Role of Participatory Forest Management in Woody Species Diversity and Forest Conservation: The Case of Gimbo Woreda in Keffa Zone South West Ethiopia

Asrat Alemayhu*   Yemiru Tesfaye

Southern Agricultural Research Institute, Bonga Agricultural Research Center, Bonga, Ethiopia, and Hawassa University, Wondo Genet College of Forestry and Natural Sciences

Abstract

Participatory forest management was started more than one decade ago in Ethiopia as one of the ways applied to reverse deforestation and depletion of natural resources. However, there are no adequate site specific empirical and quantitative studies on the effectiveness of PFM approaches in conservation of woody species diversity and forest conservation. Therefore, this study was designed to assess the impacts of PFM on woody species diversity in selected forest user groups in Gimbo Woreda, South West Ethiopia. Vegetation data were collected from different PFM user groups and adjacent Non-PFM forest blocks. A total of 63 plots measuring 20 m × 20 m were employed to collect species composition and structural data. Data for all the sapling and seedlings were also collected within subplots of 5 m X 5 m and 2 m X 2 m respectively. Accordingly a total of 73 different woody plant species (72 at PFM and 54 at Non-PFM blocks), representing 64 genera and 35 families were recorded, with 53 species shared. Woody species diversity and evenness were higher in the forest with PFM (H′ = 3.04, E = 0.76) compared to the forest without PFM (H′ = 2.8, E =0 .70). The overall average values of sapling and seedling density were also significantly ($p < .05$) higher in PFM than Non-PFM forests. However, no significant variations were observed in basal area and dominance of the species between the two forest blocks. Thus it can be concluded that participatory forest management is showing signs of delivering impact in terms of woody species diversity conservation in the study area. However, there is a gap in some of forest user groups in terms of forest protection from an illegal activities. Therefore it is important to conduct further assessments in the remaining forest user group's to have baseline data for further study and performance evaluation over all forests under PFM approaches.

Keywords: Forest User Group, Regeneration, Species diversity, Human induced disturbance.

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1. INTRODUCTION

Forests have enormous ecological, economical and socio-cultural significances (Ostrom, 1999; Robertson and Lawes, 2005). 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 (FAO, 2012). 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 (Shackleton *et al.* 2007)*. Regrettably, despite widespread acknowledgment of the significance of forests, it has been very difficult to tackle deforestation, which continues to represent a major global challenge (Winberg, 2011). Historically, strategies for forest conservation have been dominated by attempts to exclude people from designated forest reserves (Adams and Hulme, 2001). This protectionist approach viewed the development needs of local communities as being in direct conflict with the objectives of biodiversity conservation (Vodouhê *et al*. 2010). This approach has been pursued as a forest conservation strategy in Sub-Saharan countries (Guthiga, 2008). Similarly, the forest management administration over the last 50 years in Ethiopia has negatively affected the forest resource by restricting local communities' access and user right and Ethiopia continue to face the challenge of how best to manage and conserve their forests (Gebremdhin, 2008).

In response to the problems associated with the fortress approach, since the 1980s a new dialogue has arisen that stresses the need to integrate the views and aspirations of the local people in conservation (Hutton and Williams, 2003). The new approach (PFM) which views them as potential partners in biodiversity conservation (Adams and Hulme, 2001). Integrating the views and needs of local communities in conservation processes are crucial for the effectiveness of participatory forest management (PFM) in improving the forest condition and ensuring the sustainability of the livelihoods of the communities (Stellmacher, 2007; Tsegaye *et al.* 2009; Yihenew, 2002). Some experiences from around the world show that shifts from state-centered policies toward solutions at the local level, such as PFM, resulted in successful forest conservation and development (Wily, 2002).

