundera and Gadissa, 2008). The overexploitation of fuel wood as energy has also contributed to the deforestation process. In Ethiopia approximately 95 per cent of the overall energy consumption is composed of traditional biomass fuels with only 5 per cent obtained from modern energy sources (Ethiopia- UNCED, 1992). Denu (2006) additionally explained that the most causes of forest loss in our country are poverty, the increasing of population growth, exploitation of forest for different purposes such as fuel wood and construction materials without properly replantation and less attention of the government in setting out proper policy framework.

In terms of degradation, the quickly expanding population and the subsequent rising demands for crop and grazing land, construction materials, fuel-wood and charcoal are the main driving factors responsible for the loss of forest areas in Ethiopia. Besides to these, low agricultural productivity, low standard of living, lack of alternatives, and lack of appropriate land use and forest policies have been contributed forest decline in Ethiopia. The species composition and the tree density have been decreasing in almost all forested areas, which consist now mainly of deformed and over aged trees. Natural regeneration is scarce due to the high impact of livestock.

As many studies demonstrated clearance of natural vegetation to meet the demands of an ever increasing human population, transforming of existing forest to agricultural land, the increasing of livestock population that resulted in overgrazing, increasing demand for firewood and charcoal that resulted in exploitation of forest for fuel wood and construction materials are the primary cause of deforestation that we see in Ethiopia (Soromessa *et al.*, 2004 and Solomon *et al.*, 2018). Due to the above stated causes of forest decline, Ethiopia is experiencing soil erosion and fertility loss. This shows the country has limited capacity to monitor ecological degradation and provide reliable information on the processes and dynamics that lead to desertification (FAO, 2003).

All through history, people have utilized the environment resources plants, animals and others to gain extraordinary economic rewards; however, numerous of the methods are now being seen as unsustainable (Abdelfattah, 2009). According to the following authors forests undergo changes in various ways. Its areas can be reduced either by deforestation or by natural disasters such as volcanic eruptions. As a result, the expanse of forest areas are declining over the globe, mostly

through logging activities and also due to conversion of habitats to croplands (agricultural land) accounts for up to 40 percent of Ethiopian forest losses. Among the authors who reported the primary causes of Ethiopian forest decline are (GebreEgziabher, 1988; Pant and Samant, 2007; Awas, 2007; Molla *et al.*, 2009; Winberg, 2010). In the same manner (Hundera and Gadissa, 2008) revealed that environmental degradation and deforestation have been taking place for centuries in Ethiopia. Forests in the entire country declined from the original 35% to 16% in 1952, 3.6% by 1980, 2.6% by 1987, and an evaluated 2.4% in 1992. Denu (2016) in his PHD dissertation also briefly detailed those threats of biodiversity are human induced LULC change and global warming. Low living standard of the individuals and need of other alternatives are also the factor that responsible for decline of forest area. This is expressed by increasing demands for crop and grazing land and wood for fuel and construction. (Bekele *et al.*, 1999; Hundra and Gadissa 2008).As Awas (2007) stated, especially, a few of the current contributory factors accelerated the decline of woody species diversity in Ethiopia are, the size and distribution pattern of human and domestic animal populations, the level of asset utilization, market factors and policies. In addition, understanding of woody plant species conservation in a narrow sense due to low level of awareness, the attention on woody species conservation and sustainable use has so far been insufficient. Attracting rapid rate of investment for agroforestry expansion and migration of the community to delicate biological system like forests are moreover profoundly biodiversity. Almost all of these activities were done without prior environmental impact assessment. As a result, many relatively forests and forest patches are disappeared for different activities like livestock ranches, coffee plantations and tea plantations (Yeshitila 2001; Yilmishaw 2001; Tesfaye and Teketay, 2005; Hundera and Gadissa, 2008).Tedla and Lemma (1999) on their part similarly demonstrated the major causes of biodiversity decline in Ethiopia are natural land use changes, pollution, changes in atmospheric CO<sub>2</sub> concentrations, changes in the nitrogen cycle and acid rain, climate alterations, and the introduction of exotic species. To sum up this point, the very rich biodiversity of our country ethioipa is critically threatened by a number of factors and dramatically declined and still no enough attention is given by concerned government bodies.

### **2.3. Vegetation Patterns along Environmental Gradients**

Vegetation-environment connections or the relationship they have are as a rule studied along gradients. The concept of environmental gradients has been a baseline in the study of ecological theory (Belete and Demsis, 2020). As this report implied, spatial and temporal patterns of vegetation alter are affected by a huge number of components, including physical environment. To understand vegetation patterns on forest landscape, species-environment relationships are the foremost critical information required for ecological study. Plant species sharing comparable natural affinities occupy similar sites across the landscape. In this way, the variety in plant communities and species difference is connected to environmental gradients. On the other hand, (Chang-Bae lee, 2016 and Rahbek, C, 2005) demonstrated that spatial variety is one of the foremost important characteristics of biological diversity. In general, environmental drivers such as climate, regional area of a species pool, habitat heterogeneity, productivity and geological history contribute to this spatial conveyance of biodiversity at broad geographic scales, whereas at the local scale not only biotic factors such as competition and facilitation contribute to levels of biodiversity but also abiotic factors such as geomorphological heterogeneity and unsettling influence make their claim commitment or contribution (Gentili and Armiraglio,2013).

Currently, many studies justify the elevational patterns of diversity for different taxa such as plants and other animals and different patterns have been observed in different organisms and in different regions (Wang *et al.*, 2007). Intensive summary reviews conclude that three fundamental sorts of diversity patterns with expanding rise of elevation may exist: (1) monotonic decline with expanding elevation, (2) A level at lower elevation (plateau) and (3) A hump-shaped dispersion with high richness at intermediate elevation (Chang-Bae lee, 2016).Of these main types, hump-shaped distribution types were recognized as overwhelming sort .

According to Clements (1916); Pickett *et al.*, (2009) vegetation patterns are determined by a suite of factors including environmental filtering, unsettling influence history, dispersal limitation, and biotic interactions. As (Huston, 1994) stated Patterns of plant species diversity are influenced by latitudinal, altitudinal and soil slopes. The primary determinants of plant conveyance are the association impacts of climate, topography and soil so that variables such as vegetation structure and productivity moreover show complex patterns along environmental gradient (Brown, 2001).

## **2.4 Regeneration of woody species**

Regeneration is the capacity of a cell tissue or organism and an ecosystem to recoup from harm or damage and thus a key to sustainable forestry. It is a central component of woodland biological system flow and rebuilding of degraded forest lands. Sustainable forest utilization is only possible if adequate information on the regeneration dynamics and factors influencing important canopy tree species is accessible (Temesgen and Workineh, 2020 cited in Getachew *et al.*, 2010). It is a crucial process for the presence of species in a community beneath distinctive natural drivers. It could be exceptionally critical part of forest management, because it maintains the desired species composition and stocking after different unsettling influences (Zubair A. Malik & A. B. Bhatt, 2016). The potential regenerative status of tree species often frequently portrays the long run composition of forests within a stand in space and time (Henle *et al.*, 2004). As (Grubb, 1977) expressed, recovery of any species is confined to unconventional interval of habitat conditions and the degree of those conditions could be awesome determinant of its geographic dissemination. According to (Good & Good, 1972), the effective regeneration of a tree species depends on the ability of its seedlings and saplings to survive and grow. (Saikia & Khan, 2013) on their part clarified that fruitful regeneration is perhaps the single most important phase towards accomplishing long term sustainability of forests. (Temesgen and Workineh, 2020; Simon and Balcha; Tesfaye; Teketay; and E. Beck, 2010) recommended that understanding the structural pattern and regeneration status of plant species is the immediate action taken to assess the vegetation dynamics and their destruction factors. Population structure is the distribution of individuals of each species in arbitrarily to offer the overall regeneration profile of the forest based on tree density, height, frequency, diameter at breast height (DBH), species importance value, and basal area.( Aliyi *et al.*, 2015).

The population structure that has sufficient number of seedlings, saplings and young trees delineates palatable regeneration characteristics where as those with lacking number of seedlings and saplings of tree species in a forest demonstrate poor regeneration and complete absence of seedlings and saplings of tree species in a forest implies no regeneration (Saxena & Singh, 1984). (Krauchii *et al.*, 2000) in their report clarify that lack of sufficient regeneration is a key problem of mountain forests.

Generally, as numerous studies indicated, a population with sufficient number of seedlings and saplings portray portable regeneration (Pokhriyal; Uniyal; Chauhan; and Todaria, 2010) whereas insufficient number of seedlings and saplings of the species in a forest indicates poor regeneration condition (Tripathi and Khan, 2007). Moreover, the regeneration status of a forest is poor if the number of seedlings and saplings is much less than mature individuals (Aliyi *et al.*, 2015).

### 3. MATERIALS AND METHODS

#### 3.1 Description of the study area

The study was conducted in Solloka natural forest, Nonno Benja District, Jimma Zone, Oromia Regional State, Southwest Ethiopia and geographically located between  $8^{\circ} 30'0''$  to  $8^{\circ} 50'0''$ N and  $36^{\circ} 50'0''$  to  $37^{\circ} 20'0''$ E. Nonno Benja District is found at the distance of about 506 km from Addis Ababa, and 156km away from Jimma, capital of Jimma Zone. The District has 19 rural and two urban small administrative unit. Nonno Benja District is bordered in the North by East Wollega zone, in South by Chora Botor District of Jimma zone, on the West Limmu Seka District and in the East by the West shoa zone (figure: 1).

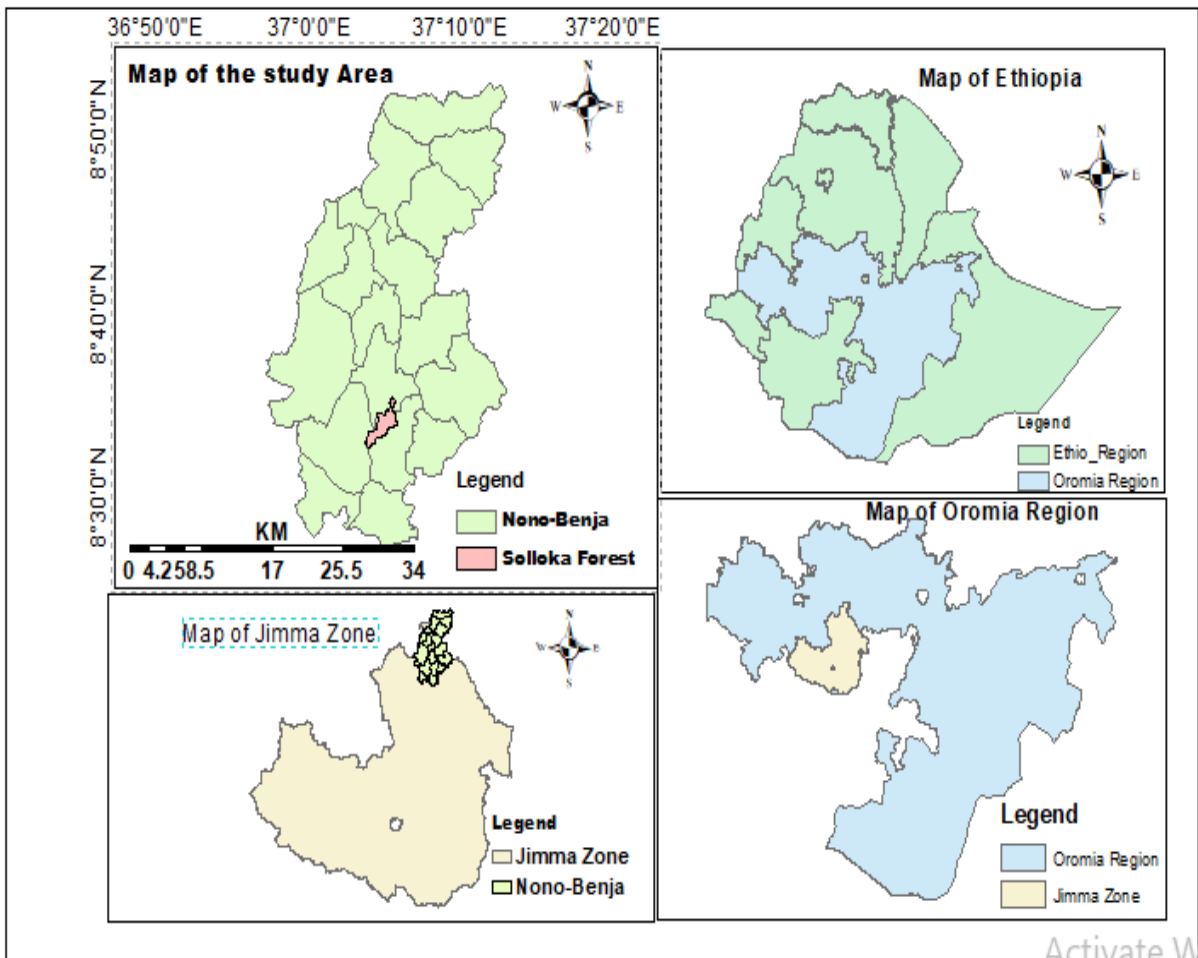


Figure 1: Map of the study area showing Ethiopia, Oromia, Jimma zone and Nonno Benja district

### **3.1.3 Climate and Topography**

#### **3.1.3.1 Temperature and rainfall**

The annual average temperature of Nonno Benja district ranges from 17.5°C to 22°C whereas the mean annual rainfall ranges from 1300-1600mm. Wet heavy rain is started from June and ends in September. October to the end of the February is characterized by dry periods (EMA, 2021). The district has three climatic zones Highland (18%), Midland (58%) and Lowland (24%) (Nonno Benja district Agriculture and Natural Resource Office, 2022). The topographic features of Nonno Benja includes mountains, hills, gorges, valleys, slopes, plateaus; a few are flat and moderately gentle lands. The altitude of the district ranges from 1600- 2600m above sea level (Nonno Benja Agricultural and Natural Resource Office, 2021).

#### **3.1.4. Demography and Land use**

The total population of Nonno Benja District is 88,204 (78,103 rural dwellers and 10,101 urban populations) (the 2021 projection). From the total population of the district, 51,790 are females and 36,417 are males. Like other parts of the country, agriculture is the main economy of the district. Among the mainly cultivated crops are maize, teff, Nug, sorghum and wheat. Coffee plantation is not well-known in the district due to the fact that there is no much forest in the district. But now, Menshen for Menshen has started preparing seedlings of coffee in one of their Kolati nursery site and distributing for farmers. The district has 75,325 cattle, 15,230 sheep, 11,159 goats, 33,267 poultry, 2,154 horses, 6,369 mules and 721 donkeys as reported by (Nonno Benja Agriculture and Natural Resource Office, 2021).

Table 1 Land use type in hectare

S/n	Land use type	Area in hectare	Percent
1	Cultivable land	34,971.5	69.4
2	Forest land	4775.9	9.5
3	Grazing land	7,882.39	15.6
4	Rocky	1,728	3.4
5	Nonarable	1,069.21	2.1
	Total	50,427	100

Source: Nonno Benja Earth and Environmental protection Office (2021)

As indicated in the table 1 above, Solloka natural forest covers 665.5 hectare of land which contributed 13.9% of the total forest of the district. It contributed only 1.3% of the total land area of Nonno Benja district. The forest has its own demarcation and an isolated map which collaborately done by Nonno Benja Earth and Environmental protection and Natural resource and climate change authority Office of the district.

### **3.2.1 Field equipment**

The materials used during the actual plan data collection in the field were GPS to document the location of species (longitude, latitude and altitude) of the study area, digital camera to take the images of the forest, clinometer to measure the angle and slope of the study area, hypsometer for measuring tree height, Compass to determine the direction and aspects of the study plots, diameter tape for measuring the diameter of tree trunk at 1.3m above the ground (DBH) and plant pressing to preserve the samples of all woody species from the study quadrat .

### **3.4 Study design**

A systematic sampling technique was used as a sampling design to collect plant data by laying as sampling design. Based on the information obtained from the reconnaissance survey, Six transect lines against the altitudinal gradient ranges from 1632m to 2060m at a distance of 500m apart from each other were established starting from the base to the top of the study area . Following the transect lines, total of 32 (20m × 20m) sample quadrats were laid for all woody species at every 50m altitudinal interval along the study transect. One hundred and sixty (5m×5m) sub plots were established to determine the regenerating capacity of the study forest 4 at each corner and 1 at the center of the main plot.

### **3. 5.Vegetation Data Collection**

Reconnaissance survey was made to the study area from May to June 2022.It was conducted to have familiarity with the vegetation, topography of the area, identify direction of the transect line; to know altitudinal gradients and familiarize with woody plant species of the area. Generally, reconnaissance survey was made to have necessary information about the study area.

A complete count and list of woody plant species from each quadrat (20 m × 20 m) were recorded ,DBH for all individuals trees and shrubs with  $DBH \geq 2.5$  cm at 1.3 m above the ground, and height  $\geq 2$ m were measured from the 20m×20m plots. Individual species with  $DBH < 2.5$  cm and height  $< 2$  m were counted as sapling and seedling from the plot. The materials used during the actual plan data collection in the field were GPS to document the location of species (longitude, latitude and altitude) of the study area, digital camera to take the images of the forest, clinometer to measure the angle and slope of the study area, hypsometer for measuring

tree height, Compass to determine the direction and aspects of the study plots, diameter tape for measuring the diameter of tree trunk at 1.3m above the ground (DBH) and plant pressing to preserve the samples of all woody species from the study quadrat .

Sample specimens for all woody species were collected, numbered, pressed, dried and taken to Herbarium for identification and storage. The identification was done in Jimma University Herbarium using botanical keys, Flora books (Flora of Ethiopia and Eritrea volume 1-8), and consulting professionals having the expertise. The voucher specimens were mounted, labelled and stored in Jimma University Herbarium by professionals.

