POPULATION STRUCTURE AND PHENOLOGY OF THE SELECTED INDIGENOUS TREE SPECIES IN MOIST EVERGREEN AFROMONTANE FORESTS OF SOUTH WEST ETHIOPIA

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M.Sc. Thesis

Submitted to the Department of Natural Resource Management College of Agriculture and Veterinary Medicine, Jimma University, in Fulfillment of the Requirements for the Degree of Master of Science in Natural Resources Management (Specialization: Forest and Nature Management)

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I have incorporated the suggestion and modification given during the internal thesis defense and got the approval of my advisors. Hence, I hereby kindly request the department to allow me to submit my thesis for external thesis defense.

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Decision/suggestion of Department Graduate Council (DGC)

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DECLARATION

I, Marshet Nigatu Gebeyehu hereby declare that the thesis entitled "Population structure and phenology of the selected indigenous tree species in moist evergreen Afromontane forests of south west Ethiopia" Submitted by me for the award of Master of Science Degree to the Department of Natural Resource Management (Specialization Forest and Nature management) of College of Agriculture and Veterinary Medicine, Jimma University, in fulfillment of the requirements for the Degree of Master Science in Forest and Nature Management, is may original work and it has not been presented for the award of any other Degree, Diploma, Fellowships or other similar titles of any other university or institution.

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BIOGRAPHICAL SKETCH

The author was born in 1995 in Oromia National Regional State, Bale Zone, and Robe city to his father Nigatu Gebeyehu Senbatu Badhane and mother Asnakech Seyoum Debale. He attended his elementary and secondary schools in Robe Alibira Junior school and robe high schools respectively. He joined the- then Hawassa University Wondo Genet College of Forestry and Natural resource management in 2013 academic year and completed his under graduate studies with BSC Degree in General forestry in June, 2015.

Soon after 6 months of his graduation, he was employed by the then Ethiopian Environment and Forest Research Institute as junior researcher in Jimma Center and served as a researcher under Tree Seed Technology Coordination Unit and Director of Environment and Forest Research in Bedele sub Center. Then in October, 2018 academic year he joined Jimma University, College of Agriculture and Veterinary Medicine for the award of Master of Science Degree in Department of Natural Resource Management (Specialization Forest and Nature management).

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LIST OF ABBREVIATIONS AND ACRONYMS

DBH:	Diameter at Breast Height
FGDs:	Focus Group Discussions
HHs:	Households
ICRAF:	International Centre for Research in Agroforestry
IUCN:	International Union for Conservation of Nature
KI:	Key Informant
NGO:	Non-Governmental Organizations
NBSAP:	National Biodiversity Strategy and Action Plan
SNNPRS:	Southern Nations, Nationalities and Peoples Regional State
SPA:	Seed Production Area
UNDP:	United Nations Development Programme

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ABSTRACT

Understanding the population structure, regeneration status, and phenology of indigenous tree species in natural forests is a basic requirement for establishing in-situ seed production sites and introduce appropriate management options. The aim of this study was, therefore, to investigate the population structure and regeneration status and reproductive phenology of Prunus africana, Pouteria adolfi- friedericii and Milicia excelsa. This study was conducted in four Afromontane forests such as Yayu, Bonga, Bebeka, and Masha, south west Ethiopia. For this, systematic sampling method was used to collect the data and accordingly, from each site ten transects of 160m long were laid out at 100 m interval along slope gradient and quadrats (size: 20 m x 20 m each) were laid at 50m interval along each transect line. In total 270 quadrats were used for vegetation data collection. To collect data on regeneration, sub sample quadrats (size: 5 m × 5m each) were established at four corners and at the center of each of the main quadrats. From each main quadrat, DBH and total height of the three study tree species were measured using a diameter tape and clinometer respectively. The results of the distribution of the population of P.africana showed broken J-shape and irregular patterns across the forests; Pouteria adolfi‐friedericii exhibited irregular and broken inverted J-shape across the forest sites; the shape of the structure for Milicia excelsa tree species observed in sampled forests was almost irregular. The regeneration status of P. africana is "good" in Bonga and Masha and "fair" in Yayu sampled natural forest; for P. adolfi‐friedericii is "good" in Masha and "fair "in Bonga and Yayu, and it is "fair" and "none" in Masha and Yayu sampled natural forests for M. excelsa tree species. The result of the phenology assessment indicated that the times of flowering and fruiting generally ranges between December and June across the forest sites. Overall, the population structure of the studied tree species vary and also similar in some cases across the inventoried forest sites. There is a slight variation in phenology among sites showing the essence of exhaustive description of these parameters prior to the establishment of the seed provenances and domestications for the desired populations of the indigenous tree species.

Keywords*: Population structure, Regeneration, phenology, Seed production*

1. INTRODUCTION

1.1 Background and Justification

Tropical forests are one of the richest and the most complex ecosystems on earth. They have enormous diversity of plant communities (Supriya and Yadava, 2006) and distinctive patterns of vegetation. They contain a variety of indigenous timber tree species which are major sources of valuable products such as; timber, food, medicines, protection of vital watersheds and habitat for a large number of important flora and fauna (Appiah, 2013). Indigenous trees in tropical forests are under intense land-use pressure, they have been cleared off due to a complex set of causes. Anthropogenic activities have been modifying tropical forest land cover for food and energy production (Takahashi *et al*., 2017) and these activities have further enhanced the rates of loss of valuable indigenous trees in tropical forests. They are being overexploited for wood and non-wood products.

Ethiopia has a wide range of natural conditions tied with the corresponding heterogeneous flora and fauna, these made the country to be one of the internationally recognized major centers for biodiversity (Tadesse, 2003; Alemayehu *et al.*, 2005). Distributions and types of vegetation in Ethiopia are determined by edaphic, topographic (altitude, slope, aspect) and climatic factors. Accordingly, the south west part of Ethiopia is covered by the moist evergreen montane forests. These moist evergreen montane forests constitute high concentrations of native species and they are major sources of livelihood in the area by providing timber and non-timber forest products (wild coffee, honey, spices) (Chilalo and Wiersum, 2011).

Three of the most important tree species found in south west part of Ethiopia, considered in this study are; *Prunus africana*, *Pouteria adolfi‐friedericii* and *Milicia excelsa.* In several countries these selected indigenous tree species have been exploited from natural forests without replacement for the last decades. Currently, these species are included in the category of the endangered valuable timber trees under Red Data List of International Union for Conservation of Nature(IUCN, 2002 and 2006).

Prunus africana, *Pouteria adolfi-friedericii and Milicia excelsa* belong to the families of *Rosaceae, spotaceae and Moracae,* respectively (Azene, 2007). The natural distribution of these species ranges across most parts of sub Saharan Africa (West, Central and East

Africa) (Azene, 2007; Bizoux *et al*., 2009), commonly spread in Guinea-Bissau east to Ethiopia and south to Angola, Zimbabwe and Mozambique (Sabu *et al*., 2018). These three tree species are also found in south western part of Ethiopia at different natural range. Usually occurs in high-rainfall areas and commonly found in Ilubabor, Kefa, and Bench-Maji zone (Azene, 2007). Knowledge of tree population structure and regeneration status is very important for understanding the reproduction and recruitment potential of selected indigenous tree species.

Population structure of these three species plays a significant role in determining the dominant status, impact of disturbance and forest successional trends. It provide the overall regeneration profile of the area based on the tree density, frequency, and diameter at breast height, height, basal area (Tesfaye *et al*., 2002; Shibru and Balcha, 2004). Investigation of the regeneration status plays a vital role to understand the growth performance of three target tree species in the study area. Study of regeneration status is one of the key parameters to determine ecosystem stability (Kadavul and Parthasarathy, 2001). In forest management regeneration study is important to know the current status and the possible changes in forest composition in the future (Malik and Bhatt, 2016).

Knowledge of phenological patterns is basic to understand the biological processes of *Prunus africana, Pouteria adolfi-friedericii and Milicia excelsa* tree species. Seasonal duration or variation of flowering and fruiting mainly determine phenological behavior of trees. The schedule of these events has important effects on plant survival, reproductive success and thus regeneration. Phenology stages are highly influenced by environmental conditions, as for example temperature and photoperiod.

In general, knowledge of population structure, regeneration status and phenology of these target tree species plays a vital role for seed production area establishment. Seed production area establishment provides a useful interim measure to obtain seed and for domestication of these target tree species into wider social and ecological environment. Therefore, the research was initiated to compare the target tree species population based on their density, regeneration status and reproductive phenology in the study sites to establish seed production area.

1.2 Statement of the problem

Nowadays, exploitation of indigenous tree species is not sustainable in Ethiopia; due to this, the indigenous tree species is declining from its natural ranges, especially for non-industrial plantations, relatively there has been little attention devoted to the practice and domestication of indigenous tree species (Nichols *et al*., 2006). South western forests have been continuously exploited through agricultural land expansion and have been used for coffee plantation. There is still a growing interest to invest on the remaining part of those forests. The increment of population and lack of proper policy framework for land use led to destruction of forests for expansion of agricultural land, illegal logging, fuelwood and overgrazing (Alemu, 2011).

It is recognized that *Prunus africana, Pouteria adolfi - friedericii* and *Milicia excelsa* are trees species that belongs to the most valuable timbers. However due to high exploitation these targeted tree species, sustainability of products and services from these species is at risk in Ethiopia. Population of these species is declining from its natural range from time to time. Associated with their high wood quality, these species are highly exploited by farmers' and loggers for domestic consumption and trade, without any consideration of their future sustainability. In south western part of Ethiopia where this research was conducted, these tree species are exploited without replacement and management.

1.3 Significance of the study

The availability of accurate data on stand structure and regeneration of *Prunus africana, Pouteria adolfi - friedericii* and *Milicia excelsa* is an essential requirement for proper management of the target species for different purposes including seed production area establishment. Information on the phenology of the target species helps planning seed collection and management of wildlings originating from seed rain. The combined information of population structure and regeneration status can explain the potentials and/or constraints of the future population dynamics of a site. The acquisition of these data sets also gives baseline information for drawing up overall management policies and recommendations. Moreover, information generated from this study is important to policy and decision makers, communities, public and private sector plantation managers, development, research and training institutions and Non-Governmental Organizations (NGOs).

1.4 Objectives

1.4.1 General objective

The general objective of the study was to evaluate Bonga, Masha, Yayu and Bebeka sampled natural forests for seed production area establishment of *Prunus africana, Pouteria adolfi friedericii,* and *Milicia excelsa* in terms of population structure, regeneration status and reproductive phenology.

1.4.2 Specific objectives

- ✓ To investigate the population structure and natural regeneration status of *Prunus africana*, *Pouteria adolfi friedericii* and *Milicia excelsa* in different natural forests

- ✓ To assess flowering and fruiting phenology of *Prunus africana*, *Pouteria adolfi‐friedericii* and *Milicia excelsa* in different natural forests

- ✓ To select the best population of *Prunus africana*, *Pouteria adolfi-friedericii* and *Milicia excelsa* for in-situ seed production area establishment

1.5 Hypotheses

- ✓ The population structure and regeneration status of *Prunus africana*, *Pouteria adolfi‐friedericii* and *Milicia excelsa* show comparable patterns among natural forest sites of south west Ethiopia.

- ✓ The flowering and fruiting phenology of *Prunus africana*, *Pouteria adolfi‐friedericii* and *Milicia excelsa* similar among natural forest sites of south west Ethiopia.

- ✓ All selected natural forest are preferable for seed production area of *Prunus africana*, *Pouteria adolfi‐friedericii* and *Milicia excelsa*

1.6 The scope of the study and limitation

The study examined the distribution and population structure of *Prunus africana, Pouteria adolfi‐friedericii* and *Milicia excelsa* existing in natural forests of south western Ethiopia and recommended superior populations for seed production area. There is lack of sufficient source available about the target species in the country due to this it was found difficult to access more reference since much is not studied and written on the area. Inaccessibility of some natural forest habitats and difficulty of crossing the forest on foot were also the other constraints.

2. LITERATURE REVIEW

2.1 Vegetation type of south-west Ethiopia

Ethiopia has the fifth largest heterogeneous flora in tropical Africa (Motuma *et al.*, 2010). Distributions and types of vegetation in Ethiopia are determined by edaphic, topographic (altitude, slope, aspect) and climatic factors. Accordingly, the south western part of Ethiopia is covered by the moist evergreen montane forests. These moist evergreen montane forests constitute high concentrations of native species and they are major sources of livelihood in the area by providing timber and non-timber forest products (wild coffee, honey, spices) (Chilalo and Wiersum, 2011).

