THE IMPACT OF PARTICIPATORY FOREST MANAGEMENT ON COMPOSITION AND REGENERATION OF SOME WOODY SPECIES: THE CASE OF CHILIMO FOREST, OROMIA REGION, CENTRAL ETHIOPIA

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BY

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THE IMPACT OF PARTICIPATORY FOREST MANAGEMENT ON COMPOSITION AND REGENERATION OF SOME WOODY SPECIES: THE CASE OF CHILIMO FOREST, OROMIA REGION, CENTRAL ETHIOPIA

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I have incorporated the suggestions and modifications given by my advisors and got the approval of my advisors. Hence, I hereby kindly request the Department to allow me to my thesis for internal thesis defense.

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Chairperson, DGC ___________________ Signature _______________ Date _________________

Chairperson, CGS ___________________ Signature _______________ Date _________________

DEDICATION

I dedicate this thesis to my heartfelt lovely wife Dibe Tesfaw, and to my beloved Father Belay Kebede and my Mother Zeritu Assefa who were tirelessly labored and sacrificed whatever they had for my education to the end.

STATEMENT OF THE AUTHOR

I declare that this thesis is my real work and that all sources of materials used for this thesis have been duly acknowledged. This thesis had been submitted in partial fulfilments of the requirements for MSc degree at Jimma University (JU) College of Agriculture and Veterinary Medicine, and it is made available at the University's Library to borrowers under rules and regulations of the Library. I solemnly declare that this thesis is not submitted to any other institutions anywhere for the award of any academic degree, diploma or certificate.

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BIOGRAPHY

The author Misgana Belay was born on April 26, 1989 in Gindeberet district, West Showa Zone of Oromia Regional State, Ethiopia. He started school in 1995 and attended it up to 1997 from grade (1-3) at Gurra Jerjera elementary school. Then, he enrolled to Kachisi elementary school in 1998 and attended his education up to 2002 from grade (4-8). Then after, he attended his education at Kachisi secondary high school starting from grade (9-12) from 2003 to 2006. Then, he joined Wolaita Sodo Universty in 2007 and attended his degree in Natural Resource Management, and awarded his Bachelor degree on 18July, 2009. Then, he was employed in Tiro Afeta district Agricultural development office of Jimma Zone on 13th November, 2009 G.C. During his stay in the office:

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LIST OF ACRONYMS AND ABBREVIATIONS

BMEMF ……………….. Belete Moist Evergreen Montane Forest

CC …………………….. Canopy Class

DBH ……………………Diameter at Breast Height

EWNHS ……………….. Ethiopian Wildlife and Natural History Society

FAO …………………… Food and Agricultural Organization

FCs ………………………Forest Cooperatives

FLR ……………………. Forest Landscape Regeneration

FUG …………………….. Forest User Group

G.C. ……………………. Gregorian Calendar

GHG ……………………. Greenhouse Gas

GPS ………………………Geographical Positioning System

IPCC ……………………..International Panel on Climate Change

IVI ……………………… Importance Value Index

NGOs ……………………Non-Governmental Organizations

PAST ……………………. Paleontological Statistics

PFM ………………………Participatory Forest Management

SFM ………………………Sustainable Forest Management

SNNPR …………………...Southern Nations, Nationalities and People's Region

SPSS …………………….. Statistical Package for Social Science

USAID ……………………United States Agency for International Development

WBISPP …………………. Woody Biomass Inventory and Strategic Planning Project

ABSTRACT

The objective of this study is to assess the impact of participatory forest management on composition and regeneration of some selected woody species at Chilimo forest. Systematic sampling method, following transect lines established along the altitudinal gradient in the forest sites was used for vegetation inventory from eighty (i.e. forty quadrats at each forest site) quadrats. From the study finding, the major family of the study woody species identified was Rosaceae,represented by two species with 18.18% family coverage.The relative number of individuals of Podocarpus falcatus, Prunus africana, Olea europaea, Hagenia abyssinica, Apodytes dimidiata, Ficus sur, Erythrina brucei, Croton macrostachyus and Maytenus arbutifolia species registered were comparatively higher in the PFM. Whereas, the number of individuals of J. procera and M. africana species occurring in Non-PFM exceeded that of the PFM forest site.The two forest sites regarded as independent but comparable forest matrices, consisting of vegetation community has 0.268 Sorensen's similarity coefficient, indicating that the two forest sites are low in their similarity.Most of the species occurrence frequency in the height size classes have shown distribution mode of increment towards sapling classes from seedling but showed decreasing trend towards mature vegetation from sapling for both Non-PFM and PFM forest sites.The study result consistently indicated that, there is 14.94% more species individuals'record with comparatively higher vegetation regeneration status at the PFM forest site but, with comparatively lower seedlings to saplings ratio at PFM forest site.63.64% of the woody species in DBH size classes have exhibited distributional structural profile of the general pattern of normal population structure where the majority of the study woody species have the highest number of individuals at lower DBH size classes showing gradual decrease towards higher DBH classes.Vegetation density is greater for PFM than for the Non-PFM forest site with a total density values of (338.75 individuals/ha) and (288.125 individuals/ha) respectively.The total basal area coverage for the overall woody species of the PFM was assessed to be (481.97m^2) whereas, for the Non-PFM forest site was (128.03m^2).But separately considering, species with the highest basal area was recorded in the PFM forest by J. procera with (392.46m^2) followed by J. procera of Non-PFM with (91.70m^2) density value. But, bigger IVI value was registered in Non-PFM by J. procera with (45.38) followed by J. procera of PFM forest site with IVI value of (40.25), which is ecologically important species at both forest sites. Therefore, on the basis of the finding, PFM needs actual and strict follow-up for effective and sustainable forest management with sound and enforcing forest policies to further improve forest condition and regeneration status.

Key words:*Basal area, Chilimo, Density, Regeneration*

1. INTRODUCTION

1.1. Background

Forests have enormous ecological, economical, and socio-cultural significances (Samuel, 2017). Forests constitute critical habitat for humanity, providing a range of ecological and environmental services including protection of biodiversity, sequestration of carbon, provisioning of fresh air, renewal of soil fertility, and maintenance of hydrological cycles. Rural communities worldwide depends on forests heavily, as these contribute significantly to their livelihoods, providing basic needs, cash resources, and safety-nets during times of crisis (USAID, 2006).

Tropical dry forests are among the most degraded and threatened of tropical ecosystems and there is an urgent need to better understand how coupled human-natural processes can work to conserve and restore them (MacFarlane *et al.*, 2015).

The sustained deforestation and depletion of forest show that the usual top down approaches that were in practice to manage forest in Ethiopia are not guarantee for the conservation of forests (Shime, 2014). It disregards traditional common property regimes, ignoring local resource people's knowledge and disempowers local community in terms of both resource ownership and responsible use.

In order to halt deforestation problem, participatory forest management became a central strategy to ensure sustainable management and conservation of forests (Ayana *et al.*, 2017). Participatory forest management (PFM) was introduced in Ethiopia around the mid-1990s as a new system of forest governance. Recent global trends in forest management have focused on the devolution of forest management from state authorities to local communities through community-based approaches to securing and managing forests (Vyamana, 2009).

In Ethiopia where forests are under PFM, FUGs are involving in forest protection and management through participating in different activities such as planting of seedlings, forest floor clearing, monitoring the forest condition, regulating harvesting of forest and collection of revenue from forest products indicates the contribution made by FUG for SFM as owners and managers. Generally, in Ethiopia where PFM has taken root, forest degradation has shown substantial decline and tree regeneration has improved (Siraj *et al.*, 2016).

Recent reviews suggest a need to evaluate forest restoration efforts with respect to both the human and natural components of specific forest ecosystem types (Chazdon, 2013) and caution against measure of success that attempt to restore forests to a ‘‘putative natural state’’.

According to Freund (2012), tropical forest regeneration is driven by a number of biotic and abiotic factors, and it can follow many trajectories depending on the type and intensity of disturbance. The exact trajectory of forest regeneration depends on a multitude of factors, including post disturbance soil characteristics, the state of the soil seed bank, the proximity to nearby undisturbed forest, and other environmental factors that may affect recruitment of new vegetation. Given the same type and intensity of disturbance, a regenerating patch with an intact soil seed bank that is close to a patch of undisturbed forest will likely recover much more quickly and have greater species richness than a regenerating patch with no soil seed bank that is farther away from primary forest. The strong induction why study on the effect of participatory forest management on composition and regeneration of the selected woody species deemed is that, because of the heavy exploitation of forest resources in the area – continuous and illegal uncontrolled logging that skims off the selected valuable timber species like *J. procera, H. abyssinica*, *P. falcatus* and *M. africana* for housing, and a few others (Erenso *et al.*, 2014).

Therefore, in this study, the impact of PFM on composition and regeneration of some selected woody species and the corresponding human-natural induced factors to forest composition and regeneration at Chilimo-Gaji Forest were assessed to identify major regenerating tree and shrub species from the selected woody species.

1.2. Statement of the Problem

Since the mid-1970s the management of forest resources in Ethiopia was mainly carried out as state and community forestry programmes (Kassa *et al.*, 2009). These non-participatory approaches failed to reduce tree felling and clearing, especially in Protected National Forest Priority Areas. In response to that in Ethiopia, decentralized forest resource management was initiated in the mid-1990s with the support of international non-governmental organizations (NGOs-PFM) to mitigate natural resource degradation and its effects on the livelihoods of people. Participatory Forest Management (PFM) is a new paradigm of forest management which is adopted and implemented in order to fulfill the interests, respecting traditional users, and hence such a bottom-up approach may encourage a sense of ownership to the rural people to conserve forest resources.

Chilimo Forest is one of the dry Afro-montane forests and the oldest remnant forests found in the central highlands of Ethiopia, harboring many endemic species (Soromessa and Kelbessa, 2013 and Kassa *et al.*, 2009). This forest is ecologically, socially, economically and culturally very important for the inhabitants residing nearby who are mostly dependent on forest product to make their living. Loss of such a forest and the various threatened species would have great implications for the environment, biodiversity and socio-economic setup of the communities. This forest harbors species that are endemic, economically and ecologically important. Such species requires urgent conservation measures that will enhance healthy regeneration and guarantee sustainable uses of these species.

Chilimo Forest is also the first natural forest in Ethiopia managed by cooperatives (Kassa *et al.*, 2009). Though better outcomes in terms of reduced deforestation rate and improved incomes were reported, it is important to examine options that in the long term would minimize trade-offs and maximize synergies between conservation and livelihoods. Even though harmonizing the need for forest conservation and improving ofpeople's livelihood necessitated, it is better to incline more towards forest conservation to ensure effective and sustainable forest management, through different environment-friendly conservation mechanisms.So that, the objective is in line with the study which is to assess the impact of PFM on composition and regeneration of woody species and improvement of forest condition of Chilimo forest by promoting PFM performances at the area while meeting people's livelihoods at the same time.

The areas that should be covered, but have not been fully worked on till today and then made the PFM effectiveness slow was the research gap observedon sustainability and policy issues, that is attained by formulating andimplementing socially suitable, environmentally sound and economically acceptablemanagement plans as well as weak forest resources enhancement as a result of low productivity and regeneration of woody species (Bane *et al.*, 2007). Weak state control over most of the regional state forests also created opportunity to free riders as it led to an open access regime which in turn created unbalanced utilization where harvest exceeds natural regeneration, thereby, resulting in lower area coverage every year (negative increment). At the *Woreda/District* level there is no strong forest institution that can produce viable economic analysis on the social, economic and environmental impact of a particular investment. A recent study showed that such investments like coffee and tea development undertaken in the south-west forests have negative impact on the local people.

1.3. Objectives

1.3.1. General objective

- To study the impact of PFM on composition and regeneration of some selected woody species at Chilimo forest.

1.3.2. Specific objectives

- To assess regeneration potential of some selected woody species.
- To compare regeneration statuses of some selected woody species of PFM and Non-PFM forest sites.
- To assess woody species composition and species individuals of PFM versus Non-PFM forest sites for the selected woody species.

1.4. Research Questions

The study has addressed the following research questions;

- What was the impact of PFM on composition and regeneration of some selected woody species at Chillimo forest?
- What were the regeneration potential of the selected woody species?
- What were the comparative regeneration statuses of some selected woody species of PFM and Non-PFM forest sites?
- What was woody species composition and species individuals of PFM versus Non-PFM forest sites for the selected woody species?

1.5. Significance of the Study

Deforestation and forest degradation were occurring in Ethiopia, especially during previous regimes for decades, operating in the usual top-down approaches to forest management and governance that are not guarantee to effective forest conservation and improvements to forest condition. In this approach, forest resources are centrally controlled by the state that does not focus on the devolution of forest tenure and management from state authorities to local communities. It also disempowers local communities in terms of both resource ownership and responsible use.

To halt the deforestation and forest degradation problem of Ethiopia, which is a popular concern of current time, a new institutional set-up with proper arrangements and synergetic human-natural influencing factors were in anticipation to bring about effective forest management and improvements to forest condition. Because, previous regimes' forest management and governance policy was outdated, lacking local community involvement and willingness in forest resource management issues as the new approach. To solve the problem, the new forest management approach has emerged– creating decentralized forest management system,which facilitates community involvement and consultation with government in all aspects of local forest resource issues like: forest management, conservation, protection and sustainability issues, awareness creation on forest and forest environment, resource ownership and responsible use, benefit sharing as well as decision making, and etc. So that, this new forest management approach by PFM is found worthy and useful in improving woody species regeneration and forest condition.

1.6. Limitation of the Study

In assessing the composition and regeneration status of woody species occurring in different management approaches and options (i.e. either local community or governmentor non-government) as well as at different forest sites, far apart some distances and in different agro-ecology, there are some environmental factors affecting the species composition and distribution as well as vegetation regeneration such as terrain physiognomic features, altitude, precipitation/rainfall pattern, soil texture, temperature and etc that may cause variations inwoody species composition, distribution and regeneration trend in general.Human population, and socio-economic and livelihood activities practiced in and around the forest areas and forest ecosystems can also cause either of the influences, determining woody species composition and recruitment potential of species.

2. LITERATURE REVIEW

2.1. Overview of Forest Resources of Ethiopia

Ethiopia owns diverse vegetation resources that include high forests, woodlands, bushlands, plantations, and trees outside forests (Gobeze *et al.*,2009) and is believed to be home for about 7,000 species of plants of which 12% are endemic and hence one of the six plant biodiversity-rich countries in Africa (Nune *et al.*, 2013).

Ethiopia has one of the largest forest resources in the horn of Africa (Gashaw *et al.*, 2015) owning a total of 59.7 million ha covered by woody vegetation among which: 3.56% are high forest (about 4.07 million ha), 49% woodland (29.24 million ha) and 44.2% shrub land or bushland (26.4 million ha) and plantations cover estimated to 955,705 ha (WBISPP, 2004). About 95% of the total high forest of the country is located in three regions namely Oromia, SNNPR and Gambela regional states (Moges and Tenkir, 2014). Oromia has the highest forest covers (2,547,632 ha) which accounts 63% of the total forest resource followed by SNNPR and Gambela. These states accounts about 19% (775,393 ha) and 13% (535,393 ha) of the total forest cover of the country respectively.

Ethiopia's forest resources covering about 50.6% of the country's total land area (1.12 million km^2) fall into six broad categories, namely, forestlands, woodlands, shrub lands, bushlands, plantations (man-made forest) and bamboos (Nune *et al.*, 2013).