### **3.6. Data analysis**

#### **3.6.1. Diversity of woody species**

The Shannon Diversity Index (sometimes called the Shannon-Wiener Index) is a way to measure the diversity of species in a community or among quadrats. The higher the value of H, the higher the diversity of species in a particular plots or community. The lower the value of H, the lower the diversity. A value of  $H = 0$  indicates a community that only has one species. Woody species diversity was calculated by using Shannon diversity index ( $H'$ ) (Kent and Coker, 1992).

Shannon diversity index is the most widely used and computed as follows.

$$H' = -\sum p_i \ln p_i, \text{ (Magurran, 1988)}$$

Where  $P_i$  is the relative abundance of the  $i$ th species,  $\ln$  is the natural logarithm.

$n$  = total number of individuals.

$S$  = number of species.

#### **3.6.2. The Shannon Equitability Index**

The Shannon equitability (evenness) is a way to measure the evenness of species in a community. The term “evenness” simply refers to how similar the abundances of different species are in the community or among a particular quadrats.

The measure of evenness ( $E$ ) which is the ratio of observed diversity to maximum diversity was calculated as:

$$E = H/H_{\max} = H/\ln S. \text{ This value ranges from 0 to 1 where 1 indicates complete evenness.}$$

### 3.6.3. Density (D)

Density is the count of individuals per unit area. The density of woody species is one of the most important structural parameters considered in the data analysis. Density per hectare of trees and shrubs were calculated by summing up all stem across all sample plots and converted into hectare and explained by using graph. Relative density was calculated as:

$$\text{Relative density} = \frac{\text{Number of individuals of species}}{\text{Total number of all individuals in the study area}} \times 100$$

### 3.6.4. Basal area

The basal area of the woody species was determined from the DBH measurement. Basal area of the woody species was calculated using the following equation:-

$$BA = \pi (D/2)^2, \text{ where, } \pi = 3.14$$

$$BA = \text{basal area (m}^2\text{)}$$

$$D = \text{diameter at breast height}$$

### 3.6.5. Frequency (F)

The frequency values obtained reflect a pattern of distribution as well as diversity. It is obtained by dividing the number of quadrats in which the species occurred by the total number of the quadrats examined from which all the species were sampled in the area under the study.

The number of plots in which a given species found in the study area is referred to as frequency. Relative frequency was calculated using the following formula after data is collected from the study area as:-

$$RF = \frac{\text{Frequency of species}}{\text{Frequency of all species}} \times 100$$

### 3.6.6. Important value Index

The Important Value Index (IVI) is a composite index based on the relative measurements of species frequency, density and basal area (Kent and Coker, 1992). This shows the importance of species in the system. Importance value index for each of woody species was calculated by summing up relative density, relative frequency and relative dominance (basal area).

$$\text{Relative dominance} = \frac{\text{Basal area of a species}}{\text{Total basal area of the whole sample}} \times 100$$

Importance value Index = Relative density + Relative dominance + Relative frequency

### 3.7. Regeneration status of woody species.

The effective regeneration of a tree species depends on the ability of its seedlings and saplings to survive and grow (Good & Good, 1972). The population structure that has sufficient number of seedlings, saplings and young trees delineates palatable regeneration characteristics where as those with lacking number of seedlings and saplings of tree species in a forest demonstrate poor regeneration and complete absence of seedlings and saplings of tree species in a forest implies no regeneration (Saxena & Singh, 1984). The regeneration status of the given natural vegetation is considered as none of regenerating if a species is absent both in sapling and seedling stages but present as mature (Temesgen and Workineh, 2020). The regeneration status of Solloka Natural forest was computed by comparing seedling and sapling with mature tree density data obtained from sample plot by interpreting (Khumbongmayum *et al.*, 2006 and Dhaulkhandi *et al.*, 2008) techniques.

If seedling is > sapling > mature tree (“good” regenerating ); mature tree > sapling > seedling (“fair” regenerating); If a species survives only in the sapling stage (“poor” regenerating); If a species is absent both in sapling and seedling stages but present as mature (“none” regenerating); if the species has no mature, but only sapling and seedling and/or seedling stages (“new” regenerating).

## 4. RESULTS AND DISCUSSIONS

### 4.1. Results

#### 4.1.1 Woody species composition

A total of 71 woody species belonging to 59 genera and 38 families were identified in Solloka natural forest. Fabaceae was the dominant family with represented by 7 species constituting 9.9 % of the total woody species identified followed by Euphorbiaceae composed of 5 species comprising 7% and Moraceae having 4 species (Appendix) .The most common growth form was Tree (56.3%) followed by shrubs (38.0%) and (5.6%) climbers (figure 2). The most frequent species was *Euclea schimperi* (90.6%) followed by *Maytenus glacilipus*, (81.2%), *Syzgium guineense*, (71.9%), *Olea europea* and *Rhus glutinosa* (71.8% each) (Appendix2).

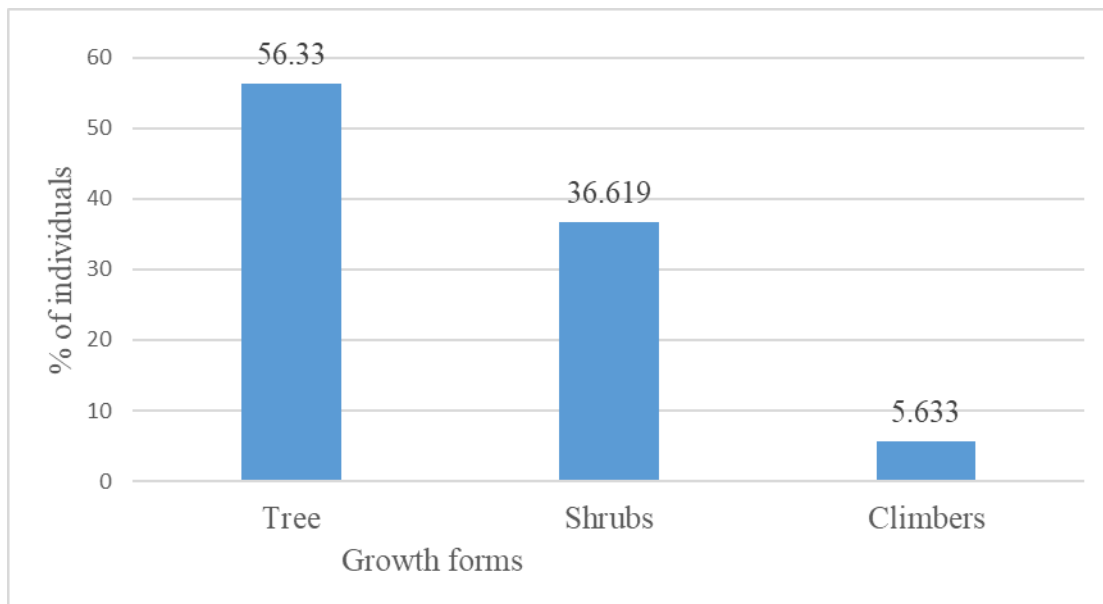


Figure: 2 Growth forms of woody species of Solloka natural forest.

## **4.1.2 Woody Species Diversity**

The diversity of woody plant species in Solloka natural forest was calculated in Shannon Wiener diversity index. Accordingly, the Shannon Wiener diversity index ( $H'$ ) of the study forest with species richness of 71 was 3.6 and the evenness was 0.84 (Appendix 6). The study revealed that Solloka natural forest was relatively more diverse and more evenness.

## **4.1.3 Structure of the forest.**

### **4.1.3.1. Density**

The total density of mature tree/shrubs, seedling and sapling of Solloka Natural forest was 2785/ha, 2673/ha and 1372/ha respectively. Tree and shrub density with  $DBH \geq 2.5\text{cm}$  and height  $\geq 2\text{m}$  were 2785/ha and those their  $DBH > 10\text{cm}$  were 685.94/ha. The density of tree and shrubs of Solloka natural forest with  $DBH > 10\text{cm}$  and  $> 20\text{cm}$  was 685/ha and 315.625/ha respectively. Analysis indicated that small sized individuals were highly concentrated at lower DBH classes suggesting that the forest was affected by human activity and existed at a stage of secondary regeneration.

Table: 2 the top 10 woody species with highest densities in Solloka natural forest in decreasing order

Name of species	Density	% density
<i>Euclea schimperi</i>	357	12.81867145
<i>Rhus glutinosa</i>	157	5.637342908
<i>Acacia spp</i>	148	5.314183124
<i>Syzgium guineense</i>	121	4.34470377
<i>Matenus glacilipus</i>	112	4.021543986
<i>Calpurina aurea</i>	103	3.698384201
<i>Bersama abyssinica</i>	100	3.590664273
<i>Dracaena afromontana</i>	94	3.375224417
<i>Mimusops kummel</i>	92	3.303411131
<i>Maesa lanceolata</i>	78	2.800718133

On the other hand, plant species with least density in the forest with decreasing order were *Flacourtia indica*, ( $7\text{ha}^{-1}$ ), *Teclea nobilis*, ( $6\text{ ha}^{-1}$ ), *Dichrostachys cinera*, ( $5\text{ ha}^{-1}$ ) *Grewa ferruginea*, ( $4\text{ha}^{-1}$ ) *Ficus vasta*, ( $3\text{ha}^{-1}$ ), *Gardenia ternifolia* and *Erythrina brucei* ( $1\text{ha}^{-1}$  each) (Appendix 3).

Table 3: Density of tree and shrubs With Different DBH classes

DBH Classes	Density ha <sup>-1</sup>	% of Density
2.5cm- 10cm	2099.23	75.37
< 20cm	2469.54	88.67
b/n 20cm and 40cm	583.6	20.95
< 50 cm	2682.83	96.33
> 50 cm	102.07	3.67

As evident from table 3 above, woody species individuals were very few in the higher diameter at breast height and much more of the individuals were dominated in the lower DBH class distributions. Woody plant species with DBH greater than 50cm were only about 3.67% suggesting that disturbance of the study forest by different pressures.

#### 4.1.2.2. DBH Class Distribution

The diameter at breast height (DBH) class distribution of the woody species of the study Forest is given in Fig.4. It was classified into 8 classes:2.5cm-10cm,10.1cm-20cm,20.1cm-30cm,30.1cm-40cm,40.1cm-50cm,50.1cm-60cm,60.1cm-70cm and >70.1cm. As shown in the figure, it is evident that about 75.4% of the individuals have DBH between 2.5 cm and 10 cm indicating the concentration of small-sized individuals in the forest. More than 88.7% of the individuals/ha in the forest had DBH less than 20 cm. About 97.8 % of tree and shrubs in the forest had DBH less than 50cm and only 2.21% of the individuals have DBH greater than 50 cm, which showed that the forest is in the stage of secondary regeneration. The number of individuals were highly decreased as the DBH class was increased indicating the forest was highly affected by human activity and there was the unwise cutting of individuals at these diameters. The biggest diameter was recorded in woody species of *Olea europea* and *Syzgium guineense* (98.7cm each) followed by *Ficus sur* (95.5cm) and *Apodytes dimidiata* for which 81.5cm diameter was recorded. Most of the species that fall between DBH class 2.5cm -10cm were *Maesa lanceolata*, *Keetia guinzii*, *Celtis africana*, *ovali folius*, *Capparis tomentosa*, *Calpurina aurea*, *Maytenus*

*glacilipus*, *Acacia sp.*, *Olea capensis*, *Teclea nobilis*, *Euclea schimperi* and *Rhus glutinosa*. Individuals that were found at higher DBH class include *Olea europea*, *Sapium ellipticum*, *Syzgium guineense*, *Apodytes dimidiata*, *Mimusopus kummel*, *cordia africana*, *Combretum adenogonium*, *Ficus sur*, *Ficus vasta* and *Ficus sycomorus* (Figure 3).

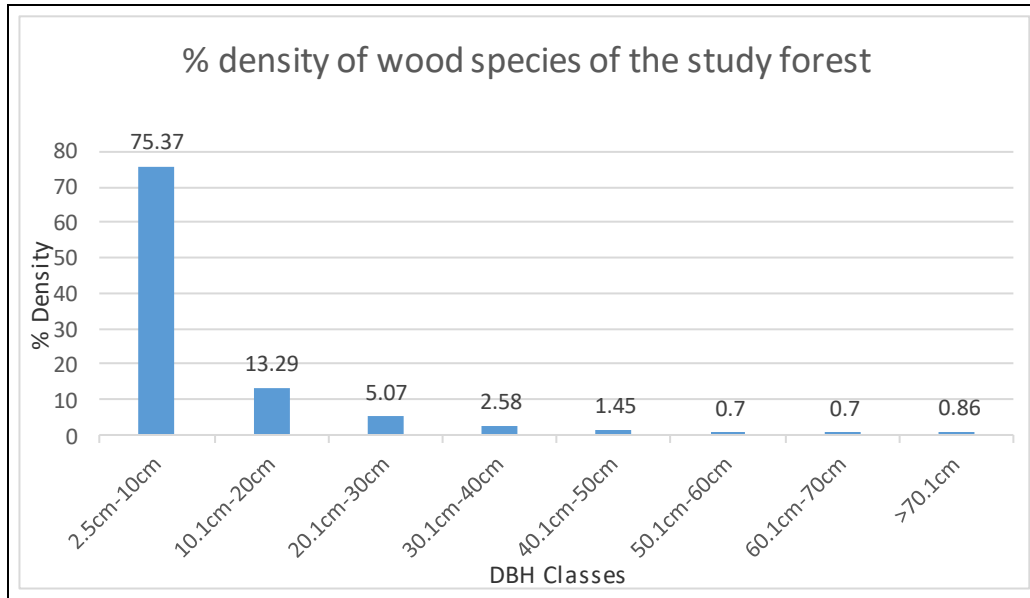


Figure 3: % Density of woody species of Solloka Natural Forest in different DBH class distribution

#### 4.1.2.3. Basal area

The overall basal area of the Solloka Natural forest was 54m<sup>2</sup>/ha. The species/ individuals relatively with highest basal area were *Olea europea* comprising 17.3% (9.36m<sup>2</sup>/ha) of the overall basal area of the forest followed by *Szygium guineense* which contributed 9.96% (5.38m<sup>2</sup>/ha), *Sapium ellipticum* 8.42% (4.55m<sup>2</sup>/ha), *Apodytes dimidiata* 7.33% (3.96m<sup>2</sup>/ha), *Mimusops kummel* 7.29% (3.94m<sup>2</sup>/ha), *Cordia africana* 4.44% (2.40m<sup>2</sup>/ha) and *Combretum adenogonium* 4.33% (2.34m<sup>2</sup>/ha) (Table 6). *Olea europea* was expected to be contributed more than the above figure but it was highly overharvested for construction and firewood by the local community. The contribution of these species for the total basal area was mostly not for their dominance in the forest but because of their highest DBH class. The lowest value was recorded in shrub species of *Erythrina brucei* (0.002109m<sup>2</sup>/ha), tree species of *Gardenia ternifolia* (0.002329m<sup>2</sup>/ha) and woody climber of *Helinus mystacinus* (0.002529m<sup>2</sup>/ha). The basal area of

woody species of the study forest (SNF)  $> 1\text{ha}^{-1}$  was given in table 4 below and for the whole individual woody species was given in appendix 4.

Table 4: The top 10 Basal areas of woody species with decreasing order in the study forest. (Basal area  $> 1\text{ha}^{-1}$ )

Species name	Basal area/ha	Dominance	RDD
<i>Olea europea L.subsp. Cuspidata</i>	9.36	7.31	17.327
<i>Syzigium guineense subsp.macrocarpum</i>	5.38	4.2	9.955
<i>Sapium ellipticum (Krauss)</i>	4.55	3.55	8.415
<i>Apodytes dimidiata E. Mey ex Arn.</i>	3.96	3.09	7.324
<i>Mimusops kummel A.Dc.</i>	3.94	3.07	7.277
<i>Cordia africana Lam</i>	2.40	1.87	4.433
<i>Combretum adenogonium Steud.</i> Ex.A.Rich	2.34	1.82	4.314
<i>Euclea schimperi (A.DC)</i>	1.97	1.53	3.627
<i>Maesa lanceolata Forssk</i>	1.53	1.19	2.820
<i>Rhus glutinosa Hochst ex Rich</i>	1.42	1.10	2.60

Key: RDD= Relative dominance

#### 4.1.2.4. Height Class Distribution

The height class distribution of woody species of Solloka Natural Forest was Classified into 6 classes: 2m-10m , 11m-20m ,21m-30m,31m-40m, 41m-50m and  $>50\text{m}$  (Table 5). 1353.125/ha (48.6%) of individuals were fall at height between 2m and 10m. From the overall individuals recorded in the forest, 2175 (78%) of woody species individuals/ha had height less than 20meters and only 53.125/ (1.9%) woody species/ha had height greater than 50m (Table8). Most of trees

representing the highest Height class in the forest contributed for upper canopy were *Olea europea*, *Cordia africana*, *Sapium ellipticum*, *Apodytes dimidiata*, *Milleta ferruginea* and *Combretum adenogonium*. The height class was constantly decreasing with increasing height of woody species in the study quadrats. As indicated in the analysis, the highest density of woody species in the study forest was concentrated in the lower height class (2m-10m), then in the second lower height class (11m-20m) followed by the third height class (21m-30m) (table 8). These could be attributed due to uncontrolled cutting and unwisely using the forest resource by local communities.

Table 5: Height class distribution

Height classes	Density/ha	%density
2m-10m	1353.125	48.6
11m-20m	821.875	29.5
21m-30m	291.4	10.46
31m-40m	165.625	5.9
41m-50	100	3.4
>50m	53.125	1.9
Total	2785.5	100

#### 4.1.2.5. Frequency

Based on the results from the analyzed values of different woody species recorded in the study forest, species frequency was classified into 5 classes; 1.0-20, 20.1-40, 40.1-60, 60.1-80 and >80 (Fig 5). According to the analyzed obtained, 50% of the species were distributed in the lower frequency classes, 14.3% in the second classes whereas 24.3%, 8.6% and 2.86% were distributed in the third, fourth and fifth classes respectively.