The two forest types Afromontane rainforest and transitional rainforest have many species in common. The characteristic species of the Afromontane rainforest are a mixture of broadleaved tree species. Afromontane rainforest that extends from 1500 to 2600 m a.s.l and transitional rainforest type that extends from 500 to 1500 m a.s.l (Girma and Maryo, 2018).

2.1.1 Species composition

The montane moist forest ecosystem is the most diverse ecosystem in composition and habitat types. These high forests are not only diverse ecosystem in their structure and composition but also hold several associated economic plants, genetic population and components. The moist forest ecosystem is the most diverse ecosystem in composition, structure and habitat types (NBSAP, 2005). The plant species composition of south-western Ethiopia forest is predominantly Afromontane rainforest type. The composition of the forest shows that it harbors important tree species. Stand structure variation and floristic composition of the forests influenced by topography, which affects soil characteristics and causing extent of damage to vegetation upon formation of the gap, temperature drainage, moisture, and nutrients to vary from ridge top to valley bottom (Enoki and Abe, 2004).

Afromontane rainforest are a mixture of broadleaved tree species and include: *Pouteria adolfi-friederici, Syzygium guineense, Polyscias fulva, Olea welwitschii, Diospyros abyssinica, Manilkara butugi, Cordia africana, Trilepisium madagascariense Croton macrostachyus, and Schefflera abyssinica.* The height and species composition of the surrounding aspects and its spatial disturbances can also affect vegetation regeneration (Demel, 2005).

2.1.2 Vegetation pattern and Environmental variables

At any site the plant diversity influenced by species abundance and distribution patterns (Palit and Chanda, 2012). Many studies have been conducted in different parts of the country to investigate the population dynamics (Hadera, 2000; Tesfaye *et al*., 2002). Despite of all these studies, there is different available scientific information on woody species diversity in natural forests of south western Ethiopia. Stand structure variation and floristic composition of the forests influenced by topography, which affects soil characteristics and causing extent of damage to vegetation upon formation of the gap, temperature drainage, moisture, and nutrients to vary from ridge top to valley bottom (Enoki and Abe, 2004).

The height and species composition of the surrounding aspects and its spatial disturbances can also affect vegetation regeneration (Demel, 2005). Understanding soil seed banks and seedling banks dynamics of forest vegetation helps to assess the potential natural regeneration of plants (Parry, 2003). A tree species is under risky condition if it have no seedling and sapling in a forest and it is suggested that these tree species are under threat of local extinction (Taye *et al*., 2002). Hence, a sufficient volume of viable seeds, appropriate edaphic and climatic conditions are crucial for a successful regeneration and establishment of seedlings. Therefore regeneration status studies and knowledge of the plant species are indispensable for setting priorities and developing management strategies of natural forests.

Large proportion of the human population depends almost entirely on natural resources for their livelihoods specially forests have been converted to different agricultural field and for coffee plantation, urban settlement, sometimes to open land by humans. The steady rises of human population have triggered unsustainable extraction of natural resources for agricultural expansion and changes in socio-economic well-being of the people (Samuel *et al.*, 2014; Solomon, 2016). Although, forests provide many valuable goods and services to mankind, man has a bad record of misuse of these forests. Present day disturbances include wind throw, both natural and man-made fires, landslides, grazing and tree felling and clearing for cultivation. Among these, the major disturbance is the extensive clearing or burning of forests and converting them into permanent agricultural land. This in fact has caused huge losses to Ethiopian forest biodiversity due to habitat destruction through deforestation, fragmentation and degradation.

Anthropogenic factor is one of the major factors for the loss of natural forests in south west Ethiopia. Ethiopian forests have fragile ecosystems with species that are extremely vulnerable to habitat change due to their limited distribution and adaptation to specific ecological niches. Also in south west Ethiopia, forest clearing has continued through time and has become more serious problem because of several interrelated problems. Increasing population also created a huge gap between supply and demand of forest products and services in south west Ethiopia. The region is highly affected by forest degradation and deforestation for agricultural expansion and coffee plantation.

The reduction of natural vegetation in many parts of Ethiopia has also lead to the threat and decline in number and distribution of many plant species (Tesfaye, 2000). It loses around 141,000 hectares of natural forest per year for many reasons (Tilahun, 2010). Actually the country lost around 14% of its forest (2.1 million hectare) between the year 1990 and 2005, and that indicate us forest degradation or forest destruction from 1990-2005 is rise by 10.4%. As the number of population continues to grow the future of the country will be very bad.

This deficit will continue to be a major threat for the few remaining natural forests. Loggers often engage in destructive exploitation without being aware of the effect of their practices on regeneration and replacement and there is poorly managed industrial log production. In order to ensure optimum protection, conservation and utilization of natural forests on sustainable basis, the major constraints which hindered the introduction of sound natural forest management must be removed. At the same time, to enhance productivity of these forests, different studies should be carried out on the establishing seed productions are very important to provide suitable management systems.

Deforestation can include not only conversion to the other cultivation or non-forest, but also it reduces forest quality, structure and density of the trees, the ecological services supplied, the biomass of plants and animals, the species diversity and the genetic diversity (Habitam, 2012). The causes of deforestation are complex and often differ in each forest and country.

2.1.3 Regeneration

The process by which plants re-establish or replace themselves by means of self-sown seed or vegetative recovery (sprouting from stumps, rhizomes or roots) are known as natural regeneration (Castro, 2005). Regeneration status is a fundamental component for tropical dynamics forest ecosystem (Getachew *et al.*, 2010). It's essential for maintenance and preservation of biodiversity (Rahman, 2011). Natural forest regeneration is a natural biological process of forest resource reproduction or it is the act of renewing tree cover by establishing young trees naturally**.** Plants expand and maintain their populations in time and space by the complex process called natural regeneration (Habitam, 2012). Regeneration is a main process of building a forest by which trees and forests survive, substitute or restore (Tyagi *et al*., 2013) during this process tree-dominated plant communities develop and evolve, which has far-reaching impact on the structure of forests in the future (Han and Wang, 2000).

Seedling and saplings density are considered as an indicator of regeneration potential of the species (Arya and Ram, 2011). Different types of disturbances like logging, gap formation, litter fall, herbivory can affect the successful regenerative status of species composing the forest stand spatially and temporally (Khumbongmayum *et al*., 2005; Ceccon *et al*., 2006; Guarino and Scariot, 2012). Management of regeneration is an essential component of sustainable forest practice as it ensures the future growing stock (Level, 2010), as well as to identify plant species for conservation priority whereas, population structure plays a vital role in determining the dominant status of tree species and development within the forest stand.

Variation revealed in south western Ethiopia forests in their pattern of regeneration both through differences in constituent species and the environmental variables in which they grow. They regenerate from one or more pathways: the soil seed bank (dormant seeds in the soil), the seedling bank (established, suppressed seedlings in the understorey), seed rain (recently dispersed seeds), and coppice (root/shoot sprouts of damaged individuals) (Getachew *et al*., 2002). The magnitude and frequency of disturbance would affect the species demography, composition and the regenerative process. Regeneration of tree species is commonly assessed by the size-classes distributions of measured as diameter at breast height (DBH) or height.

A successful natural regeneration status is indicated by density of seedlings, saplings, and young trees in a given population (Pokhriyal *et al*., 2010) and the number of seedling of any species can be considered as the potential regeneration status of that species (Negi and Nautiyal, 2005). Regeneration of tree species is commonly assessed by the distributions of size-classes measured as diameter at breast height (DBH) or height. The size class structure of the species show whether regeneration is taking place or not. Recently different study indicated that forest plantations can foster the regeneration of indigenous woody species under their canopy and catalyze the subsequent succession processes (Feyera *et al.*, 2001).

Soil seed banks and vegetative parts are the strategies were the plants regenerate (Garwood, 1989). Forest environment can be restored with natural regeneration through seedling establishment and it results high-quality forests with high biodiversity (Wang *et al*., 2008). There are different ecological factors that affect regeneration potential of a given forest in general and a species in particular. In many ecosystems, either decreasing or increasing disturbances are changes overall community structure (Shafroth, 2002). Man-made or natural disturbances have much influence on community composition, tree population structure and regeneration ability of forest ecosystems (Lalfakawma, 2010). Although many known and unknown causative factors affect the process of natural regeneration, the major factors include climate, soil, seed, biotic conditions (Tyagi *et al*., 2011).

Identifying of factors preventing or seedling establishment promoting of woody species may help in future rehabilitation and restoration of degraded tropical forestlands through the application of the appropriate management scheme. Climatic factors and biotic interference influence the regeneration of different species in the vegetation (Daulkhandi *et al*., 2008). Management of regeneration is an important component of sustainable forest management practice as it ensures the future growing stock (Level, 2010). The knowledge of regeneration status and population structure of a plant community is a prerequisite to understand the overall function and structure of any ecosystem (Singh *et al*., 2016), whereas understanding diversity of woody species and socioeconomic factors causing devastation of natural forests ecosystem is crucial in the management of the remnant forest ecosystems (Yakob and Fekadu, 2016).

For the rehabilitation and restoration also it is important to enhance the natural regeneration of trees and create self-sustaining communities. The improvement of natural regeneration in stands may also be the most cost-effective way to obtain a species-rich productive stand (Liira, 2011). To planning and carrying out management activities understanding of the natural regeneration processes and dynamics is plays crucial role (Mwavu and Witkowski, 2009; Puhlick, 2012).

The height and species composition of the surrounding aspects and its spatial disturbances can also affect vegetation regeneration (Demel, 2005). Understanding soil seed banks and seedling banks dynamics of forest vegetation helps to assess the potential natural regeneration of plants (Parry, 2003). A tree species is under risky condition if it have no seedling and sapling in a forest and it is suggested that these tree species are under threat of local extinction (Taye *et al*., 2002). Hence, a sufficient volume of viable seeds, appropriate edaphic and climatic conditions are crucial for a successful regeneration and establishment of seedlings. Therefore regeneration status studies and knowledge of the plant species are indispensable for setting priorities and developing management strategies of natural forests.

Forest communities' nature are largely depends on the ecological characteristics, sites, species diversity and regeneration status of species (Khumbongmayum *et al*., 2006). Better understanding on woody species diversity, composition, population structure, and other ecological perspectives is very crucial for conservation and sustainable utilization of forest resources. It's also important for developing management strategies and setting priorities (Zegeye *et al.,* 2011). Generally, the abundance, distribution and diversity patterns of species can result from the interaction between a biotic and biotic factor at different spatial and temporal scales (Feyera, 2006). Variations in climate, rainfall distribution and temperature are generally reflected in the structure of communities and species composition. Therefore plant species abundance and distribution in response to environmental variables helps to generate information for a better understanding and managing of ecosystem.

The growth of tropical forest trees is often observed to vary with changes in the soil profile. Soil and climate diversity of where forests grow determines site qualities. The best sites combine good weather conditions, topography and soil characteristics (Skovsgaard and Vanklay, 2008). Natural vegetation may respond to environmental and ecological gradients in many ways. Altitude is one of the most important environmental parameters that determine species diversity and distribution pattern. With increasing altitude (elevation) species diversity generally tends to decrease. It affects moisture, radiation, temperature, and atmospheric pressure there by influencing the growth and development of plants and the distribution of vegetation (Getachew *et al*., 2005).

Another important factor that can determine the species diversity and composition by influencing the level of temperature or availability of moisture content, and wind blow on different parts of the mountains is Aspect. It results in variation of microclimatic conditions and soil development that in turn affects the richness and dispersion of species in different exposure of a single mountain. On the other hand, slope is also another environmental parameter or factor which can affect plant species diversity, richness, dispersion and growth mainly because of its effects on soil drainage and depth.

2.1.4 Flowering and fruiting phenology of trees

Phenology is the study of the effects of weather and climate on plant life stages, including flowering, fruiting, leafing and defoliation. It is the study of the periodicity or timing of recurring biological events. In the case of plants, phenological events involve germination, flowering, fruiting and leaf flushing. The schedule of these events has important effects on plant survival, reproductive success and thus regeneration. Phenology of a species is determined by examining the seasons of the influence of local climatic conditions on the behavior of a species in its natural habitat. Knowledge of seasonal manifestation of a biological phenomenon of leafing, flowering and fruiting can contribute effectively to the development of strategies for the use and sustainable management of this species.

Knowledge of phenological patterns is basic to the understanding of biological processes of trees, of the interactions with other organisms and of the functioning of the ecosystems. Flowering and fruiting duration have important consequences on population genetic structure and response to selection (Garrison *et al.*, 2008; Hirao and Kudo, 2008). Trees grow when the environmental conditions are permissive. These phenology stages are highly influenced by environmental conditions, as for example temperature and photoperiod. Seasonal duration or variation of flowering and fruiting mainly determine phenological behavior of trees.