Table 1: Forest resource accounts for Ethiopia

Forest category	**Total area (ha)**	**Share as % of country's total area**
Forest land	3,403,441	3.0
Wood land	26,219,177	23.4
Shrub land	22,897,872	20.4
Bush land	2,182,853	1.9
Plantation(man-made forest)	955,705	0.9
Bamboo (lowland and highland)	1,101,201	1.0
Total	**56,760,249**	**50.6**

Source: WBISPP (2004) and (Nune *et al.*, 2013)

Land use/land cover statistics in Ethiopia indicates that woody vegetation including high forests cover 50% of the land (Moges *et al.*, 2010 and WBISPP, 2004) following the definitions of FAO in which the vegetation of Ethiopia that may qualify as 'forests' are natural high forests , woodlands, plantations and bamboo forests, with an estimated area of 35.5 million ha. If the shrub lands are added to this (considering the definition of IPCC for forest), the estimated cover is 50.6% (61.62 million ha). The next largest land use type is cultivated land with 18.6%. On the other hand, the recent data on forest resources of Ethiopia as reported in (FAO, 2011) puts Ethiopia among countries with forest cover of 10-30%. According to this report, Ethiopia's forest cover is 12.2 million ha (11%), clearly underestimated compared to the IPCC definition. It further indicated that the forest cover shows a decline from 15.11 million ha in 1990 to 12.2 million ha in 2010, during which 2.65% of the forests cover was deforested. The cover belonging to other wooded land remained constant in the same period.

The natural high forests of Ethiopian are mainly found in the highlands where annual rainfall distribution and amount is better (Tesfaye, 2015).

Montane forests are the main constituents of the natural vegetation in the Ethiopian highlands (Yirdaw, 2002). Most afro-montane tree species have wide geographical distributions and wide ecological amplitudes. Many also exhibit a wide range of growth forms. Dry afro-montane forests and moist afro-montane forests are the dominant vegetation types found in the highlands. However, the dry afro-montane forests are the most dominant one in the central, northern and western Highlands. The dry afro-montane forests are dominated by both broadleaved and coniferous species such as: *Juniperus procera, Podocarpus falcatus* and *Olea europaea ssp. cuspidiata* (Tesfaye, 2015). Dry evergreen montane forests are very complex vegetation type occurring in areas of relatively high humidity, with limited and unreliable rain and prolonged dry season. During the dry season, temperature increases and day time humidity drops down and water courses either dry up or greatly diminish inflow (Teketay, 2005).

According to USAID (2008), Ethiopian highlands cover more than 50% of the country's land area with afro-montane vegetation, of which dry afro-montane forests form the largest part. Several names have been employed to refer to dry afro-montane forests in Ethiopia, e.g. tropical high montane conifer forest, montane dry evergreen forest, highland *Juniperus-Podocarpus* forest, dry montane forest, upland dry evergreen forests, upland dry evergreen forest and mixed upland evergreen forest, coniferous forest and undifferentiated forest. The dry afro-montane forests are either *Juniperus-Podocarpus* forests or predominantly *Podocarpus* forests, both with broad-leaved species.

Man-made plantation forests are also another form of forests widely practiced and found in the country (Teketay, 2005). The dominant plantation forests are composed of four genera (*Eucalyptus, Cupressus, Pinus* and *Acacia*). Eucalyptus accounts for the lion's share of the plantation forest in the country (90%) followed by *Cupressus lusitanica*, *Juniperus procera* and *Pinus spp.* respectively (WBISPP, 2004; Moges *et al.*, 2010 and Bekele, 2011).

2.1.1. Woody species diversity

Natural forest is one of the richest ecosystems in plant species diversity and used as a home of many and diversified plant species. Ethiopia is one of the richest countries in having plant species diversity. The geographical location of Ethiopia covers wide agro-climatic zones and important center of biological diversity (Mengistu and Asfaw, 2016). This wide ecological condition of Ethiopia has created diverse and conducive environments for the development of a variety of flora. There are about 7,000 different flowering plants grown in Ethiopia, out of which about 12% of them are endemic for the country. Ethiopia has the fifth largest floral diversity in tropical Africa, which mainly is as a result of the great variations in altitude (ranging from 110 m to over 4,530 m.a.s.l), topography, rainfall and temperature in the country that have provided favorable environmental conditions necessary for the evolution and persistence of a wide variety of floral, as well their associated faunal species. However, this tremendous wealth of natural resources and biological diversity of the country has been facing serious conservation challenges due to the high (~3% per annum) growth rate of the country's human population (Endris *et al.*, 2017). Tree species diversity is fundamental to overall forest biodiversity, because trees provide resources and habitats for almost all other forest species (Feroz *et al.*, 2016). In addition, structural diversity measured as variation across a vertical stand profile also appears to be a good ecological indicator of the conservation of woody species diversity.

2.1.2. Structure and composition

Woody vegetation is characterized by its plant morphological characters (structure) or the recognized plant species (composition) (Bajigo and Tadesse, 2015).

The presence of wider altitudinal coverage enhances the diversity of climate, topography, and soil type and vegetation resources (Tesfaye, 2015). Ethiopian is endowed with various landscape types resulted in different agroecological zones and vegetation types. The vegetation types varied from tropical rain forest and cloud forests in the southwest to the desert scrubs in the east and northeast and diversified agroforestry practices and systems in the central highlands (Pohjonen and Pukkala, 1990). The structure and species composition of the natural vegetation types are also diverse due to the presence of wider physiognomic and climatic landscapes in the country.

Trees in a forest can be assigned to one of five canopy classes (CC) and structures in forest ecosystem (MacFarlane *et al.*, 2015) as:

(a) Suppressed (S) – All parts of the tree's crown are below that of surrounding trees.

(b) Mostly Suppressed (M) – Most of tree's crown is below crowns of surrounding trees, but the highest parts extend into gaps in the canopy of taller competitor's.

(c) Co-dominant (C) – The tree's crown is actively competing with neighboring crowns and is only partially shaded by them.

(d) Dominant (D) – Most of the tree's crown is above its immediate neighbors.

(e) Emergent (E) – Tree's crown extends well above the surrounding canopy.

2.2. Trends of Forest and Forestry

Despite their wide reaching significance, forest resources of Ethiopia have been declining both in size (deforestation) and quality (degradation) (Gobeze *et al.*, 2009; Reusing, 2000 and WBISPP, 2004). The annual deforestation rates declined over time, from 800,000 ha during the 1950s (Pohjonen and Pukkala, 1990) to 200,000 – 300,000 ha between 1967 and 1979, and 163,600 ha between 1986 and 1990 (Reusing, 2000) and 141,000 ha between 1990 and 2005 (FAO, 2006b). Regardless of the high rate of deforestation, Ethiopia still owns some forest resources. Ethiopia owns 4.072 million ha of high forests, 29.24 million ha of woodlands, 26.4 million ha of bushlands and 0.216 million ha of plantations. These forest resources together cover about 53% of the country's landmass.

According to Moges *et al*. (2010), forest resources in Ethiopia have experienced so much pressure due to increasing need for wood products and conversion to agriculture. The trend in Ethiopia today is to protect the remaining natural forests for their various social, economic and environmental values. On the other hand, there is increasing demand for wood and wood products. To strike the balance between the two interests, afforestation/reforestation (or plantations) is very important. Plantations are even-aged forest stand deliberately established by humans on formerly non-forested lands or deforested lands. The purpose can be wood production or protection under the ownerships of the private sector, individual farmers, the community, or state. The size of plantation ranges from less than a hectare to several hundreds of hectares of land (large scale plantations). Size of large scale state or community plantations depend on whether the plantation is integrated with a processing industry, availability of market or the wood requirements of communities. According to historical records, afforestation started in the early 1400s by the order of King Zera-Yaqob (1434-1468). Modern tree planting using introduced tree species (mainly Australian Eucalyptus) started in 1895 when Emperor Menelik II (1888-1892) looked into solutions for alleviating shortage of firewood and construction wood in the capital, Addis Ababa. However, the historic rapid expansion of large scale and community plantations occurred during the Dergue regime, which resulted in the establishment of large scale plantations. These plantations have often been established for supplying the huge demand for wood products in Ethiopia. Today, tree plantations cover approximately 500,000 ha (WBISPP, 2004), out of which 133,041 ha were established as community plantations between 1978 and 1989. Eucalyptus species (58%) and *Cupressus* (29%) are the dominant plantation species. Other species include *Juniperus procera* (4%), *Pinus* species (2%) and the rest (7%).

Currently, forest-cover gain is increasingly manifest at large scales following decades of deforestation (Sloan, 2016). Forest-cover gain has entailed new forest geographies reflecting the changing drivers, agents, and contexts of forest-cover change. These geographies are the physical manifestations of intangible processes by which different agents and trends of land-cover change interact to collectively form a single landscape.

2.3. PFM and Forest Condition

Participatory Forest Management (PFM), as it stands today in Ethiopia, is a management regime aimed at achieving better and sustainable forest development through balancing conservation and utilization by mobilizing, organizing, participating and transferring management responsibilities to local communities living in and around forest areas where resources are linked directly (Temesgen and Limenih, 2012). It is, therefore, characterised to critically involve those communities and giving them clear responsibilities in forest protection and management aspects ensuring user rights of the available resources.

According to Banana *et al.* (2011), decentralization of authority over forests to local levels of government and to communities assumes that these entities will be able to design institutions in-line with the needs and desires of local forest users and this is expected to lead to better forest management and thus improved forest condition. The impacts of participatory forestry are physically visible and are used to measure the tangibility of the impact of PFM, such as forest regeneration with more natural regeneration of indigenous plants, healthy seedlings, smaller number of livestock in the forest, significant reduction in the number of intruders and reduced use of exploitation trails, reduced felling of trees, better use of dead wood than in previous years, better grass growth and effective utilization, closing up of bushes, significant reduction in the number of charcoal burning sites, reduced pit-sawing activities, reappearance of wildlife species in areas managed by FUGs and growth of a sense of civic responsibility (Siraj *et al.*, 2016).

PFM and Non-PFM forest sites are compared, in their species composition as well as from the number of seedlings, saplings and mature vegetation which constitutes the whole study woody species at the site.

Tropical forest plants regenerate from one or more pathways (Teketay, 2005): (i) seed rain: recently dispersed seeds; (ii) soil seed bank: dormant seeds in the soil; (iii) seedling bank or advance regeneration: established, suppressed seedlings in the under-storey; and (iv) coppice: root or shoot sprouts of damaged individuals.

Natural regeneration fundamentally depends on the alignment of ecological and social factors at landscape scales (Chazdon, 2013). Changes in species composition, forest structure, and population dynamics are the outcome of coupled human and ecological systems, environmental conditions, and stochastic events. Even after many decades, regenerating forests will not replicate copies of the forests that were replaced by prior land-use change. Several management options can catalyze natural regeneration, including active suppression of weeds, removal of exotic species, protecting sites from fire and overharvesting, providing perches and roosts for seed-dispersing birds and bats, and planting seeds or nursery-grown seedlings of native forest species not present in the seed rain.

In natural forests, the onset of regeneration processes depends on the creation of open patches (gaps) as a result of the death and felling of mature trees' gaps become preferential sites for natural regeneration, and the characteristics of mature forest ecosystems largely depend on gap recruitment dynamics (Borghetti and Giannini, 2009). In managed forests, the onset of natural regeneration depends on the application of appropriate regeneration cuttings, reducing canopy cover and thus creating the necessary growing space for the recruitment of the new generation of trees. Regeneration cuttings should be intended, to some extent, as a means to reproduce patch disturbances occurring in natural forests.

Vegetative regeneration presents an alternative regeneration pathway that can be used to maintain existing trees in a forest, facilitating the adaptation of associated species by avoiding substantial changes in species composition, and therefore promoting current forest persistence (Sjölund and Jump, 2013).

2.3.1. Forest and woody species regeneration

Forest resources are the fruits of evolution that are developed through the combined influence of physical environment and people and play important economic, social and cultural roles, particularly in the lives of local communities (Erenso *et al.*, 2014).

The natural regeneration of tree species in forests has important roles in the plant population and the promotion of forest resources, as well as the maintenance of biological diversity (Yu *et al.*, 2013). Although natural forest regeneration and forest succession can proceed very rapidly in minimally degraded landscapes and in areas conserving high levels of remnant old growth forests (Sloan and Martinez-Ramos *et al.*, 2016), but restoration of biodiversity and ecosystem services in highly degraded areas may require active restoration interventions. Aligning restoration goals and practices with natural forest regeneration can achieve the best possible outcomes for recovering ecosystem functions, services, and biodiversity in ways that improve livelihoods and promote strong local governance and stewardship.

Natural forest regeneration can provide a number of ecosystem services including timber and non-timber products, carbon sequestration, protection of soil and water resource, pest mitigation, and cultural services that support local livelihoods of inhabitants of mosaic landscapes (Uriarte and Chazdon, 2016). Natural regeneration, however, is just one landscape component along with agriculture, forestry, and conservation areas. Balancing different ecosystem services in a way that minimizes tradeoffs among services at relevant scales is a key to the success of FLR initiatives.

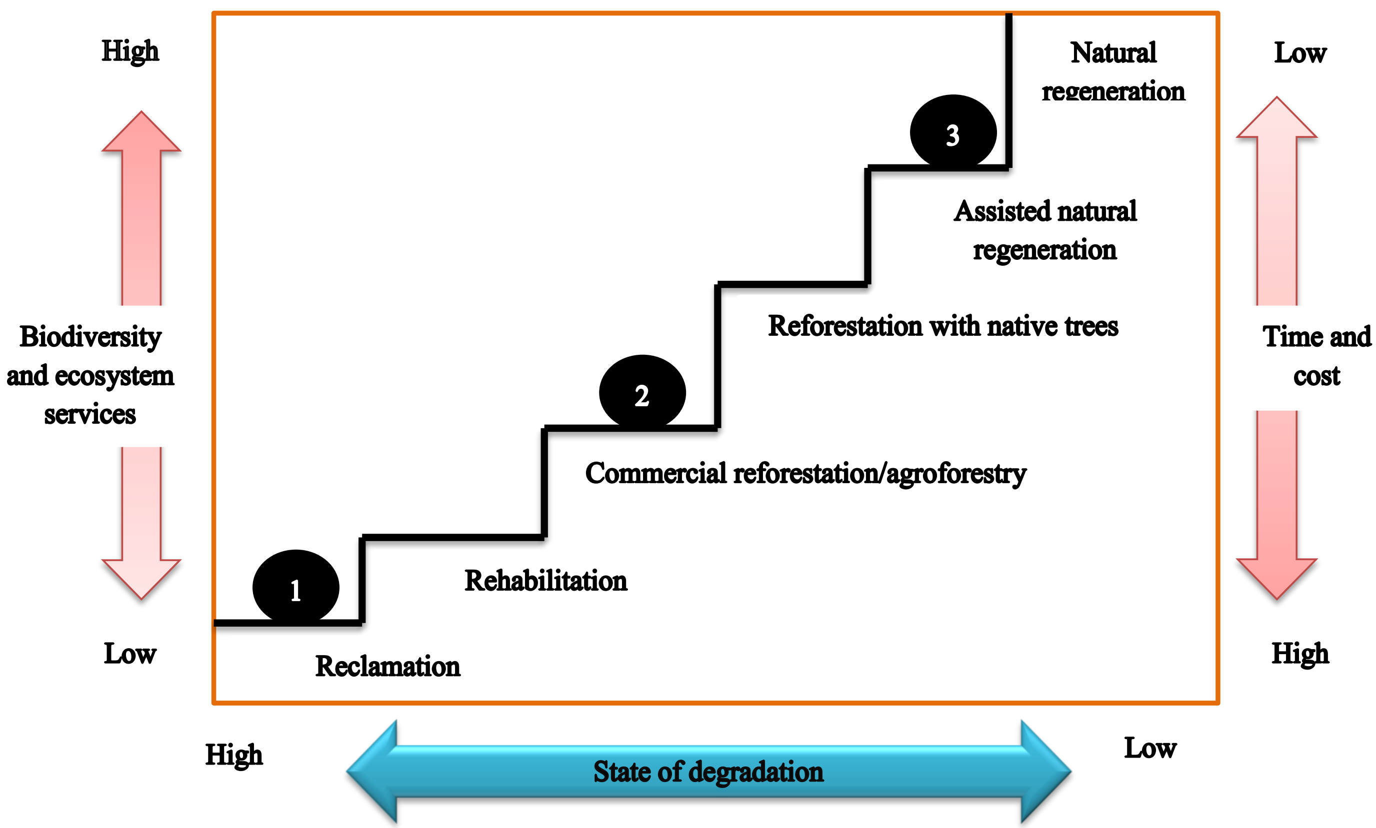


Fig. 1: The restoration staircase

Source: Chazdon (2008)

2.3.1.1. Influencing factors

Natural forest regeneration is driven by emergent processes at both local and landscape scales (Uriarte and Chazdon, 2016). Natural regeneration potential increases with proximity to forest remnants, rainfall, and soil fertility and is reduced after intensive land uses. Effective and affordable forest landscape regeneration will require consideration of multiple management practices together with landscape and local environmental factors that determine successional trajectories and the extent and persistence of natural regeneration. From a landscape perspective, preservation of remnant forest is a key (Uriarte and Chazdon, and Martinez-Ramos *et al.*, 2016). Tree populations in forest remnants act as sources of propagules, particularly during the early stages of succession and for late successional species

Forest remnants are critical as habitat for pollinators, seed dispersers, and predators of pests and pathogens (Uriarte and Chazdon, 2016). Remnant forest patches do not need to be pristine to host many important generalist seed dispersers. Preservation of old growth forests or well-developed second growth forests at the landscape scale is likely to improve the quality and extent of regenerating forests in their vicinity (Sloan, 2016). At the local scale, FLR must consider the legacies of prior agriculture land uses on natural regeneration potential because they influence the structural, compositional, functional, and dynamical attributes of regenerating forests (Chazdon, 2013).