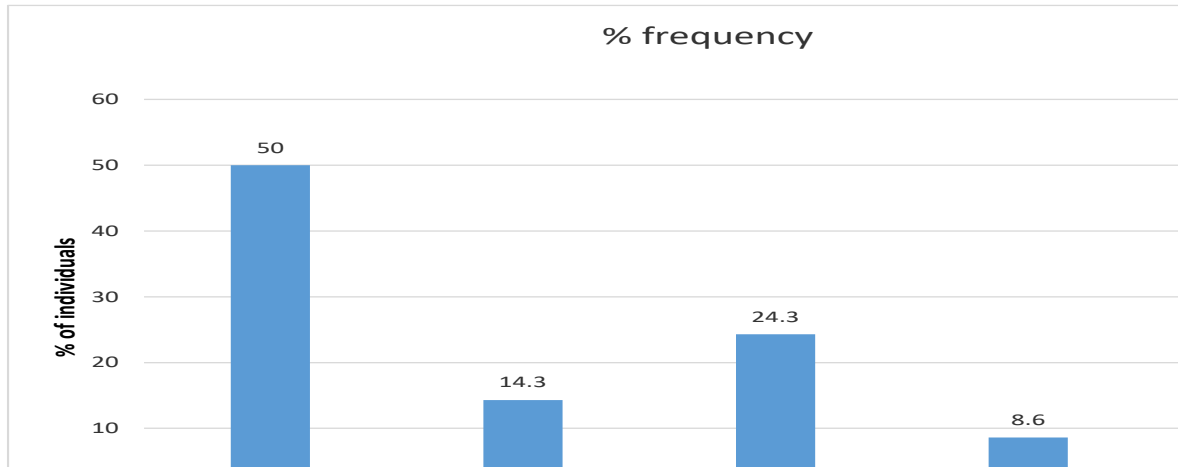


Figure 4: % frequency distribution of woody species of the study forest

The above figure showed that most of the species found to be in the lower frequency distribution while very few woody species were in the last higher frequency distributions. Percent of individuals were decreasing except in the second (20.1-40) as frequency distribution class was increasing indicating the heterogeneity (diversity) of the forest (Temesgen and Workineh, 2020 cited in. Abyot *et al.*, 2014).

Table 6: 17 most frequent woody species with their % frequency > 50% in the Solloka Natural Forest (Appendix 2) for the whole species

Scientific name	Frequency	%Frequency	Relative frequency
<i>Euclea schimperi</i> (A.DC)	29	90.6	4.559748428
<i>Syzgium guineense</i> (Wild) Dc.	23	71.9	3.616352201
<i>Rhus glutinosa</i> Hochst ex Rich	23	71.88	3.616352201
<i>Olea europea</i> subsp. Cuspidata	23	71.88	3.616352201
<i>Apodytes dimidiata</i> E. Mey ex Arn.	21	65.6	3.301886792
<i>Bersama abyssinica</i> Fresen	21	65.6	3.301886792
<i>Combretum adenogonium</i> Steud. Ex.A.Rich	20	62.5	3.144654088
<i>Nuxia oppositifolia</i> (Hochst.) Benth	19	59.4	2.987421384
<i>Maytenus glacilipus</i>	26	81.2	4.088050314
<i>Keetia guinzii</i> (Sond.)	19	59.4	2.987421384
<i>Dracena afromantana</i> Mildbr	18	56.3	2.830188679
<i>Myrsine africana</i> L.	16	50	2.51572327
<i>Olinia rochetiana</i> Thunb.	16	50	2.51572327
<i>Bridelia micrantha</i> ( Hochst) Baill	16	50	2.51572327
<i>Oncoba spinosa</i> Forssk	16	50	2.51572327
<i>Calpurina aurea</i> (Aiton)	16	50	2.51572327
<i>Ritchiea albersii</i> Gilg	16	50	2.51572327

#### 4.1.2.7. Dominance

The overall basal area of Sollka Natural forest would be 54m<sup>2</sup>/ha. The total dominance would be found to be 42.56 (Appendix 4). Woody species having a value of IVI greater than 5.00 can be considered dominant because of the relative ecological role it plays in the ecosystem (Gurmessu, 2010). As analysis briefly indicated in the table 7 under species IVI below, 21 (32.4%) woody species were selected as dominant species in the study forest. *Olea europea*, *Euclea schimperi*, *Syzygium guineense*, *Apodytes dimidiata*, *Rhus glutinosa*, *Mimusops kummel*, *Combretum adenogonium*, *Sapium ellipticum*, *Bersama abyssinica*, *Nuxia oppositifolia*, *Dracaena afromantana*, *Maytenus glacilipus*, *Cordia africana*, *Acokanthera schimperi*, *Keetia guinzii*, *Maesa lanceolata*, *Olinia rochetiana*, *Bridelia micrantha*, *Ritchiea albersii* *Croton macrostachyus* and *Myrsine africana* were among the dominant species which had relatively more relative dominance and important value index greater than 5.0. The woody species selected above were contributed 222 (74%) of the total IVI value of the study forest which had the sum total of 300.

#### 4.1.2.6. Species Important Value Index

Important value index (IVI) is a useful parameter to determine the ecological importance of species. It is a composite index based on the relative measurements of species frequency, density and basal area (Kent and Coker, 1992). IVI was computed by summing up relative frequency, relative dominance, and relative density. The total IVI of the examined forest was 300 (Appendix 5 ).The highest important value index was observed for *Olea europea* 28.7 (9.5%), *Euclea schimperi* 25.154 (8.385%), *Syzygium guineense* 19.058 (6.353%), *Apodytes dimidiata* 16.189 (5.396%), *Rhus glutinosa* 14.624 (4.87%), *Mimusops kummel* 11.043 (3.681%), *Combretum adenogonium* 9.986 (3.329%), *Sapium ellipticum* 9.798 (3.266%), *Bersama abyssinica* 9.196 (3.0%) and *Nuxia oppositifolia* 8.555 (2.852%) in the study forest. The least IVI was recorded for woody species *Rhamnus tridentata* (0.027447), *Acanthus eminence*(0.27409),*Helinus mystacinus*(0.24603),*Gardenia ternifolia* (0.18956) and *Erythrina brucei* (0.0189160) which together constituted 0.4% of the total IVI analyzed for the forest .The top 21 important value index of woody species with decreasing order of Solloka Natural forest was shown in table 7 below.

Table 7: The top 21 species important value index  $\geq 5$  of Solloka Natural Forest

Species name	Relative frequency	Relative density	Relative dominance	IVI
<i>Olea europea</i> subsp. <i>Cuspidata</i>	4.559748428	12.81907433	11.32120573	28.7
<i>Euclea schimperi</i> (A.DC)	3.616352201	4.347826087	17.19008089	25.1543
<i>Syzgium guineense</i> subsp. <i>macrocarpum</i>	3.616352201	5.638148668	9.803745313	19.0582
<i>Apodytes dimidiata</i> E.Mey ex Arn.	3.616352201	5.329593268	7.243140794	16.1891
<i>Rhus glutinosa</i> Hochst ex Rich	3.301886792	4.039270687	7.283001914	14.6242
<i>Mimusops kummel</i> A.Dc.	3.144654088	3.590462833	4.308249897	11.0434
<i>Combretum adenogonium</i> Steud. Ex.A.Rich	3.301886792	3.730715288	2.954207915	9.98681
<i>Sapium ellipticum</i> (Krauss)	4.088050314	3.309957924	2.400081161	9.79809
<i>Bersama abyssinica</i> Fresen	2.987421384	3.394109397	2.815121787	9.19665
<i>Nuxia oppositifolia</i> (Hochst.) Benth	2.201257862	1.935483871	4.417898372	8.55464
<i>Dracaena afromantana</i> Mildbr	2.830188679	2.720897616	2.619954504	8.17104
<i>Maytenus glacialipus</i>	2.987421384	2.833099579	2.139777062	7.9603
<i>Cordia africana</i> Lam	2.51572327	2.55259467	1.708792213	6.77711
<i>Acokanthera schimperi</i> (A.Dc.)	2.51572327	2.52454418	1.679879167	6.72015
<i>Keetia guinzii</i> (Sond.)	2.358490566	1.935483871	2.363013067	6.65699
<i>Maesa lanceolata</i> Forssk	2.51572327	2.21598878	1.314837183	6.04655
<i>Olinia rochetiana</i> Thunb.	2.51572327	2.580645161	0.83706888	5.93344
<i>Bridelia micrantha</i> (Hochst) Baill	2.51572327	2.384291725	0.794143426	5.69416

<i>Ritchiea albersii</i> Gilg	2.51572327	2.21598878	0.808830548	5.54054
<i>Crotton macrostachyus</i> Del.	1.729559748	1.430575035	2.044138743	5.20427
<i>Myrsine africana</i> L.	1.41509434	1.206171108	2.38827638	5.00954

Important Value Index of the whole woody species encountered in the study Forest with the percent they contributed to the total species recorded in the forest is shown in figure 6 below. It is classified into 6 IVI classes distributions. In the figure, number of individuals and percent of their contribution is detailed in parallel.

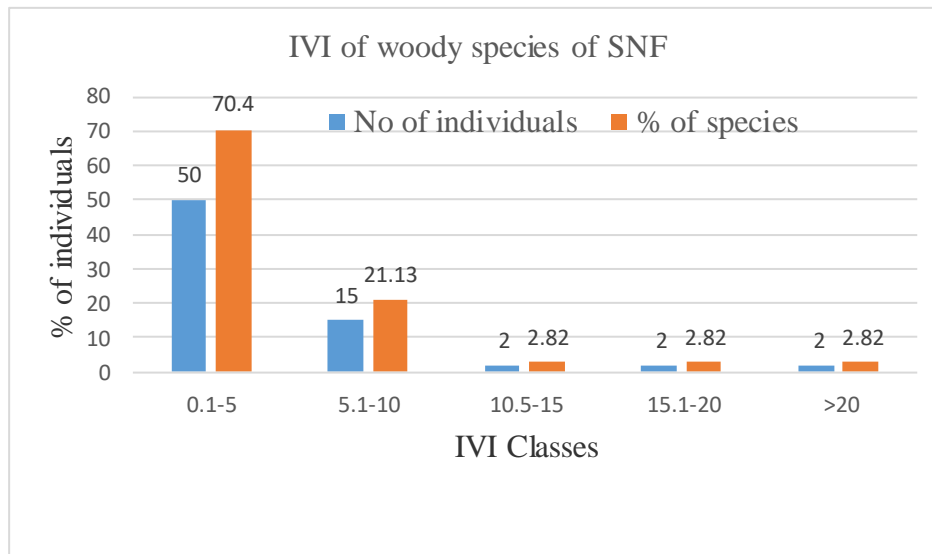


Figure5: Important Value index class distribution of Solloka Natural forest

#### 4.1.2.9. Population Structure

The analysis of the population of 33 selected woody species was made in the study forest. The result showed that four general patterns of regeneration were recognized and one woody species was taken as the representative of the pattern (Figure 7).

The first pattern of population was formed by species that have highest density in the lowest diameter at breast height (2.5cm-10cm) and totally absent from other DBH class distribution. This population pattern was represented by *Rhamnus staddo* and *Erythrina brucei* (figure7a).

The second pattern of population was formed by species that highly concentrated in the lower diameter at breast height and gradually decreasing in the second DBH distribution class and ends in the second lower DBH distribution classes. This pattern of population was represented by *Acacia sp.* and possessed by *Calpurina aurea*, *Schrebera alata*, *Bridelia micrantha*, *Dodonaea viscosa*, *Premna schimperi*, and *Celtis africana* (figure 7b).

The third pattern was exhibited by woody species well dominated in the lower DBH classes and extremely decreasing in the second and third then ends in the fourth diameter at breast height that totally absent in the higher diameter at breast height classes distributions. This pattern was represented by *Euclea schimperi* that include *Bersama abyssinica*, *Nuxia oppositifolia*, *Acokanthera schimperi*, *Oncoba spinosa*, *Terminalia laxiflora*, *Crotton macrostachayus*, *Rhus sandiwickensi*, and *Ficus sur* (figure7c).

The fourth population pattern was formed by woody species with inverted J- curve. These species had the highest density of individuals in the lower diameter at breast height gradually decreasing and less concentration of density in the higher diameter at breast height indicating good reproduction and recruitment potential in the forest. The representative species of this pattern is *Syzgium guineense* which include *Olea europea*, *Combretum adenogonium* and *Apodytes dimidiata* (figure7d).

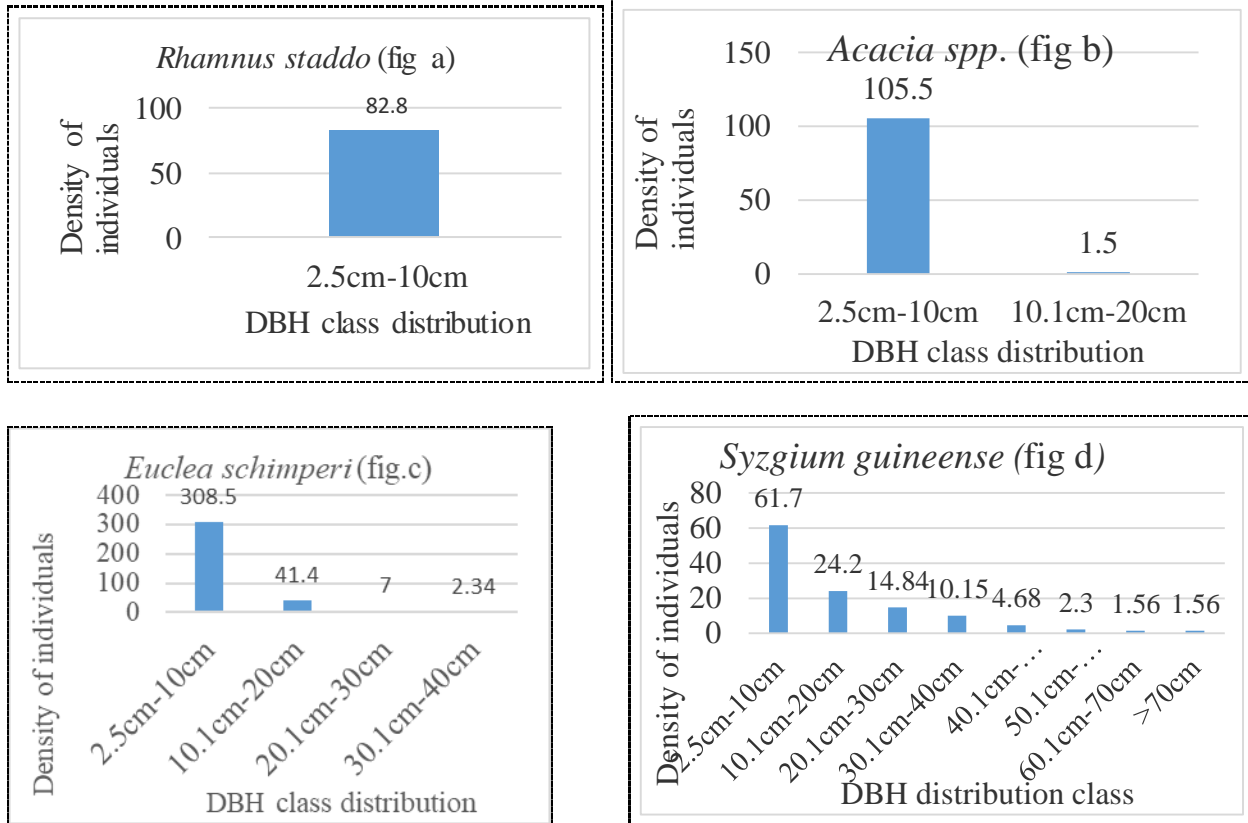


Figure 6: Population structure of selected woody species

#### 4.1.2.10. The Regeneration Status of Solloka Natural Forest

The regeneration and recruitment condition of plant species in a specific vegetation is one of the significant factors that are useful to study their conservation status (Temesgen and Workineh, 2020 cited in Bekele *et al.*, 2002).

The regeneration status of Solloka Natural forest was computed by comparing seedling and sapling with mature tree density data obtained from sample plot by interperating (Khumbongmayum *et al.*, 2006; Dhaulkhandi *et al.*, 2008) techniques.

The total density of mature tree, seedling and sapling was  $2785\text{ha}^{-1}$ ,  $2673\text{ha}^{-1}$  and  $1372\text{ha}^{-1}$  respectively. From the overall woody species encountered in the forest, 11 (15.5%) species had no both seedling and sapling and they were represented only by mature tree. Woody species with no seedling and sapling in any natural forest is under risky condition and it is suggested that these species are under threat of local extinction (Atspha *et al.*, 2019).

The species under this condition were *Cordia africana*, *Stereospermum kunthianum*, *Acacia abyssinica*, *Hypericum quartinianum*, *Grewia bicolor*, *Entada abyssinica*, *Phoenix reclinata*, *Ficus sychomorus* and *Dichrostachys cinera*. About (45%) of the woody species had less sum total of seedling and sapling than the matured tree of the overall tree and shrubs in the study forest. Some of the trees and shrubs that were categorized under this status were *Rhus glutinosa*, *Mimusops kummel*, *Combretum adenogonium*, *Sapium ellipticum*, *Bersama abyssinica*, *Dracaena afromantana*, *Maytenus glaucilipus*, *Acokanthera schimperi*, *Keetia guinzii*, *Olinia rochetiana*, *Calpurina aurea*, *Carrisa spinarum* and *Premna schimperi*. On the other hand, 10 (14%) of species such as *Apodytes dimidiata*, *Nuxia oppositifolia*, *Bridelia micrantha*, *Croton macrostachyus*, *Clusia lanceolata*, *Schrebera alata*, *Flacourtia indica*, *Grewia ferruginea*, *Erythrina brucei* and *Ocimum gratissimum* were represented by possessing greater sum total of seedling and sapling than mature individuals. 2 (2.8%) Individuals were represented by sapling and mature tree but lacked seedling in the study quadrat. Those species under this category were *Teclea nobilis* and *Ficus thonningi* whereas 17(24%) of the total woody species recorded were lacked sapling and represented only by seedling and matured species. Some of the species under this status were *Rhamnus staddo*, *Lancelota trifolia*, *Coffee arabica*, *Landolphia buechanani*, *Ficus vasta*, *Acanthus eminence* and *Gardenia ternifolia*.