However, the PFM institutionalization process and its subsequent performance have proved controversial among different stakeholders. Some claim that a major transformation has taken place consequent to PFM on the management of physical resources, institutional arrangements and livelihoods of resource-dependent communities and decline in the deforestation rate and an increase in forest regeneration (Takahashi and Todo, 2012; Tsegaye *et*

al. 2009). While other studies in contrary to this indicated the less emphasis of forest conservation, unsatisfactory seedling establishment and regeneration and lacking follow-up action (Coulibaly-Lingani *et al*. 2014, Tekalign *et al*. 2015)*.* Forests under participatory forest management are expanding in coverage in Ethiopia. However, it is still unclear whether the management strategy can really lead to the desired results and it needs to be investigated further (Winberg, 2011). Since, Participatory forestry methods are still in an exploratory phase, it is important to monitor and evaluate in order to transform participation from being an empty promise into being a workable tool.

A number of studies were conducted on different aspects of the impacts of PFM performance. For example, its impacts on forest conservation (Mamo *et al.* 2016), livelihood and forest status (Tsegaye *et al*. 2009), species composition and forest structure (Akililu *et al*. 2016), local communities attitude *(*Tesfaye*, 2017),* institutional arrangements versus local practice (Alemayehu *et al*. 2015), lessons learnt and challenges encountered (Mulugeta and Melaku, 2008) and farmers participation (Girma and Zegeye, 2017) are to name but a few. However, empirical and quantitative evidence remains scarce and are also area limited. Therefore, this paper examined whether PFM management is delivering improved forest condition in terms of woody species diversity, regeneration status, and structure in selected forest user groups in the study area.

2. Materials and methods

2.1. *Description of the study area*

The study was carried out in an afro-montane rainforest of Gimbo district (Kaffa Zone, Southwestern Ethiopia). The study area is located at altitudes between 1000 and 3500 m above sea level and it far 432km from Addis Ababa and 705 km from Hawassa town on the road to Bonga. It found within the geographical location lies within 07°4'00"- 7°35'00"N latitude and 36°1'30"-36°31'00"E longitude.
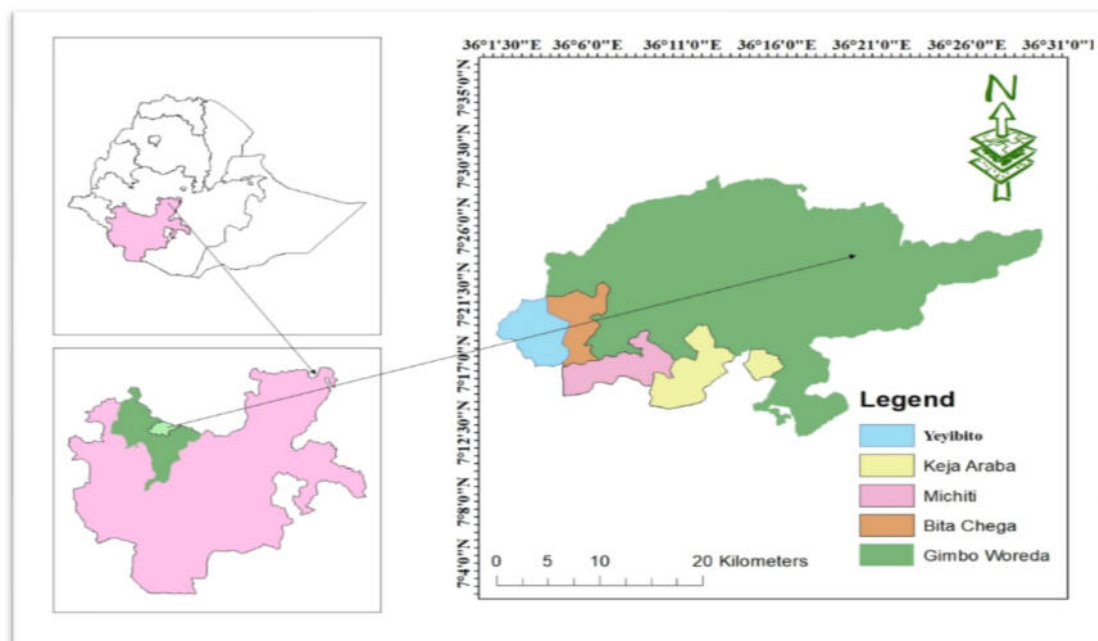

Figure 1: Map of the Study Area

The soils of the area are deep, clay red soils with an agric B-horizon dystric-nitosols. The soils have good agricultural potentialities, good physical properties and uniform profile. They are porous, clay-to-clay loam texture, and have low base saturation with less than 5.5 pH values and well drained (CBFED, 2004).