Depending on the degree of prior disturbance, FLR will require different approaches (Martinez-Ramos *et al.*, 2016) such as: (a) first step is determining the inherent capacity of the system to regenerate and (b) identification of native or introduced tree species with high potential for natural regeneration. Species selected for regeneration should also provide desirable timber or non-timber forest products if farmers are to invest the resources necessary to ensure success.

Successful regeneration in forests largely depends on stand structure and site factors such as topography and soil properties (Chai and Wang, 2016). The characteristics of forest stands influence the availability of resources necessary for successful establishment and growth. Topographical factors such as elevation, slope gradient, slope aspect, and slope position (Yu *et al.*, 2013) are related to, and indicators of, several abiotic factors (Powers *et al.*, 2009), such as drainage conditions and nutrient flow. All these factors have multi-dimensional and multi-scaled effects on the patterns of species in montane forests and significantly affect the establishment and survival of tree seedlings. The physicochemical properties and parental materials of the soil can affect the growth and diversity of these plants (XU *et al.*, 2007). Forest characteristics, topography, and soil properties are interrelated in the growth and establishment of species in regenerating forests, but their effects are difficult to study in isolation.

Natural regeneration depends on many factors (Rodriguez-Garcia *et al.*, 2010), and many significant biotic and abiotic factors. The following environmental factors influence forest regeneration and establishment as: topography including elevation, slope gradient, slope aspect, and slope position, soil properties such as pH and levels of organic matter, total nitrogen, total phosphorus, total potassium, available nitrogen, available phosphorus, and available potassium and forest stand characteristics such as shrub cover, herb cover, canopy closure, average tree height, stand density, and the number of tree species.

Forest regeneration is driven by a number of biotic and abiotic factors, and it can follow many trajectories depending on the type and intensity of disturbance. Seed dispersal is one such biotic factor (Freund, 2012). Many tree species in tropical forests depend on frugivorous animals for dispersal, thus their ability to colonize secondary forest depends on how those animals interact with the post-disturbance landscape. Regeneration of previously forested land is possible if the area is left alone after a disturbance (provided it has not entered an alternative stable state), and secondary regrowth has been observed across. Secondary regrowth can restore ecosystem function and services (e.g., timber provisioning, carbon sequestration, etc).

2.3.1.1.1. Human influences

According to Limenih and Bekele (2008), given the opportunity, communities whose livelihood depends on forests are better positioned to manage the resource as well as resolve conflict over the same. One of the empowering tools is decentralization. A highly centralized system suffocates local initiatives, knowledge and institutions. Decentralization provides authority in which local government bodies and communities exercise power over key resources. State monopoly of property ownership does not only degrade forest access right of locals but also their age-old traditional systems of forest resource management, including local knowledge and institutions. The action of local people is often governed by the apparently informal, but customary/traditional rules regarding use of natural resources. Though the extent differs from site to site, PFM helped several forest species to regenerate, and to form healthy/viable vertical and horizontal stand structure. For instance, in Borana of Ethiopia, the local communities have shown a deep awareness of the locally relevant ecological factors that effect natural regeneration. Using their traditional knowledge on *Juniperus procera*, a species that had lost regeneration for long, has made a comeback (Siraj *et al.*, 2016).

Integrating the views and needs of local communities in conservation processes are crucial to/for the effectiveness of PFM in improving the forest condition and ensuring the sustainability of the livelihoods of the communities (Stellmacher, 2007; Limenih and Bekele, 2008).In traditional societies, sustainable forest resource management is driven by the beliefs and behaviors of human communities, and local cultures are strengthened by their intimate connections to the natural environment that sustains them (Negi, 2010).

Positive human-induced factors influencing forest regeneration and establishment include tree planting, competing vegetation control, and other management treatments to encourage desirable reproduction and limit negative abiotic and biotic factors (McWilliams *et al.*, 2015).

Sacred forest sites are among conservation sites of forest vegetation (Gashaw *et al.*, 2015). These conserved forest patches are found around the world in places of worship are on way of stewardship to protect the forest ecosystem integrity to meet the need of current and future generation (Limenih and Kassa, 2014). It provides cultural values, in addition to its services as key habitat for diversity of fauna and flora. In addition, rehabilitation has been becoming the solution in different vegetation degraded areas to meet the conservation and economic development needs.

Past and current management affects successional trajectories. The type of land use before its abandonment has an effect on the structure and rate of biomass accumulation, the species richness and composition, and the relative proportion of dispersal syndromes of the plants in successional forests (Derroire, 2016). This is due to several reasons: different past land uses have different impact on the soil (e.g. compaction, erosion, fertility). The vegetation present at the time of abandonment also differs between past land uses. The duration and intensity of the previous land use are also important factors.

In cultural landscapes, sprouting ability is maintained through regular management; therefore, the dynamics of vegetative regeneration are different from that of a natural unmanaged population of the same species (Sjölund and Jump, 2013).

2.3.1.1.2. Ecological influences

Plant communities can recover from disturbance through ecological succession, a process that implies sequential changes in the community attributes (i.e., species richness, composition, and diversity) over time (Alvarez-Anõrve *et al.*, 2012).

Natural regeneration can successfully occur only if a sufficient amount of "growing space" is available for seed germination and subsequent growth of seedlings. Canopy trees strongly determine the understory light regime and tend to reduce the growing space for the recruitment of young trees into the canopy layer, thus consolidating their dominance (Borghetti and Giannini, 2009). The direction of the forest relative to the dominant winds can affect the relative proportion of seeds with different dispersal syndromes dispersed into successional forests. Scattered trees and live-fences improve seed dispersal in the landscape by acting as stepping stones and corridors for animal dispersers.

2.3.2. Prospects of physical forest cover and trending

Growth of forest and other woody vegetation in Ethiopia is primarily determined by the amount of rainfall, modified by local topography and drainage properties (Moges *et al.*, 2010).

Currently, there is growing recognition that deforestation and forest degradation should be reduced. In the country, the government has identified the forestry sector as one of the pillars of green economy that the country is planning to build by 2030 (Gashaw *et al.*, 2015). The following major targets were set for the forestry sectors: afforestation on 2 million ha, reforestation on 1 million ha and improved management of 3 million ha of natural forests and woodlands. Through proper management of 5 million ha of forests and woodlands, Ethiopia hopes to achieve 50% of its total domestic greenhouse gas (GHG) emissions abatement potential by 2030 (Limenih and Kassa, 2014).

Analysis of satellite images in Ethiopia indicated that forest cover increased by up to 15.6% between 2001 and 2006 during the time the forest blocks were under community management but on the contrary, deforestation of up to 16% was observed in the forest areas outside PFM (Bekele, 2011).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted at Chilimo forest, located in West Showa Zone of Oromia National Regional State, Ethiopia, which is situated 7km north of Ginchi town, Capital of Dendi District on the main road running to Ambo, at 90 km west of Addis Ababa. This area is at the western end of a chain of hills and ridges that stretches 200 km from north of Addis Ababa westwards up to the Gedo Highlands. River valleys and gorges cut through the hills. Chilimo forest is geographically located between 38°05'E to 38º15'E longitude and 9°00'N to 10º08'N latitude with an altitudinal range between (2,000 to 3,200) m.a.s.l. (Shime, 2014). Chilimo forest is one of the few remnants of dry Afro-montane forest that remain on Ethiopian Central Plateau (EWNHS, 1996). It is one of Government's Forest Priority Area surrounded by 7 Kebeles and the oldest PFM sites in Ethiopia. Boda/Dereba forest (i.e. the Non-PFM) is also one of the dry remnant forest found in the highlands of West Showa Zone of Dendi district, located on south of Chilimo National Forest Priority Area, 22km away from Dendi district capital, Ginchi; on the road running from Ginchi to Busa town (Erenso *et al*., 2014). It has 130 ha forest area coverage.

The main species in the canopy layers, especially in Chilimo forest are *Juniperus procera*, *Podocarpus falcatus*, *Prunus africana*, *Olea europaea subspecies cuspidata*, *Hagenia abyssinica*, *Apodytes dimidiata*, *Ficus spp*., *Erythrina brucei*, and *Croton macrosytachus* (Limenih and Bekele, 2008; Soromessa and Kelbessa, 2013). This makes it the main source of indigenous tree seeds for the central highlands. This forest is also home to some 150 bird species, of which five are Ethiopian endemics and many more are Afro Tropical Highlands' biome species (EWNHS, 1996).

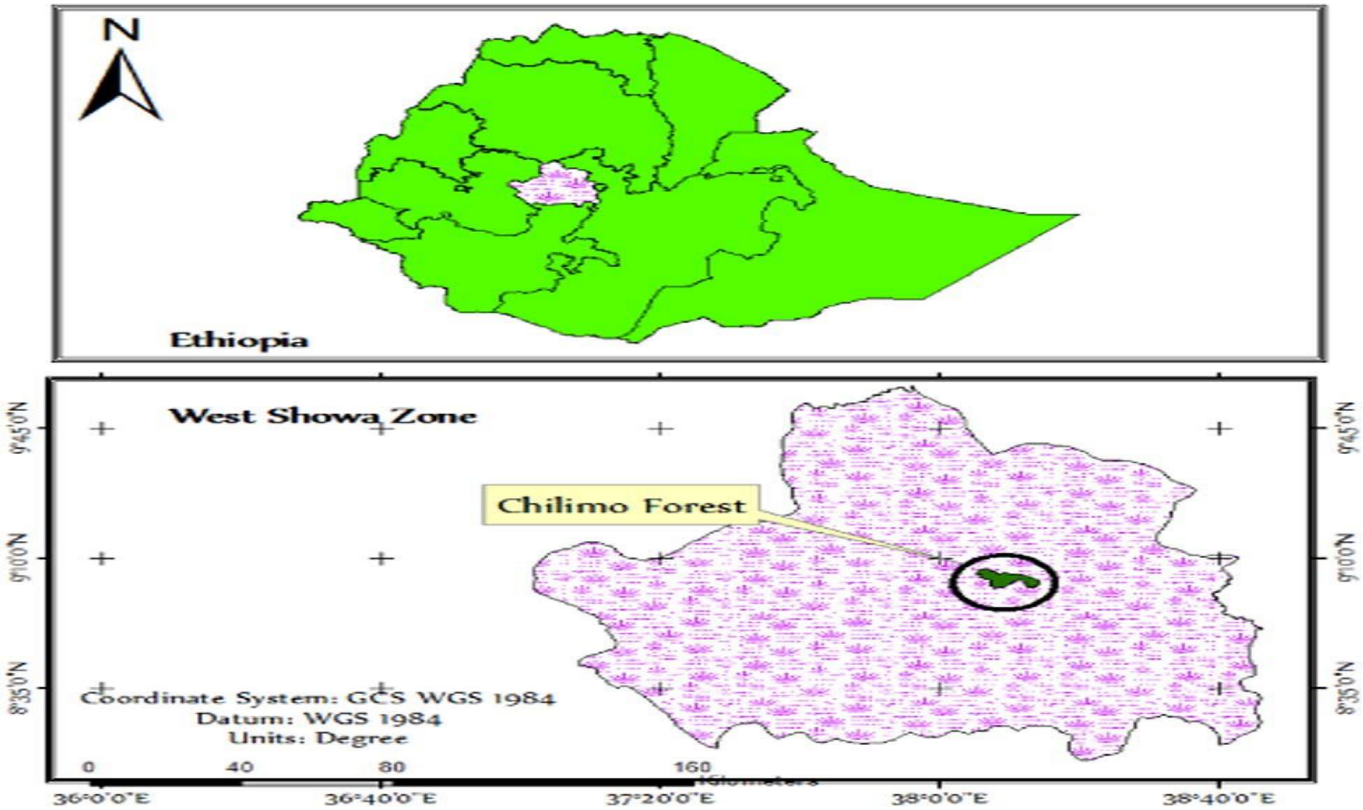


Fig. 2: Location map of the study area

3.1.1. Climate and agro-ecology

Dendi district has a tropical climate that is modified by altitude, and the mean maximum temperature is 23.3ºC while the minimum temperature is 9.6ºC (Shime, 2014). The diverse topographic features of the area represent a diverse climatic condition. The District encompasses **'highland'** and **'mid-highland'** agro-ecological zones. From an agricultural point of view it is actually unimodal, because farmers can only grow one rain fed crop per year. The agricultural season is closely associated with the rain fall pattern. The mean annual rainfall is 1, 264 mm, with a bimodal rainfall distribution of lower precipitation from November to January and there are five rainy months, May-September, with a peak in July (Tolessa *et al*., 2017). In the same way, Boda/Dereba forest also has similar geology and soils with exactly same agro-climatic zones to Chilimo forest (i.e. which is under PFM) (Erenso *et al.*, 2014).

3.1.2. Geology and soils

The main rock type in the area is basalt, and some areas are covered with other volcanic rocks of more recent formation (Tolessa *et al*., 2017). The soils are reddish brown, gravelly and shallow at higher altitudes, while at lower sites they tend to become dark-grey and deep. The soils in the surrounding low plains are vertisols, black soils with characteristic high clay content.

3.1.3. Socio-economic and livelihood activities

Agriculture remains the main occupation for most communities in the area. The forest is also a good contributor to the livelihood of the locals living in and around the forest. Major forest products exploited were firewood, charcoal and timber (Limenih and Bekele, 2008).

Communities inside and around the Chilimo forest engage in traditional agricultural activities such as animal raising and crop cultivation (Kebebew, 2012). Local communities use this forest also as a grazing land for their cattle. The forest is important to local people for grazing, fodder, commercial timber, subsistence food and fuelwood extraction, including herbal medicine for humans and animals, farm implements and construction poles, and occasionally non timber forest products. The community in the Boda/Dereba forest area also lead similar socio-economic and livelihood activities with heavy settlements occasionally practicing illegal cutting of forest patches to expand farmland (Erenso *et al.*, 2014).