Analysis showed that the total density of matured tree was more than both seedling and sapling individuals in the forest and the ratio of seedling to sapling, seedling to mature and sapling to mature tree was (1.9:0.9 and 0.5) respectively. The absence of very important economic and ecological woody species like *Cordia africana*, *Ficus sychomorus* and *acacia abyssinica* were due to the fact that matured individuals of these species were harvested for construction, timber production and for production of charcoal. Especially, *Cordia africana* for its high demand of timber production and *Acacia abyssinica* for its charcoal consumption were highly harvested by the local community and they are under threat. As analysis indicated 26 (36.6%) woody species showed “good regenerating” whereas 32 (45%), 11 (15.5%), and 2 (2.8%) showed “fair”, “none” and “poor: regenerating respectively but “new” regenerating status of the woody species was not observed in the study quadrats. The regeneration status of tree /shrubs of the study forest was briefly analyzed in the following (Figure 7).

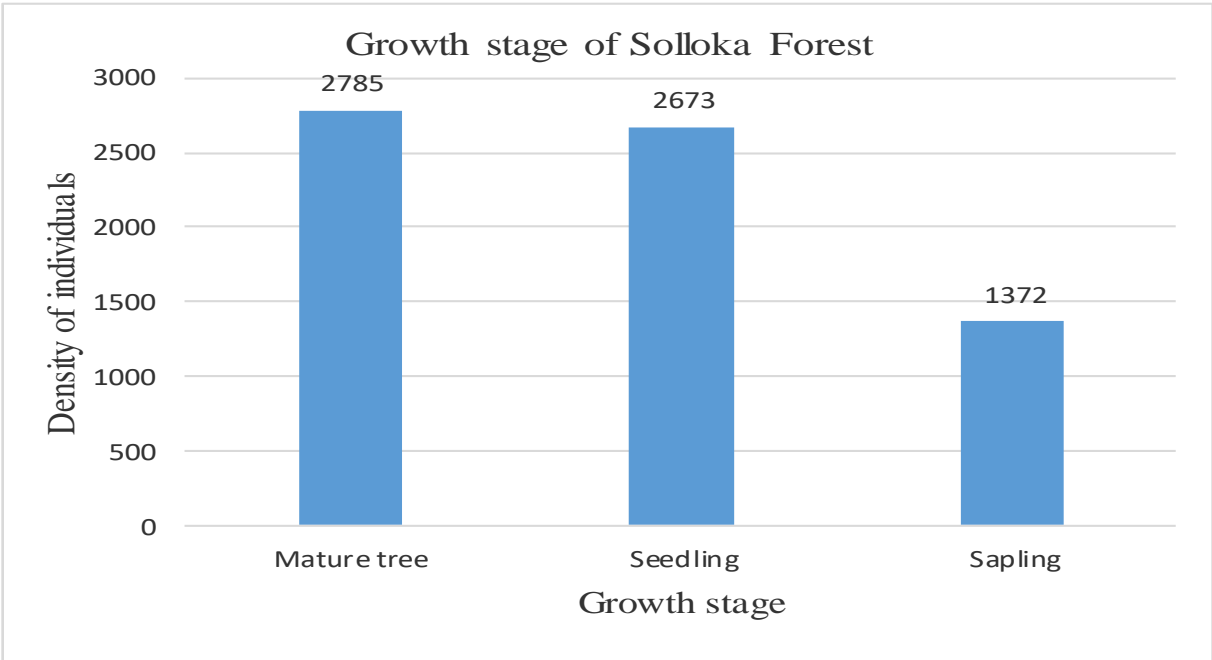


Figure 7: Growth Stage of mature, seedling and Sapling of the study forest

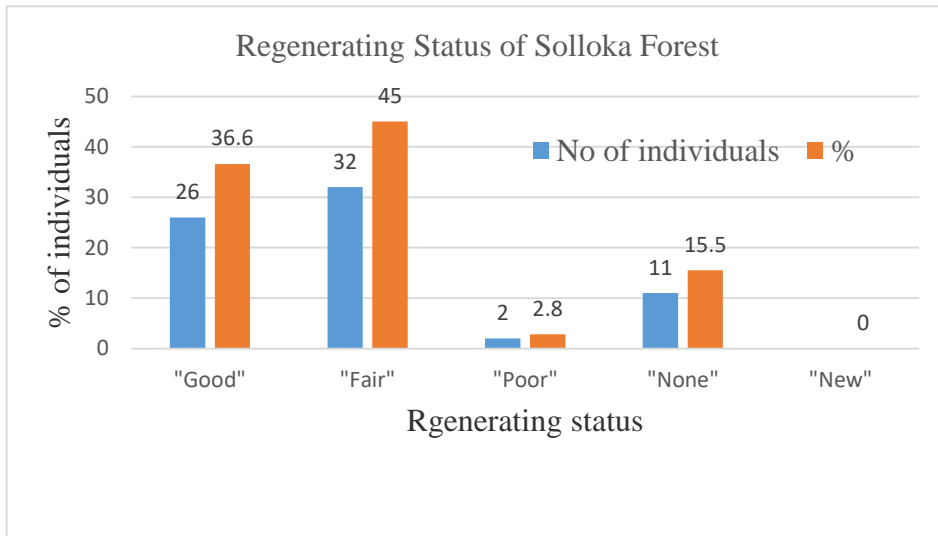


Figure 8: The regenerating status of woody species by % of number of species of Solloka Natural Forest

Table 8: The regenerating status of the top 17 woody species with “good’ and” fair” of the study forest

Species name	Seedling	Sapling	Mature tree	Regenerating status
<i>Olea europea</i> L.subsp. Caspidata	90	71	76	Good
<i>Euclea schimperi</i> (A.DC)	324	211	357	Fair
<i>Syzigium guineense</i> (Wild) Dc.	105	68	121	Fair
<i>Apodytesdimidiata</i>	92	59	50	Good
<i>Rhus glutinosa</i> Hochst ex Rich	60	30	157	Fair
<i>Mimusops kummel</i> A.Dc.	24	10	92	Fair
<i>Combretum adenogonium</i> Steud. Ex.A.Rich	27	22	62	Fair
<i>Sapium ellipticum</i> (Krauss)	9	13	17	Fair
<i>Brsema abyssinica</i> Fresen	82	55	100	Fair
<i>Nuxia oppositifolia</i> (Hochst.) Benth	257	125	42	Good
<i>Draceina afromantana</i> Mildbr	35	11	96	Fair
<i>Maytenus glacilipus</i>	34	21	113	Fair
<i>Acokanthera schimperi</i> (A.Dc.) Schewinf.	61	47	62	Fair
<i>Keetia guinzii</i> (Sond.)	71	33	71.5	Fair
<i>Maesa lanceolata</i> Forssk	24	33	79	Fair
<i>Olinia rochetiana</i> Thunb.	25	5	47	Fair

<i>Bridelia micrantha</i> ( Hochst) Baill	85	55	52	Good
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#### 4.1.2.11. Threats for Solloka Natural Forest

The most important causes of deforestation in Ethiopia is cutting trees with the aim of expanding agricultural land to feed the rapidly growing population and it is estimated to take place at the rate of 200,000 ha/year (Hundera and Gadissa, 2008). In the study forest, Complete clearing of forest was critically observed with the aim of expanding agricultural and grazing land by the local community. Cutting trees of economic and ecological importance for construction, fire wood, and charcoal and timber production are the main threats to woody species in the study forest. Illegal settlement of local communities in the forest was also one of the major problem to threats of forest resources. The main reason for these problems was lacking awareness of the nearby communities by concerned government officials. It is not only the communities that had no understanding of forest resources, but also the concerned officials. Due to these reasons the very economic and ecological woody species like *Cordia africana* for its high timber production and *Acacia abyssinica* for its charcoal production were under threat in the forest and they were at the stage of “none” regenerating status. The study forest was highly known with the *Olea europea* but now it was over harvested than ever before for its construction and fire wood. The following pictures showed the reality of the above justifications.



**Figure 9 A: Complete clearance Forest**

**Figure 9 B: Complete clearance Forest**



**Figure 9C: Illegal settlement in the forest.**  
**construction purposes**



**Figure9 C: Cutting trees for**

## 4.2. DISCUSSION

### 4.2.1. Woody species Composition.

The examined forest had relatively high species richness than other forests, for instance, Protected Woodland of Dugda District for which very least species richness was identified (19) (Ereso,2021) ,Yemrehane Kirstos Church forest for which only 39 species recorded (Ayanaw ,2016) and Lammo Natural forest which had species richness of 54 (Bekele and Abebe,2016). The forest had very close figure of species richness with Gura Ferda and Aba Sena forests, Kafta Sheraro National Park which had 66, 69 and 70 species richness respectively (Denu,2006;Fekadu *et al.*,2019 and Temesgen and Workineh,2017). But Belete forest for which 79 species recorded (Hundera and Gadissa, 2008) was slightly more species richness than that of Solloka Natural Forest. Other Afromontane forests of Ethiopia such as Yayu, Maji, Birhane Kontir and Harena forests have less species richness than that of Solloka natural forest which had 30, 37, 45 and 46 woody species richness respectively (Senbeta *et al*, 2014).All the species recorded from the study area were Angiosperms.

The dominance of Fabaceae has been reported from different woody species studies done by different authors (Denu, 2007; Denu, 2019; Didata *et al.*,2010; Gebrehiwot and Hundera, 2014; Hundera and Gadissa, 2008; Temesgen and Workineh, 2020; Addi *et al.*, 2020; Ereso, 2021and Adamu *et al.*, 2011;Birhanu *et al.*,2021). Fabaceae is one of the species rich family in the flora of Ethiopia and Eritrea (Kelbessa and Demissew, 2014) and its top dominance position might be due to the fact that it has effective pollination and seed dispersal mechanism that adapted them to a wide range of ecological condition in the past (Kelbessa and Soromessa 2008).The dominance of Fabaceae may indicate that the environmental conditions in these area would be more hospitable for this family (Didata *et al.*, 2010).

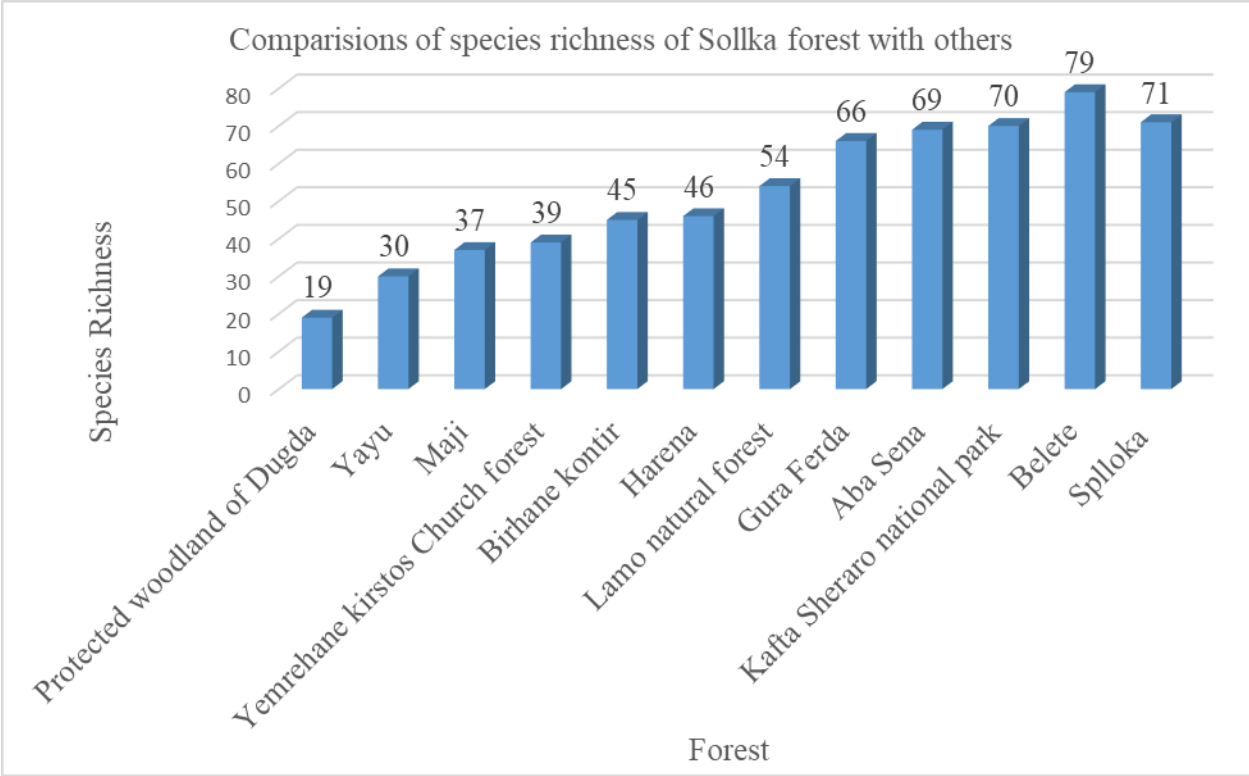


Figure 10: Summary of Comparisons of species richness of Solloka natural forest with other 11 forests of Ethiopia

#### **4.2. 2. Species Diversity and evenness of Solloka forest**

The relatively high value of Shannon Diversity index (3.6) and evenness (0.84) suggested that the study forest has more species diversity with more even distribution of species within the study quadrats. This could be realized with the observed topographic and / or elevational variation ranged from 1630-2060m a s l. and species richness occurred in the study plots.

Shannon Wiener Diversity value ranged from 1.5 to 3.5 and to exceed 4 is very rare (Coker, 1992).According to Coker (1992) stated above, the result of the present study suggested that Solloka natural forest had relatively high value of Shannon Wiener diversity index ( $H' = 3.6$ ) indicating more heterogenous than that of Maji forest ( $H' = 1.54$ ),Harena ( $H' = 2.6$ ),Yayu ( $H' = 2.8$ ) and Birhane Kontir forests ( $H' = 2.83$ ) ( Senbeta *et al.*,2014) and more or less similar species diversity with that of Aba Sena, Metema woodland vegetation and Bonga forests for which Shannon diversity value were ( $H' = 3.76, 3.67$  and  $3.17$ ) respectively (Fekadu *et al.*, 2019; Adamu *et al.*,2012 and Senbeta *et al.*,2014). In contrast to Hirmi woodland vegetation which had Shannon Wiener diversity value 4.21, Solloka natural forest is relatively less diverse in plant species (table 9).

Table 9: Summary of comparison of species diversity and evenness of Solloka natural forest to other Ethiopian Forests

No	Forests	Shannon wiener value	Evenness	References
1	Yemrehane Kirstos Church Forest	2.88	0.79	Ayanaw (2016)
2	Maji forest	1.54	0.31	Senbeta <i>et al</i> (2014)
3	Aba Sena Forest	3.76	0.62	Fekadu <i>et al</i> (2019)
4	Hirmi woodland Vegetation	4.21	0.95	Girmay <i>et al</i> (2020)
5	Metema woodland Vegetation	3.67	0.82	Adamu <i>et al</i> (2012)
6	Harena forest	2.60	0.51	Senbeta <i>et al</i> (2014)
7	Bonga forest	3.17	0.67	Senbeta <i>et al</i> (2014)
8	Yayu forest	2.8	0.63	Senbeta <i>et al</i> (2014)
9	Birhane Kontir forest	2.83	0.54	Senbeta <i>et al</i> (2014)
10	Solloka forest	3.6	0.84	Current study

Regarding the Shannon evenness, the current study had relatively more woody species evenness than Maji, Harena and Yayu forests (Senbeta *et al.*, 2014) and Aba Sena forest (Fekadu *et al.*, 2019) and more or less similar plant species evenness with Metema woodland vegetation (Adamu *et al.*,2012). But Hirmi woodland vegetation has more evenness than the study forest. Low species richness and evenness in a given vegetation are due to anthropogenic disturbances like grazing, selection of trees for firewood which considerably reduced species richness (Senbeta *et al.*, 2014).

### 4.2.3. Structure of the study forest

#### 4.2.3.1. Density

The total density of woody species of Solloka Natural Forest was 2785.5 individuals  $\text{Ha}^{-1}$  which is higher than Yemrehane kirstos church forest: (506.6 individuals  $\text{ha}^{-1}$  (Ayanaw,2018);Kafta Sheraro National Park ( $466 \pm 12.8$  individuals  $\text{ha}^{-1}$  (Temesgen and Workineh, 2020),Magada forest:(959 individuals  $\text{Ha}^{-1}$  Bekele,2005);Denkoro forest,(526 stems  $\text{ha}^{-1}$ ,Ayalew *et al*,2006);Adelle forest,898 individuals  $\text{ha}^{-1}$  and Boditi forest, 498 individual  $\text{ha}^{-1}$  (Yineger *et al*,2008). Similarly, the density of Solloka Natural forest is relatively greater than Belete forest (Hundera and Gadissa, 2008). The overall density of the examined forest was also much denser than that of Gura Ferda forest (Denu, 2006), Chato natural forest (Abdena, 2010), Masha Anderacha (Yeshitila and Bekele, 2003) and Gelesha forest (Alemu *et al.*, 2015).