2.1.5 Seed Production and dispersal

A seed has been defined as a 'mature ovule' or a reproductive unit formed from fertilized ovule, consisting of an embryo, reserve food and a protective cover (Copeland and Donald, 2012). Tree species vary in their frequency and quantity of seed production. Some species produce seeds irregularly whiles others produce seeds regularly. Sometimes empty seeds are also formed**.** Seed predators like small animals and insects dispersed a large proportion of seeds reaching the ground**.** The tree seed also become infected by fungi (Luchi *et al.*, 2012). If seeds are buried in the soil by burrowing worms, rodents, other animals or by non-biological physical agents to form a seed bank the chances of seed survival are increased (Hirao and Kudo, 2008)**.** Through producing abundant seeds at regular and long intervals the tree species may also enhance their survival. Well dispersed seeds have long viability and comprise the majority of seeds in the seed bank just below the soil surface. Seeds are of a short lifespan, surviving from several weeks to several months.

Seed predation shows no particular pattern. It can vary markedly from year to year, tree to tree and habitat to habitat. The susceptibilities different species to different seed predators are vary (Hirao and Kudo, 2008). Seed dispersal is an integral component of regenerative and successional processes in tropical ecosystems (Hardwick *et al*., 2004). Tropical trees disperse their seeds by means such as wind, insects, birds, and other animals**.** The most common in overstorey tree species is wind dispersal (Hira and Kudo, 2008). Seed dispersal is an important process in maintaining diversity of forest and regenerating disturbed areas to the original forest structure. Seed dispersal also provides new genetic material inputs into isolated remnant areas. In subtropical areas wind and birds are the main dispersal agents. In tree improvement programmes seed quality is an integral component of great relevance.

Seed quality has a direct impact on the success of tree planting and growth activities. It is comprised of three components. Physical quality: Quality related to physical characteristics, such as size, color, age, seed coat condition, occurrence of cracks, pest and disease attacks, or other damage. Physiological quality: Quality related to the characteristics of physiological, such as moisture content, maturity and germination ability. Genetic quality: Quality related to characteristics inherited from the parent trees.

Forest seeds have great variation in shape, size, viability, dormancy, moisture content, and etc. It needs special techniques for collection, handling, processing and storage.

2.2 Taxonomy of *Prunus africana*, *Pouteria adolfi‐friedericii* and *Milicia excelsa* tree species

2.2.1 *Prunus africana*

Prunus africana tree species is commonly known as the African Cherry (Oromic; *Homi*, Amharic; *tikur inchet*), which belongs to subfamily *Prunoideae* within the *Rosaceae* family. There are around 200 species in the genus of *Prunus,* divided into two sub-genera: *Padus* (deciduous) and *Laurocerasus* (evergreen). The *Laurocerasus* sub genus includes *P. africana,* the only one found in Africa (Navarro-Cerrillo *et al.,* 2008). *Prunus africana* listed as vulnerable by International Union for Conservation of Nature due to unsustainable levels of harvesting of its bark across Africa (IUCN, 2002). It is an evergreen tree up to 40 m height in forests, the high foliage is open, the branches often pendulous, but in grassland the tree is more rounded and compact with a thick, fissured bark and straight bole that can reach a diameter of 1.5m (Betti, 2008; Orwa *et al*., 2009).

Its leaves are leathery, glossy dark green above, oval to 10 cm, margin with shallow rounded teeth, leaf stalk typically pink to 2 cm and simple while the flowers are small, green-white and fragrant, Sprays on stalks about 8cm long (Navarro-Cerrillo *et al.*, 2008). Flowers are produced in elongated clusters and are basically insect pollinated (Hall *et al.,* 2000). The fruit of *Prunus africana* is rounded about 1 cm and it is dark red.

2.2.2 *Pouteria adolfi‐friedericii*

Pouteria adolfi‐friedericii is a plant species of the family Spotaceae. Locally in Ethiopia it is known as *Guduba* or *Suduba* (Oromic), *Keraro (*Amharic*)*. It is upper-storey tree found in Ethiopia particularly in Moist and Wet Weyn Dega agro climatic zones of Sidamo, Gamo Gofa, Ilubabor, Wolega, Kefa, Arsi, Shoa and Bale (Azene, 2007). It is very large tree up to 50 m tall; bole up to 1.5–2m in diameter, branchless for up to 27 m, straight and cylindrical, sometimes fluted, often with wide buttresses; bark surface greyish brown, shallowly fissured, inner bark Pale, grey-brown, smooth to lightly fissured, much white latex if cut and an unpleasant smell; crown dense, rounded; young branches densely reddish brown hairy.

Its leaves are stiff and usually smaller, dark shiny green above, hairy pale orange below, 10-20 pairs prominent veins, the tip pointed, twisted stalk to 2 cm. Flowers of *Pouteria adolfi - friedericii* are cream-green, very small and its flower stalks brown, hairy, soon falling to the ground, the fruits are hard, green, narrow to 4 cm with a beak, the soft hairy skin milky but inside is one shiny brown seed to 3 cm long with a large white scar (hilum).

2.2.3 *Milicia excelsa*

Milicia excelsa also commonly known as the African teak or Iroko belongs to Moraceae family and in Ethiopia locally it's known as *Gonji* (Benchgna), *sachu* (Oromic). It contains two species, which are closely related: *Milicia excelsa* and *Milicia regia.* Both are among the most useful indigenous tropical rain forest tree species. It covering both the dry semi-deciduous forest and the rain forest zones (Ouinsavi *et al*., 2005).

Iroko is a highly valuable commercial timber in Africa (PROTA, 2008). It is the most valuable timber tree species (Ouinsavi and Sokpon, 2010), due to its attractive appearance, durability, stability and good working properties. It grows up to 50m tall with a thick, pale grey then brown, with milky latex, as in all parts and straight bole that can reach a two meter in diameter.

Its leaves are long, oval, rather thin to a well-pointed tip, pairs of clear side veins, the base somewhat rounded, often unequal sided, leaf edge finely toothed and wavy. Flowers are small green spikes *M.excelsa* fruits are like a long green mulberry, the loose fleshy pulp attracting birds and bats. Currently, the *Milicia excelsa* trees species is categorized as one of the endangered valuable timber species under Red Data List of International Union for Conservation of Nature (IUCN, 2006). *Milicia excelsa* occur at less than one tree per hectare (Appiah, 2011). It exhibits a potentially wide-ranging wind-mediated pollen dispersal mechanism as well as very efficient seed dispersal mediated by large frugivorous bats (Bizoux *et al*., 2009).

2.3 Socio economic and ecological significance of *Prunus africana*, *Pouteria adolfi‑friedericii* and *Milicia excelsa* tree species

2.3.1 *Prunus africana*

Prunus africana is a high valuable tree for furniture (veneer and paneling), firewood, charcoal, poles, bee forage, shade, windbreak and etc. *Prunus africana* is also used in traditional medicine; it's stem bark decoctions used for treating and managing malaria, chest pain and fever. The wood has been used by farmers as a source of axe and hoe handles. The bark has been ground and drunk as tea against urinary tract problems, allergies, inflammation, kidney disease, malaria, stomachache and fever, among other illnesses (Orwa *et al*., 2009). *Prunus africana* timber product is heavy, hard, durable, close, straight grained, strong, red-brown, planes well, takes a high polish, but splits and twists.

It is used for heavy construction work, furniture, flooring, turnery, moldings, poles and mortars. Liquid extracts from the bark are used in the treatment of prostate disorders. Various communities have traditionally harvested the bark, mainly for medicinal purposes. But lately, there has been an increase in the practice as the bark has fetched high demand on international trade as a remedy against prostate disorders. Planting *P.africana* reduce soil erosion.

2.3.2 *Pouteria adolfi‑friedericii*

Pouteria adolfi-friederici one of the best and highly valuable tree for furniture, light construction, joinery, veneer and plywood, pulpwood cabinet work, boats, light flooring, interior trim, vehicle bodies, boxes, and crates. *Pouteria adolfi-friederici* tree has a high value for honey production (Gebrehiwot and Hundera, 2014). Its bark decoction has been used to treat stomach problems or disorder and also the wood of *Pouteria adolfi-friederici* is used for fuel and to make charcoal. In Ethiopia the fruits are used as a traditional taenicidal drug, usually as a paste in barley porridge. The fruits are susceptible to attack by fungi, termites and boring insect. The roots of *Pouteria adolfi-friederici* tree forming a symbiotic association with a fungus and used to provide shade in plantations.

2.3.3 *Milicia excelsa*

Milicia excelsa tree species is one of the best and highly valuable hardwoods for decorative and structural uses, a versatile timber, suitable for ship, boat and general building, railway sleepers, light duty flooring, satisfactorily sliced veneer and ply wood and so on. It also used for construction work, marine carpentry, sleepers, sluice gates, framework, trucks, draining boards, outdoor and indoor joinery, stairs, doors, frames, garden furniture, cabinet work, paneling, flooring and profile boards. It is also used for carving, domestic utensils, musical instruments and toys. As it is resistant to acids and bases, it is used for tanks and barrels for food, chemical products and for laboratory benches.

The wood of this native tree species is also used as firewood and for making charcoal. The ripe fruits and cooked young leaves of *Milicia excelsa* are edible. The fruit juice is used for flavorings in India. Mature leaves have been used as sandpaper. The bark is used for dyeing leather cloth and for roofs of houses. Formerly the bark of young trees was used for making loincloths. The tree is used for soil conservation, mulch production, as an ornamental and shade tree. In Nigeria it is one of the most important timber trees and it is planted to mark boundaries between farms or villages. It has also been planted to attract edible caterpillars.

Different report has indicated that various part of *Milicia* is largely used in traditional medicine (Nichols and Vanclay, 2012) and it is widely used in African traditional medicine. A root decoction is taken to treat female sterility. A decoction of the root and stem bark *Milicia excelsa* is taken as aphrodisiac. The latex from the stem is applied on wounds, sores, burns and other skin problems. Leaves are eaten to treat fever, insanity and are externally applied to treat snakebites (PROTA, 2008). It is also taken against stomach problems, hypertension, it is used for treatment of tumors and obstructions of the throat.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

The study was conducted on natural forests found in Bonga, Bebeka, Masha and Yayu areas of south western Ethiopia. Bonga forest is found in Kafa zone, Masha forest in Sheka zone and Bebeka forest in Bench Maji zone of Southern Nations, Nationalities and Peoples Regional States (SNNPRS) and Yayu forest in Illubabor zone of Oromia National Regional State (Fig. 1). Geographically, Bonga forest lies between 7^{o} 00' -7^{o} 25'N latitude and 35^{o}55'-36^{o} 37' E longitude (Nune, 2008).

Masha forest is located in the geographical range of 7°24′–7°52′N latitude and 35°13′–35°35′E longitude (Fig.1). Whereas, Bebeka natural forest is located within 07° 16' N and 36° 15' E longitude (Mihreiu, 2004). Similarly, Yayu forest is located between 8°21'–8° 26' N latitude and 35° 45'–36° 3'E longitude (Woldegeorgis and Wube, 2012). The altitudinal range of Bonga, Masha, Bebeka, and Yayu, natural forest is 1520-1780 m a.s.l., 1700–3000 m a.s.l., 1000 -1350 m a.s.l., 1200 -2000 m a.s.l, and respectively.