3.2. Study Design

Study design used in vegetation inventory for seedlings, saplings, including the mature vegetation was conducted using systematic sampling;because,systematic sampling provides a degree of control and sense of process, and also conducive to covering a wide study area since the study objects are systematically selected and represented in the sampling system. During inventory, sampling was conducted following transect lines established along altitudinal gradient in the forest matrices. This study was conducted in both PFM (i.e. Chilimo forest) and Non-PFM (Boda/Dereba forest) forest sites for woody species composition and regeneration status comparison. In that, four transect lines were established along the gradient in the forest landscape within both the PFM and non-PFM forest sites separately, leaving a buffer zone of some distances from the forest edge towards the inside to avoid edge effect. Along each of the transect lines, (i.e. ten quadrats within the PFM at every 200minterval along the transect lines (Hundera and Gadissa, 2008; Gobeze *et al.*, 2009; Molla and Kewessa, 2015), and the other ten quadrats within Non-PFM forest site at every 100m interval along transect lines between successive quadrats), with inventory quadrat dimension of (**20mx20m=400m^2** each) laid on forests' ground to carry out the selected woody species inventory for regeneration assessment, and to compare regeneration status in both the PFM and Non-PFM forest sites. The distance between successive transect lines established for vegetation inventory at both PFM and Non-

PFM forest sites is set to be 300m. The first and onset, head transect line with quadrat on ground was laid randomly starting from the bottom side and then, such a process continued for the overall eighty quadrats established along the eight transect lines separately (i.e. four in PFM and the other four in Non-PFM forest sites). This inventory design have taken into account and worked for tree and shrub species seedlings', saplings' including the mature vegetation. Also at the same time, selected woody species inventory from the quadrats and measurement,to classify and record them within the pre-designed size classes, and total species count was undertaken.

3.3. Sampling Techniques

As previous finding shows, the dominant woody species known to be found at Chilimo and the surrounding forest are *J. procera, P. falcatus, P. africana, O. europaea, and H. abyssinica* (Soromessa and Kelbessa, 2014). So that, deliberate inventory for the selected woody species of tree and shrub type seedlings' recommended to be in height classes ≤ 1.5m and saplings within height classes > 1.5m to 5m, including the mature vegetation within height classes > 5m of nine (**9**) species from tree type: (*Juniperus procera, Podocarpus falcatus, Prunus africana, Olea europaea subspecies cuspidata, Hagenia abyssinica, Apodytes dimidiata, Ficus spp., Erythrina brucei, and Croton macrosytachus* species)and some other plants (*Myrsine africana and Maytenus arbutifolia* from dominant shrub species) in the forest landscape on each and every quadrats along transect lines were selectively measured(i.e. seedlings within **0.10 ≤ X ≤ 1.5m** and saplings within **1.5 < X ≤ 5m** height classes were measured using **graduated measuring staff/measuring stick**, and the mature vegetation with trunk height of **5 < X ≤ 35m** using **Suunto clinometer**), counted and recorded each, as per the design parameters considered for vegetation regeneration assessment. Whereas, DBH for both tree and shrub species seedlings, saplings and the mature vegetation were measured and recorded at one tenth of the respective height of the target study woody species encountered (Gobeze *et al.*, 2009; Feroz *et al.*, 2016, Endris *et al.*, 2017, and Elliott *et al.*, 1997). So that, the selected sample woody species seedlings' and saplings', including the mature vegetation's DBH were measured using **diameter tape** and/or **caliper** as appropriate,and then recorded and listed within DBH size classes for both tree and shrub type woody species (i.e. DBH classes: a = 0.10 ≤ X ≤ 10.06cm, b = 10.06< X ≤ 20.02cm, c = 20.02< X ≤ 29.98cm, d = 29.98< X ≤ 39.94cm, and e = 39.94< X ≤ 49.90cm) during vegetation inventory.

But, in this sampling techniques, tree and shrub species seedlings, saplings and mature vegetation with trunk height < 0.10m and DBH < 0.10cm were not recorded since it is too small to measure and most importantly also because of its' low survival and establishment possibility (Endris *et al.*, 2017).

3.4. Data Collection Method

Primary data sources were employed as input to thesis research preparation. The required primary data which are pertinent to the thesis work as input, in vegetation regeneration assessment were collected through inventory. The inventory was carried out starting from March 30-April 17, 2018.

In the process, identification, measurement and recording for the selected woody species on the important variables were carried out. While conducting vegetation inventory for regeneration assessment, experienced local people and experts for species identification at seedling and sapling stage including the mature were used.

During inventory, the selected woody species of tree and shrub type were measured, counted and recorded at each and every laid quadrats along the transect lines, established in the forest landscapes of PFM and Non-PFM forest sites.

While conducting vegetation inventory and recording within the height and DBH size classes, for the selected tree and shrub type seedlings, saplings,including mature vegetation, the distance of each and every seedlings, saplings and the mature vegetation from the nearby and closest mature/mother vegetation of the type was considered, and measured using **measuring tape** and then recorded to identify it, as an agent for regeneration influencing factor around. Location and altitude of inventory quadrats along the transect lines were also recorded using **GPS-Garmin 72** to identify favorable locations for every selected sample woody species for regeneration assessment and identification of variations in species occurrence (density and frequency as well as dominance level) of the selected woody species (seedlings, saplings and mature of tree and shrub type).

3.5. Data Analysis

After collecting and recording all the input data on variables and the parameters dealt with on selected woody species of seedlings, saplings and the mature vegetation, data analysis was carried out using different computing formulae. In this, important value analysis for the distribution of plant species in the forest landscape of forest sites within the various established DBH and height size classes: basal area (the actual space covered by the tree and shrub species), density, frequency, abundance, dominance and Importance Values Index (IVI) formulae (Endris *et al.*, 2017) were used.

Therefore, density and relative density of each selected woody species were computed (Kent and Coker, 1992) as:

$$\boldsymbol{Density\ (D)\ =\ \frac{Number\ of\ individuals\ of\ species\ 'a'}{Total\ sampled\ (quadrat\ area)\ (ha)}}$$

$$\boldsymbol{Relative\ density\ (RD)\ =\frac{Number\ of\ individuals\ of\ species\ 'a'x100}{Total\ number\ of\ individuals\ of\ all\ species}}$$

Frequency and relative frequency of occurrence of species was also calculated (Kent and Coker, 1992) through:

$$\boldsymbol{Frequency\ (F) = \frac{Number\ of\ quadrats\ in\ which\ species\ 'a'occurred}{Total\ number\ of\ quadrats\ studied}}$$

$$\boldsymbol{Relative\ frequency\ (RF)\ = \frac{Frequency\ of\ occurrence\ of\ species\ 'a'x100}{Total\ frequency\ of\ occurrence\ of\ all\ species}}$$

The number of individuals of different species in the community in the area was computed as:

$$\boldsymbol{Abundance\ (A) = \frac{Total\ number\ of\ individuals\ of\ species\ 'a'in\ all\ quadrats}{Total\ number\ of\ quadrats\ in\ which\ 'the\ species'\ occurred}}$$

The coverage value of a species with respect to the sum of coverage of the rest of the species (Mueller-Dombois and Ellenberg, 1974) in the area was calculated using:

$$\boldsymbol{Dominance\ (Do) = Total\ basal\ cover\ of\ species\ 'a'in\ (ha)}$$

$$\text{BA} = \frac{\prod (DBH)^2}{4}$$

where, $\pi = 3.14$

BA = basal area (m^2)

DBH = diameter at breast height in (cm)

Diameter for both woody species seedlings and saplings were measured using diameter tape, but caliper used for the mature vegetation measurement, and then the input diameter value used in basal area calculation.

$$\boldsymbol{Relative\ dominance\ (RDo) = \frac{Total\ basal\ area\ of\ species\ 'a'X\ 100}{Total\ basal\ area\ of\ all\ the\ species}}$$

To determine the overall importance of each species in the community structure (Kent and Coker, 1992), below formula was used:

$$\boldsymbol{Importance\ Value\ Index = Relative\ frequency + Relative\ density + Relative\ dominance}$$

$$\boldsymbol{IVI}\ (\%) = \boldsymbol{RF + RD + RDo}$$

Sorensen's similarity coefficient was calculated (Whittaker, 1975 and Kent and Coker, 1992) for phytogeographic comparisons of vegetation in both the PFM and Non-PFM forest blocks as:

$$\mathrm{Ss} = \frac{2a}{(2a + b + c)}$$

where, Ss = Sorensen's similarity coefficient, a = number of species common to both samples, b = number of species in sample 1, and c = number of species in sample 2

For timely, precise and relevant statistical results, some important software was used. In that, SPSS-Version 20 was used in the analysis of the comparative vegetation composition, distribution and individual's occurrence frequency of target study woody species of PFM and Non-PFM forest sites. Microsoft Excel also used, to analyze vegetation growth variables' output result such as density, frequency, abundance, dominance/basal area and importance value index of study vegetation to assess vegetation regeneration status. Additionally, PAST-Version 3.18was used to analyze and derivesymmetry and species likelihood (normal distribution model).

4. RESULTS AND DISCUSSION

4.1. Woody Species Composition

The selected woody species for study is composed of eleven native and four exotic species of tree and shrub type, generally classified into twelve families (**Table 2**). When taxonomically aggregated, the study woody species inventoried for regeneration status assessment consists of eleven definitive species taxon varying in their characteristic habit/growth form. This finding agrees with the study on useful trees and shrubs of Ethiopia by (Fichtl and Adi, 1994, and Bekele-Tesemma and Tengnäs, 2007). The major familywas Rosaceae, represented by two species with 18.18% family coverage. From the selected study woody species, it was discovered that *J. procera*and *M. africana*with (37.31%) and (30.15%) coverage respectively for theNon-PFM, as well as *J. procera*and *O. europaea*with (30.26%) and (23.25%) one after the other for the

PFM forest sitehave been found to be the most dominant and abundant species at the site. This study result is consistent with study conducted on Chilimo forest by (Soromessa and Kelbessa, 2014).

Table 2: Study woody species with their possible classification units

Scientific name	Local name	Origin	Family	Growth form
Juniperusprocera	Gaattiraa	Indigenous	Cupressaceae	Tree
Podocarpusfalcatus	Birbirsa	Indigenous	Podocarpaceae	Tree
Prunusafricana	Gurraa	Indigenous	Rosaceae	Tree
Olea europaea	Ejersa	Indigenous	Oleaceae	Tree
Hageniaabyssinica	Heexoo	Indigenous	Rosaceae	Tree
Apodytesdimidiata	Calalaqaa	Indigenous	Icacinaceae	Tree
Ficus sur	Harbuu baddaa	Indigenous	Moraceae	Tree
Erythrinabrucei	Waleensuu	Endemic	Fabaceae	Tree
Croton macrosytachyus	Bakkanniisa	Indigenous	Euphorbiaceae	Tree
Myrsineafricana	Qacama	Indigenous	Myrsinaceae	Shrub
Maytenusarbutifolia	Kombolcha	Indigenous	Celastraceae	Shrub

4.2. Species Occurrence Frequency

From the finding, frequency of occurrence of species in the PFM and Non-PFM forest sites differed, so that the number of individuals of *P. falcatus, P. africana, O. europaea, H. abyssinica, A. dimidiata, F. sur, E. brucei, C. macrostachyus and M. arbutifolia* species encountered and registered were comparatively higher in the PFM. Whereas, the number of individuals of *J. procera* and*M. africana*species occurring in Non-PFM exceeded that of the PFM forest site. Because, *M. africana* is the highly extracted species for housing and other different domestic purposes due to its characteristic durability for use, since it is robust and slender in its nature, and prone to be extracted mostly from the PFM forest site by local residents. *J. procera* species is also being exploited as timber and for other different construction purposes by local residents from the forest site.From the study species, none of *H. abyssinica, A. dimidiata, F. sur, E. brucei* species recorded in Non-PFM forest sites at all. As the study result of the inventory of woody species for regeneration assessment indicated, the entire eleven target study woody species were evident to be found and have been recorded in the PFM. But, on the contrary only seven of the study woody species have been recorded in the Non-PFM forest site. In the forest sites, some species exhibited J-shape (**Fig 5a, 5b, 5j and 5l**) and many others showed bell-shape profile (**Fig 5c, 5d, 5e, 5i, 5m, 5n and 5o**) in their distributional pattern. Some others showed irregular shapes with unusual pattern. On the other hand, at some points on the graphically represented study woody species; there were broken-spaces/gaps in vegetation distributional structural profile indicating that, there was no actual/live vegetation record at the area for the respective study woody species in the forest sites.

From the gathered data analysis summary, differences in number of individuals of woody species, species composition as well as species distribution observed in both forest sites across the forest patches and matrices along slope with altitudinal gradient change. These observable variations in number of individuals of species, woody species composition and distribution may be attributed to the relative direction of vegetation to the daily sun exposure and other environmental variables such as soil properties, moisture, terrain physiognomic features, and altitudinal and slope aspect. This agrees with the result obtained by (Didita *et al.*, 2010) that, differences in the species composition of the plant communities are attributed to environmental variables such as soil properties, moisture and aspect.

The two forest sites regarded as independent but comparable forest matrices, consisting of vegetation community has 0.268 Sorensen's similarity coefficient, indicating that the two forest sites are low in their similarity.