Solloka natural forest has a close proportion (24.6%) of tree density with diameter at breast height  $>10\text{cm}$  when compared to Masha Anderacha forest (22%) (Yeshitila and Bekele, 2003). Gelesha and Gura Ferda forests with proportion of woody species density with  $\text{DBH} > 10\text{cm}$  (56.6% and 64.5%) (Alemu *et al.*, 2015) and (Denu, 2006) respectively showed strong variability with that of current study. Coming to the  $\text{DBH} > 20\text{cm}$ , the study forest has more or less similar proportion (11.33%) of woody species density with that of Masha Anderacha forest (9.3%) (Yeshitila and Bekele, 2003) and showed very least proportion with Gelesha forest (45.9%) and Gura Ferda forest (34.2%) (Alemu *et al.*, 2015 and Denu, 2006) respectively.

There is variations in the forests listed above regarding their densities. Variation of densities might be observed due to topographic gradients, habitat preferences and the degree of anthropogenic disturbances (Girmay *et al.*, 2020). Variation in species composition and age structure are also the possible reason for dynamics of woody species densities of the forests (Ademoh *et al.*, 2017 cited in Temesgen and Workineh, 2020).

From all the encountered and identified families of woody species of Solloka Natural forest, Fabaceae was found to be the highest density of woody species individuals (14%) followed by Ebenaceae and Anacardiaceae (12.8% and 6.8%) respectively. On the Other hand, the least number of woody species density were recorded in family Papilionoidaceae which contributed

only 0.028% of the overall density of the forest followed by Thymelaceae and Areaceae comprising 0.11% each.

The ratio of the individuals >10cm and 20cm were considered as the measure determination of size class distributions (Grubb *et al.*, 1963). Comparisons of the ratio a/b density of Solloka forest and other Ethiopian forest was given in table10. The a/b ratio of Solloka Natural forest was 1.9 which suggested the predominance of small trees individuals over large sized woody species. Similar results were reported from other Ethiopian forests. For instance, the ratio density at DBH class > 10cm to density at DBH class >20 cm of Magada forest was 1.8 (Bekele, 2005), Gura Ferda, Denkoro and Belete forests were 1.9 (Denu, 2006; Ayalew *et al.*, 2006; Hundera and Gadissa, 2008). On the other hand, Belete forest had 2.04 a/b ratio density at DBH class >10cm to density at DBH class >20cm (Gebrehiwot and Hundera, 2014), 2.25 and 2.52 for Boditi and Adelle forests respectively (Yineger *et al* 2008) indicating Belete, Boditi and Adelle forests had more small tree individuals than Solloka Natural forest. The finding of the study revealed that the current study had small a/b density ratio than Dangila church forest and Gelesha forests which their a/b ratio was 1.25 and 1.29 respectively (Birhanu *et al.*, 2021 and Alemu *et al.*, 2015) suggesting that the two forests had relatively least number of small tree than Solloka Natural forest and vice versa. Comparing to Chato natural forest, the density ratio of the woody species with diameter at breast height >10cm to 20cm of the current study was slightly more than it (Abdena, 2010). But the a / b ratio density of the current study was far less than that of Masha Anderacha forest (Yeshitila and Bekele, 2003). This finding revealed that Masha Anderacha forest was relatively high disturbances than Solloka natural forest.

The concentration of very large sized woody species over small ones, and the absence of large scale anthropogenic activity suggest that the forests are in a good state of primary forest regeneration. Solloka Natural forest falsify this notion by having large proportion of small tree individuals over large ones indicating the forest was affected by local community for different purposes and grazing pressure.

Table 10: Summary of comparison of woody species density of Sollka Natural forest with other 10 forests regarding with DBH >10cm and >20cm

DBH >10 =A, DBH >20 =B

No	Forests	DBH >10cm	DBH >20	Ratio (A/B)	References
1	Gura Ferda	500.5	265.5	1.9	Denu (2006)
2	Belete	613	323	1.9	Hundera and Gadissa (2008)
3	Magada	608	332	1.8	Bekele (2005)
4	Denkoro	526	285	1.8	Ayalew <i>et al</i> (2006)
5	Chato	333	194	1.71	Abdena (2010)
6	Dodola	521	351	1.5	Hundera <i>et al</i> (2007)
7	Gelesha forest	315.42	244.58	1.29	Alemu <i>et al</i> (2015)
	Belete	305.07	149	2.04	Gebrehiwot and Hundera (2014)
8	Komto	545	215	2.5	Gurmessa (2010)
9	Adele	432	174	2.52	Yineger <i>et al</i> (2008)
10	Boditi	283	125	2.25.	Yineger <i>et al</i> (2008)
11	Solloka	615	315	1.9	Current study

#### 4.2.3.2. Diameter at Breast Height

Diameter distribution plays a considerable role in a particular forest and enable to determine optimum overexploiting that improves stand structure (Zheng LF, Zhou XN, 2010 cited in Getaneh, 2018). Unlike to similar study conducted in Lamo Natural forest and Yemrehane Kirstos Church Forest (Bekele and Abebe, 2016; Ayanaw, 2016) that showed irregular shaped pattern of distributions of woody species across the DBH classes, the tree and shrubs distributions at the diameter at breast height of Solloka natural forest showed an inverted J-shaped pattern of distribution suggesting that the highest percentage of woody species individuals were dominated in the lower DBH classes and declining as the diameter at breast height increases.

The current study is similar in distribution of woody species across diameter at breast height with Magada forest (Bekele, 2005), Belete, Adelle and Boditi forests (Gebrehiwot and Kitessa,2014; Yineger *et al.*,2008 ) respectively which showed an inverted J- shaped pattern of tree and shrubs distributions suggesting that a good potential of reproduction and recruitment . Werganbula forest, Dangila Church forest, Dello Mena Woodland Vegetation and Wanzaye natural forests also among Ethiopian forests which had an inverted J-shaped pattern of woody species (Sileshi *et al.*,2022;Birhanu *et al* 2021; Didata *et al.*, 2010 and Getnet ,2018) respectively.

The significant reason that high percentage of trees in the lower DBH class distributions and a tiny percentage of woody species at higher DBH class was also done for the possible reason that the declining of density of plant species at higher diameter at breast height and maximum density of woody species at lower one. Over exploiting of forest resource without any replacement, illegal settlement and using the forest area for grazing land are the critical threats to plant species in the forest. According to Gurmessa (2010) selective cutting and exploiting of woody species by local community for different purposes are chronic challenges faced forest ecosystems that made declining of the plant species density in a given vegetation.

Comparisons of percent of woody species of Solloka natural forest with diameter at breast height between 10cm and 2.5cm,  $\geq 20$ cm and  $\geq 50$ cm of Solloka natural forest was given in table11.

Table 11: Percent Comparisons of DBH classes of woody species of SNF with some other 4 forests

No	Forest	DBH classes in % of species ha <sup>-1</sup>			References
		≤10cm	≥20cm	>50cm	
1	Ylat forest	97.15	0	0	Tegegne and Bikila (2017)
2	Jibat Forest	54.5	17.3	11.4	Burju <i>et al</i> (2013)
3	Gura Ferda forest	35.6	9.8	3.6	Denu (2006)
4	Belete forest	55	74	7.6	Hundera and Gadissa (2008)
5	Solloka Forest	75	11.36	2.21	Current study

As indicated in the above table, in all forests the concentration of small sized individuals were highly observed in the lower DBH classes distributions indicating that the forests were affected by anthropogenic activity. Percent of individuals were decreasing as the DBH distributions increasing as result showed from the examined forest. As shown in table 5, Solloka forest had the smallest % of individuals ha<sup>-1</sup> in DBH classes distribution > 50cm next to Ylat forest that had no woody species totally observed at this diameter.

#### 4.2.3.3. Basal area

The basal area distribution is very crucial criteria for identifying and sorting forest type based on the maturation stand (Getaneh, 2018 cited in Sokpon N, Biaou SH, 2001). The total basal area of Solloka Natural forest was 54m<sup>2</sup> Ha<sup>-1</sup>. The normal basal area for tropical Africa forests is ranged from 23-37m<sup>2</sup>/Ha (Denu, 2006; cited in Lamprecht, 1989). According to Gebrehiwot (2014; cited in Midgleya and Niklas, 2004) the mean total basal area of tropical forests is 35m<sup>2</sup> Ha<sup>-1</sup>. Therefore, the overall basal area of Solloka Natural forest when compared to tropical forests was found to be far higher than the average basal area of the tropical forests. Thus, it fulfills the standard criteria given for tropical forests regarding the basal area.

Basal area of Solloka Natural forest was far greater than reported for many other forests of Ethiopia, for example, Hirmi woodland vegetation ( $14\text{m}^2/\text{ha}$ ) (Girmay *et al.*,2020),Boditi Forest  $23\text{m}^2/\text{ha}$  and Adelle Forest ( $26\text{m}^2/\text{ha}$ ) (Yineger *et al.*,2008), Werganbula forest ( $32.07\text{m}^2/\text{ha}$ ) (Sileshi *et al.*,2022), Wanzaye Natural forest ( $23.3\text{m}^2/\text{ha}$ ) (Getnet 2018) and Lammo Natural forest ( $13\text{m}^2/\text{ha}$ ) (Bekele and Abebe,2016). A resemblance figure of basal area with the current study is reported in Aba Sena forest ( $51.6\text{m}^2/\text{ha}$ ) (Fekadu *et al.*, 2019). But Dangila Church forest ( $98.4\text{m}^2 /\text{ha}$ ) (Birhanu *et al* .,2021), Gelesha forest ( $98.87\text{m}^2/\text{ha}$ ) (Alemu *et al.*,2015),Dodola forest ( $129\text{m}^2/\text{ha}$ ) (Hundera *et al.*, 2007), Gura Ferda forest ( $90.6\text{m}^2/\text{ha}$ ) (Hundera and Deboch, 2008), Belete forest ( $90.6\text{m}^2/\text{ha}$ ) (Hundera and Gadissa, 2008), Kafta Sheraro National Park ( $79.3\text{m}^2/\text{ha}$ ) (Temesgen and Workineh, 2020) and Bibita forest ( $69.9\text{m}^2/\text{ha}$ ) (Denu, 2006) were far greater basal area than Solloka Natural forest.

Eventhough about 75% of all the woody species individuals had DBH less than10cm, (DBH class 1) the percentage contribution of these classes to the total basal area was only7.2% while individuals in the DBH class  $>50\text{cm}$  (DBH class 5 and above) had a density of about 2.21% of the total, but they contributed to about 50.7% of the total basal area analyzed for the forest.

Table 12: Summary of Comparison of Basal area of Solloka forest with other 15 Ethiopian forests

No	Forest name	Basal area (m <sup>2</sup> )/ha	References
1	Hirmi woodland vegetation	14	Girmay <i>et al</i> (2020)
2	Lammo Natural forest	13	Bekele and Abebe (2016)
3	Boditi Forest	23	Yineger <i>et al</i> (2008)
4	Wanzaye Natural forest	23.3	Getnet (2018)
5	Werganbula forest	32.07	Sileshi <i>et al</i> (2022)
6	Dangila Church forest	98	Birhanu <i>et al</i> (2021)
7	Adele	26	Yineger <i>et al</i> (2008)
8	Gelesha forest	98.87	Alemu <i>et al</i> (2015)
9	Gura Ferda	69.9	Denu (2006)
10	Dodola	129	Hundera (2007)
11	Belete	90.6	Hundera and Gadissa (2008)
12	Aba Sena	51.68	Fekadu <i>et al</i> (2019)
13	Kafta Sheraro National park	79.3	Temesgen and Workineh (2017)
14	Jibat Forest	60.9	Burju <i>et al</i> (2013)
15	Denkoro Forest	45	Ayalew <i>et al</i> (2006)
16	Solloka natural forest	54	Current study

#### **4.2.3.4. Height Class**

Most of the trees and shrubs individuals in the forest belong to the first height class (2.5m-10m) followed by second height class (11-20m) while the least number of individuals corresponds to the highest height class that indicated the most encountered species in the forest about 75% were short (< 10m ) in height. Only about 1.9% of woody species individuals reached sixth height class (> 50m). Height can be used as implication of age of the forest (Denu, 2006; Burju *et al.*, 2013). Accordingly, in Solloka Natural forest, the old trees are existed in the height class > 30m (height class 3 and above) which contributed 11.4% of the total plant species in the forest.

The height class distributions showed the same manner as Diameter at breast height class distributions indicating that the forest possesses large proportions of small trees and shrubs which in turn suggesting that the forest was in secondary stage of regenerations.

The current study had similar analysis with that of Denkoro forest (Ayalew *et al.*, 2006), Komto, Hirni woodland vegetation and Jibat forests (Gurmessa, 2010; Girmay *et al.*, 2020; Burju *et al.*, 2013).

Selective cutting of plant species at highest height, for different purposes by local communities was the most significant reason that made the woody species small in height in the study forest. The size class analysis of the Solloka natural forest showed that over exploiting of woody species individuals at highest DBH and height classes without any knowledge of sustainable use of woody individuals.

#### **4.2.3.5. Frequency**

Frequency clearly shows the homogeneity and diversity of a given species in a particular Forest (Haileab *et al.*, 2001 cited in Temesgen and Workineh, 2020). Similar species composition was observed when low value in lower frequency and high value in higher frequency is analyzed for any particular vegetation (Lamprecht, 1989 cited in Temesgen and Workineh, 2020). In a reverse way, Solloka Natural Forest had relatively high species diversity due to the fact that of higher percentage numbers of species were occurred / or existed in the lower frequency distributions than the higher one.

Small frequency implies a compact distribution of species in the forest whereas a large frequency suggested wide distribution of species (Bekele, 2005). Accordingly, in the current study *Euclea*

*schimperi* 90.6% followed by *Maytenus glacilipus* 81.2% and *Syzgium guineense* 71.9% were the species with wide distribution in the study quadrat while *Erythrina brucei*, *Gardenia ternifolia*, *Helinus mystcinus*, *Rhamnus tridentata* and *Acanthus eminence* were those species with a clumped distributions, hence, rare in distribution in the forest. The reason why *Euclea schimperi*, *Maytenus glacilipus* and *Syzgium guineense* were the most frequent in the study quadrat was due to the fact that they have less demand for timber and charcoal production.

#### **4.2.3.6. Important Value Index**

The important value index is used to compare ecological importance of woody species of a given forest (Temesgen and Workineh, 2020 cited in Lamprecht, 1989). It is also used to measure the species conservation priority in a given vegetation (Girmay *et al*, 2020 cited in kent, 2012). The Species Importance value Index of Solloka Natural forest was varies between 0.189 and 28.7. As the computed analysis of the forest realized, the highest basal area of the species made the woody species to have large values of relative dominance, hence, got the highest Important Value Index. The high value recorded for *Olea europea* was due to the fact that it has relatively high basal area whereas the dominance of *Syzgium guineense* is for its less demand for timber and charcoal production and construction purpose by local communities. Eventhough the IVI value computed for *Cordia africana* was 6, it is not economically significant and role playing species in the forest since it was restricted to only a few quadrats and it is not considered as the dominant specie in the current study. The reason why its IVI value was high in the forest is the fact that it had relatively high dominance. *Euclea schimperi* was ranked 2<sup>nd</sup> in IVI analysis of the forest due to its highly densed in the examined quadrats.

About 29.6% of the overall species recorded in the forest were found in the higher IVI distribution whereas 70.4% of the species fall in the lower IVI distributions. The analysis of the forest regarding Important Value Index (IVI) is comparable with Komto forest (Gurmesssa, 2010), Belete forest (Gebrehiwot and Hundera, 2014), Dirki and Jato Woodland vegetation (Tadesse, 2015) and Lamo Natural forest (Bekele and Abebe, 2016) which the analysis of their IVI indicate a high percentage of woody species in the lower IVI classes and certain figures of species in the higher IVI class distributions.

Woody species with highest figure of IVI (greater than 5.00) is taken as the most dominant species of any particular forest (Ayyanaw, 2016). Accordingly, woody species which ranked

less than 22 in their IVI were strongly affected by anthropogenic activity and grazing pressure which need immediate conservation and proper management.

#### **4.2.4. The Regeneration Status of Solloka Natural Forest**

Woody species composition was counted and analysis of the density of Solloka Natural Forest were done during the study. The number and the type of seedlings and saplings in a particular vegetation cover shows the regeneration condition of that vegetation cover (Denu, 2006). Accordingly, the density of seedling, sapling and matured tree were found to be 2674, 1372 and 2785.5 individuals/ha respectively. As the computed analysis of the forest regarding density of woody species indicated, the density of matured trees were higher than both seedling and sapling of woody species individuals hence, the forest was found to be categorized and fall under “fair” regenerating condition following the analysis method set by (Dhaulkhandi *et al.*, 2008).

The species that made the largest contribution to the seedling counts per hectare were *Euclea schimperi*, *Nuxia oppositifolia*, *Myrsine africana*, *Clausena anista*, *Vernonia auriculifera*, and *Syngium guineense* contributing 41.8% of the overall density of Seedling. On the other hand, woody species with largest contribution to sapling were *Euclea schimperi*, *Nuxia oppositifolia*, *Acacia Sp*, *Olea europea*, *Syngium guineense* and *Apodytes dimidiata* comprising 22.2% of the total sapling counted in the forest. The finding of the study revealed that *Euclea schimperi* and *Nuxia oppositifolia* were the plant species those strongly contributed to both seedling and sapling of the study forest.

Eventhough the regeneration status of SNF was falls under “fair” regenerating status, some woody species which were either generating poorly or not regenerating at all have been observed. Some of the species that were poorly regenerating are *Ficus thonningi* and *Teclea nobilis* whereas woody species that showed none regenerating condition in the forest were *Cordia africana*, *Acacia abyssinica*, *Stereospermum Kunthianum*, *Grewia bicolor*, *Entada abyssinica*, *Phoenix reclinata* and *Osyris quadripartita* which had no both seedling and sapling totally.