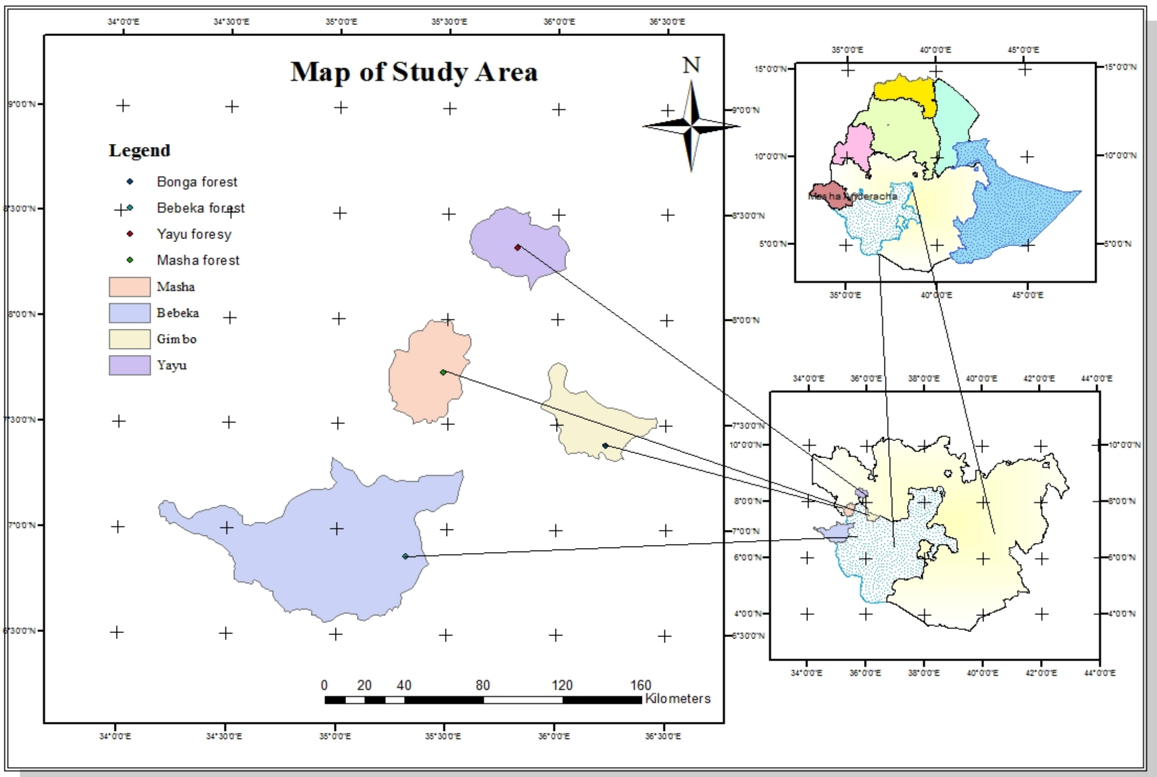

Figure 1: Map of the study area.

3.1.1 Climate

Bonga forests receive mean annual rainfall of 794 mm with maximum and minimum temperature of 26.4^0C and 11.9^0C respectively (Assefa, 2010). The rainy months of Bonga forest are from March to October, but a maximum between May and October. From November to February are relatively dry months. Yayu forest has a mean annual rainfall of 1900 mm with a minimum and maximum temperature of 7.6 °C and 34.7°C (Woldemariam, 2003). According to the meteorological data from the National Meteorological Service Agency of Ethiopia, the mean annual rainfall and temperature of Masha natural forest is 2192 mm and 16.7°C respectively (Assefa *et al*., 2014), the mean annual rainfall of Bebeka natural forest is 2200mm and the mean annual temperature is about 25° C.

3.1.2 Soils

The soils of the study area differ in color and types depending on the topography and types of the parent materials. Most parts of the south western Ethiopia underlie by Cenozoic and Proterozoic volcanic sediments (Schlüter, 2008). Bonga soils are characterized as deep red to brown red, lateritic loams or clay loams of volcanic origin with high or medium fertility (Schmitt, 2006). Whereas the commonly observed soils in Masha Woreda vary in color from black to red. Regarding the types Nitosols, Vertisols, Fluvisols, Cambisols are the dominant soils types in the area. The dominant soil type of Yayu forest is Nitosols. These types of soils are deep, reddish-brown and clayey soil with relatively high organic matter content. Nitosols has a crumb and/or sub-angular structure and well drained. The soils of Bebeka forest are sandy loam, moderately drained, reddish soil; 15-20cm thick litter and humus.

3.1.3 Vegetation

The moist evergreen montane forest consists of high forests of the country mainly the south west forests. The moist forest ecosystem is the most diverse ecosystem in composition, structure and habitat types (NBSAP, 2005), consequently it is rich in biodiversity with a number of endemic species. Some of the characteristic plant species of the forests include; *Pouteria adolfi-friederici, Prunus africana, Albizia gummifera, A. schimperina, A. grandibracteata, Blighia unijugata, Cassipourea malosana, Celtis africana, Croton macrostachyus, Ekebergia capensis, Euphorbia ampliphylla, Ficus sur, F. ovata, F. thonningii, Hallea rubrostipulata, Ilex mitis, Macaranga capensis, Olea* *capensis ssp. welwitschii, Polyscias fulva, Schefflera abyssinica, Sapium ellipticum, and Syzygium guineense ssp. Afromontanum* (Woldemariam, 2003).

A discontinuous lower canopy of small trees (less than 10 m high) includes *Allophylus abyssinicus, Apodytes dimidiata, Bersama abyssinica, Brucea antidysentrica, Calpurnia aurea, Canthium oligocarpum, Chionanthus mildbraedii, Clausena anisata, Cyathea manniana, Deinbollia kilimandscharica, Dracaena afromontana, D. fragrans, D. steudneri, Ehretia cymosa, Ensete ventricosa, Erythrina brucei, Galiniera saxifraga, Lepidotrichilia volkensii, Lobelia giberroa, Millettia ferruginea, Nuxia congesta, Oncoba routledgei, Oxyanthus speciosus ssp. stenocarpus, Phoenix reclinata, Pittosporum viridiflorum 'ripicola', Psychotria orophila, Ritchiea albertsii, Rothmannia urcelliformis, Solanecio gigas, Solanecio mannii, Teclea nobilis, Trema orientalis, Turraea holstii, Vepris dainellii* and *Coffee Arabica* (Woldemariam, 2003).

3.2 Sampling Design

3.2.1 Population structure

The study forests were selected based on the potential of the populations of the three study species by reviewing the existing literature, from previous fieldwork experience and in consultation with experts and community leaders in the respective Woredas and peasant associations. Moreover, reconnaissance survey was conducted to determine representative habitat of study area, distance between transect line, and distance between plots along transect line. Systematic sampling method was used to collect the data, ten line transects were laid down along the gradient at each 100 m interval.

Sample quadrats each measuring 400 m^2 (20 m x 20 m) for tree and sapling were laid at each 50 m interval along each transect line. Within the main quadrats sub quadrat of 25 m^2 (5 m × 5 m) for seedling of the target tree species were laid out at the four corners and center. A total of 270 quadrats (90 quadrats for *P.africana* in Adela, Sherah, and Dogii sites, 120 quadrats for *P.adolfi-friedericii* in Adela, Gorashewi, Durani, and Duduka sites and 60 quadrats for *M. excelsa* in Kebereta and Dawe sites) were sampled. The target species not found in all sampled areas this may due to altitude and other ecological condition.

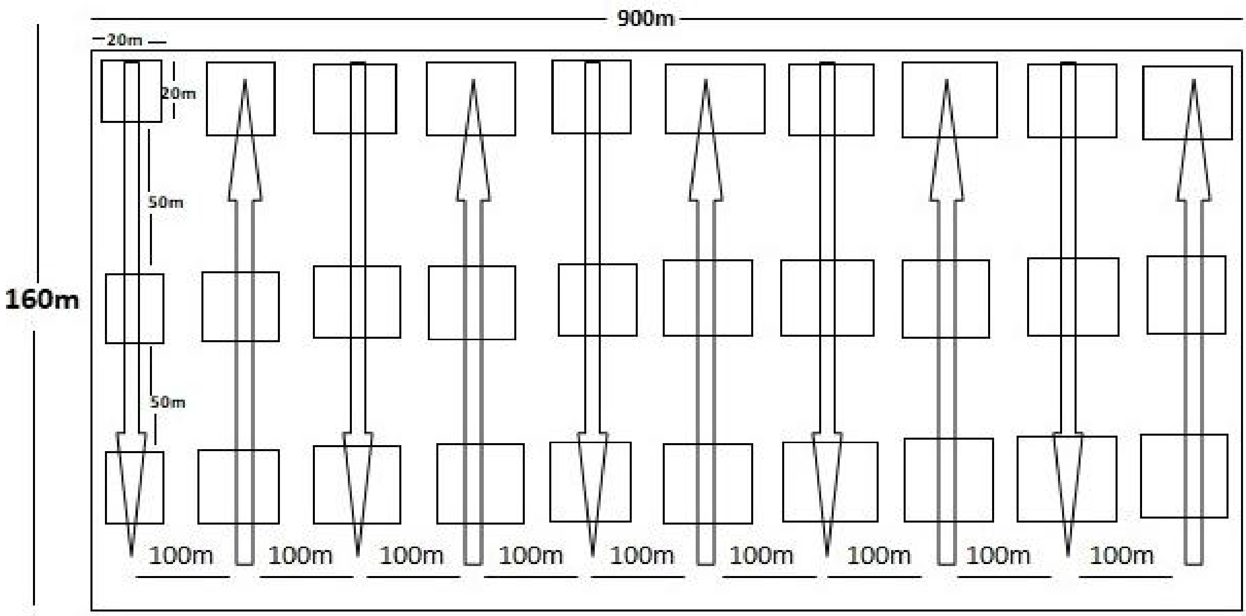

Figure 2: Sample size of transects and quadrats.

3.2.2 Phenology

Kebeles which are proximate to the sampled natural forest are purposively selected for the survey. The selection was made through discussion with experts of Woreda Office of Environmental Protection, Forest and Climate Change (woreda EFCC), Kebele administrators of respective sites (, and with the help of field observation by researchers).

3.2.2.1 Key informant (KI) selection

In this study, key informants (KI) are referred as knowledgeable farmers, and experts who have deeper knowledge about representative forest and lived in the area for long years. The selection of key-informants was done by the help of the kebele administrators. Five key informants from each Kebeles were used for selection of households. A total 20 KIs were selected from Yeyibto Kebele (Bonga-woreda), Achibo Kebele (Yayu woreda), Yina Kebele (Masha woreda) and Abeyi five (Bebeka). The information taken from key informants was used for selection and triangulation of HHs surveyed data. The detail of checklist of key informant interview is given in (Appendix I).

3.2.2.2 Household interview

A total of 120 elders (a minimum of 30 elders from each study site) who lived in the area for long years and know more about the forest and tree species found in the representative forests were selected for household interview by the help of key informants. The number HH selected for the interview is limited to 30 from each study site, because the number of people living within the proximity of selected forests is low. The household (HH) interview was conducted to assess indigenous knowledge of local community on phenology of flower and fruit of *Prunus africana*, *Pouteria adolfi friedericii* and *Milicia excelsa* tree species in each natural forest. The developed questionnaires were administered with the selected households by local language. The detail of checklist of HHs questionnaires is given in (Appendix II).

3.2.2.3 Focus group discussion participant selection

For focus group discussions (FGD), individuals who have deeper knowledge about representative forests from households were purposively selected. Based on the objective of the research, two FGDs groups, each having 7-8 members, were selected from each Kebele which are proximate to the selected natural forest. Flowering and fruiting season (months) were mainly discussed during focus group meeting (Appendix III**)**.

3.3 Data Collection

3.3.1 Population structure

Data collection was conducted during January to February, 2020. The wildlings (seedlings) were recorded from sub sample plots for the sizes diameter <3.5 cm and height <0.5m; saplings diameter of 3.5–10cm and height 0.5m –2m. DBH and total height were measured in quadrats for trees with minimum sizes DBH >10cm and height >2m (Bharali *et al*., 2012 ; Dhaulkhandi *et al*., 2008; Gebrehiwot and Hundera, 2014). DBH were measured with diameter tape and total heights were measured with clinometer.

3.3.2 Phenology

Data on phenology study was collected from both primary and secondary sources. The primary data were collected with questionnaire survey at household level, using key informant interview and focus group discussions. While, secondary data was collected from reports in government offices, from published and grey literature.

3.4 Data Analysis

3.4.1 Population structure of target species

All data for the study three tree species were entered, cleaned, organized and summarized in Microsoft Excel spread sheets and SPSS software. Eight DBH classes (i.e., 10.1 - 20 cm, 20.1 - 30 cm, 30.1 - 40 cm, 40.1 - 50 cm, 50.1 - 60 cm, 60.1 - 70 cm, 70.1 - 80 cm, >80 cm) were established based on the DBH size ranges measured for the three tree species, Basal area (BA) was calculated using the formula:

$$\text{Basal area} = (A) = \pi r^2 \qquad \text{where: } \pi=3.14$$

Density estimates obtained from transects were used to calculate the number of individuals of target tree species in the study area. It was a count of the numbers of individuals of a species within the quadrat. It was computed per hectare basis (Kent and Coker, 1992). Afterwards, the sum of individuals of the target species was calculated and analyzed in terms of species density per hectare.

$$\text{D (density)} = \frac{\text{number of stems of species counted}}{\text{sample area}}$$

Height: Individual trees having height greater than or equal to 2 m and DBH ≥10 cm within sampling quadrats were collected and analyzed by classifying into seven classes (2 -10 m, 11 - 19 m, 20 - 28 m, 29 - 37 m, 38 - 46 m, 47 -55 m, >55 m). Population structure was summarized using histograms of diameter size classes. ANOVA was used to test for difference in basal area, DBH, height and number of trees among different natural forest. Finally, all selected natural forests were compared in terms of their population structure and then the best natural forest was recommended for seed production area establishment.