The mean annual temperature ranging between 15.1^0C and 22.5^0C with warmest month January, February and March. The study area receives the highest amount of rainfall in Ethiopia with annual rainfall between 1401-2000 mm. The largest amount of rain occurs between May and September (Ayele, 2011).

The forest in this region fragmented with some undisturbed forest parts and large areas of degraded and disturbed forest. Forest in the study area is classified in the vegetation of Ethiopia referred to as moist evergreen montane forests and located within altitudinal range of 1100-2700 m. above sea level. The forests in this area are normally the richest in species (Friis *et al*. 1982) and a source of fuel wood, charcoal and timber (Ensermu and Teshome, 2004). The major land cover of Gimbo Woreda is forest and agriculture associated with human settlement. The forests found in the study area are among the remnant forests in Ethiopia where, different kinds of mammals and birds dwell. The main sources of livelihood are forest utilization, livestock rearing and agriculture (Aklilu *et al*. 2014a)*.* The most income sources of the population are from small-scale agriculture, wild coffee and

other non-timber forest products (Melaku and Tsegaye, 2005).

2.2. PFM approach

In Ethiopia the conventional forest management alienates local communities from participating in forest conservation and protection (Abdurahiman and Tsegaye, 2002), which leads to illegal and unsustainable forest resource utilization. Hence, a resulting paradigm shift is necessary in forest management to involve local community in management of natural resources. Thus Ethiopian government has taken actions to stop forest losses and give the chance for NGOs to participate in SFM, through PFM practices. As a result, a number of NGOs and bilateral programs have launched PFM in the country. In this arrangement the government holds ownership of the forest, while the local communities, organized in FUGs, have use rights (Aklilu et al. 2016). PFM was introduced to Ethiopia in the mid of 1990s, by International NGOs such as the FARM Africa, SOS Sahel, GTZ, and JICA (Temesgen et al. 2007), with thematic area of promoting sustainable management and conservation of forest ecosystems and improving the livelihood of people living in or around. The few PFM pilot activities that started in Ethiopia include projects at Chilimo and Bonga forests by FARM Africa, at Borena by FARM Africa and SOS Sahel, at Adaba Dodolla by GTZ, and Belete Gera forest by JICA (Temesgen et al. 2007). PFM pilot activities in Bonga covered three districts namely, Gimbo, Decha and Gewata. In this PFM processes seven forest user groups were formed in Gimbo district. Out of seven old forest user groups three (Wacha, Agama and Matapa) were selected based on the availability of baseline/reference data for comparison purpose of forest status after the introduction of the PFM approach in the study area particularly in the selected FUGs. And Non-PFM forest patches adjacent to each PFM forest patches were selected to have comparison on the current status of the PFM forest.

2.3. Sampling design and data collection

Both primary and secondary data source were used for the study. Primary data was obtained from forest inventory and secondary data from prior baseline data from FARM Africa documents and different literatures. Scholars in the past have used various methods for measuring the condition of a forest, depending upon individual preferences, research objective, and availability of data. Despite these variations, forest ecologists generally agree that both structure and diversity-related variables should be given consideration in order to fully understand the condition of a forest (Gautam, 2007). Accordingly, the study used the following biological variables: basal area of trees ($\geq$10 cm DBH), density of trees, density of saplings (trees with DBH b/n 1.5 & 10 cm), and density of seedling (trees with height <1.5m) and richness of woody plant species.