In contrast to Gura Ferda forest (Denu, 2006), Belete forest (Gebrehiwot and Hundera, 2014), Dirki and Jato Woodland Vegetation (Tadesse, 2015), Yemrehane Kirstos Church forest (Ayanaw, 2016) which showed “good” regenerating status, the current study reversely fall under

“fair” regenerating condition. These dissimilarity observed in the forests listed above with the current study might be due to dissimilarity of climatic condition (Gebrehiwot and Hundera, 2014). In addition to the above factor degree of disturbances might be the significant causes of dissimilarity of forests regarding the regeneration status of a particular vegetation even though they are located in similar climatic conditions.

Poor and none regenerating condition of woody species of a particular vegetation might have observed through extreme anthropogenic disturbances such as firewood collection, fire, overgrazing, poor biotic potential of tree species which affect the fruiting and seed germination or successful conversion of seedling to sapling stage (Temesgen and Workineh,2020 cited in Gebeyehu *et al*,2019). Accordingly, Solloka natural forest was under grazing pressure, irregular settlement, agricultural land expansion and over utilization of woody species by local communities.

## 5. CONCLUSION AND RECOMMENDATION

### 5.1. CONCLUSION

Solloka Natural forest is relatively woody species rich forest with 71 different plant species. Plant species of different life forms belonging to 59 genera and 38 families were identified from the forest. Out of the overall woody plant species recorded and identified, the largest proportions (56.3%) were trees and the remaining 38% and 5.6% were shrubs and woody climbers respectively. The top three dominant families in the forest with the plant species richness 7, 5 and 4 were Fabaceae, Rubiaceae and Moraceae respectively.

Density of woody species analysis of the forest showed declining of tree species with increasing diameter at breast height and height class distributions. The forest is characterized by the presence of higher percentage of tree densities in the lower class sizes and a tiny percentage of woody species in the higher one suggesting the forest is in a good potential of regeneration.

IVI of plant species of Solloka Natural Forest ranged between “0.189 to 28.7”. *Olea europea*, *Euclea schimperi*, *Syzgium guineense* and *Apodytes dimidiata* were the species with relatively the highest IVI in the study area which constitute 29.7% of the total IVI of the forest but *Erythrina brucei*, *Gardenia ternifolia*, *Helinus mystacinus* and *Acanthus eminence* were the plant species with least IVI comprising only 0.3% of the overall 300 IVI value computed for the forest.

The population structure of tree species showed variations among size class distributions. Some woody species occurred in all size classes while the majority of plant species populations concentrated in lower classes. Few of them were existed in certain DBH and height classes and totally absent from the other classes.

Anthropogenic activities such as timber and charcoal production, firewood collection, cutting trees for construction and different purposes and grazing pressure are strongly affecting plant species in the forest. As a result woody species like *Cordia africana*, *Acacia abyssinica*, *Entada abyssinica* and *Stereospermum kunthianum* had neither seedling nor sapling and in “none” regenerating status thus, need prior conservation.

The analysis of woody species of Solloka natural forest regarding the Shannon Wiener diversity and equitability showed relatively more species diversity and evenness.

## 5.2. RECOMMENDATION

Many information about the current study were obtained from every analysis of the forest which used to take necessary measures on issues that made the forest to decline at alarming rate. Based on the information obtained from the analysis of the structure of the study forest, population structure and regeneration status, the following recommendations are forwarded for the effective management and sustainable utilization of the forest resources.

- Complete clearance of the forest for expansion of agriculture and grazing land, over harvesting of woody species including very important species which regulate the entire ecosystem and illegal settlements are the critical problems faced the study forest and its resources. This made the rapid declined of woody species resulted in decreasing of large-sized individuals in the higher Diameter at Breast Height and Height class distributions. The continuous and regular disturbance of forest resources by cattle might lead to abnormally small size trees that resulted in retarding woody individual regeneration is also highly observed in the forest. The local communities do not feel as the owner of the forest resource that they had not carried out any responsibilities for the damaging of species. So, the concerned government officials should create continuous awareness and short term training to ensure the sustainable utilization of the resources.
- Eventhough it is not included in my study, timber and charcoal production was highly observed by local communities that made declining of *Cordia africana*, *Acacia abyssinica* and other woody species. Prior conservation is very critical for these economic and ecological importance trees. Developing conservation strategy for such species should be done by Natural resource and Climate Change Authorities of the District.
- The Forest (SNF) has its own map and boundary demarcations. Applying rule of law on those illegally overharvesting of resources might be the responsibility of the concerned government bodies.
- An evolvment of local community especially the full use of indigenous knowledge of people and empowering them in order to manage the forest resources is the best method and another best alternative for the long-term resource security.

- Indigenous woody species should be planted in all directions of the forest that can be used as a buffer zone in collaboration with local community and other concerned bodies.
- The plant species with IVI value less than 5.00 should be given proper attention and conserved in-situ with district Agriculture and Natural Resource office by the involvement of the local community.
- The present study was limited to diversity, structural analysis and regeneration status of the forest thus, further study might be recommended on herbaceous plants, soil characteristics and land use management system.
- Solloka natural forest should be recognized and included in forest priority areas for further conservation and meaningful management of the forest resources.

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## 7. Appendixes

Appendix 1: List of woody species recorded from Sollka Forest.

S/no	Scientific name	Local name	Famiky	Habit
1	<i>Clausena anista</i> (Wild) <i>Hook.f.ex.Benth</i>	Ulmaayii	Rutaceae	Shrub
2	<i>Euclea schimperi</i> (A.DC)	Mi'eessaa	Ebenaceae	Tree
3	<i>Myrsine africana</i> L.	Qacama	Myrsinaceae	Shrub
4	<i>Rhus glutinosa</i> Hochst ex Rich	Xaaxessaa	Anacardiaceae	Tree
5	<i>Draceina afromantana</i> Mildbr	Rukiinsa	Agavaceae	Tree
6	<i>Ficus sycomorus</i>	Odaa	Moraceae	Tree
7	<i>Premna schimperi</i> Engl.	Urgeessaa	Vebeaceae	Tree/shrub
8	<i>Olinia rochetiana</i> Thunb.	Soolee adii	Oliniaceae	Shrub
9	<i>Acacia</i> sp	Doddota	Fabaceae	Shrub
10	<i>Carissa spinarum</i> L.	Agamsa	Apocynaceae	Shrub
11	<i>Olea europea</i> L.subsp. <i>Caspidata</i>	Ejersa	Oleaceae	Tree
12	<i>Rhoicissus tridentata</i>	Laaluu /Hidda reeffaa	Vitaceae	Climber
13	<i>Albizia gummifera</i>	Mukarbaa	Fabaceae	Tree
14	<i>Dodonaea viscosa</i>	Ittacha	Spindaceae	Shrub
15	<i>Ficus vasta</i> Forssk	Qilxuu	Moraceae	Tree
16	<i>Rhamnus staddo</i>	Qadiidaa	Rhamnaceae	Tree/shrub

17	<i>Clutia lanceolata</i> Forssk	Ulefoonii	Euphorbiaceae	Shrub
18	<i>Bridelia micrantha</i> ( Hochst) Baill	Rigaaraabaa/ Duuloo	Euphorbiaceae	Shrub
19	<i>Dichrostachys cinera</i> L.	Baatee	Fabaceae	Tree
20	<i>Hypericum quartinianum</i> A.Rich	Rigaa Qaalluu	Clusiaceae	Shrub
21	<i>Oncoba spinosa</i> Forssk	Akuukkuu	Salicaceae	Tree
22	<i>Nuxia oppositifolia</i> (Hochst.) Benth	Qana'ee	Loganiaceae	Tree
23	<i>Maytenus glacilipus</i>	Hacaacee	Celasteraceae	Shrub
24	<i>Mimusops kummel</i> A.Dc.	Qolaatii	Sapotaceae	Tree
25	<i>Ficus sur</i>	Harbuu	Moraceae	Tree
26	<i>Brsema abyssinica</i> Fresen	Lolchiisaa	Melanthaceae	Tree
27	<i>Combretum adenogonium</i> Steud. Ex.A.Rich	Addajaboo	Combretaceae	Tree
28	<i>Syzygium guineense</i> (Wild) Dc.	Bddeessaa/Goosuu	Myrtaceae	Tree
29	<i>Maesa lanceolata</i> Forssk	Abbayyii	Myrsinaceae	Tree
30	<i>Calpurina aurea</i> (Aiton)	ceekaa	Fabaceae	Shrub
31	<i>Capparis tomentosa</i> Lam	Arangamaa gurraacha	Cannabaceae	Climber
32	<i>Acokanthera schimperi</i> (A.Dc.) Schewinf.	Qaraaruu	Apocynaceae	Tree
33	<i>Pittosporum viridiflorum</i> Sims	Luqqee	Pittosporaceae	Tree
34	<i>Stereospermum kunthianum</i> Cham.	Botoroo	Bigoniaceae	Tree

35	<i>Milleta ferruginea (Hochst.) Baker</i>	Sootalloo adii	Fabaceae	Tree
36	<i>Ovali folius Forssk</i>	Qacama Re'ee	Euphorbiaceae	Shrub
37	<i>Ritchiea albersii Gilg</i>	Marqaa Qamalee	caparidaceae	shrub
38	<i>Ficus thonningii Blume</i>	Dambii	Moraceae	Tree
39	<i>Terminalia laxiflora Engl &amp;Diels</i>	Dabaqqaa	Combretaceae	Tree
40	<i>Keetia guenzii (Sond.)</i>	Gaallee	Rubiaceae	Shrub
41	<i>Apodytesdimidiata</i>	Wandabiwoo	Icacinaceae	Tree
42	<i>Sapium ellipticum (Krauss)</i>	Bosoqa	Euphorbiaceae	Tree
43	<i>Celtis africana Brum.f.</i>	Ca'ii	Cannabaceae	Tree
44	<i>Ozora insignis Del</i>	Gaarrii	Anacardiaceae	Tree
45	<i>Flacoutrtia indica (Burm.f.) Merr</i>	Hudhaa	Salicaceae	Shrub
46	<i>Gardenia ternifolia (Schu.)</i>	Kambeela	Rubiaceae	Tree/shrub
47	<i>Crotton macrostachus Del.</i>	Bakkanniisa	Euphorbiaceae	Tree
48	<i>Rhus sandwicensi</i>	Darakkuu	Anacardiaceae	Tree
49	<i>Erythrina brucei</i>	Waleesuu korma	Papilionoidaceae	Shrub
50	<i>Acacia abyssinica subsp</i>	Laaftoo	Fabaceae	Tree
51	<i>Landolphia buchananii (Halier.f.)</i>	Geebboo	Apocynaceae	Climber

	<i>Staps</i>			
52	<i>Teclea nobilis Del.</i>	Hadheessa korma	Rutaceae	Tree
53	<i>Olea capensis L.</i> <i>subsp. macrocarpa</i>	Gagamaa	Oleaceae	Tree
54	<i>Cordia africana Lam</i>	Waddeessaa	Boraginaceae	Tree
55	<i>Phoenix reclinata Jack.</i>	Meexxii	Arecaceae	Shrub
56	<i>Coffee arabica L.</i>	Buna	Rubiaceae	Shrub
57	<i>Schrebera alta (Hochst.) Welw</i>	Karrawaayyuu	Oleaceae	Tree
58	<i>Grewia ferruginea Hochst ex</i> <i>A.Rich</i>	Buruurii	Tiliaceae	Shrub
59	<i>Entada abyssinica Steud.ex.</i> <i>A.Rich</i>	Hambalaa	Fabaceae	Tree/shrub
60	<i>Grewia ferruginea Hochst ex</i> <i>A.Rich</i>	Dhoqonuu	Tiliaceae	Shrub
61	<i>Osyris quadripartita</i>	Waattoo	Santalaceae	Tree
62	<i>Acanthus eminence C.B.Blake</i>	Sokorruu	Acanthaceae	Shrub
63	<i>Rhamnus tridentata L'Herit.</i>	Geeshoo	Rhamnaceae	Shrub
64	<i>Vernonia auriculifera Heirm.</i>	Reejjii	Asteraceae	Shrub
65	<i>Grewia bicolor</i>	Harooressa	Tiliaceae	Tree
66	<i>Helinus mystacinus (Ait) E. Mey</i>	Hoomachoo	Rhamnaceae	Climber
67	<i>Vernonia adoensis</i>	Sooyyamaduuadaa	Asteraceae	Shrub
68	<i>Gnidia glauca (Fresen.) Gilg</i>	Qaqaroo	Thymelaceae	Shrub

69	<i>Osyris lanceolata Hochst. Steud</i>	Wantafullasaa	Santalaceae	Tree
70	<i>Lantana trifolia L.</i>	Irbaata Durbaa	Veberaceae	Shrub
71	<i>Ocimum gratissimum L.</i>	Hancabbii	Lamiaceae	Shrub

Appendix 2: Frequency, % frequency and relative frequency of species.

Name of species	Frequency	%Frequency	Relative frequency
<i>Euclea schimperi</i> (A.DC)	29	90.6	4.559748428
<i>Syzgium guineense</i> (Wild) Dc.	23	71.9	3.616352201
<i>Rhus glutinosa</i> Hochst ex Rich	23	71.88	3.616352201
<i>Olea europea</i> subsp. Caspidata	23	71.88	3.616352201
<i>Apodytesdimidiata</i>	21	65.6	3.301886792
<i>Brsema abyssinica</i> Fresen	21	65.6	3.301886792
<i>Combretum adenogonium</i> Steud. Ex.A.Rich	20	62.5	3.144654088
<i>Nuxia oppositifolia</i> (Hochst.) Benth	19	59.4	2.987421384
<i>Maytenus glacialipus</i>	26	81.2	4.088050314
<i>Keetia guinzii</i> (Sond.)	19	59.4	2.987421384
<i>Draceina afromantana</i> Mildbr	18	56.3	2.830188679
<i>Myrsine africana</i> L.	16	50	2.51572327
<i>Olinia rochetiana</i> Thunb.	16	50	2.51572327
<i>Bridelia micrantha</i> ( Hochst) Baill	16	50	2.51572327
<i>Oncoba spinosa</i> Forssk	16	50	2.51572327
<i>Calpurina aurea</i> (Aiton)	16	50	2.51572327
<i>Ritchiea albersii</i> Gilg	16	50	2.51572327
<i>Rhoicissus tridentata</i>	15	46.88	2.358490566

<i>Acokanthera schimperi</i> (A.Dc.) Schewinf.	15	46.8	2.358490566
<i>Mimusops kummel</i> A.Dc.	14	43.8	2.201257862
<i>Clausena anista</i> (Wild) Hook.f.ex.Benth	13	40.63	2.044025157
<i>Premna schimperi</i> Engl.	13	40.63	2.044025157
<i>Carissa spinarum</i> L.	13	40.63	2.044025157
<i>Terminalia laxiflora</i> Engl &Diels	13	40.6	2.044025157
<i>Acacia</i> sp	13	40.6	2.044025157
<i>Maesa lanceolata</i> Forssk	11	34.4	1.729559748
<i>Milletia ferruginea</i> (Hochst.) Baker	9	28.1	1.41509434
<i>Croton macrostachus</i> Del.	11	34.4	1.729559748
<i>Cordia africana</i> Lam	9	28.1	1.41509434
<i>Ficus sur</i>	8	25	1.257861635
<i>Clusia lanceolata</i> Forssk	7	21.9	1.100628931
<i>Stereospermum kunthianum</i> Cham.	7	21.9	1.100628931
<i>Celtis africana</i> Brum.f.	7	21.9	1.100628931
<i>Ozora insignis</i> Del	7	21.9	1.100628931
<i>Hypericum quartinianum</i> A.Rich	6	18.8	0.943396226
<i>Rhus sandwicensi</i>	6	18.8	0.943396226
<i>Albizia gummifera</i>	6	18.6	0.943396226
<i>Capparis tomentosa</i> Lam	7	21.9	1.100628931
<i>Schrebera alata</i> (Hochst.) Welw	5	15.6	0.786163522

<i>Acacia abyssinica</i> subsp	5	12.6	0.786163522
<i>Dodonaea viscosa</i>	4	12.5	0.628930818
<i>Rhamnus staddo</i>	4	12.5	0.628930818
<i>Flacoutrtia indica</i> (Burm.f.) Merr	4	12.5	0.628930818
<i>Phoenix reclinata</i> Jack.	4	12.5	0.628930818
<i>Coffee arabica</i> L.	4	12.5	0.628930818
<i>Entada abysini nica</i> Steud.ex. A.Rich	4	12.5	0.628930818
<i>Grewia bicolor</i>	4	12.5	0.628930818
<i>Ficus sycomorus</i>	3	9.4	0.471698113
<i>Dichrostaxhys cinera</i> L.	3	9.4	0.471698113
<i>Pittosporum viridiflorum</i> Sims	3	9.4	0.471698113
<i>Ovali folius</i> Forssk	3	9.4	0.471698113
<i>Sapium ellipticum</i> (Krauss)	3	9.4	0.471698113
<i>Teclea nobilis</i> Del.	3	9.4	0.471698113
<i>Olea capensis</i> subsp.macrocarpa	3	9.4	0.471698113
<i>Ficus vasta</i> Forssk	2	6.3	0.314465409
<i>Ficus thonningii</i> Blume	2	6.3	0.314465409
<i>Landolphia buchananii</i> (Halier.f.) Staps	2	6.3	0.314465409
<i>Grewia ferruginea</i> Hochst ex A.Rich	2	6.3	0.314465409
<i>Vernonia adoensis</i>	2	6.3	0.314465409
<i>Gnidia glauca</i> (Fresen.)Gilg	2	6.3	0.314465409

<i>Osyris lanceolata</i> Hochst. Steud	2	6.3	0.314465409
<i>Lantana trifolia</i> L.	2	6.3	0.314465409
<i>Ocimum gratissimum</i> L.	2	6.3	0.314465409
<i>Grewia ferruginea</i> Hochst ex A.Rich	2	6.25	0.314465409
<i>Osyris quadripartita</i>	2	6.25	0.314465409
<i>Vernonia auriculifera</i> Heirm.	2	6.25	0.314465409
<i>Acanthus eminence</i> C.B.Blake	1	3.13	0.157232704
<i>Rhamnus tridentata</i> L'Herit.	1	3.13	0.157232704
<i>Helinus mystacinus</i> (Ait) E. Mey	1	3.13	0.157232704
<i>Gardenia ternifolia</i> (Schu.)	1	3.1	0.157232704
<i>Erythrina brucei</i>	1	3.1	0.157232704
	636		100

Appendix 3: List of density of woody species with their decreasing order.