3.4.2 Regeneration

The regeneration status of target species in each forest habitat were analyzed by comparing the population density of seedling, sapling and matured trees (Dhaulkhandi *et al*., 2008 ; Gebrehiwot and Hundera, 2014) as follows: 1) "good" regeneration, if density of seedling > sapling > mature tree; 2) "fair" regeneration, if density of seedling > sapling < mature tree; 3) "poor" regeneration, if a species survives only in the sapling stage, but not as seedlings; 4) "none", if a species is absent both in sapling and seedling stages, but present as mature; and 5) "new", if a species has no mature, but only sapling and/or seedling stages. All selected natural forests were compared in terms of their regeneration status and then the best natural forest was recommended for seed production area establishment.

3.4.3 Phenology

Phenology data which were collected from primary sources was checked, coded, encoded in a computer and analyzed using descriptive statistics.

4. RESULTS AND DISCUSSION

4.1 Population Structure of target species

4.1.1 DBH, Density and Basal area

4.1.1.1 *Prunus africana*

A total of 71 individuals of *P. africana* were recorded in 33 plots out of 90 plots sampled in Adela site (Bonga), Sherah site (Masha) and Dogii site (Yayu) natural forests. In Adela site a total of 14 trees of *P. africana* were recorded in 10 plots out of 30, in Sherah site a total of 46 trees were recorded in 16 plots out of 30 plots and in Dogii site a total of 11 trees were recorded in 7 plots out of 30 plots. There is no recorded number of individual of *P.africana* tree species in Bebeka sampled natural forest; this may due to altitude and other ecological condition. The sampled forests represent mean densities per ha of 72, 39 and 35 in Sherah site, Dogii site and Adela site natural forest respectively (Table 1).

The highest number of individuals of overall distribution of *P.africana* by diameter class in Adela site natural forest was at the lower (at <10cm) (Fig. 3), the highest number of individuals of *P.africana* in Sherah site natural forest was also at the lower (<10cm) and middle (at 40.1-50cm) diameter class (Fig. 3), while in Dogii site natural forest, the highest frequency was at >80cm (Fig. 3). The density of *P.africana* was significantly higher in Sherah site natural forest than Dogii and Adela site.

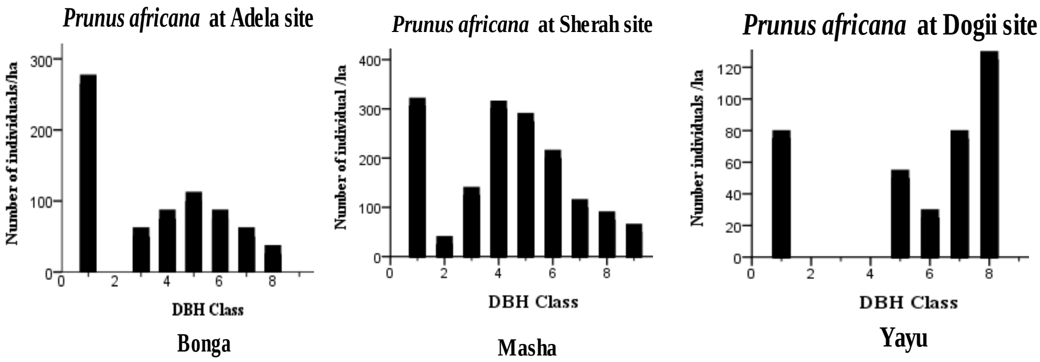

Figure 3: Population structure of *P. africana* in Adela, Sherah and Dogii sites natural forests.

DBH class versus number of individuals of *Prunus africana* pattern in Adela site natural forest was formed Irregular shape (Fig.3), in which they are distributed differently in almost all classes. Some DBH classes had large number of individuals while, other DBH classes had small number of individuals. In higher DBH classes the low number of individuals is due to past harvesting which targets mature trees and only left few reproducing individuals leading to a decline in the overall density.

The population structure of *Prunus africana* tree graph in Sherah site also shows that Irregular pattern. Different literature also stated that the irregular pattern distribution might be due to selective cutting by the local people for construction and firewood (Gebrehiwot and Hundera, 2014).

The DBH class distribution patterns of *Prunus africana* in Dogii natural forest form broken J-shape pattern; which shows a type of frequency distribution in which there is a low number of individuals and even nothing in the lower diameter classes but increases towards the higher classes. It indicates a poor reproduction and recruitment of species which may be associated with intense competition from the surrounding trees.

According to Feyera *et al*. (2007) low number of individuals in the lower diameter class shows that a poor reproduction and recruitment of species due to intense competition from the surrounding trees and capacity of this species indicates the management and conservation problems.

Table 1: Density, DBH, Height, and Basal area of *Prunus africana* tree among sampled natural forests

Natural Forests	**Density trees/ha) (Mean ± SD)**	**DBH (cm) (Mean ± SD)**	**Height (m) (Mean ± SD)**	**Basal area(m^2/ha)**
Adela(n=30)	34.97±1.066	50.35±0.911	25.57±0.721	73.71 ±1.247
Sherah(n=30)	71.85 ±0.406	52.3 ±0.952	25.3 ±1.322	244.25 ±1.103
Dogii(n=30)	39.27 ±0.713	62 ±0.946	27.26 ±1.39	101.48 ±0.853
P. value	0.01	0.022	0.048	0.001

Where SD=standard deviation

Mean density, mean DBH, and basal area of *Prunus africana* of the three sites were found to be significantly difference (P<0.05). Stem/ha and basal area of *Prunus africana* tree species in Sherah site (Masha) was greater than Adela (Bonga), and Dogii (Yayu) site (P<0.05). The mean DBH of *Prunus africana* tree species in Dogii site (Yayu) was greater than Adela (Bonga), and Dogii (Yayu).

4.1.1.2 *Pouteria adolfi friedericii*

A total of 142 individuals of *P. adolfi*‑*friedericii* were recorded in 56 plots out of 120 plots in sampled natural forests of four sites. In Adela site (Bonga) natural forest 27 trees of *P.adolfi*‑*friedericii* were recorded in 11 plots out of 30 plots, in Gorashewi site (Masha) natural forest 61 trees of *P. adolfi*‑*friedericii* were recorded in 17 plots out of 30 plots, in Durani (Yayu) natural forest 22 trees of *P. adolfi*‑*friedericii* were recorded in 14 plots out of 30 plots and in Duduka site (Bebeka) natural forest 32 trees of *P. adolfi*‑*friedericii* were recorded in 14 plots out of 30 plots.

The density of *P.adolfi-friedericii was* significantly higher in Gorashewi natural forest than Adela, Duduka and Durani site natural forests (Table 2). In Adela site natural forest the highest number of individuals of *P.adolfi*‑*friedericii* by diameter class was at 30-40cm (Fig.4), in Gorashewi site natural forest was at > 80.1cm (Fig. 4), in Durani site natural forest the highest number of individuals of *P. adolfi*‑*friedericii* was at 30.1-40cm (Fig 4), while in Duduka site natural forest the highest number of individuals of *P.adolfi*‑*friedericii* was at <10cm (Fig.4).

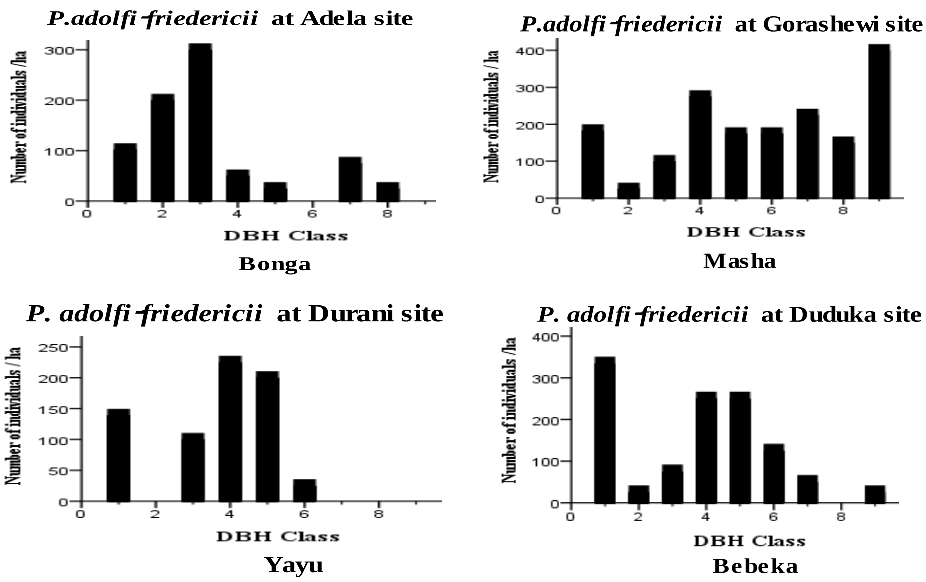

Figure 4: Population structure of *P.adolfi*‑*friedericii* in Adela, Gorashewi, Durani, and Duduka sites natural forests

DBH class versus number of individuals of *P. adolfi*‑*friedericii* pattern in Adela site natural forest was formed broken inverted J-shape; in which the density of individuals in the lower DBH class is very high but becoming lower in the highest DBH classes even nothing in some DBH classes like class five. According to Gebrehiwot and Hundera (2014) this pattern showed that there is selective cutting of the species for different purposes like for construction and fuel wood.

DBH class versus number of individuals of *P.adolfi*‑*friedericii* pattern in Gora Shewi site natural forest was formed Irregular shape, in which they are distributed differently in almost all classes. Some DBH classes had large number of individuals while, other DBH classes had small number of individuals. The reason for such irregularities is overgrazing which affects the seedlings under the mother tree (Taye *et al*., 2002).

The *P.adolfi*‑*friedericii* tree species diameter-class distributions versus number of individuals also form Irregular shape type of graph in Durani site natural forest. It have low number of individuals and even absence in lower and higher diameter classes but, in the middle diameter classes it have higher number of individuals. The DBH class distribution patterns of *P.adolfi*‑*friedericii* in Duduka site natural forest was also characterized by higher individuals at middle stage than mature aged population.

Table 2: Density, DBH, Height, and Basal area of *P. adolfi*‑*friedericii* among sampled natural forests

Natural Forests	**Density trees/ha) (Mean ±SD)**	**DBH (cm) (Mean± SD)**	**Height (m) (Mean ±SD)**	**Basal area(m^2/ha)**
Adela (n=30)	61.29±0.59	29.00± 1.11	25.48±1.49	62.53±1.126
Gorashewi (n=30)	95.24±0.58	64.73±1.46	26.12±0.91	589.00±1.126
Durani(n=30)	78.51±0.72	38.02±0.7	24.72±0.71	65.21±0.548
Duduka(n=30)	57.09±1.00	44.64±1.70	29.9±1.38	134.99±1.100
P value	0.033	<0.04	<0.046	<0.001

Where SD=standard deviation

Mean density, mean DBH, and basal area of *P.adolfi*‑*friedericii* of the four sites were also found to be significantly difference (P<0.05). Stem/ha, mean DBH and basal area of *P.adolfi*‑*friedericii* species in Gorashewi site (Masha) was greater than (Adela) Bonga, Duduka site (Bebeka), and Durani (Yayu) site (P<0.05). The density, DBH and height of *P. adolfi*‑*friedericii* were significantly higher in Gora Shewi site natural forest than Adela, Duduka and Durani sampled natural forests.

4.1.1.3 *Milicia excelsa*

A total of 20 individuals of *M. excelsa* mature trees were recorded in 15 plots out of 60 plots in Dawe site (Yayu) and Kebereta site (Bebeka) natural forests. In Dawe site natural forest 6 trees of *M. excelsa* were recorded from 4 plots out of 30 plots, while in Kebereta site natural forest 14 trees of *M. excelsa* were observed from 11 plots out of 30 plots. There is no recorded number of individual of *M. excelsa* tree species in Bonga and Masha sampled natural forests; this may occurred due to altitude and others ecological condition.

The density and DBH of *M. excelsa* trees were significantly highest in Bebeka Kebereta natural forest than Yayu Dawe site natural forest (Table 3). In Yayu Dawe site natural forest, the highest frequency of overall distribution of *M. excelsa* by diameter class was at 10.1-20cm (Fig.5), while in Bebeka Kebereta natural forest the highest frequency of *M. excelsa* was at 30.1-40 cm (Fig.5).