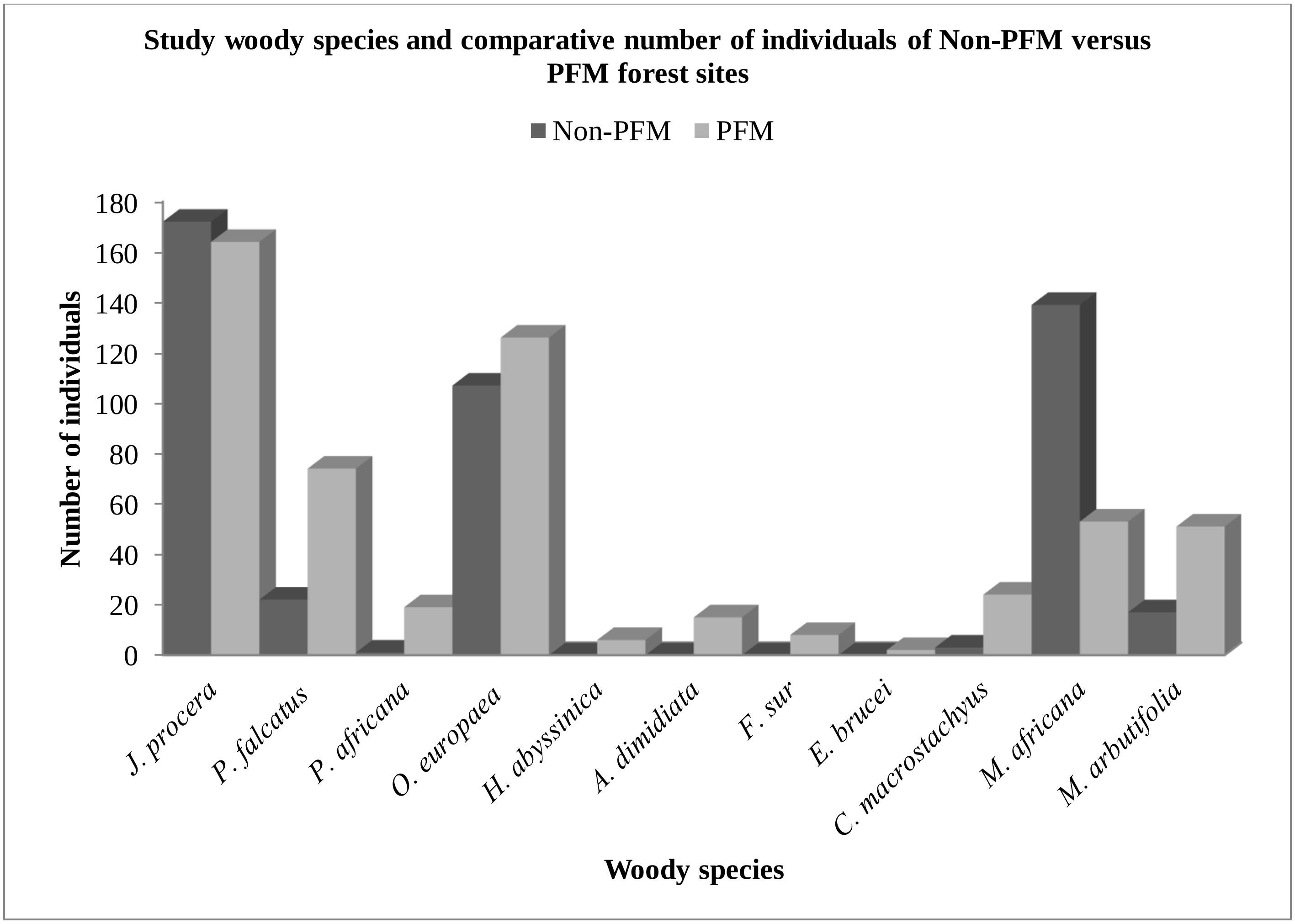


Fig. 3: Woody species composition and comparative number of individuals

***PFM forest block = Chilimo forest**

***Non-PFM forest block = Boda/Dereba forest**

4.2.1. Species occurrencelikelihood trend (normal distribution)

In species likelihood analysis, species distribution and occurrence frequency in the Non-PFM and PFM forest site independently progresses by a factor of (+0.69178) with y-intercept of (+20.281), and standard error of mean (S.E-Mean) of x-coefficient (a-value) of (±0.14766) and intercept (b-value) of (±11.008) respectively indicating that there is positive increment and change in species occurrence and distribution across the forest blocks, with highly significant distribution at (slope = 0; $p < 0.05$) and x-intercept of (-

29.3171239). This graph (**Table 3**) shows that, there is a symmetrical change in species occurrence and distribution across the forest blocks.

Table 3: Normal distribution, identity link for species likelihood

Dispersion *phi*: 911.78 (estimated)	
Slope *a:0.69178*	Std. err. *a:0.14766*
Intercept *b: 20.281*	Std.err. *b: 11.008*
Log likelihood: *-4.5*	
G:21.948	*p*(slope=0): $2.801*10^{-6}$

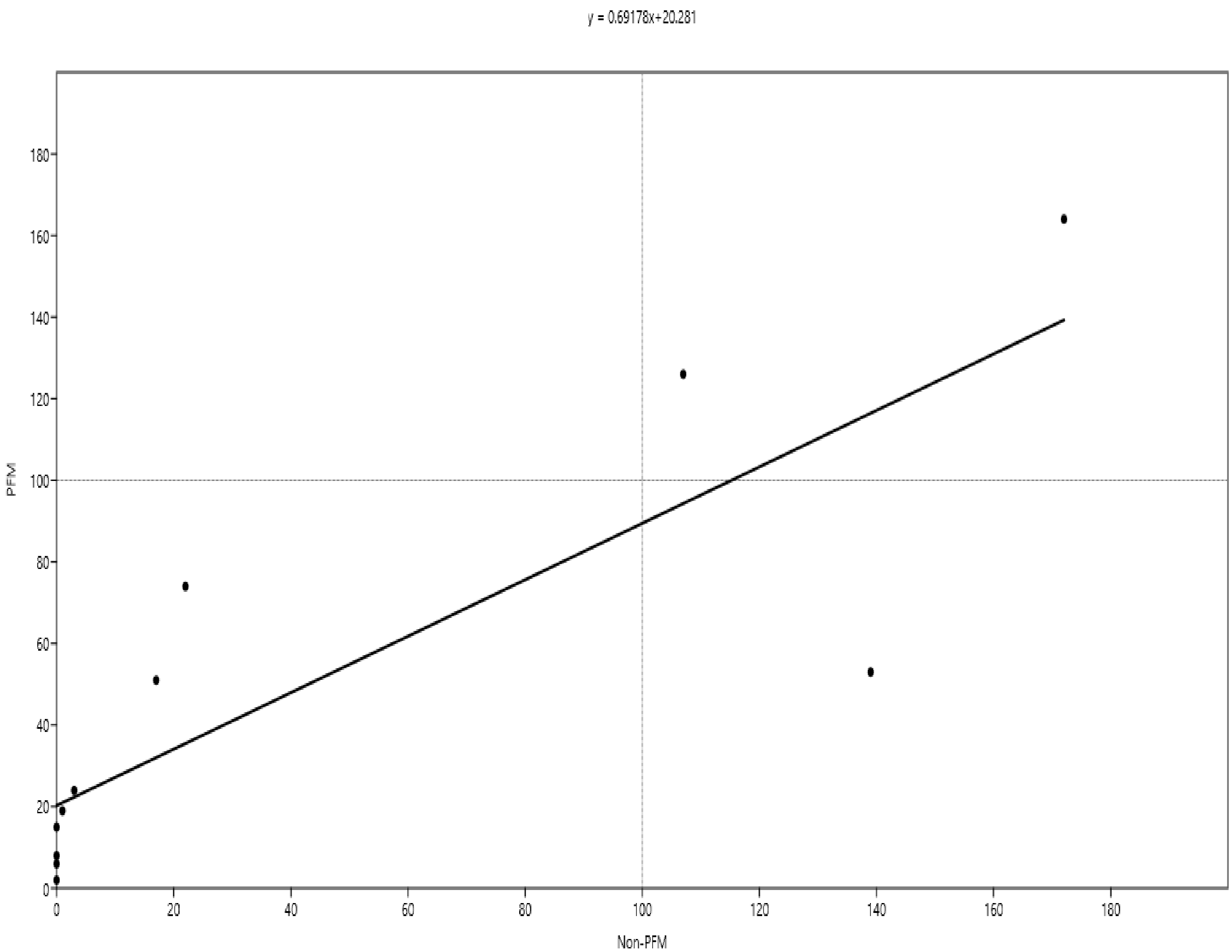


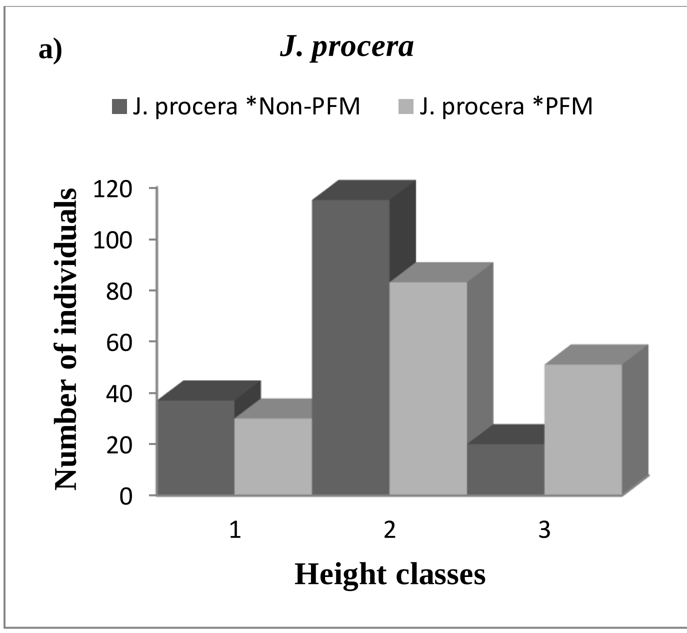
Fig. 4: Generalized linear model for species occurrence likelihood for the respective Non-PFM and PFM forest sites

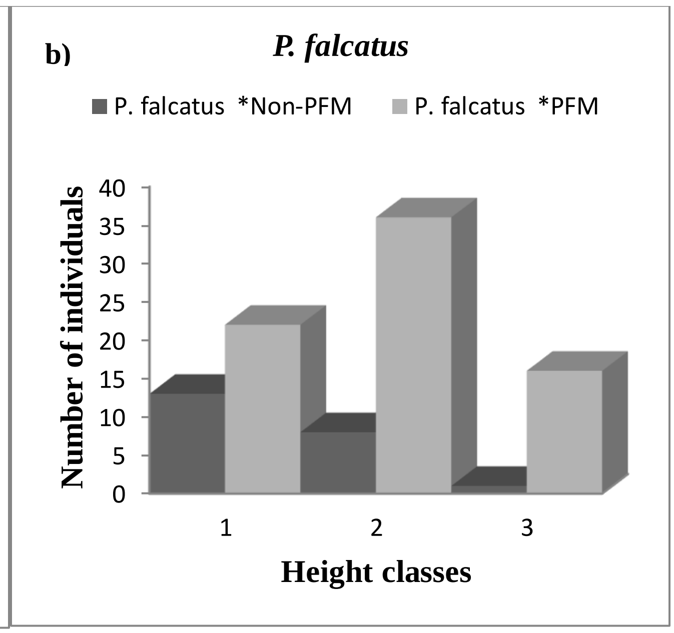
4.3. Species' Structural Arrangements and Profiles

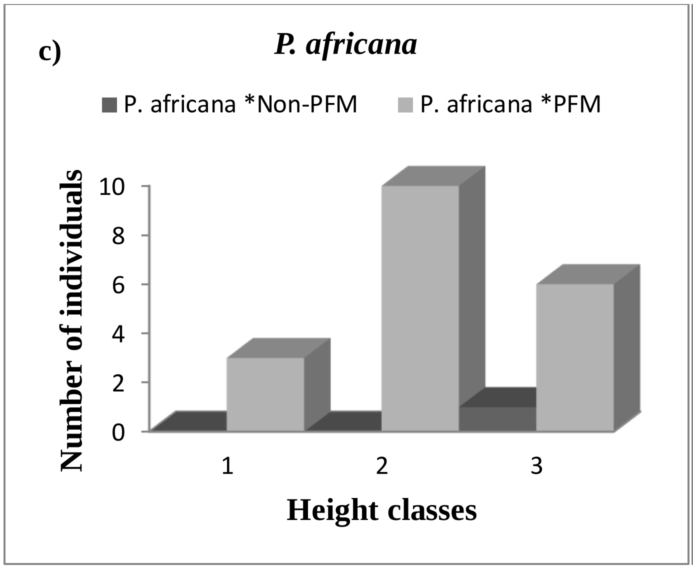
During inventory of seedlings and saplings of woody species, including the mature vegetation for regeneration status assessment, a total of 1,003species individuals for the eleven study species from a total of eightyquadrats (i.e. laid along the four transects,established in Non-PFM and PFM forest sitesalong the altitudinal gradient starting from the bottom side of the forests' landscape- from every quadrats of thetwo forest sites,with fixed quadrat dimension of (20m*20m = 400m^2 each)) recorded. Then, vegetation inventory was conducted accordingly as per the pre-designed study design. So that, when conducting the practical on-ground inventory of seedlings and saplings including the mature vegetation for the selected woody species of tree and shrub type, recording and listing of each and every species was madewithin the appropriate height and DBH size class categories. Accordingly, the selected study woody species seedlings' and saplings', including the mature vegetation's DBH were also measured and recorded within the appropriate pre-defined DBH size classes for both tree and shrub type woody species. From the analysis summary, the study woody species were self-explanatory as depicted on the respective species-specificindicative summary graphs (i.e. number of species individuals in the height and DBH size classes) (**Fig. 5 and 6**), in their distributional structural profiles, consistently exhibiting differing structural patterns due to differences in number of species individuals and species occurrence frequency across the size classes.So that, along with the respective study woody species' height and DBH measurement and recording within the pre-designed size classes, the analysis summary graphical portray clearly implied that, there existed concrete information that there was moderately effective and sustainable forest management, especially in the PFM forest site.

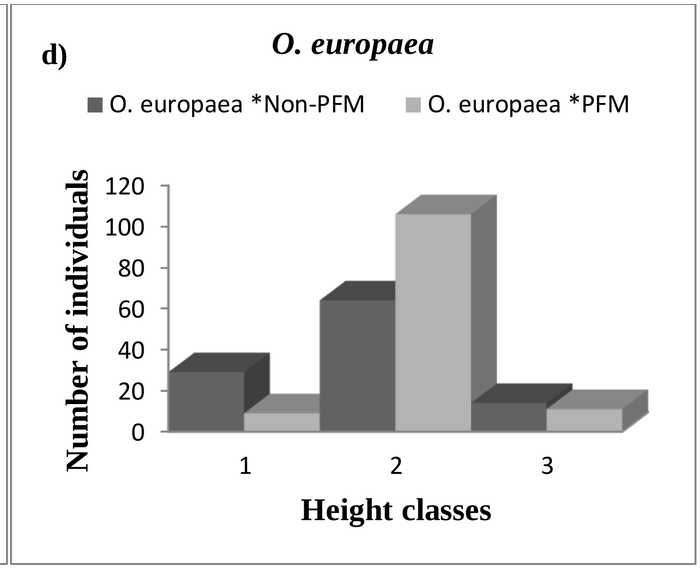
4.3.1. Species'height profiles

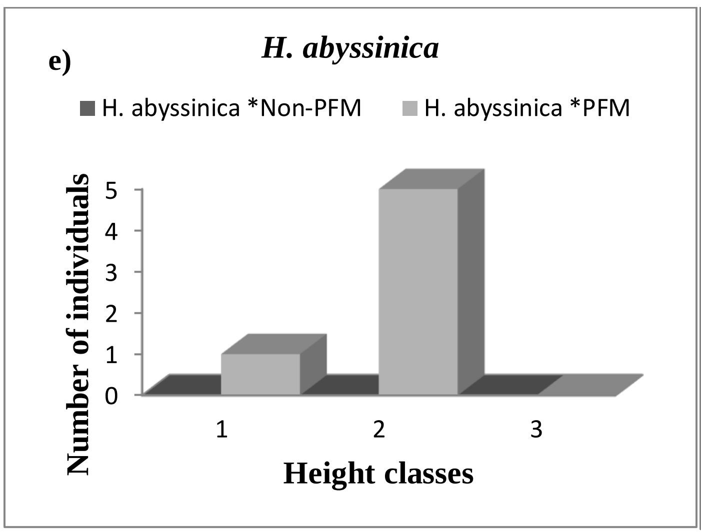
Great variation in target study woody species for species individuals observed within allstudy quadrats, even within every single height size class categories between and within Non-PFM and PFM forest sites. The structural profiles and patterns difference and dissimilarity of species exhibited within height size classes were due to the differing number of individuals observed and recorded,and differences in species distribution evident in the size classes. In the same way, comparatively higher numbers of species individuals have been recorded in the PFM forest site, excluding for*J. procera* and *M. africana* species which are far greater in Non-PFM. But, most of the species occurrence frequency in the height size classes have shown distribution mode of increment towards sapling classes from seedling but showed decreasing trend towards mature vegetation from sapling for both Non-PFM and PFM forest sites. Most of the distributional profiles exhibited almost nearly bell-shaped patterns (**Fig. 5a, 5b, 5c, 5d, 5e, 5f, 5h, 5i, 5j** and **5k**) and few of them showed J-shape profile (**Fig. 5c**) and inverted J-shape pattern (**Fig. 5c**), and the other one showed U-shape curve (**Fig. 5g**).This trend also implies that, the number of species individuals recorded in the middle height classes (i.e. for sapling classes)wasbigger as compared with number of species individuals registered in the seedling classes.