Name	woody species density	% density
<i>Euclea schimperi</i> (A.DC)	357	12.81867
<i>Rhus glutinosa</i> Hochst ex Rich	157	5.637343
<i>Acacia sp</i>	148	5.314183
<i>Syzgium guineense</i> (Wild) Dc.	121	4.344704
<i>Maytenus glacilipus</i>	113	4.057451
<i>Calpurina aurea</i> (Aiton)	104	3.734291
<i>Brsema abyssinica</i> Fresen	100	3.590664
<i>Dracaena afromantana</i> Mildbr	96	3.447038
<i>Mimusops kummel</i> A.Dc.	92	3.303411
<i>Maesa lanceolata</i> Forssk	79	2.836625
<i>Olea europea</i> subsp. Caspidata	76	2.728905
<i>Milleta ferruginea</i> (Hochst.) Baker	72	2.585278
<i>Keetia guinzii</i> (Sond.)	71	2.549372
<i>Premna schimperi</i> Engl.	70	2.513465
<i>Carissa spinarum</i> L.	66	2.369838
<i>Combretum adenogonium</i> Steud. Ex.A.Rich	62	2.226212
<i>Acokanthera schimperi</i> (A.Dc.) Schewinf.	62	2.226212
<i>Clausena anista</i> (Wild) Hook.f.ex.Benth	56	2.010772
<i>Ritchiea albersii</i> Gilg	54	1.938959

<i>Rhoicissus tridentata</i>	54	1.938959
<i>Bridelia micrantha</i> ( Hochst) Baill	52	1.867145
<i>Apodytesdimidiata</i>	50	1.795332
<i>Ovali folius</i> Forssk	50	1.795332
<i>Olinia rochetiana</i> Thunb.	47	1.687612
<i>Nuxia oppositifolia</i> (Hochst.) Benth	42	1.508079
<i>Myrsine africana</i> L.	40	1.436266
<i>Terminalia laxiflora</i> Engl &Diels	38	1.364452
<i>Coffee arabica</i> L.	35	1.256732
<i>Crotton macrostachyus</i> Del.	34	1.220826
<i>Oncoba spinosa</i> Forssk	23	0.825853
<i>Clutia lanceolata</i> Forssk	23	0.825853
<i>Cordia africana</i> Lam	21	0.754039
<i>Rhus sandwicensi</i>	19	0.682226
<i>Ficus sur</i>	18	0.64632
<i>Sapium ellipticum</i> (Krauss)	17	0.610413
<i>Landolphia buchananii</i> (Halier.f.) Staps	17	0.610413
<i>Ozora insignis</i> Del	15	0.5386
<i>Capparis tomentosa</i> Lam	15	0.5386
<i>Hypericum quartinianum</i> A.Rich	14	0.502693
<i>Schrebera alata</i> (Hochst.) Welw	12	0.43088

<i>Olea capensis</i> subsp.macrocarpa	12	0.43088
<i>Celtis africana</i> Brum.f.	11	0.394973
<i>Acacia abyssinica</i> subsp	10	0.359066
<i>Grewia bicolor</i>	9	0.32316
<i>Dodonaea viscosa</i>	9	0.32316
<i>Rhamnus staddo</i>	9	0.32316
<i>Ficus thonningii</i> Blume	9	0.32316
<i>Osyris lanceolata</i> Hochst. Steud	9	0.32316
<i>Acanthus eminence</i> C.B.Blake	9	0.32316
<i>Osyris quadripartita</i>	8	0.287253
<i>Ficus sycomorus</i>	7	0.251346
<i>Stereospermum kunthianum</i> Cham.	7	0.251346
<i>Albizia gummifera</i>	7	0.251346
<i>Flacoutrtia indica</i> (Burm.f.) Merr	7	0.251346
<i>Grewia ferruginea</i> Hochst ex A.Rich	7	0.251346
<i>Vernonia auriculifera</i> Heirm.	7	0.251346
<i>Helinus mystacinus</i> (Ait) E. Mey	7	0.251346
<i>Pittosporum viridiflorum</i> Sims	6	0.21544
<i>Teclea nobilis</i> Del.	6	0.21544
<i>Dichrostachyus cinera</i> L.	5	0.179533
<i>Grewia ferruginea</i> Hochst ex A.Richb	4	0.143627

<i>Vernonia adoensis</i>	4	0.143627
<i>Ocimum gratissimum</i> L.	4	0.143627
<i>Entada abyssinica</i> Steud.ex. A.Rich	3	0.10772
<i>Phoenix reclinata</i> Jack.	3	0.10772
<i>Ficus vasta</i> Forssk	3	0.10772
<i>Gnidia glauca</i> (Fresen.)Gilg	3	0.10772
<i>Lantana trifolia</i> L.	3	0.10772
<i>Rhamnus tridentata</i> L'Herit.	3	0.10772
<i>Gardenia ternifolia</i> (Schu.)	1	0.035907
<i>Erythrina brucei</i>	1	0.035907
	2785	100

Appendix 4: Basal area in m<sup>2</sup>, hectare basis, dominance and relative dominance of woody species of SNF.

Name	Basal area m <sup>2</sup>	Basal area/ha	Dominance	Relative dominance
<i>Olea europea</i> subsp. Caspidata	11.98669566	9.364605984	7.316098425	17.19008089
<i>Euclea schimperi</i> (A.DC)	7.89431117	6.167430602	4.818305157	11.32120573
<i>Syzgium guineense</i> (Wild) Dc.	6.83618141	5.340766727	4.172474005	9.803745313
<i>Apodytesdimidiata</i>	5.078459375	3.967546387	3.099645615	7.283001914
<i>Rhus glutinosa</i> Hochst ex Rich	5.050664095	3.945831324	3.082680722	7.243140794
<i>Mimusops kummel</i> A.Dc.	3.080613965	2.40672966	1.880257547	4.417898372
<i>Combretum adenogonium</i> Steud. Ex.A.Rich	3.00415575	2.34699668	1.833591156	4.308249897
<i>Sapium ellipticum</i> (Krauss)	2.523055155	1.97113684	1.539950656	3.618305113
<i>Brsema abyssinica</i> Fresen	2.05997816	1.609357938	1.257310889	2.954207915
<i>Nuxia oppositifolia</i> (Hochst.) Benth	1.96299298	1.533588266	1.198115833	2.815121787
<i>Draceina afromantana</i> Mildbr	1.82690224	1.427267375	1.115052637	2.619954504
<i>Maytenus glacialipus</i>	1.67358389	1.307487414	1.021474542	2.400081161
<i>Cordia africana</i> Lam	1.66535238	1.301056547	1.016450427	2.38827638
<i>Acokanthera schimperi</i> (A.Dc.) Schewinf.	1.647736195	1.287293902	1.005698361	2.363013067
<i>Keetia guinzii</i> (Sond.)	1.49207305	1.16568207	0.910689117	2.139777062
<i>Maesa lanceolata</i> Forssk	1.42538416	1.113581375	0.869985449	2.044138743

<i>Olinia rochetiana</i> Thunb.	1.191546005	0.930895316	0.727261966	1.708792213
<i>Bridelia micrantha</i> (Hochst) Baill	1.17138485	0.915144414	0.714956573	1.679879167
<i>Ritchiea albersii</i> Gilg	0.916839965	0.716281223	0.559594705	1.314837183
<i>Crotton macrostachus</i> Del.	0.621009575	0.48516373	0.379034164	0.890587792
<i>Myrsine africana</i> L.	0.583690675	0.45600834	0.356256516	0.83706888
<i>Calpurina aurea</i> (Aiton)	0.564	0.440625	0.344238281	0.808830548
<i>Oncoba spinosa</i> Forssk	0.553758625	0.432623926	0.337987442	0.794143426
<i>Milleta ferruginea</i> (Hochst.) Baker	0.342059825	0.267234238	0.208776749	0.490546872
<i>Carissa spinarum</i> L.	0.332569175	0.259819668	0.202984116	0.476936362
<i>Rhoicissus tridentata</i>	0.32104145	0.250813633	0.195948151	0.460404489
<i>Premna schimperi</i> Engl.	0.31924789	0.249412414	0.194853448	0.457832351
<i>Clausena anista</i> (Wild) Hook.f.ex.Benth	0.301263375	0.235362012	0.183876572	0.432040817
<i>Acacia sp</i>	0.23134578	0.180738891	0.141202258	0.331772223
<i>Terminalia laxiflora</i> Engl &Diels	0.214607225	0.167661895	0.130985855	0.307767517
<i>Ficus sur</i>	0.20643145	0.16127457	0.125995758	0.296042665
<i>Ficus sycomorus</i>	0.204308025	0.159615645	0.124699722	0.292997468
<i>Rhus sandwicensi</i>	0.20219873	0.157967758	0.123412311	0.289972535
<i>Ozora insignis</i> Del	0.191423035	0.149549246	0.116835349	0.274519146
<i>Acacia abyssinica subsp</i>	0.179935345	0.140574488	0.109823819	0.258044687
<i>Stereospermum kunthianum</i> Cham.	0.17876962	0.139663766	0.109112317	0.256372925
<i>Celtis africana</i> Brum.f.	0.17326834	0.135365891	0.105754602	0.248483557

<i>Clutia lanceolata</i> Forssk	0.16217001	0.12669532	0.098980719	0.232567479
<i>Albizia gummifera</i>	0.158930315	0.124164309	0.097003366	0.227921443
<i>Capparis tomentosa</i> Lam	0.117837135	0.092060262	0.071922079	0.168989848
<i>Hypericum quartinianum</i> A.Rich	0.093174005	0.072792191	0.0568689	0.133620535
<i>Schrebera alata</i> (Hochst.) Welw	0.092754815	0.072464699	0.056613046	0.133019376
<i>Pittosporum viridiflorum</i> Sims	0.09033623	0.07057518	0.055136859	0.129550891
<i>Grewia bicolor</i>	0.08732811	0.068225086	0.053300848	0.125236956
<i>Dodonaea viscosa</i>	0.083656665	0.06535677	0.051059976	0.119971749
<i>Flacourtia indica</i> (Burm.f.) Merr	0.082835555	0.064715277	0.05055881	0.118794197
<i>Entada abyssinica</i> Steud.ex. A.Rich	0.08074981	0.063085789	0.049285773	0.115803037
<i>Rhamnus staddo</i>	0.05344751	0.041755867	0.032621771	0.076648899
<i>Phoenix reclinata</i> Jack.	0.043918395	0.034311246	0.026805661	0.062983226
<i>Coffea arabica</i> L.	0.0415265	0.032442578	0.025345764	0.059553017
<i>Olea capensis</i> L. subsp.macrocarpa	0.036427925	0.028459316	0.022233841	0.052241168
<i>Ficus thonningii</i> Blume	0.035912965	0.028057004	0.021919534	0.051502665
<i>Dichrostachys cinerea</i> L.	0.03404074	0.026594328	0.020776819	0.048817713
<i>Teclea nobilis</i> Del.	0.028116345	0.021965895	0.017160855	0.040321558
<i>Ovali folius</i> Forssk	0.02712175	0.021188867	0.016553802	0.038895213
<i>Landolphia b Buchananii</i> (Halier.f.) Staps	0.02566479	0.020050617	0.015664545	0.036805791
<i>Ficus vasta</i> Forssk	0.020778165	0.016232941	0.012681985	0.029797898
<i>Grewia ferruginea</i> Hochst ex A.Richb	0.01975845	0.015436289	0.012059601	0.028335528

<i>Osyris lanceolata</i> Hochst. Steud	0.01761383	0.013760805	0.010750629	0.025259936
<i>Vernonia adoensis</i>	0.01553515	0.012136836	0.009481903	0.022278908
<i>Gnidia glauca</i> (Fresen.)Gilg	0.014564105	0.011378207	0.008889224	0.020886335
<i>Grewia ferruginea</i> Hochst ex A.Rich	0.011413115	0.008916496	0.006966013	0.016367511
<i>Osyris quadripartita</i>	0.01100884	0.008600656	0.006719263	0.015787741
<i>Lantana trifolia</i> L.	0.007084625	0.005534863	0.004324112	0.010160037
<i>Ocimum gratissimum</i> L.	0.007081485	0.00553241	0.004322195	0.010155534
<i>Vernonia auriculifera</i> Heirm.	0.00541493	0.004230414	0.003305011	0.007765533
<i>Rhamnus tridentata</i> L'Herit.	0.003511305	0.002743207	0.00214313	0.005035551
<i>Acanthus eminence</i> C.B.Blake	0.00324833	0.002537758	0.001982623	0.004658419
<i>Helinus mystacinus</i> (Ait) E. Mey	0.00323734	0.002529172	0.001975916	0.004642659
<i>Gardenia ternifolia</i> (Schu.)	0.002982215	0.002329855	0.0018202	0.004276785
<i>Erythrina brucei</i>	0.0027	0.002109375	0.001647949	0.003872061
Total	69.73072005		42.56025394	100.0005967

Appendix 5: Important Value Index of woody species of Solloka natural forest

Name	Relative frequency	Relative density	Relative dominance	IVI
<i>Olea europea</i> subsp. <i>Caspidata</i>	4.559748428	12.81907433	11.32120573	28.7
<i>Euclea schimperi</i> (A.DC)	3.616352201	4.347826087	17.19008089	25.1543
<i>Syzgium guineense</i> (Wild) Dc.	3.616352201	5.638148668	9.803745313	19.0582
<i>Apodytesdimidiata</i>	3.616352201	5.329593268	7.243140794	16.1891
<i>Rhus glutinosa</i> Hochst ex Rich	3.301886792	4.039270687	7.283001914	14.6242
<i>Mimusops kummel</i> A.Dc.	3.144654088	3.590462833	4.308249897	11.0434
<i>Combretum adenogonium</i> Steud. Ex.A.Rich	3.301886792	3.730715288	2.954207915	9.98681
<i>Sapium ellipticum</i> (Krauss)	4.088050314	3.309957924	2.400081161	9.79809
<i>Brsema abyssinica</i> Fresen	2.987421384	3.394109397	2.815121787	9.19665
<i>Nuxia oppositifolia</i> (Hochst.) Benth	2.201257862	1.935483871	4.417898372	8.55464
<i>Draceina afromantana</i> Mildbr	2.830188679	2.720897616	2.619954504	8.17104
<i>Maytenus glacilipus</i>	2.987421384	2.833099579	2.139777062	7.9603
<i>Cordia africana</i> Lam	2.51572327	2.55259467	1.708792213	6.77711
<i>Acokanthera schimperi</i> (A.Dc.) Schewinf.	2.51572327	2.52454418	1.679879167	6.72015
<i>Keetia guinzii</i> (Sond.)	2.358490566	1.935483871	2.363013067	6.65699
<i>Maesa lanceolata</i> Forssk	2.51572327	2.21598878	1.314837183	6.04655
<i>Olinia rochetiana</i> Thunb.	2.51572327	2.580645161	0.83706888	5.93344

<i>Bridelia micrantha</i> ( Hochst) Baill	2.51572327	2.384291725	0.794143426	5.69416
<i>Ritchiea albersii</i> Gilg	2.51572327	2.21598878	0.808830548	5.54054
<i>Croton macrostachus</i> Del.	1.729559748	1.430575035	2.044138743	5.20427
<i>Myrsine africana</i> L.	1.41509434	1.206171108	2.38827638	5.00954
<i>Calpurina aurea</i> (Aiton)	2.358490566	2.019635344	0.460404489	4.83853
<i>Oncoba spinosa</i> Forssk	0.471698113	0.252454418	3.618305113	4.34246
<i>Milleta ferruginea</i> (Hochst.) Baker	2.044025157	1.851332398	0.432040817	4.3274
<i>Carissa spinarum</i> L.	2.044025157	1.823281907	0.457832351	4.32514
<i>Rhoicissus tridentata</i>	2.044025157	1.795231417	0.476936362	4.31619
<i>Premna schimperi</i> Engl.	2.044025157	1.683029453	0.307767517	4.03482
<i>Clausena anista</i> (Wild) Hook.f.ex.Benth	2.044025157	1.514726508	0.331772223	3.89052
<i>Acacia sp</i>	1.729559748	1.26227209	0.890587792	3.88242
<i>Terminalia laxiflora</i> Engl &Diels	1.41509434	1.346423562	0.490546872	3.25206
<i>Ficus sur</i>	1.257861635	0.841514727	0.296042665	2.39542
<i>Ficus sycomorus</i>	1.100628931	0.841514727	0.232567479	2.17471
<i>Rhus sandwicensi</i>	1.100628931	0.757363254	0.256372925	2.11437
<i>Ozora insignis</i> Del	1.100628931	0.701262272	0.248483557	2.05037
<i>Acacia abyssinica subsp</i>	1.100628931	0.64516129	0.274519146	2.02031
<i>Stereospermum kunthianum</i> Cham.	0.943396226	0.589060309	0.289972535	1.82243
<i>Celtis africana</i> Brum.f.	1.100628931	0.532959327	0.168989848	1.80258
<i>Clutia lanceolata</i> Forssk	0.943396226	0.561009818	0.227921443	1.73233