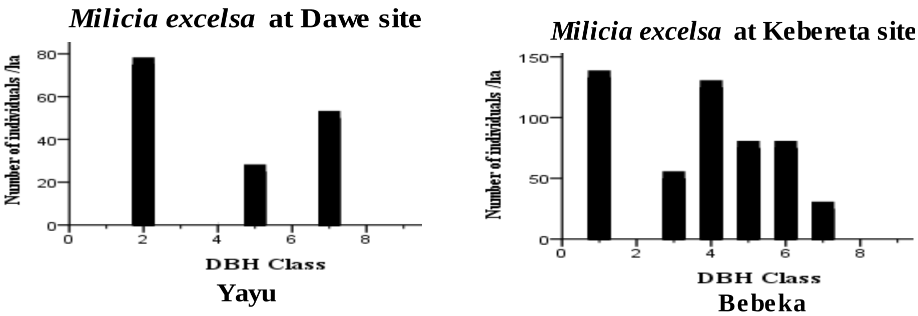

Figure 5: Population structure of *M. excelsa* in Dawe and Kebereta site natural forest

Milicia excelsa DBH-class distribution in Dawe and Kebereta site natural forests were formed irregular shape **(**which they are distributed differently in almost all classes). Some DBH classes had large number of individuals while other DBH classes had small number of individuals and even some were missed, this might be due to selective cutting by the local people for construction and firewood.

Table 3: Density, DBH, Height, and Basal area of *M. excelsa* among sampled natural forests

Natural Forests	Density trees/ha) (Mean ±SD)	DBH (cm) (Mean ±SD)	Height (m) (Mean ±SD)	Basal area(m^2/ha)
Dawe(n=30)	37.48±0.549	37.55±0.711	21.58±1.026	23.36±0.850
Kebereta(n=30)	38.80±0.746	44.83±0.885	24.39±0.908	59.26±0.596
P value	0.044	0.04	0.046	0.033

Where SD=standard deviation

Mean density, mean DBH, and basal area of *M. excelsa* of the two sites were found to be significantly different (P<0.05). Stem/ha, mean DBH and basal area of *M. excelsa* species in Kebereta site (Bebeka) was greater than Dawe site (Yayu) (P<0.05).

4.1.2 Height

4.1.2.1 *Prunus africana*

In Adela site natural forest the highest number of individuals of *P. africana* by height class distribution was at (<2m) followed by the fourth height class (20 - 28 m) (Fig. 6). The least number of individuals corresponds to the highest height class (>37m) and even absence of large individuals in the forest might be associated with the selective cutting of species for various purposes.

The highest height distribution of *P. africana* in Sherah site natural forest was at the fourth height class (20 - 28 m) followed by the first height class (<2m) (Fig. 6). The least number of individuals corresponds to the lowest height class (11-19m) and even absence of large individuals in the forest might be associated with the selective cutting of species for various purposes.

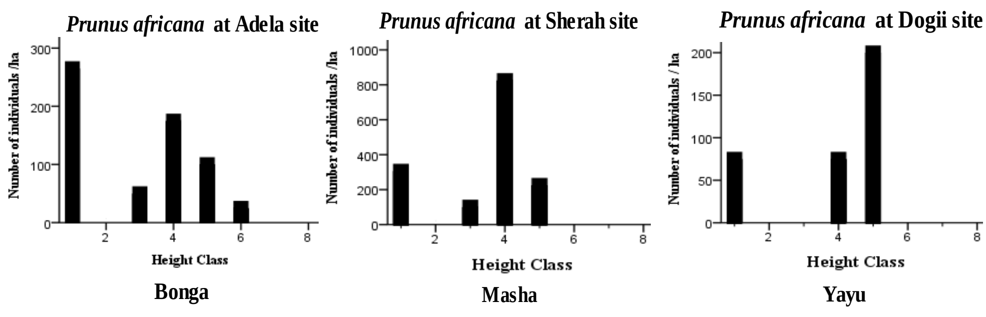

Figure 6: Population structure of *P. africana* in Adela, Sherah, and Dogii sites natural forests.

The height distribution patterns of *P. africana* in Dogii natural forest form broken J-shape; which shows a type of frequency distribution in which there is a low number of individuals and even nothing in the lower diameter classes but increases towards the higher classes. It indicates a poor reproduction and recruitment of species which may be associated with intense competition from the surrounding trees.

4.1.2.2 *Pouteria adolfi-friedericii*

The highest height distribution of *P. adolfi-friedericii* in Adela site natural forest was at the fifth height class (29 - 37 m) followed by the fourth height class (20 - 28 m) (Fig.7). The least number of individuals corresponds to the highest height class (>37m) and even absence of large individuals. This indicates that most of the recorded species of the forest were < 37m in height (shown in figure 7). It consists with study result that was concluded that few in number or the absence of large individuals in the forest might be associated with the selective cutting of species for various purposes such as construction, fuel (Gebrehiwot and Hundera, 2014). The height distribution patterns of *P. adolfi-friedericii* in Gorashewi natural forest was characterized by higher individuals at middle stage than young and mature aged population.

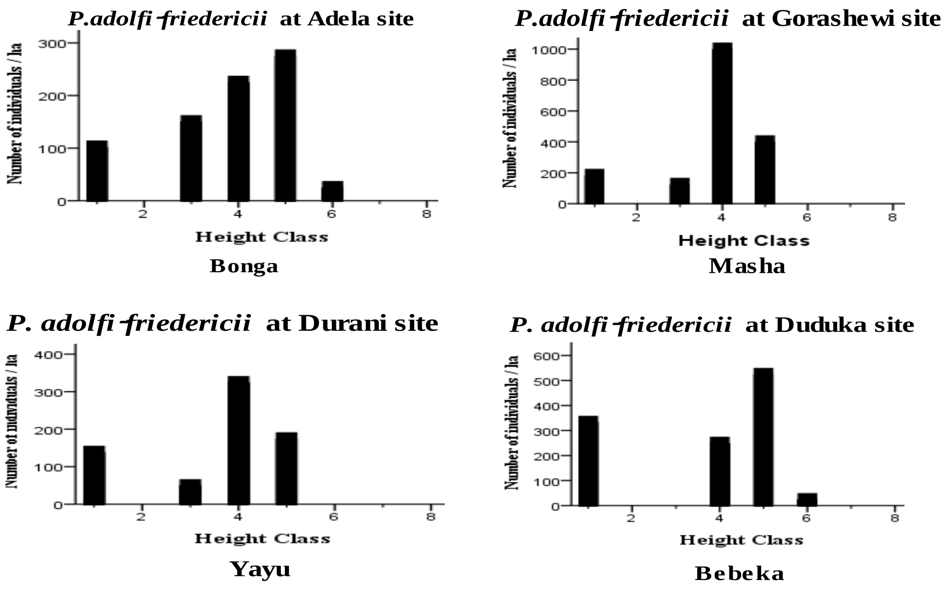

Figure 7: Population structure of *P. adolfi-friedericii* in Adela, Gorashewi, Durani, and Duduka sites natural forests.

The *P. adolfi-friedericii* tree species height class distributions versus number of individuals in Durani site natural forest have low number of individuals and even absence in lower and higher height classes but, in the middle height classes it have higher number of individuals. The height distribution patterns of *P. adolfi‑friedericii* in Duduka site natural forest was also characterized by higher individuals at middle stage than young and mature aged population.

4.1.2.3 *Milicia excelsa*

The height distribution patterns of *M. excelsa* in Dawe site natural forest was also characterized by higher individuals at lower and middle stage and lower at mature aged population (Fig.8). In Kebereta site natural forest *M. excelsa* was also characterized by higher individuals at middle stage than young and mature aged population.

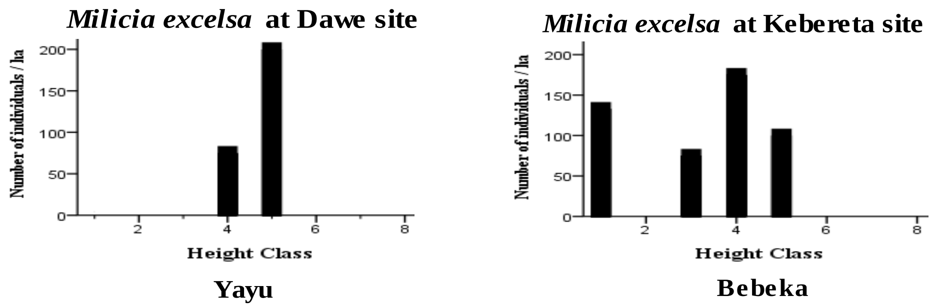

Figure 8: Population structure of *M. excelsa* in height-class distribution in Dawe and Kebereta site natural forest

4.2 Regeneration status of the target tree species

4.2.1 *Prunus africana*

The density of mature trees, saplings and seedlings of *P. africana* varied among all sampled natural forests. Density of all age classes was higher in Sherah site natural forest than in Adela and Dogii site natural forests. Saplings were missing in Dogii site natural forests (Fig. 9).

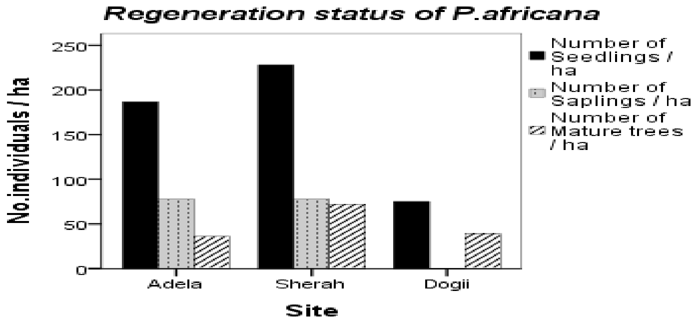

Figure 9**:** Regeneration status of *P. africana* in Adela, Sherah and Dogii site natural forests.

These Representative figures showed that the seedling, sapling and mature tree of *P. africana* tree species in different samples natural forests. In Adela and Sherah site natural forests the regeneration status represents good regeneration and recruitment (which seedling > sapling >mature tree stage). While, in Dogii site natural forests the graph showed fair regeneration. The population structure and regeneration status of *P. africana* was significantly higher and good in Sherah site natural forest than others. So, Sherah site natural forest is good and favorable for seed production area than the others selected sampled natural forests.

4.2.2 *Pouteria adolfi - friedericii*

Density of seedlings of *P. adolfi - friedericii* was higher in Duduka site natural forest than others selected natural forest while, in terms of sapling and mature trees Gorashewi site natural forest was higher than others (Fig.10). So, the result of the study showed that regeneration status of *P. adolfi - friedericii* in Gorashewi (Masha) and Duduka (Bebeka) site are at good regeneration status (Fig. 10) *i.e.* seedlings >saplings >Mature trees while, in Adela (Bonga) and Durani (Yayu) site natural forests it shows fair regeneration because the density of seedling > sapling < mature tree.

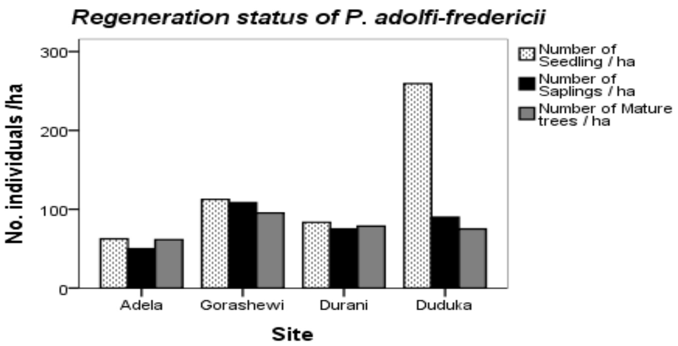

Figure 10: Regeneration status of *P. adolfi- friedericii* in Adela, Gorashewi, Durani, and Duduka natural forests

These Representative figures show that the seedling, sapling and mature tree of *P.adolfi-friedericii* tree species in different samples natural forests. In Duduka and Gorashewi site natural the regeneration status represents good regeneration and recruitment which seedling > sapling >mature tree. While, in Adela and Durani site natural forests the graph shows that fair regeneration. In terms of seedlings, saplings and mature trees, Gora Shewi site natural forest was higher than others and followed by Duduka site natural forest. The presence of good regeneration potential shows suitability of a species to the environment. Climatic factors and biotic interference influence the regeneration of different species in sampled natural forests. Higher seedling density values get reduced to sapling due to biotic disturbance and competition for space and nutrients

So, the present study showed that population structure and regeneration status of *P. adolfi - friedericii* are good and suitable for seed production area in Gora Shewi natural forest than others selected natural forests. The population structure and regeneration status of *P. adolfi- friedericii* in Duduka site natural forest are also suitable for seed production area next to Gorashewi While, in Adela and Durani site natural forest the population structure and regeneration status of this target tree species on this study shows that the number of individuals is low and even absence in some diameter classes and its regeneration status is fair when we compare with others.