Number of sample plots per patches was calculated using the principles of proportional allocation according to area of each forest patches. The sampling method was based on line transect approach (Marshall *et al*. 2008) widely suggested to estimate relative density in tropical forests. Sample points along the linear transects were used to collect diversity data and to describe forests structure (Terborgh *et al*. 2008). In each transect line sample plots were ranged at fixed intervals along linear transects.

Six neighboring forest patches, three with PFM and the other without PFM, but adjacent to each other identified and an inventory was carried out using systematic sampling design to collect vegetation data. A total of 63 square sampling plots, 20 x 20 meter were laid at every 200 m along transect lines and transect apart each other by 500m and systematic sampling design was used to select the first transect line and first plot randomly. Accordingly, all woody plant species including trees and shrubs were collected within the main plots, and 5 m x 5 m and 2 m x 2 m sub-plots were laid, four at the corners and one in the middle, for sapling and seedling data collection respectively. Height and diameter at breast height (DBH) of each tree and shrub species with height >1.5 m and DBH>2.5 cm were measured. In this study individuals having <1.5m height were counted as seedlings, individuals having >1.5 m height and DBH less than 10cm, were counted as sapling and individuals having DBH >10cm, were counted as tree (Ensermu and Teshome, 2004).

2.4. *Data Analysis*

The status of woody species diversity was examined by estimating stem density, importance value index (IVI), forest structure, population structure and diversity pattern (Fisseha, 2008). Stem density was calculated as

$$\textbf{\textit{Density}} \ (\%) = \frac{\textit{Number of individuals of species in all quadrats}}{\textit{Total area sampled}} * 100$$

Frequency is the proportion of plots in which a species occurred. It is a measure of occurrence of a given species in a given area, which indicates how the species is dispersed and is an ecologically meaningful limit. Frequency of plant species was calculated as;

$$\textbf{Frequency} = \frac{\textbf{Number of quadrats in which a species occur}}{\textbf{Total number of quadrats thrown in the study sits}} \ x100$$

Importance Value Index (IVI) allows a comparison of ecological significance of species in a given forest type and depicts the sociological structure of a population in its totality in the community and it is a good index for summarizing vegetation characteristics and ranking of species (Kendeya, 2003).

$$Relative\ Frequency = \frac{Frequency\ of\ a\ species}{Sum\ of\ frequency\ of\ all\ species} * 100$$

$$Relative\ Density = \frac{Number\ of\ individuals\ of\ a\ species\ occurred}{Total\ number\ of\ individuals\ of\ all\ species} * 100$$

$$Relative\ Basal\ Area = \frac{basal\ area/ha\ of\ a\ single\ species}{sum\ of\ basal\ area/ha\ of\ all\ species} * 100$$

Therefore, IVI was calculated as:

Importance Value Index (IVI) = $R.density + R.frequency + R.basal\ area$

Regeneration status of sample species in the forest was analyzed by comparing seedling with sapling and sapling with matured trees data according to (Kflay and Kitessa, 2014). To compare woody species diversity of the different forest patches Shannon-wiener diversity and Simpson's diversity indices were computed. The Shannon diversity index was calculated as:

$$H' = -\sum_{I=1}^{S} PI\ LN\ PI$$

Where **H'** Is Shannon diversity index and **Pi** is proportion of individuals found in the **i**th Species.

Simpson's diversity index is derived from a probability theory and it is the probability of picking two different species at random (Krebs, 1999). Simpson's diversity (D) was calculated as:

$$D = 1 - \sum P_i^2$$

Where **D** is Simpson's diversity index and **P$_i$** is proportion of individuals found in the **i**th species.

Data was analyzed descriptively and using independent t- test. Significant differences in mean values for woody species diversity was tested by least significance difference at $p<0.05$. All statistical computations was made using SPSS statistical Software.