<i>Albizia gummifera</i>	0.943396226	0.617110799	0.133620535	1.69413
<i>Capparis tomentosa</i> Lam	0.786163522	0.448807854	0.258044687	1.49302
<i>Hypericum quartinianum</i> A.Rich	0.786163522	0.504908836	0.133019376	1.42409
<i>Schrebera alata</i> (Hochst.) Welw	0.628930818	0.448807854	0.119971749	1.19771
<i>Pittosporum viridiflorum</i> Sims	0.628930818	0.420757363	0.076648899	1.12634
<i>Grewia bicolor</i>	0.628930818	0.364656381	0.118794197	1.11238
<i>Dodonaea viscosa</i>	0.628930818	0.336605891	0.115803037	1.08134
<i>Flacoutrtia indica</i> (Burm.f.) Merr	0.471698113	0.3085554	0.292997468	1.07325
<i>Entada abyssinica</i> Steud.ex. A.Rich	0.628930818	0.3085554	0.125236956	1.06272
<i>Rhamnus staddo</i>	0.628930818	0.336605891	0.062983226	1.02852
<i>Phoenix reclinata</i> Jack.	0.628930818	0.336605891	0.059553017	1.02509
<i>Coffea arabica</i> L.	0.471698113	0.252454418	0.129550891	0.8537
<i>Olea capensis</i> subsp.macrocarpa	0.471698113	0.3085554	0.048817713	0.82907
<i>Ficus thonningii</i> Blume	0.471698113	0.252454418	0.052241168	0.77639
<i>Dichrostachys cinera</i> L.	0.471698113	0.252454418	0.040321558	0.76447
<i>Teclea nobilis</i> Del.	0.471698113	0.252454418	0.038895213	0.76305
<i>Ovali folius</i> Forssk	0.314465409	0.252454418	0.051502665	0.61842
<i>Landolphia buchananii</i> (Halier.f.) Staps	0.314465409	0.252454418	0.029797898	0.59672
<i>Ficus vasta</i> Forssk	0.314465409	0.224403927	0.036805791	0.57568
<i>Grewia ferruginea</i> Hochst ex A.Richb	0.314465409	0.224403927	0.028335528	0.5672

<i>Osyris lanceolata</i> Hochst. Steud	0.314465409	0.196353436	0.022278908	0.5331
<i>Vernonia adoensis</i>	0.314465409	0.196353436	0.020886335	0.53171
<i>Gnidia glauca</i> (Fresen.)Gilg	0.314465409	0.140252454	0.025259936	0.47998
<i>Grewia ferruginea</i> Hochst ex A.Rich	0.314465409	0.140252454	0.016367511	0.47109
<i>Osyris quadripartita</i>	0.314465409	0.140252454	0.010160037	0.46488
<i>Lantana trifolia</i> L.	0.314465409	0.140252454	0.010155534	0.46487
<i>Ocimum gratissimum</i> L.	0.314465409	0.112201964	0.015787741	0.44246
<i>Vernonia auriculifera</i> Heirm.	0.314465409	0.112201964	0.007765533	0.43443
<i>Rhamnus tridentata</i> L'Herit.	0.157232704	0.112201964	0.005035551	0.27447
<i>Acanthus eminence</i> C.B.Blake	0.157232704	0.112201964	0.004658419	0.27409
<i>Helinus mystacinus</i> (Ait) E. Mey	0.157232704	0.084151473	0.004642659	0.24603
<i>Gardenia ternifolia</i> (Schu.)	0.157232704	0.028050491	0.004276785	0.18956
<i>Erythrina brucei</i>	0.157232704	0.028050491	0.003872061	0.18916
	100	100	100	300.001

Appendix 6: Shannon Wiener Diversity Index of woody species of Solloka Natural Forest.

Species name	Abundance	pi	Lnpi	piLnpi
<i>Euclea schimperi</i> (A.DC)	457	0.128191	-2.05424	-0.26333
<i>Rhus glutinosa</i> Hochst ex Rich	201	0.056381	-2.87561	-0.16213
<i>Acacia</i> sp	190	0.053296	-2.9319	-0.15626
<i>Syzgium guineense</i> (Wild) Dc.	155	0.043478	-3.13549	-0.13633
<i>Maytenus glacilipus</i>	144	0.040393	-3.20911	-0.12962
<i>Calpurina aurea</i> (Aiton)	133	0.037307	-3.28857	-0.12269
<i>Brsema abyssinica</i> Fresen	128	0.035905	-3.32689	-0.11945
<i>Draceina afromantana</i> Mildbr	121	0.033941	-3.38313	-0.11483
<i>Mimusops kummel</i> A.Dc.	118	0.0331	-3.40823	-0.11281
<i>Maesa lanceolata</i> Forssk	101	0.028331	-3.5638	-0.10097
<i>Olea europea</i> subsp. Caspidata	97	0.027209	-3.60421	-0.09807
<i>Milleta ferruginea</i> (Hochst.) Baker	92	0.025806	-3.65713	-0.09438
<i>Keetia guinzii</i> (Sond.)	91	0.025526	-3.66806	-0.09363
<i>Premna schimperi</i> Engl.	90	0.025245	-3.67911	-0.09288
<i>Carissa spinarum</i> L.	85	0.023843	-3.73627	-0.08908
<i>Combretum adenogonium</i> Steud. Ex.A.Rich	79	0.02216	-3.80947	-0.08442
<i>Acokanthera schimperi</i> (A.Dc.) Schewinf.	79	0.02216	-3.80947	-0.08442
<i>Clausena anista</i> (Wild)	72	0.020196	-3.90225	-0.07881

Hook.f.ex.Benth				
<i>Ritchiea albersii</i> Gilg	69	0.019355	-3.94481	-0.07635
<i>Rhoicissus tridentata</i>	69	0.019355	-3.94481	-0.07635
<i>Bridelia micrantha</i> (Hochst) Baill	66	0.018513	-3.98926	-0.07385
<i>Apodytesdimidiata</i>	65	0.018233	-4.00453	-0.07301
<i>Ovali folius</i> Forssk	64	0.017952	-4.02004	-0.07217
<i>Olinia rochetiana</i> Thunb.	60	0.01683	-4.08457	-0.06874
<i>Nuxia oppositifolia</i> (Hochst.) Benth	54	0.015147	-4.18994	-0.06347
<i>Myrsine africana</i> L.	51	0.014306	-4.24709	-0.06076
<i>Terminalia laxiflora</i> Engl &Diels	48	0.013464	-4.30772	-0.058
<i>Coffee arabica</i> L.	45	0.012623	-4.37226	-0.05519
<i>Croton macrostachus</i> Del.	43	0.012062	-4.41772	-0.05329
<i>Oncoba spinosa</i> Forssk	30	0.008415	-4.77772	-0.04021
<i>Clutia lanceolata</i> Forssk	30	0.008415	-4.77772	-0.04021
<i>Cordia africana</i> Lam	27	0.007574	-4.88308	-0.03698
<i>Rhus sandwicensi</i>	25	0.007013	-4.96004	-0.03478
<i>Ficus sur</i>	23	0.006452	-5.04343	-0.03254
<i>Sapium ellipticum</i> (Krauss)	22	0.006171	-5.08788	-0.0314
<i>Landolphia buchananii</i> (Halier.f.) Staps	21	0.005891	-5.1344	-0.03024
<i>Ozora insignis</i> Del	20	0.00561	-5.18319	-0.02908
<i>Capparis tomentosa</i> Lam	19	0.00533	-5.23448	-0.0279

<i>Hypericum quartinianum</i> A.Rich	18	0.005049	-5.28855	-0.0267
<i>Schrebera alata</i> (Hochst.) Welw	16	0.004488	-5.40633	-0.02426
<i>Olea capensis</i> subsp.macrocarpa	16	0.004488	-5.40633	-0.02426
<i>Celtis africana</i> Brum.f.	15	0.004208	-5.47087	-0.02302
<i>Acacia abyssinica</i> subsp	13	0.003647	-5.61397	-0.02047
<i>Grewia bicolor</i>	12	0.003366	-5.69401	-0.01917
<i>Dodonaea viscosa</i>	12	0.003366	-5.69401	-0.01917
<i>Rhamnus staddo</i>	12	0.003366	-5.69401	-0.01917
<i>Ficus thonningii</i> Blume	11	0.003086	-5.78102	-0.01784
<i>Osyris lanceolata</i> Hochst. Steud	11	0.003086	-5.78102	-0.01784
<i>Acanthus eminence</i> C.B.Blake	11	0.003086	-5.78102	-0.01784
<i>Osyris quadripartita</i>	9	0.002525	-5.98169	-0.0151
<i>Ficus sycomorus</i>	9	0.002525	-5.98169	-0.0151
<i>Stereospermum kunthianum</i> Cham.	9	0.002525	-5.98169	-0.0151
<i>Albizia gummifera</i>	9	0.002525	-5.98169	-0.0151
<i>Flacoutrtia indica</i> (Burm.f.) Merr	9	0.002525	-5.98169	-0.0151
<i>Grewia ferruginea</i> Hochst ex A.Rich	9	0.002525	-5.98169	-0.0151
<i>Vernonia auriculifera</i> Heirm.	9	0.002525	-5.98169	-0.0151
<i>Helinus mystacinus</i> (Ait) E. Mey	8	0.002244	-6.09948	-0.01369
<i>Pittosporum viridiflorum</i> Sims	8	0.002244	-6.09948	-0.01369
<i>Teclea nobilis</i> Del.	7	0.001964	-6.23301	-0.01224

<i>Dichrostachys cinera</i> L.	7	0.001964	-6.23301	-0.01224
<i>Grewia ferruginea</i> Hochst ex A.Richb	5	0.001403	-6.56948	-0.00921
<i>Vernonia adoensis</i>	5	0.001403	-6.56948	-0.00921
<i>Ocimum gratissimum</i> L.	5	0.001403	-6.56948	-0.00921
<i>Entada abyssinica</i> Steud.ex. A.Rich	5	0.001403	-6.56948	-0.00921
<i>Phoenix reclinata</i> Jack.	4	0.001122	-6.79262	-0.00762
<i>Ficus vasta</i> Forssk	4	0.001122	-6.79262	-0.00762
<i>Gnidia glauca</i> (Fresen.)Gilg	4	0.001122	-6.79262	-0.00762
<i>Lantana trifolia</i> L.	4	0.001122	-6.79262	-0.00762
<i>Rhamnus tridentata</i> L'Herit.	3	0.000842	-7.08031	-0.00596
<i>Gardenia ternifolia</i> (Schu.)	1	0.000281	-8.17892	-0.00229
<i>Erythrina brucei</i>	1	0.000281	-8.17892	-0.00229
	3565			-3.6338
				H'=3.6
				J=3.6/ln71
				J=0.84

Appendix:7 Proportion of Family species composition.

S/no	Family	No of Genera	% of Genera	No of species	% of species
1	Fabaceae	5	8.8	7	9.9
2	Euphorbiaceae	5	8.475	5	7
3	Moraceae	1	1.695	4	5.6
4	Oleaceae	2	3.389	3	5.6
5	Apocynaceae	3	5	3	4.2
6	Anacardiaceae	2	3.389	3	4.2
7	Rhamnaceae	2	3.389	3	4.2
8	Tiliaceae	1	1.695	3	4.2
9	Rubiaceae	3	5	3	2.8
10	Rutaceae	2	3.389	2	2.8
11	Myrsinaceae	2	3.389	2	2.8
12	Vebenaceae	2	3.389	2	2.8
13	Salicaeae	2	3.389	2	2.8
14	Combretaceae	2	3.389	2	2.8
15	Canabaceae	2	3.389	2	2.8
16	Santalaceae	1	1.695	2	2.8
17	Asteraceae	1	1.695	2	2.8
18	Ebenaceae	1	1.695	1	1.4
19	Agavaceae	1	1.695	1	1.4

20	Oliniaceae	1	1.695	1	1.4
21	Vitaceae	1	1.695	1	1.4
22	Spindaceae	1	1.695	1	1.4
23	Clusiaceae	1	1.695	1	1.4
24	Loganiaceae	1	1.695	1	1.4
25	Clasteraceae	1	1.695	1	1.4
26	Sapotaceae	1	1.695	1	1.4
27	Melianthaceae	1	1.695	1	1.4
28	Myrthaceae	1	1.695	1	1.4
29	Pittosporaceae	1	1.695	1	1.4
30	Biginoniaceae	1	1.695	1	1.4
31	Icacianaceae	1	1.695	1	1.4
32	Papilonoidaceae	1	1.695	1	1.4
33	Boraginaceae	1	1.695	1	1.4
34	Arecaceae	1	1.695	1	1.4
35	Acanthaceae	1	1.695	1	1.4
36	Thymelaceae	1	1.695	1	1.4
37	Lamaceae	1	1.695	1	1.4
38	Cupparidaceae	1	1.695	1	1.4
	38	59	100	71	100

Appendix 8: The regenerating status of woody species of the study forest

Species name	Seedling	Sapling	Mature tree	Regenerating status
<i>Olea europea</i> L.subsp. Caspidata	90	71	76	Good
<i>Euclea schimperi</i> (A.DC)	324	211	357	Fair
<i>Syzgium guineense</i> (Wild) Dc.	105	68	121	Fair
<i>Apodytesdimidiata</i>	92	59	50	Good
<i>Rhus glutinosa</i> Hochst ex Rich	60	30	157	Fair
<i>Mimusops kummel</i> A.Dc.	24	10	92	Fair
<i>Combretum adenogonium</i> Steud. Ex.A.Rich	27	22	62	Fair
<i>Sapium ellipticum</i> (Krauss)	9	13	17	Fair
<i>Brsema abyssinica</i> Fresen	82	55	100	Fair
<i>Nuxia oppositifolia</i> (Hochst.) Benth	257	125	42	Good
<i>Draceina afromantana</i> Mildbr	35	11	96	Fair
<i>Maytenus glacialipus</i>	34	21	113	Fair
<i>Acokanthera schimperi</i> (A.Dc.) Schewinf.	61	47	62	Fair
<i>Keetia guinzii</i> (Sond.)	71	33	71.5	Fair
<i>Maesa lanceolata</i> Forssk	24	33	79	Fair
<i>Olinia rochetiana</i> Thunb.	25	5	47	Fair
<i>Bridelia micrantha</i> ( Hochst) Baill	85	55	52	Good

<i>Ritchiea albersii</i> Gilg	32	2	54	Fair
<i>Crotton macrostachus</i> Del.	34	46	34	Fair
<i>Myrsine africana</i> L.	199	10	40	Good
<i>Calpurina aurea</i> (Aiton)	75	33	104	Fair
<i>Oncoba spinosa</i> Forssk	43	15	23	Good
<i>Milleta ferruginea</i> (Hochst.) Baker	33	24	72	Fair
<i>Carissa spinarum</i> L.	32	6	66	Fair
<i>Rhoicissus tridentata</i>	1	0	54	Fair
<i>Premna schimperi</i> Engl.	36	42	70	Fair
<i>Clausena anista</i> (Wild) Hook.f.ex.Benth	164	28	56	Good
<i>Acacia</i> sp	15	85	148	Fair
<i>Terminalia laxiflora</i> Engl &Diels	40	18	38	Good
<i>Ficus sur</i>	2	0	18	Fair
<i>Ficus sycomorus</i>	1	0	7	Fair
<i>Rhus sandwicensi</i>	0	0	19	None
<i>Ozora insignis</i> Del	32	2	15	Good
<i>Acacia abyssinica</i> subsp	0	0	10	None
<i>Stereospermum kunthianum</i> Cham.	0	0	7	None
<i>Celtis africana</i> Brum.f.	28	2	11	Good
<i>Clutia lanceolata</i> Forssk	48	29	23	Good
<i>Albizia gummifera</i>	12	0	7	Good

<i>Capparis tomentosa</i> Lam	24	3	15	Fair
<i>Hypericum quartinianum</i> A.Rich	0	0	14	None
<i>Schrebera alata</i> (Hochst.) Welw	22	32	12	Good
<i>Pittosporum viridiflorum</i> Sims	1	0	6	Fair
<i>Grewia bicolor</i>	0	0	9	None
<i>Dodonaea viscosa</i>	10	7	9	Good
<i>Flacourtria indica</i> (Burm.f.) Merr	9	11	7	Good
<i>Entada abyssinica</i> Steud.ex. A.Rich	0	0	3	None
<i>Rhamnus staddo</i>	7	0	9	Fair
<i>Phoenix reclinata</i> Jack.	0	0	3	None
<i>Coffea arabica</i> L.	15	0	35	Fair
<i>Olea capensis</i> subsp.macrocarpa	2	4	12	Fair
<i>Ficus thonningii</i> Blume	0	4	9	Poor
<i>Dichrostachys cinerea</i> L.	0	0	5	None
<i>Teclea nobilis</i> Del.	0	32	6	Poor
<i>Ovali folius</i> Forssk	24	0	50	Fair
<i>Landolphia buchananii</i> (Halier.f.) Staps	13	0	17	Fair
<i>Ficus vasta</i> Forssk	1	0	3	Fair
<i>Grewia ferruginea</i> Hochst ex A.Richb	43	24	4	Good
<i>Osyris lanceolata</i> Hochst. Steud	0	23	9	Fair
<i>Vernonia adoensis</i>	13	0	4	Good

<i>Gnidia glauca</i> (Fresen.)Gilg	7	0	3	Good
<i>Grewia ferruginea</i> Hochst ex A.Rich	26	9	7	Good
<i>Osyris quadripartita</i>	0	0	8	None
<i>Lantana trifolia</i> L.	8	0	3	Good
<i>Ocimum gratissimum</i> L.	22	4	4	Good
<i>Vernonia auriculifera</i> Heirm.	117	0	7	Good
<i>Rhamnus tridentata</i> L'Herit.	0	0	3	None
<i>Acanthus eminence</i> C.B.Blake	43	0	9	Good
<i>Helinus mystacinus</i> (Ait) E. Mey	8	0	7	Good
<i>Gardenia ternifolia</i> (Schu.)	6	0	1	Good
<i>Erythrina brucei</i>	21	8	1	Good
Total	2673ha <sup>-1</sup>	1372ha <sup>-1</sup>	2785ha <sup>-1</sup>	Fair