4.2.3 *Milicia excelsa*

The density values of mature trees, saplings and seedlings of *M. excelsa* trees were varied among all selected natural forests. Density of all age classes was higher in Kebereta site natural forest than Dawe site natural forest. Seedlings and saplings were missing in Yayu sampled natural forest (Fig.11). So, the present study showed that regeneration status of

M. excelsa in Kebereta site was at fair regeneration because the density of seedling > sapling < mature tree, while, the regeneration status of *M. excelsa* in Dawe site natural forest is none because, both in sapling and seedling stages is absent.

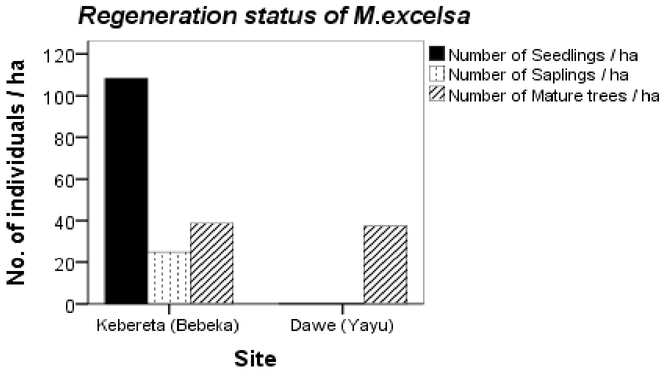

Figure 11: Regeneration status of *M. excelsa* in Dawe and Kebereta site natural forest.

In Kebereta site natural forest number of seedling > sapling < tree/shrub state, this pattern shows “fair” regeneration. The target species individuals (*M. excelsa*) in Dawe site natural forest were nothing in seedling and sapling stages but relatively many individuals in mature tree stage. It consists with study result that was concluded that “fair” regeneration pattern shows poor reproduction and hampered regeneration (Dhaulkhandi *et al*., 2008).

Milicia excelsa tree species population structure has highest proportion of individuals and it has fair regeneration status in Kebereta site natural forest when we compare with Dawe site natural forest, its favorable for seed production area establishment for *M. excelsa* tree species than existing sampled natural forest. While in Dawe site natural forest number of individuals of *M. excelsa* is low and seedlings and saplings were missing when we compare with Kebereta site natural forest.

4.3 Flowering and fruiting phenology of the study tree species

4.3.1 *Prunus africana*

In this study, findings from key informant interviews, households and focus group discussions showed that flowering period of *P.africana* tree species happens during October and extends till December (Fig.12) and its fruiting time ranges from January to March (Fig.13). Flowering and fruiting duration of native tree species is varies from year to year as well as from site to site within a particular region.

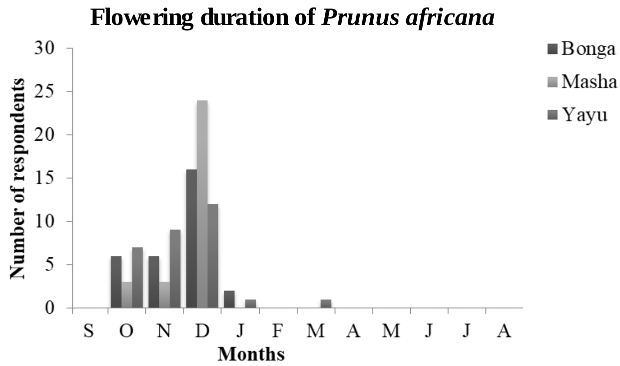

Figure 12: Flowering duration of *P.africana* in Bonga, Masha, and Yayu natural forests as stated by respondents

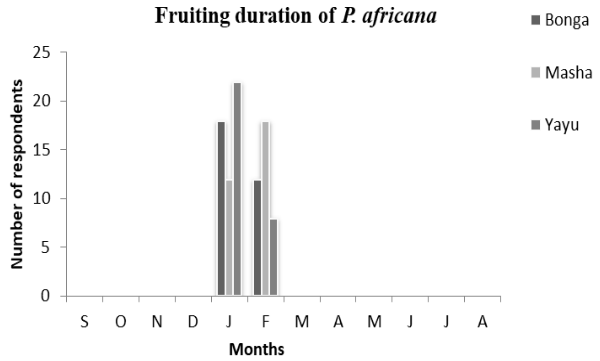

Figure 13: Fruiting Duration of *P. africana* in Bonga, Masha, and Yayu natural forests as stated by respondents

The graph indicated that the majority (53.3%) of household respondents out of selected representative elders stated that flower initiation and expansion of *P. africana* in Bonga sampled natural forest was occurred during December and the others respondents indicates that the flowering duration of this tree species happened during October (20% HHs) and November (20%HHs) month. The pattern of the graph also indicates that 80% participants from Masha sampled natural forest expressed that flower initiation and expansion of *P. africana* was during December and 10% respondents in this house hold questionnaire stated that the events occurred during October. Out of thirty selected households' 10% elders in Masha sampled natural forest determined that the flower initiation and shedding occurred within one month which is November.

Among the total respondents from Yayu Sampled natural forest 73.3% respondents stated that flowering initiation and expansion of *P. africana* occurred in December and the other 26.7% elders said that in October. Most of the respondent from three selected sampled natural forest 60%, 40%, 73.3% respondents from Bonga, Masha and Yayu respectively stated January month for fruiting duration of *P. africana*. The others 40%, 60%, 26.7% respondents from Bonga, Masha, and Yayu respectively indicated February month for fruiting duration of *P. africana*.

4.3.2 *Pouteria adolfi friedericii*

The study indicates that both flower initiation and open flowering stages in phenology of *P. adolfi friedericii* happens in sampled area occurs during February, extends up to early May (Fig.14). Timing of fruit happens during the early April up to June which is seasonal (Fig.15). Flowering and fruiting duration are significantly seasonal.

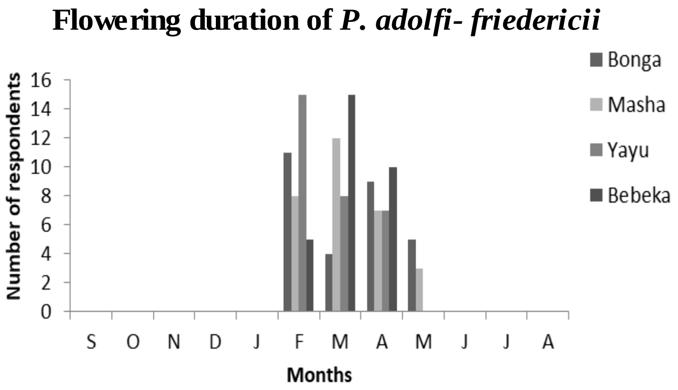

Figure 14: Flowering duration of *P. adolfi- friedericii* in Bonga, Masha, Yayu, and Bebeka natural forests as stated by respondents

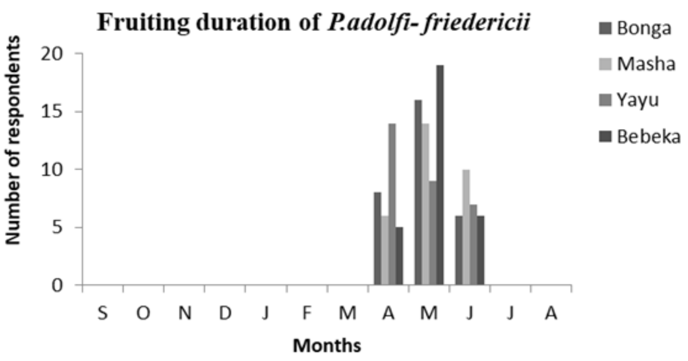

Figure 15: Fruiting time of *P.adolfi- friedericii* in Bonga, Masha, Yayu, and Bebeka natural forests as stated by respondents.

Most of sample households 36.7%, 26.7%, 50%, 16.7% and 13.3%, 40%, 26.7%, 50% respondents from Bonga, Masha, Yayu, and Bebeka sampled natural forest answered February and March months respectively for flower initiation and expansion of *Pouteria adolfi- friedericii* tree species and the others 30%, 23.3%, 23.3%,33.3% respondents from

Bonga, Masha, Yayu, and Bebeka respectively stated April month. The remain 16.7% respondents in Bonga sampled natural forest area and 10% elders respondents in Masha sampled natural area confirmed that May months for flower initiation and expansion of *P.adolfi- friedericii* tree species.

The result also shows that most of participants from the area of sampled natural forest confirm that fruiting duration of *P. adolfi friedericii* was in the month of May. The result indicates that among total respondents 53.3%, 46.7%, 30%, 63.3% respondents from Bonga, Masha, Yayu, and Bebeka respectively confirmed in May month. The others 20%, 33.3%, 23.3%, 20% and 26.7%, 20%, 46.7%, 16.7% respondents from Bonga, Masha, Yayu, and Bebeka sampled natural forests stated that June and April month respectively for fruiting *P. adolfi friedericii*.

4.3.3 *Milicia excelsa*

Flowering time is fairly short in *M. excelsa* tree species it takes place at a range of different times, but often occurs in January and February (Fig.16). Fruiting time of *M.excelsa* most of the time ranges from February to March (Fig.17). Rainfall, moisture, temperature and photoperiod are the factors which may influence the timing of flowering and fruiting (Gunter *et al*., 2008), due to that the respondents stated with ranges. It seems that the pattern of fruiting and flowering in this study may coincide with the seasonality due to fluctuation of rainfall, temperature and moisture. Trees grow when the environmental conditions are permissive. These phenology stages are highly influenced by environmental conditions. The exact duration of flowering and fruiting could be site specific (Anderson *et al*., 2005)

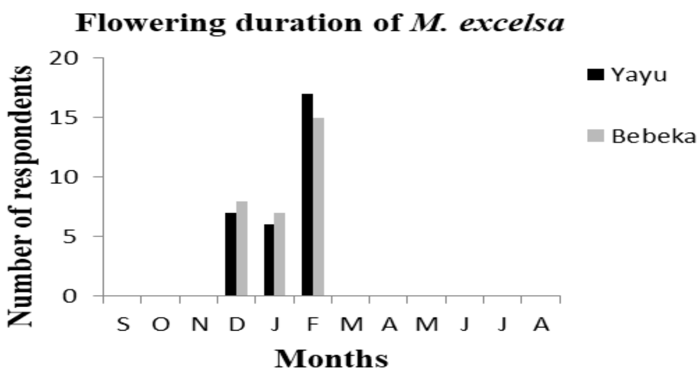

Figure 16: Flowering duration of *M. excelsa* in Yayu and Bebeka natural forests as stated by respondent

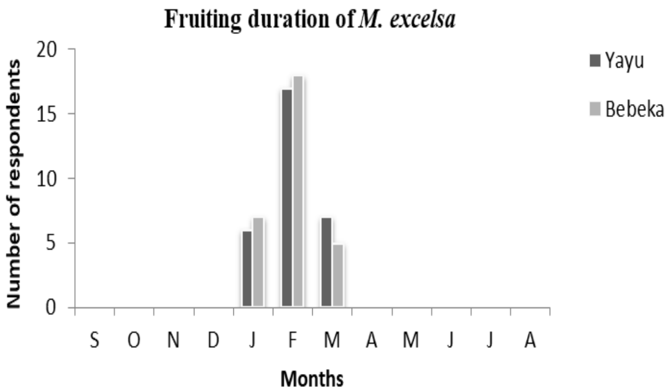

Figure 17: Fruiting Duration *M. excelsa* in Yayu and Bebeka natural forests as stated by respondents

Most of respondents mentioned February month for flower initiation and expansion of *M. excelsa* in both selected sampled natural forest area. Out of 60 sample households (56.7% from Yayu and 50% from Bebeka) answered February month, the others 20% and 23.3% sample HHs from Yayu and Bebeka respectively confirmed January month and the remain 23.3% elder from Yayu and 26.7 % elders from Bebeka stated December. The most result from HH questionnaires showed that the exact fruiting duration of *M. excelsa* was happened during February (in which 56.7%, 60% respondents from Yayu and Bebeka sampled natural forest respectively confirmed that the event occurred in this month). The other 20%, 23.3% and 23.3%, 16.7% from Yayu and Bebeka stated that January and March respectively.

The respondents from all selected site in south western Ethiopia stated almost the same duration (months) for flowering and fruiting (Fig. 18), it seems that the pattern of fruiting and flowering in this study may coincide with the seasonality. The higher similarities were recorded on flowering and fruiting duration of target species among the sampled natural forests (Fig. 18).