3. RESULTS AND DISCUSSION

3.1. Woody species composition

A total of 73 woody species belonging to 64 genera and 35 families were recorded including regeneration and saplings in the different forest patches. Out of the total woody species identified, 72 (98.63%) of them were recorded in the PFM forests, while 54 (73.97%) species in the Non-PFM forests. Only one species (1.37%) encountered in the Non-PFM forest was absent from the PFM forest, while eighteen (24.65%) species found in PFM forest were not encountered in the Non-PFM forest, whereas 53 (72.6%) species were shared by both forest blocks. Out of 35 families, seven were exclusively found in PFM forest and 28 are shared families. Of all the families, Fabaceae, Moraceae, Celastraceae are the most dominant with each contributing 4 species (5.5%) next to Rubiaceae with 8 species (10.95%). It is also followed by Araliaceae, Dracaenaceae, Oleaceae, Rutaceae families each with 3 species (4.1%) and Acanthaceae, Boraginaceae, Lamiaceae, Myrtaceae, Sapindaceae, Melianthaceae, families each have 2 species (2.7%) are also very important families in terms of species richness. The highest number of families were recorded in PFM forest as compared to adjacent Non PFM forest patches and Rubiaceae was the most dominant family with more numbers of species in all FUGS. Overall analysis of the habit or life forms of species recorded from the different forest patches indicate that the highest proportion (57.5%) of trees, 26% tree/shrubs and followed by the shrubs that make up 8.2% of the total and woody climbers contributes for 8.2% (Table1).

Table 1: List of woody species encountered in in the studied forest patches with corresponding family, local names and life form.

No.	Scientific Names	Family	Local Name	Life form	PFM	Non-PFM
1	*Acanthus eminens*	Acanthaceae	Pheco	S	√	√
2	*Albizia gummifera*	Fabaceae	Catoo	T	√	√
3	*Allophylus abyssinicus*	Sapindaceae	She'o	T	√	√
4	*Allophylus rubifolius*	Sapindaceae	Gurasado	S/T	√	X
5	*Apodytes dimidiata*	Icacinaceae	Wundafo	Tree	√	√
6	*Bersama abyssinica*	Melianthaceae	Boqqo	Tree	√	√
7	*Brucea antidysentricu*	Simaroubaceae	Nukasho	S/T	√	√
8	*Canthium oligocarpum Hiern*	Rubiaceae	Xixirabo	T	√	√
9	*Cassipourea malosana*	Rhizophoraceae	Woralo	T	√	√