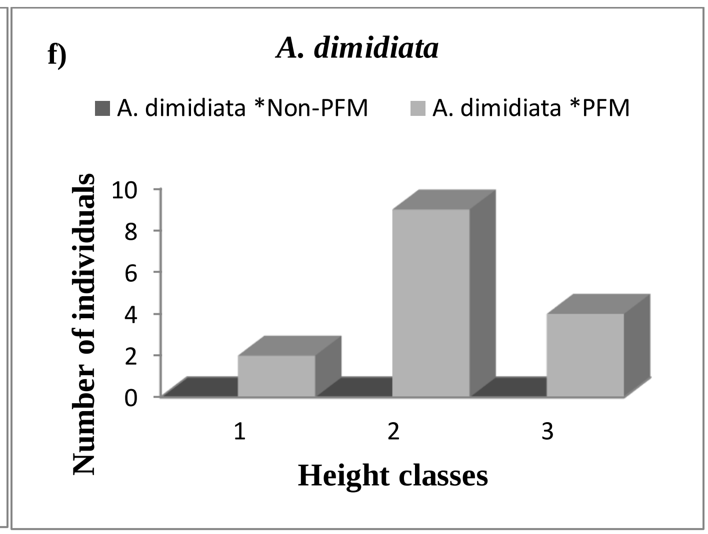


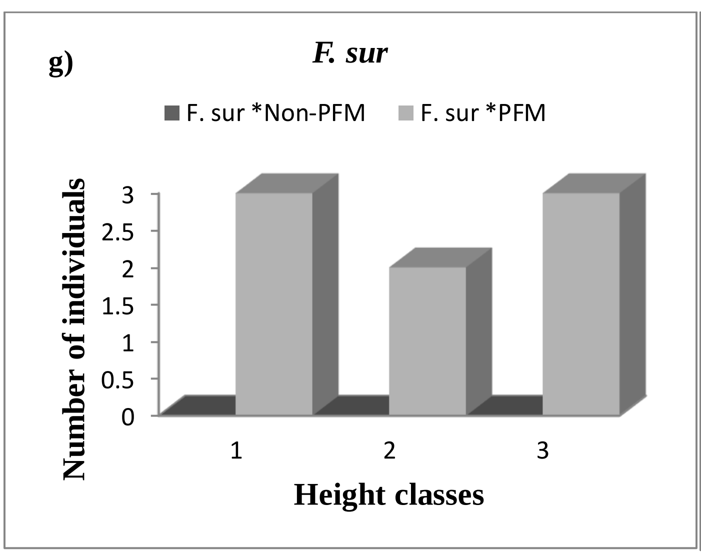


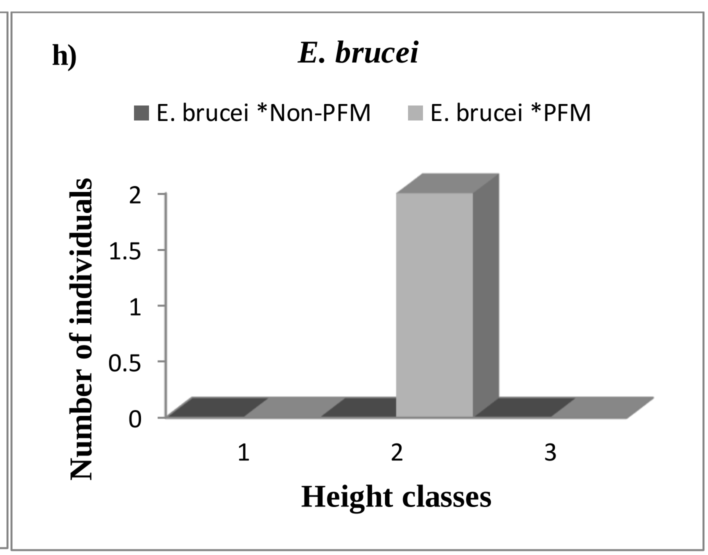

c)
P. africana
P. africana *Non-PFM
P. africana *PFM
Number of individuals
0
2
4
6
8
10
1
2
3
Height classes

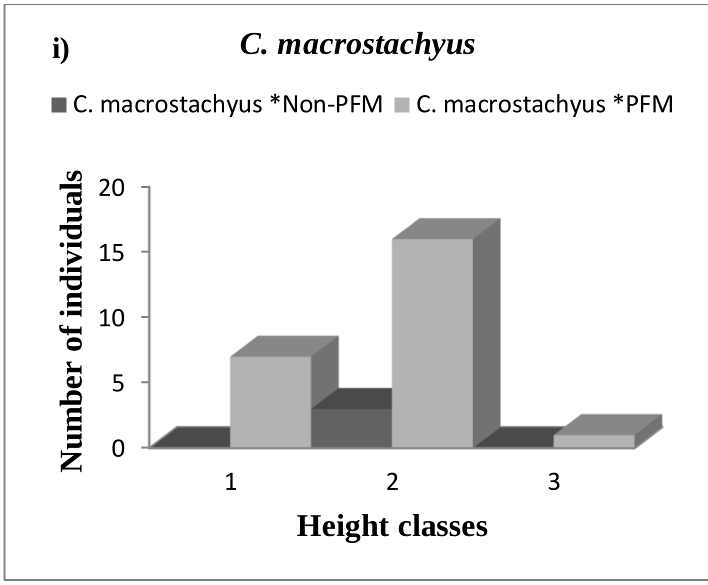

d)
O. europaea
O. europaea *Non-PFM
O. europaea *PFM
Number of individuals
0
20
40
60
80
100
120
1
2
3
Height classes

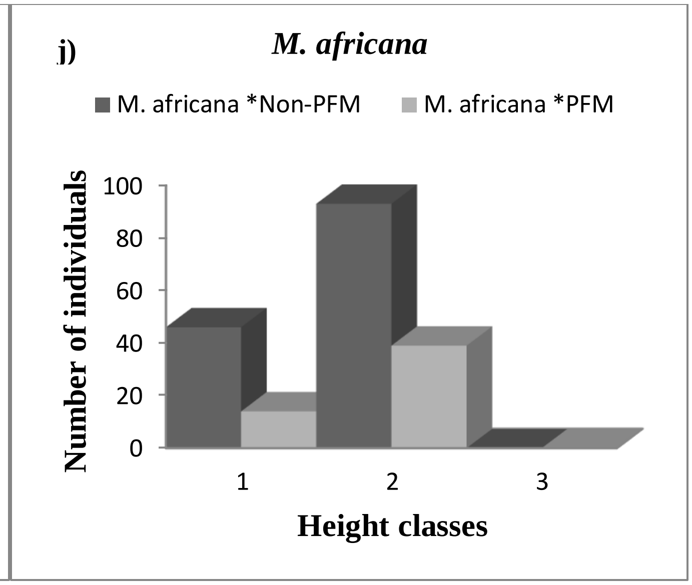

e)
H. abyssinica
H. abyssinica *Non-PFM
H. abyssinica *PFM
Number of individuals
0
1
2
3
4
5
1
2
3
Height classes

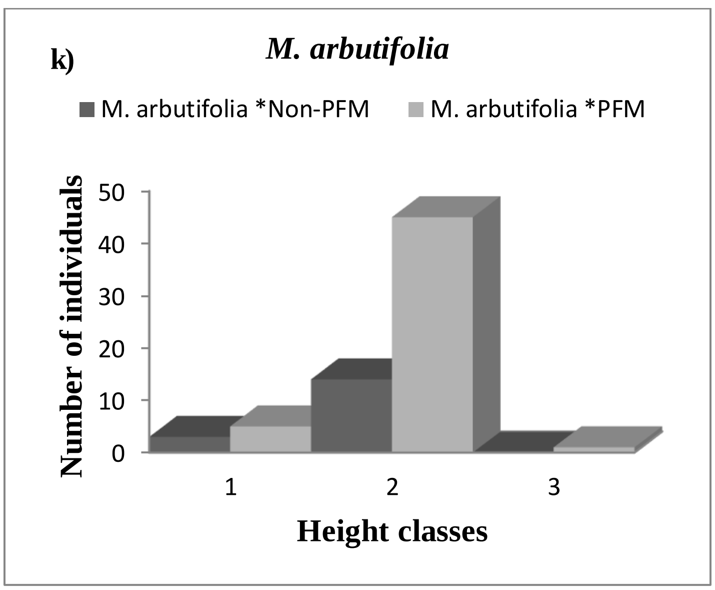

f)
A. dimidiata
A. dimidiata *Non-PFM
A. dimidiata *PFM
Number of individuals
0
2
4
6
8
10
1
2
3
Height classes


g)
F. sur
F. sur *Non-PFM
F. sur *PFM
Number of individuals
0
0.5
1
1.5
2
2.5
3
1
2
3
Height classes


h)
E. brucei
E. brucei *Non-PFM
E. brucei *PFM
Number of individuals
0
0.5
1
1.5
2
1
2
3
Height classes





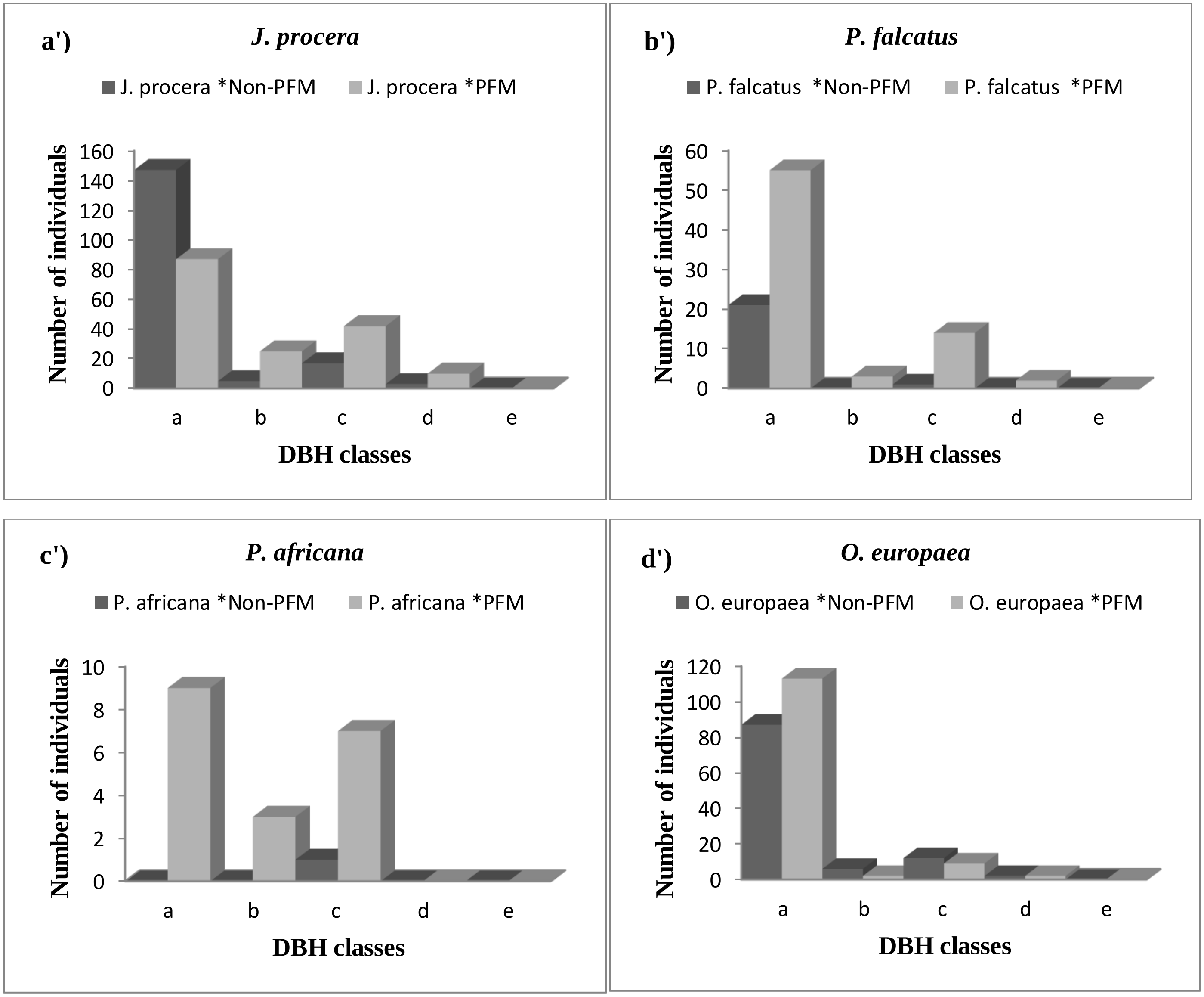


Note: Notations for species distribution by height size classes:
1 = $0.10 \leq X \leq 1.50$m … **(Seedling classes)**
2 = $1.50 < X \leq 5.00$m … **(Sapling classes),** and
3 = $5.00 < X \leq 35.00$m … **(Mature vegetation classes)**

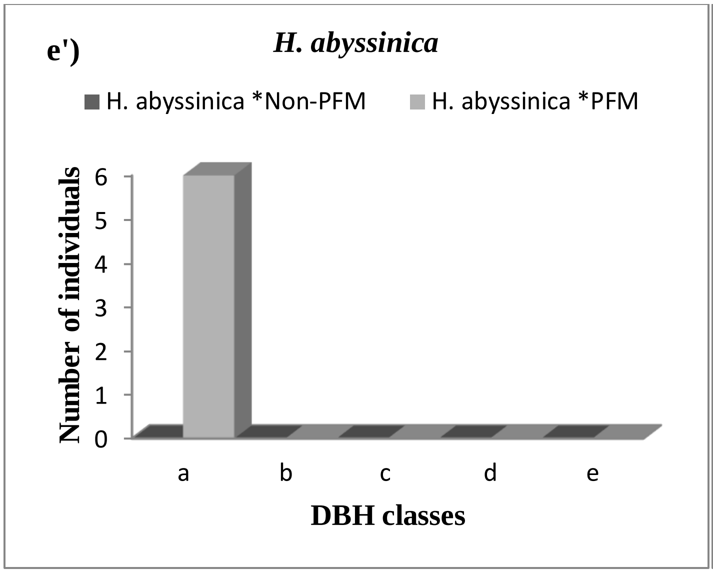
Fig. 5: Representations for species height profiles