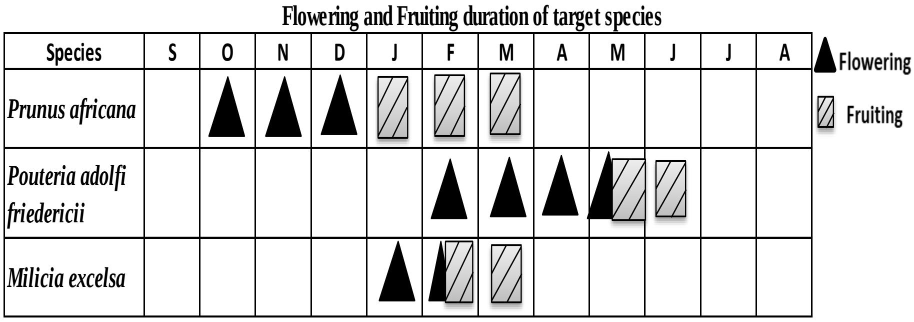

Figure 18: Flowering and Fruiting duration of *P. africana*, *P.adolfi- friedericii* and *M. excelsa* species in Bonga, Masha, Yayu, and Bebeka natural forest of south western Ethiopia.

A large number of trees of good phenotype and ability to flower and seed in a particular environment should be a prerequisite to establish seed production area. According to Tomar (2018) when natural stands chosen for its conversion to SPA, it's important to consider tree species with sufficient size and sufficient number of good phenotypes and sufficient seed production. Natural forests with healthy, big in diameter and good looking tall trees are preferable for seed production area.

In this study, findings from key informant interviews, households and focus group discussions showed that flowers initiation and expansion of *Prunus africana* tree species happens during October, extends till December and its fruiting time ranges from January to March. Flowering and fruiting duration of native tree species is varies from year to year as well as from site to site within a particular region.

The study result indicates that both flower initiation and open flowering stages in phenology of *Pouteria adolfi friedericii* happens in sampled area occurs during February, extends up to early May. Timing of fruit happens during the early April up to June which is seasonal. Flowering and fruiting duration are significantly seasonal. Flowering time is fairly short in *M. excelsa* tree species it takes place at a range of different times, but often occurs in January and February. Fruiting time of *Milicia excelsa* most of the time ranges from February to March. The result of the phenology assessment indicated that the times of flowering and fruiting generally ranges between December and June across the forest sites.

There is a slight variation in phenology among sites and similar in some cases across the inventoried forest sites. The high similarity recorded on flowering and fruiting duration of target species among the sampled natural forests could be due to have related climatic conditions. The result of this study was also helpful to design treatment to break seed dormancy. Example, for seeds produced during the rainy season the seed might respond well to soaking and seeds produced during dry season might respond to desiccation or heat treatment. However, further data collection will be needed to support these findings. Based on the findings, indigenous knowledge can provide information on the phenology status of target species especially in under-researched areas such information can complement scientific data to inform policy on best practices to establish seed production area, increase forest cover, through indicating adaptive tree species in the areas.

In this study, respondents also noted that anthropogenic factors such as illegal harvesting and pressure from human population increase also influence the population structure and regeneration status of the target tree species. For instance, trees belonging to the target species within the study site are destructed by deforestation. During data collection similar observations have been made in the study site, where target trees and trees associated with target species utilized for different purposes are declining due to illegal logging**.** Climatic factors in agroecosystems are critical to determine production and multiple stressors interact to the population dynamics and phenological status of target species (Mubaya *et al*., 2012).

Individuals of any species are more vulnerable at young stages to any kind of environmental stress and anthropogenic disturbance (Tesfaye *et al*., 2002; Nagamatsu *et al*., 2002). Hence, such human-induced activity alters the population structure and regeneration status of target species. Climatic and biotic factors influence the regeneration of different species in the vegetation (Daulkhandi *et al*., 2008). The increment of population and lack of proper policy framework for land use causes destruction forests, through expansion of agricultural land, illegal logging, fuelwood and overgrazing (Alemu, 2011).

5. CONCLUSIONS AND RECOMMENDATION

5.1 Conclusions

This study assessed the population structure, regeneration status and phenological duration of *Prunus africana, Pouteria adolfi-friedericii* and *Milicia excelsa* under different natural forests of south western Ethiopia. The result of these findings also indicates that the presences of the target tree species are relatively low in all selected natural forests and it also showed that the variation of site qualities influences both population structure and regeneration status of target species. The regeneration status of some target tree species of the study sites is satisfactory which shows "good" regeneration status but the other target tree species falls under "fair" and "poor" regeneration status.

Target tree species represented by "poor" or "no" regeneration of growth, survival, and reproduction potential were at risk in future, therefore it needs urgent conservation priority and management. Based on population structures and regeneration status results Masha sampled natural forest is more preferable for seed production area establishment than others sampled natural forests for *Prunus africana* and *Pouteria adolfi-friedericii* and Bebeka sampled natural forest also more preferable for *Milicia excelsa* tree species seed production area establishment than others sampled natural forests.

Flowering and fruiting period of target tree species ranges from two to three months. Based on the findings, indigenous knowledge can provide different months for flowering and fruiting duration of target tree species in different natural forests. The result shows that flowering duration of *Prunus africana* in all sampled natural forest ranges from October to December and its fruiting duration is from January to end of March months. Flowering duration of *Pouteria adolfi friedericii* is from February to early May according to the result of this study. Timing of fruit happens during the early April up to June which is seasonal. The study results also showed that *Milicia excelsa* tree species flowering and fruiting duration is fairly short, its flowering period is from January to mid-February and its fruiting time is from mid-February to end March.

5.2 Recommendation

Some of the target tree species have population structures that showed patterns with few numbers of individuals. Such species require urgent management and conservation measures that enhance healthy regeneration. Hence the following recommendations are forwarded on the basis of the findings of the present study.

- Management, conservation and monitoring practices of natural forests are crucial because, the edges of sampled natural forests are easily accessible for destruction, the people disturbing and reducing the size of the forest for agricultural expansion and coffee plantation.
- It is better to think of enrichment planting of indigenous tree species which are currently not regenerating themselves.
- Further research is required to ascertain the distribution of target tree species and also determine appropriate conservation measure to improve the population structure of indigenous tree species.
- There is also a need for an integration of indigenous knowledge with modern conservation approaches in the planning and implementation process. Local knowledge not only provides information on the use of species, but can also contribute to valuable information on how to maintain and conserve indigenous tree species.

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7. APPENDICES

Date: ------------------

ID: --------------------

Field Survey Form to assess the population status (population dynamics) of targeted species: *Prunus africana*, *Pouteria adolfi-friederici* and *Milicia excelsa*.

Table I: Special (target) plant survey form

Plant's botanical name	
Plant's vernacular name	
Plant's common name	
Survey site (forest name)	
Forest size (area)	
Location (GPS)	
Altitude	
Slope	
Temperature	
Humidity/rainfall	
Other information	
INVESTIGATORS (Name)	
REMARK	

Table II: Population density and abundance (trees and saplings) record within 20m by 20m and seedling record within 5m by 5m quadrats along a transect line

Transect line	**Total count (Abundance)**				**Density (per ha)**		
	plot	**seedling**	**sapling**	**Tree**	**seedling**	**sapling**	**Tree**
I	a						
	b						
	c						
II	a						
	b						
	c						
III	a						
	b						
	c						
IV	a						
	b						
	c						
V	a						
	b						
	c						
VI	a						
	b						
	c						
VII	a						
	b						
	c						
VIII	a						
	b						
	c						
IX	a						
	b						
	c						
X	a						
	b						
	c						

Table III Dendrological data measurement (stem height of individual trees with DBH ≥10cm and height > 2m in each transect line.

Transect line	Quadrant	Plant No̲	BASAL AREA MEASUREMENT				Stem height (m)
			Girth (G), at $BH_{1.3m}$	Diameter (D, cm) at $BH_{1.3m}$ = G/ π	Radius (r) = D/2, cm	Area (m^2) = πr^2	
I	a						
	b						
	c						
II	a						
	b						
	c						
III	a						
	b						
	c						
1V	a						
	b						
	c						
V	a						
	b						
VI	a						
	b						
	c						
	c						
VII	a						
	b						
	c						
VIII	a						
	b						
	c						
IX	a						
	b						
	c						
X	a						
	b						
	c						
	Total area (TA, m^2), height						
	Mean area, mean height ($\overline{x}$)						
	*Basal area (m^2/ha) = TA*10000/total area of quadrants*						

Appendix I: Checklist for key informants

1) How is the abundance of *Prunus africana*, *Pouteria adolfi-friederici* and *Milicia excelsa* tree species in your locality? How is the trend of area cover by this species (የዝርያዎች ብዛት ምን ይመስላል/ የአካባቢዉየነ ዚህ ዝርያ ሽፋን ምን ይመስላል)?

2) When does the target species flower, Fruit and Ripe? (የዝርያዎቹ የአበባ፤ የፍሬ፤ የመበሰል እና ዘር ለማሰብሰብ ዝግጁ የሚሆኑበት ጊዜ መቼ ነው?

3) Does the community produce seedlings of this species? How they collect, process and sow the seeds in the nursery? (ማህበረሰቡ እነ ዚህን ዝርያዎች ችግኝ ያፈላል ወይ? የምታፈሉ ከሆነ ዘሩን እንደት ትሰበስባለችሁ፤ ታጣራላችሁ እና እንደት ትዘሩታላችሁ?

4) How long does seedling take to reach plant able size (ምን ያክል ጊዜ ዝርያዎቹ በችግኝ ጣቢያ ይፈጃሉ ለተከላ ብቁ ለማሆን)?

5) What field management does it require before, during and after planting in the field (እነ ዚህ ዝርያዎች ከተከላ በፊት፤ በተከላ ወቅት እና ከተከላ በኃላ ምን አይነት እንክብካቤ ይፈልጋሉ?

Data for Tree seed phenology assessment

Appendix II: Question for household interview

Part I. Area description

1. Name of enumerator --

    Signature--

2. Date of interview---------------------------------------

3. Name of district--

4. Name of Kebele administration---------------------------Got-----------------------

5. Questioner no -----------------------------------

Part II. Can you provide the following information?

A) Name of the households____

B) Sex: _________________ C) Age_______ D) Family size_________

Part III.

A) Forest Priority Area name:____

B) Zone____

C) District/ Woreda ____

D) Locality/site ____

E) Are there any *Milicia excelsa, Prunus africana* and *Pouteria adolfi‐friedericii* tree species tree in your surrounding (በእናንተ አካባቢ ጎንጅ፤ ቀረሮ እና ጥቁር እንጨት ይገኛሉ ወይ)? If yes where (ዝርያዎቹ በየትኛው ደን/አከባቢ/መንደር በስፋት ይገኛሉ)?

____

____

____

F) When does the target species flower, Fruit and Ripe? (የ ዝርያዎቹ የ አበባ፤ የ ፍሬ፤ የ መበሰል እና ዘር ለማሰብሰብ ዝግጁ የ ሚሆኑበት ጊዜ መቼ ነ ው?

Species	Flowering (የ አበባ ሁኔ ታ)		Fruiting (የ ፍሬ ሁኔ ታ)		
	Month of first flowering (የ አበባ ማበብ)	Month of peak flowering (የ አበባ መርገ ፍ)	Month of first fruiting (እንቡጥ መጀመር)	Duration of fruiting (ማዘግ)	Month of peak Fruiting(መበሰል)
Milicia excelsa					
Prunus africana					
Pouteria adolfi-friedericii					
Remark					

Appendix III: Checklist for focus group discussion

1) Why the target species (*Milicia excelsa, Prunus africana* and *Pouteria adolfi-friedericii) tree* species abundance reduce from your surrounding natural forests (የጎንጅ፤ ቀረሮ እና ጥቁር እንጨት ዝርያዎች ሽፋን በአከባቢያቹ እነ ዲቀንስ ያደረጉተ ዋናዋና ምክንያቶች ምንምን ናቸው)?ሀ

2) In what way does we increase the abundance or improve the trend of area cover by this species and the role expected from community to increase the abundance of species (የዝርያዎቹ ሽፋን/ እነ ዲጨምር ምን መደረግ አለበት)? የእነ ዝህን ዝርያዎች ሽፈን ለሜጨምር ከማህበረሰቡ ምን ይጠበቃል?

3) When does the target species flower, Fruit and Ripe? (የዝርያዎቹ የአበባ፤ የፍሬ፤ የመበሰል እና ዘር ለማሰብሰብ ዝግጁ የሚሆኑበት ጊዜ መቼ ነ ው?