No.	Scientific Names	Family	Local Name	Life form	PFM	Non-PFM
10	*Celtis africana*	Ulmaceae	Uffo	T	√	√
11	*Chionanthus mildbraedii*	Oleaceae	Shigayo	S/T	√	√
12	*Clausena anisata*	Rutaceae	Emicho	S/T	√	√
13	*Coffea arabica L.*	Rubiaceae	Bunno	S/T	√	√
14	*Combretum paniculatum Vent.*	Combretaceae	Bagee Qombo	WC	√	√
15	*Cordia africana*	Boraginaceae	Di'o	T	√	√
16	*Croton macrostachyus*	Euphorbiaceae	Waggo	T	√	√
17	*Cupressus lusitanica*	Cupressaceae	Ciido	T	√	X
18	*Dalbergia lactea Vatka*	Fabaceae	Bitbitoo	WC	√	√
19	*Dinbollia kilimandscharica*	Sapindaceae	Qaqiracho	T	√	√
20	*Diospyros abyssinica*	Ebenaceae	Kuri	T	√	X
21	*Dracaena afromontana*	Dracaenaceae	Emo	S/T	√	√
22	*Dracaena fragrans*	Dracaenaceae	Shigiro	T	√	√
23	*Dracaena steudneri*	Dracanaceae	Yudo	T	√	X
24	*Ehretia cymosa*	Boraginaceae	Wogamo	S/T	√	√
25	*Ekeberigia capensis*	Rhizophoraceae	Orooro	T	√	√
26	*Elaeodendron buchananii*	Celastraceae	Washo	T	√	√
27	*Embelia schimperi*	Myrsinac	Dupho	WC	√	√
28	*Eucalyptus spp*	Myrtaceae	Bahirzaf	T	√	X
29	*Euphorbia ampliphylla Pax*	Euphorbiaceae	Gacho	T	√	√
30	*Fagaropsis angolensis*	Rutaceae	Yayo	T	√	√
31	*Ficus ovata*	Moraceae	Caroo	T	√	√
32	*Ficus palmata L*	Moraceae	Shoto	T	√	√
33	*Ficus sur*	Moraceae	Capharo	T	√	√
34	*Flacourtia indica*	Flacourtiaceae	Humo	S/T	√	√
35	*Galiniera saxifraga*	Lamiaceae	Dido	S/T	√	√
36	*Hippocratea africana*	Celastraceae	Phi'o	WC	√	√
37	*Hippocratea goetzei*	Celastraceae	Qawe Qombo	WC	√	X
38	*Ilex mitis*	Aquifoliaceae	Qeto	T	√	√
39	*Justicia schimperiana*	Acanthaceae	Shashero	S	√	X
40	*Landolphia buchananii*	Apocynaceae	Yemo	WC	√	√
41	*Lepidotrichilia volkensii*	Meliaceae	Shahino	S/T	√	√
42	*Macaranga capensis*	Euphorbiacee	Shakero	T	√	X
43	*Maesa lanceolata*	Myrsinaceae	Caggo	T	√	X
44	*Maytenus undata*	Celastraceae	Shiikkoo	S/T	√	√
45	*Millettia ferruginea*	Fabaceae	Bebero	T	√	√
46	*Ocntea kenyensis*	Lamiaceae	Najo	T	√	√
47	*Olea welwitschi*	Oleaceae	Yaho	T	√	√
48	*Oxyanthus speciosus DC.*	Rubiaceae	Ophero	T	√	√
49	*Pavetta oliveriana*	Rubiaceae	Tushimo	S/T	√	X
50	*Phoenix reclinata Jacq.*	Arecaceae	Yebo	T	√	√
51	*Pittospnrum viridiflarum*	Pittosporaceae	Shollo	S/T	√	√
52	*Podocarpus falcatus*	Podocarpaceae	Zigiba	T	√	X
53	*Polyscias fulva*	Araliaceae	Karasho	T	√	√

No.	Scientific Names	Family	Local Name	Life form	PFM	Non-PFM
54	*Poureria adolfifreiderici*	Sapotaceae	Shao'o	T	√	√
55	*Prunes africana*	Rosaceae	Omo	T	√	√
56	*Psychotria orophila*	Rubiaceae	Aemato	S/T	√	√
57	*Rhamnus prinoides*	Rhamnaceae	Gesho	S/T	√	X
58	*Rothmannia urcelliformis*	Rubiaceae	Dibo	T	√	√
59	*Rytigynia neglecta*	Rubiaceae	Naxacho	S/T	√	X
60	*Sapium ellipticum*	Euphorbiaceae	Shedo	T	√	√
61	*Schefflera volkensii*	Araliaceae	Qero	T	X	√
62	*Schefllera abyssinica*	Araliaceae	Butto	T	√	√
63	*Senna didymobotrya*	Fabaceae	Shillishillo	S	√	X
64	*Solanecio gigas*	Asteraceae	Doo'iroo	S	√	√
65	*Solanecio mannii (hook f.)*	Asteraceae	Amittibalo	S/T	√	√
66	*Syzygium guineense*	Myrtaceae	Yino	T	√	√
67	*Trichilia dregeana*	Meliaceae	Timo	T	√	X
68	*Trilepisium madagascariense*	Moraceae	Gabo	T	√	√
69	*Turraea holstii*	Meliaceae	Macce Kucoo	S/T	√	X
70	*Vangueria madagascariensis*	Rubiaceae	Mesho	T	√	X
71	*Vepris dainellii*	Rutaceae	Mengiraxo	S/T	√	√
72	*Vepris nobilis (Teclea nobilis)*	Rutaceae	Shengaro	S	√	√
73	*Vernonia auriculifera*	Asteraceae	Dangirato	S	√	X