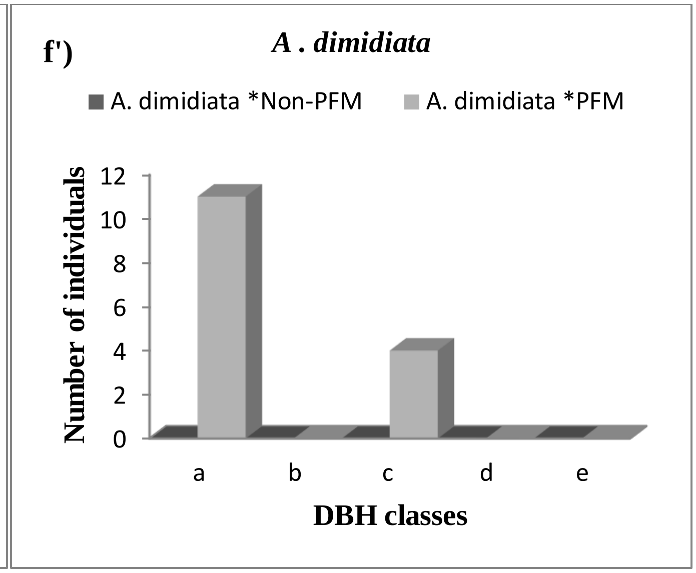
4.3.2. Species' DBH profiles

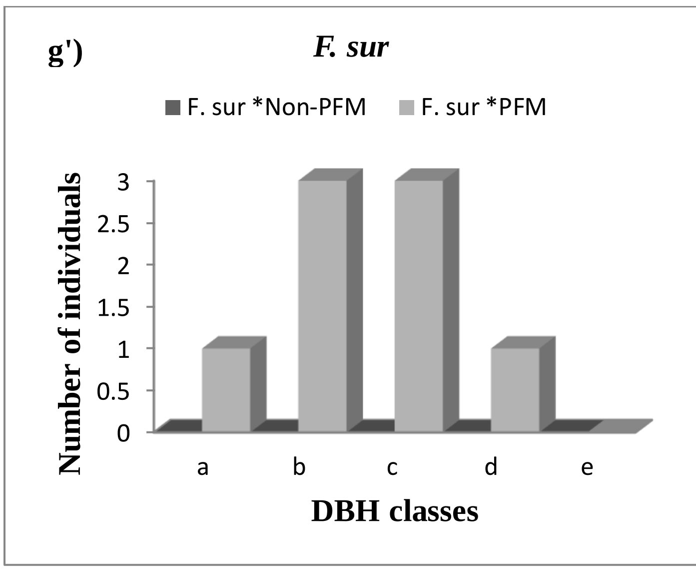
As the analysis of the gathered data revealed, some woody species like *C. macrostachyus, M. africana and M. arbutifolia* recorded at Non-PFM forest site, and *H. abyssinica and M. africana* registered at PFM lie in the higher lower single/first DBH size class because of their relatively smaller bole sizes. In the result summary, variations in number of species individuals occurring within the DBH size classes as well as species density across the forest blocks observed. As a result of the revealed variations in number of species individuals occurringwithin the DBH size classes, varying structural pattern observed – with species individuals' DBH class coverage of 89.81%, 2.39%, 6.72%, 1.08% and 0% at Non-PFM as well as 75.28%, 7.01%, 14.94%, 2.77% and 0% at PFM forest sites up the DBH classes respectively. So, generally briefing, higher number of species individuals lies in the lower DBH size classes, with sharply decreasing trends up the DBH size classes. The study result also consistently indicated that, there is 14.94% more species individuals' record with comparatively higher vegetation regeneration status at the PFM forest site. In species distribution depicting graphs, decrease in number of species individuals with increase in DBH size observed (**Fig. 6h'**),showing sharp and continuous inverted J-curve. This finding result is similar with (Soromessa and Kelbessa, 2014) that, the number of individuals of species decreases with increase in DBH size.This also more or less agrees with the result obtained by (Didita *et al.,* 2010) that, pattern of normal population structure where species pertinent to the study has the highest number of individuals at lower DBH and height classes with gradual decrease towards high DBH and height size classes.So that, 63.64% of the species in DBH size classes (i.e. **Fig. 6a', 6b', 6d', 6e', 6i', 6j' and 6k'**) have exhibited distributional structural profile of the general pattern of normal population structure where the majority of the study woody species have the highest number of individuals at lower DBH size classes showing gradual decrease towards higher DBH classes. This distributional pattern also indicates that, there is healthy regeneration (good reproduction) and recruitment potential of the vegetation. Some also showed U-shape profile (**Fig. 6c' and 6f'**) kin their distributional pattern. On the contrary, some ~~most~~ of the species have exhibited bell-shaped curves (**Fig. 6g'**) in general. In some DBH size classes even no species inventory and record was evident for the Non-PFM site showing that it is devoid-of-vegetation, forming one of the earlier described patterns probably indicating that, there was selective and discriminate cutting of woody species/vegetation. This is also because of the removal of tress for different purposes, like for construction and fuelwood. This goes in line with study on Belete forest (Gebrehiwot and Hundera, 2014) described as; density of individuals in the lower DBH class is very high but becoming lower in the higher DBH classes due to selective cutting.

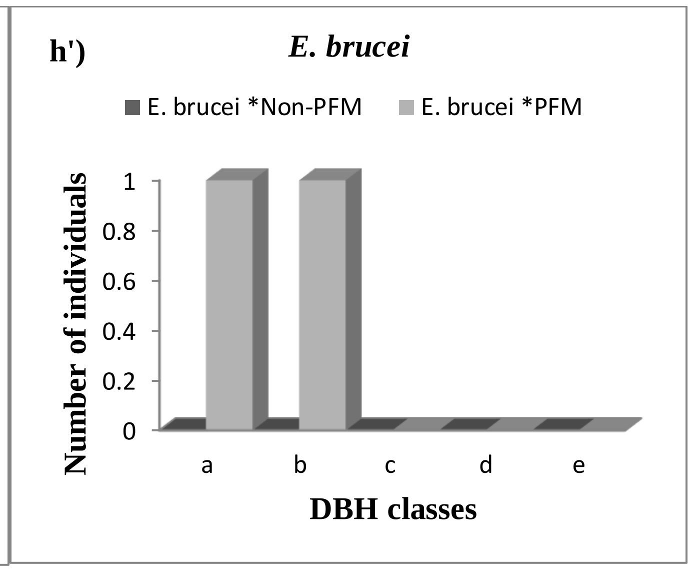


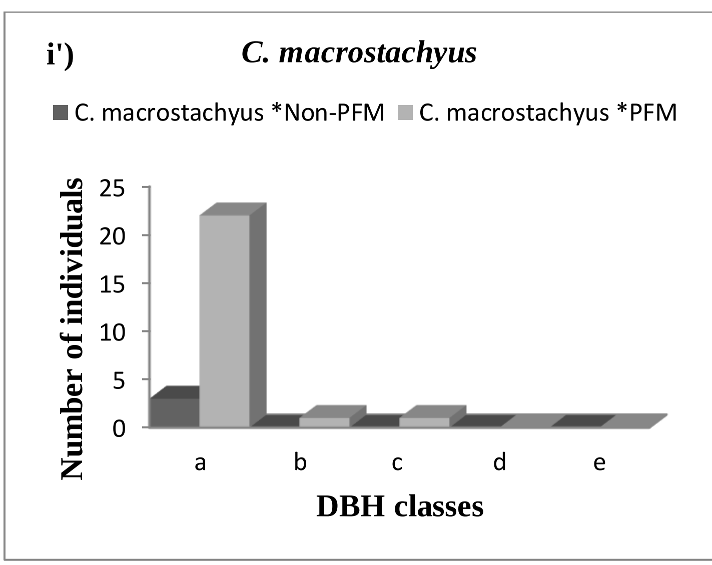
a')
J. procera
J. procera *Non-PFM
J. procera *PFM
Number of individuals
0
20
40
60
80
100
120
140
160
a
b
c
d
e
DBH classes
b')
P. falcatus
P. falcatus *Non-PFM
P. falcatus *PFM
Number of individuals
0
10
20
30
40
50
60
a
b
c
d
e
DBH classes
c')
P. africana
P. africana *Non-PFM
P. africana *PFM
Number of individuals
0
2
4
6
8
10
a
b
c
d
e
DBH classes
d')
O. europaea
O. europaea *Non-PFM
O. europaea *PFM
Number of individuals
0
20
40
60
80
100
120
a
b
c
d
e
DBH classes

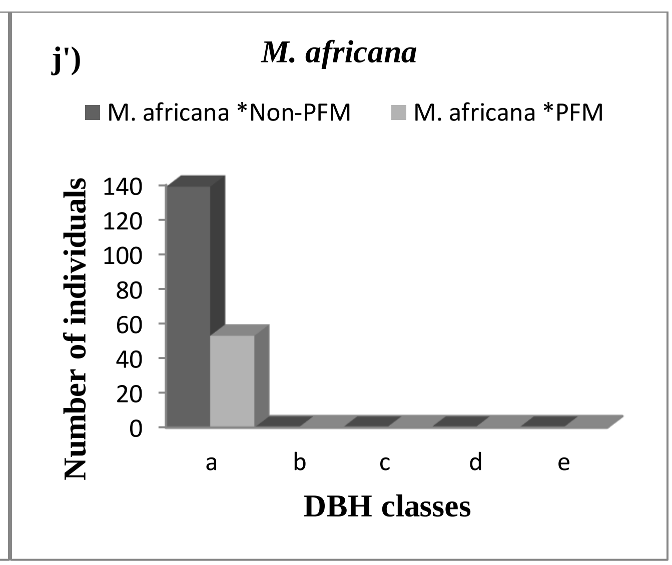

e')
H. abyssinica
H. abyssinica *Non-PFM
H. abyssinica *PFM
Number of individuals
0
1
2
3
4
5
6
a
b
c
d
e
DBH classes

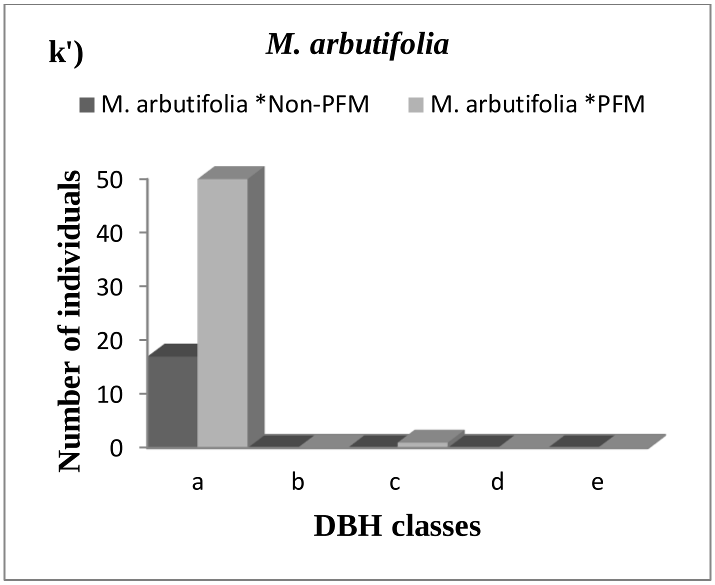

f')
A . dimidiata
A. dimidiata *Non-PFM
A. dimidiata *PFM
Number of individuals
0
2
4
6
8
10
12
a
b
c
d
e
DBH classes


g')
F. sur
F. sur *Non-PFM
F. sur *PFM
Number of individuals
0
0.5
1
1.5
2
2.5
3
a
b
c
d
e
DBH classes


h')
E. brucei
E. brucei *Non-PFM
E. brucei *PFM
Number of individuals
0
0.2
0.4
0.6
0.8
1
a
b
c
d
e
DBH classes


i')
C. macrostachyus
C. macrostachyus *Non-PFM
C. macrostachyus *PFM
Number of individuals
0
5
10
15
20
25
a
b
c
d
e
DBH classes


j')
M. africana
M. africana *Non-PFM
M. africana *PFM
Number of individuals
0
20
40
60
80
100
120
140
a
b
c
d
e
DBH classes



Note: Representations for species distribution by DBH size classes:

a = 0.10 ≤ X ≤ 10.06cm,
b =10.06 < X ≤ 20.02cm,
c = 20.02 < X ≤ 29.98cm,
d = 29.98 < X ≤ 39.94cm, and
e = 39.94 < X ≤ 49.90cm

Fig. 6: Representations for species DBH profiles

4.4. Vegetation Growth Variables and Regeneration Status Analysis Result of the Forest Sites

As evidentin the study result for regeneration status assessment, the relative number of individuals of seedlings and saplings, includingthe mature vegetation recorded in both the PFM and Non-PFM forest sites vary. Accordingly, the number of individuals of study vegetation encountered and recorded in the PFM is bigger by 14.94%. Comparatively, seedlings to saplings ratio at Non-PFM exceeds that of the PFM forest site, provided that the number of individuals of species recorded in the Non-PFM is greater by 36.898% in the seedling classes, but lower by the same 36.898% in the sapling classes.

The number of individuals of saplings recorded in both PFM and Non-PFM are bigger than the number of saplings in the respective forest sites, indicating that woody species of the forest performs well and so in fair regeneration status. The study also revealed that, even though mature vegetation of study woody species are in constant growth trending at the anterior part of the edge of the forest, exploitative deforestation was evident, especially on *O. europaea,* extracted mainly for charcoal making, tends to be used as source of income. In the same way, *J. procera* is also under exploitative deforestation and degradation impact. This finding is consistent with study result by (Soromessa and Kelbessa, 2013) in which *J. procera* is more affected than *P. falcatus* as pole for different construction purposes where inhabitants are more closer/nearby to the forest boundary in residence, tending to cause forest cover shrinkage.

In general, vegetation density for PFM is greater than for the Non-PFM forest site with a total density values of (338.75 individuals/ha) and (288.125 individuals/ha) respectively.

Table 4: Vegetation regeneration status

Forest sites	Vegetation density (individuals/ha)			Total density	Seedling to sapling ratio (in number of individuals)
	Seedlings/ha	**Saplings/ha**	**Mature vegetation/ha**		
Non-PFM	80	185.625	22.5	**288.125**	1:2.29
PFM	60	220.625	58.125	**338.75**	1:3.52
Total	**140**	**406.25**	**80.625**	**626.875**	**1:2.90**

From the species growth variables analysis result for vegetation regeneration assessment, the average overall vegetation density per hectare for Non-PFM site was (**41.164±16.919** individuals/ha), whereas for the PFM (30.797±10.010[a] individuals/ha) (**Table 5**). This also shows the generalgross density values of the entire study woody species, confirming that the density values of seedling and saplings are considered as regeneration potential of the species. From the analysis, the number of seedling < sapling > matures trees. This finding is inconsistent with that of (Kuma and Shibru, 2015), in which species is in good regeneration if the number of seedling < sapling > mature trees. But, the finding is consistent with the study on BMEMF by (Gebrehiwot and Hundera, 2014): 1) on the basis of regeneration category as "good" regeneration, if present in seedling > sapling > mature tree; 2) "fair" regeneration, if present in seedling < sapling > mature tree" in the following categories, and otherwise if not. In this case, the difference and dissimilarity in the number of individuals as well as species individuals observed and recorded in the height size classes in the case of such similar study that made number of seedlings and saplings recorded, different from this new finding is that, woody species with trunk height of ≤ 3.5m are classified as seedlings for these authors' case. Comparatively, bigger average species abundance (**2.485±0.298**individuals/quadrat)and basal area (**43.864±35.174**$\mathbf{m^2}$), including average DBH of (**8.549±1.956**cm) recorded in the PFM. On the contrary, the overall species in the Non-PFM forest site have relatively high ecological importance with IVI value of (**14.286±10.275**). For almost all vegetation growth variables,but not for the basal area, relatively bigger standard error of mean incurred in the Non-PFM forest site.

Table 5: Vegetation growth variables'possible ranges and their limits

Forest blocks	Average DBH (cm)	Individuals (N)	Species occurrence frequency (f) by quadrats	D	F	A	BA	RD	RF	RDo	IVI
Non-PFM	5.98±2.879[a]	**65.857±27.07**	**21.00±6.690**	**41.164±16.919**	**0.527±0.166**	2.249±0.493[a]	18.289±13.155[a]	**14.286±5.872**	**14.284±4.551**	**14.284±10.275**	**14.286±10.275**[a]
PFM	**8.549±1.956**	49.273±16.017[a]	18.546±4.513[a]	30.797±10.010[a]	0.467±0.113[a]	**2.485±0.298**	**43.864±35.174**	9.093±2.955[a]	9.092±2.213[a]	9.091±7.298[a]	9.090±3.768

[a]The comparative growth variables with possible lower bound values from the forest sites
Bold-faced numbers indicate variables with the highest upper bound possible values in the comparisons

Species inventory and analysis summary result showed that, higher number of species individuals recorded by *J. procera* (30.26%) and *O. europaea* (23.25%) followed by *P. falcatus* (13.65%), andthe least by *E. brucei (0.37%)*at PFMforest site. *O. europaea* species also has highest relative frequency of occurrence with (18.63%) followed by *J. procera* (18.14%), and the least by *E. brucei*species with (0.49%) (**Table 6**). Additionally, *J. procera*species has the highest basal area with (392.46m^2) followed by *O. europaea* (44.26m^2), and the least by *H. abyssinica and E.brucei* with (0.04m^2) each. But, the total basal area coverage for the overall study woody species assessed was (481.97m^2). *J. procera* was also the densiest species with (102.5 individuals/ha) followed by *O. europaea*with(78.75 individuals/ha), and the last and least *by E. brucei* (1.25 individual/ha). In the same way, *J. procera* has biggest IVI value of (43.27), implying that *J. procera* species have the highest ecological importance at the PFM forest site. Whereas, the least IVI value was recorded by *E. brucei* (0.29) with an indication of least ecological importance.

Table 6: Species growth variables' analysis output for the PFM forest site

Woody species	Average DBH (cm)	Individuals (N)	Species occurrence frequency (f) by quadrats	D	F	A	BA	RD	RF	RDo	IIVI
J. procera	13.63	164	37	102.5	0.93	4.43	392.46	30.26	18.14	81.43	**43.27**
P. falcatus	8.96	74	29	46.25	0.73	2.55	34.48	13.65	14.22	7.15	**11.67**
P. africana	14.36	19	9	11.88	0.23	2.11	5.84	3.51	4.41	1.21	**3.04**
O. europaea	5.96	126	38	78.75	0.95	3.32	44.26	23.25	18.63	9.18	**17.02**
H. abyssinica	3.69	6	3	3.75	0.08	2	0.04	1.11	1.47	0.01	**0.86**
A. dimidiata	7.77	15	9	9.38	0.23	1.67	1.07	2.77	4.41	0.22	**2.47**
F. sur	22.35	8	2	5	0.05	4	2.51	1.48	0.98	0.52	**0.99**
E. brucei	11.34	2	1	1.25	0.03	2	0.04	0.37	0.49	0.01	**0.29**
C. macrostachyus	3.37	24	12	15	0.3	2	0.51	4.43	5.88	0.11	**3.47**
M. africana	0.94	53	31	33.13	0.78	1.71	0.2	9.78	15.2	0.04	**8.34**
M. arbutifolia	1.67	51	33	31.88	0.83	1.55	0.57	9.41	16.18	0.12	**8.57**
Total	**8.26**	**542**	**204**	**338.75**	**5.1**	**27.33**	**481.97**	**100**	**100**	**100**	**100**

***Keys:**DBH = Diameter at breast height, D = Density, F = Frequency, A = Abundance,

BA = Basal area, RD = Relative density, RF = Relative frequency,
RDo = Relative dominance, and IVI = Importance Value Index

Higher number of species individuals registered by *J. procera* (37.31%) and *M. africana* (30.15%) subsequently followed by *O. europaea* (23.21%), and the least by *P. africana (0.22%)* at Non-PFM forest site.Frequency of occurrence of *J. procera* and *M. africana* was (100%) each followed by *O. europaea* (95%) (**Table 7**).But, the least frequently occurring species was *P. africana* with (3%) coverage per species occurrence by quadrat. Species with relatively largerbasal area was *J. procera* (91.70m^2)and*O. europaea* (34.63m^2)respectively. However, species with the least basal area record was *C. macrostachyus*. In the same way, species with larger IVI are the same *J. procera* and *O. europaea* with IVI value of(45.38m^2) and (25.37m^2) respectively, and least by *P. africana* species with (0.31) value. Bigger density was recorded by *J. procera*(107.5m^2) and *M. africana*(86.88m^2) species and the least by *P. africana*species with density value of (0.63m^2). Besides, *J. procera* was also an abundant woody species with abundance value of (4.30) followed by *M. africana* (3.48) and least abundant species were*C. macrostachyus* and *P. africana* with abundance value of(1.0 individual/species quadrat) each.

Table 7: Species growth variables' analysis output for the Non-PFM forest site

Woody species	Average DBH (cm)	Individuals (N)	Species occurrence frequency (f) by quadrats	D	F	A	BA	RD	RF	RDo	IIVI
J. procera	6.28	172	40	107.5	1	4.3	91.7	37.31	27.21	71.62	**45.38**
P. falcatus	2.68	22	12	13.75	0.3	1.83	0.27	4.77	8.16	0.21	**4.38**
P. africana	22.5	1	1	0.63	0.03	1	0.04	0.22	0.68	0.03	**0.31**
O. europaea	6.21	107	38	66.88	0.95	2.82	34.63	23.21	25.85	27.05	**25.37**

C. macrostachyus	2.33	3	3	1.88	0.08	1	0	0.65	2.04	0	**0.9**
M. africana	0.95	139	40	86.88	1	3.48	1.36	30.15	27.21	1.07	**19.48**
M. arbutifolia	0.91	17	13	10.63	0.33	1.31	0.02	3.69	8.84	0.01	**4.18**
Total	**4.30**	**461**	**147**	**288.13**	**3.68**	**15.73**	**128.03**	**100**	**100**	**100**	**100**

4.4.1. Species density of the forest sites

Lower number of species individuals and species density per hectare was recorded by *J. procera* (164 individuals and 102.5 individuals/ha) and *M. africana* (53 individuals and 33.13 individuals/ha) species of the PFM when compared with the same *J. procera* and *M. africana*species of the Non-PFM forest site. Woody species with the highest densitywasrecorded in Non-PFM by*J. procera*species with(107.5 individuals/ha) and in PFM by *J. procera*species with (102.5 individuals/ha) in general. On the contrary, least density wasregistered by *P. africana* species in Non-PFM but,*E. brucei* species in the PFM forest sites with density values of (0.63 individual/ha) and (1.25 individuals/ha) respectively.

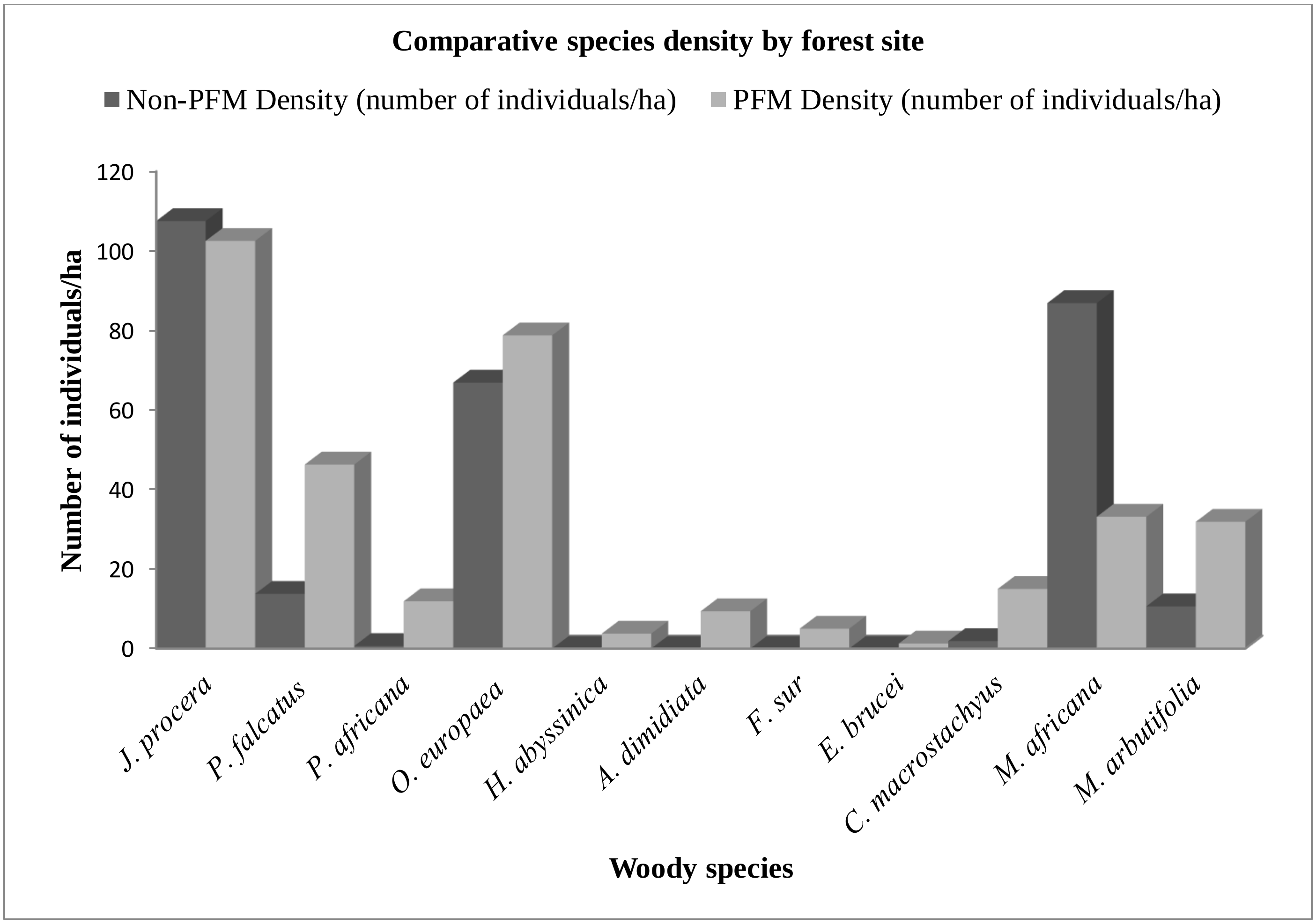


Fig. 6: Species density of both Non-PFM and PFM forest sites

Vegetation regeneration analysis for the entire study species also revealed that the overall total density for Non-PFM forest site was (288.13 individuals/ha), whereas for the PFM forest site was (338.75 individuals/ha), indicating that the highest density was recorded in the PFM forest site.

5. CONCLUSION

The study results showed that,variations in the number of species occurring as well as species individuals recorded at the forest sites (i.e. both at PFM and Non-PFM forest sites) are dependent up on both environmental factors affecting species distribution, and socio-economic and livelihood activities practiced in the area.

Higher study woody species' saplings occurrence frequency and record but comparatively, lower number of seedlings and mature vegetation at both forest sites imply that, species in the forest sites are under fair regeneration status.

The existence of majority of study woody species individuals with relatively higher species distribution in the lower DBH classes are the indicators of species' recruitment potential with overall higher sapling's and seedling's individuals respectively .

Sensible forest management and governance approaches such as participatory forest management would positively influence woody species composition, distribution as well as the overall regeneration status.

Bigger basal area as well as density in both forest sites is the results of positive impacts of the work participatory forest managementapproach and sound conservation initiative.

As IVI value of species in the forest site increase, the ecological importance of species in the forest site also increases, so that species with relatively bigger IVI value is species with higher ecological importance value.

6. RECOMMENDATIONS

On the basis of the findings of the present study, the following recommendations are suggested:

For the respective forest blocks, especially the PFM requires strict follow-up for satisfactory improvement of forest condition, and sound implementing policies to further improve forest regeneration status.

Enhancing eco-friendly use of forest resources (e.g. eco-tourism and honey production) and diversification of non-forest use livelihood mechanisms to avoid deforestation and also to ensure forest sustainability.

Creating alternative energy and income generation sources for the highly forest dependent individuals (i.e. the poor) of the community to ensure effective and sustainable forest conservation and management through participatory way.

Framework policy redesigning and reform on enforcing and implementing law on effective and sustainable forest management urged, to fully combat human-induced impacts to forest resources as drivers of deforestation and forest degradation.

Coherence and honest integration of the locals, forest cooperatives (FCs) and concerning forest sectors with governmental and non-governmental organizations in forest management, and enhancement of forest condition through combating of the proximate drivers of deforestation are mandatory.

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8. APPENDICES

Appendix A: Species composition and regeneration inventory format

Quadrat (1, 2, 3, …, 80)	Tree & shrub species (T & S)	Seedling		Sapling		Mature vegetation		DBH classes within (0.10 ≤ X ≤ 49.900cm)						Remarks		
		(0.10 ≤ X ≤ 1.5m)	Total seedlings within (0.10 ≤ X ≤ 1.5m) height classes	(1.5 < X ≤ 5m)	Total saplings within (1.5 ≤ X ≤ 5.0m) height classes	(5 < X ≤ 35m)	Total matures within (5 < X ≤ 35m) height classes	a = 0.10 ≤ X ≤ 10.06cm	b = 10.06 < X ≤ 20.02cm	c = 20.02 < X ≤ 29.98cm	d = 29.98 < X ≤ 39.94cm	e = 39.94 < X ≤ 49.90cm	Total diameter (cm)	Location (x, y - GPS reading) ~ at higher and lower altitude on the target quadrat	Altitudinal range (m.a.s.l)	Direction, Soil type/color, Slope (%), Dominant woody species, …
	J. procera (Gaattiraa habashaa)															
	P. falcatus (Birbirsa)															
	P. africana (Gurraa)															
	O. europaea (Ejersa)															
	H. abyssinica (Heexoo)															
	A. dimidiata (Calalaqaa)															
	Ficus sur (Harbuu baddaa)															

M. arbutifolia (Kombolcha)	*M. africana (Qacama)*	*C. macrostachyus (Bakkannisa)*	*E. brucei (Waleensuu)*

Appendix B: Descriptive statistics (relationships and variations between species of the two forest sites)

		Statistic	Bootstrap[a]			
			Bias	Std. Error	95% Confidence Interval	
					Lower	Upper
J. procera	Mean	168.00	.02	2.81	164.00	172.00
	Std. Deviation	5.657	-2.794	2.830	0.000	5.657
	N	2	0	0	2	2
P. falcatus	Mean	48.00	-.10	18.28	22.00	74.00
	Std. Deviation	36.770	-18.164	18.393	0.000	36.770
	N	2	0	0	2	2
P. africana	Mean	10.00	-.04	6.33	1.00	19.00
	Std. Deviation	12.728	-6.288	6.367	0.000	12.728
	N	2	0	0	2	2
O. europaea	Mean	116.50	-.04	6.68	107.00	126.00
	Std. Deviation	13.435	-6.637	6.720	0.000	13.435
	N	2	0	0	2	2
H. abyssinica	Mean	3.00	-.01	2.11	0.00	6.00

	Std. Deviation	4.243	-2.096	2.122	0.000	4.243
	N	2	0	0	2	2
A. dimidiata	Mean	7.50	-.03	5.27	0.00	15.00
	Std. Deviation	10.607	-5.240	5.306	0.000	10.607
	N	2	0	0	2	2
F. sur	Mean	4.00	-.02	2.81	0.00	8.00
	Std. Deviation	5.657	-2.794	2.830	0.000	5.657
	N	2	0	0	2	2
E. brucei	Mean	1.00	.00	.70	0.00	2.00
	Std. Deviation	1.414	-.699	.707	0.000	1.414
	N	2	0	0	2	2
C. macrostachyus	Mean	13.50	-.04	7.38	3.00	24.00
	Std. Deviation	14.849	-7.336	7.428	0.000	14.849
	N	2	0	0	2	2
M. africana	Mean	96.00	.17	30.24	53.00	139.00
	Std. Deviation	60.811	-30.041	30.419	0.000	60.811
	N	2	0	0	2	2
M. arbutifolia	Mean	34.00	-.07	11.95	17.00	51.00
	Std. Deviation	24.042	-11.877	12.026	0.000	24.042
	N	2	0	0	2	2

a. Unless otherwise noted, bootstrap results are based on 1,000 bootstrap samples