Note. (√) indicate presence and (X) indicate absence. T=Tree, S=Shrub, S/T=Shrub/Tree

3.2. *Woody Species Diversity and Similarity Indices*

Plant species diversity is mostly influenced by human impact and forests with low levels of disturbance has high species diversity compared to disturbed forest (Engida and Teshoma, 2012). Woody plant species diversity index (H′) for all plant species in PFM and Non-PFM were 3.04 and 2.8, respectively, while the corresponding average values of evenness index (E) were 0.76 and 0.7 in PFM and Non-PFM forests, respectively. Simpson's index for woody plant species in PFM and Non-PFM forest were 0.92 and 0.88 was significantly different, whereas the dominance of species in both blocks was not significantly different (Table 2). This showed that PFM forests had the high number of species diversity and more distribution of plant species than Non-PFM forests. However species diversity, species evenness and Simpson index were slightly higher in adjacent Non-PFM forest than in Matapa PFM forest. And this may be due to the influence of human disturbance factors resulted from dependency of group members on forest and forest products. Therefore it's important to note that group formation alone without monitoring and evaluation of the performance of FUGs is not the success by itself.

Table 2: Species Diversity, Species Richness and Evenness of D/t Forest Patches.

Characteristics	Wacha		Matapa		Agama		Avg. PFM	Avg. Non PFM	P-value
	PFM	Non PFM	PFM	Non PFM	PFM	Non PFM			
Species diversity (H`)	3.08	2.65	2.78	2.84	3.26	2.91	**3.04**	**2.8**	
Species richness (S)	54	52	55	54	58	55	**56[b]**	**54.00[a]**	0.010*
Evenness (E)	0.77	0.67	0.69	0.73	0.82	0.7	**0.76[b]**	**0.70[a]**	0.027*
Simpson index	0.93	0.86	0.87	0.88	0.94	0.9	**0.92[b]**	**0.88[a]**	0.013*
Dominance	0.07	0.09	0.13	0.16	0.06	0.11	**0.08[a]**	**0.12[a]**	0.11
Basal area (m²/ha)	22.65	27.6	37.6	38.2	26.59	25.57	**28.9[a]**	**30.46[a]**	0.07
Seedling (ha⁻)	59062	48266	67292	56319	71458	61356	**65937[b]**	**55313[a]**	0.00*
Sapling (ha⁻)	18100	17902	16100	16859	26633	21939	**20278[b]**	**18900[a]**	0.003*
Matured Tree (ha⁻)	604	418	335	391	613	431	**517[b]**	**413[a]**	0.006*

*significant at p<0.05 and Means with the same letters across row are not significantly different (P > 0.05) with respect to forest management approaches.

3.3. Regeneration Status

Regeneration is an indication of forest condition improvement (Yadav *et al*. 2002). Regeneration of the forest under PFM management has exhibited advanced number of seedling and sapling than compared to the forest under Non-PFM. The average number of seedling and sapling recorded in three PFM forests was 65937 and 20278 per hectare, respectively. Whereas in Non-PFM forests 55313 and 18900 seedling and saplings per hectares, respectively. The difference in the density of sapling and seedling were significant at p<.05 (Table 2). Similarly, forests under PFM management has a high number of average matured tree density (517.3/ha) than Non-PFM forests (413/ha).

Regeneration status of the forest under different forest user group exhibited different performance. The maximum number of seedling, sapling and matured trees were recorded in Agama PFM forest over the rest FUGs. Similarly in all FUGs the total number of seedling per hectare were higher as compared to respective adjacent Non-PFM forest patches. Wacha and Agama PFM exhibited more density of sapling and matured tree as compared to adjacent forest without PFM, Whereas Matapa PFM revealed low density of sapling and matured tree per hectare as compared to forest under Non-PFM. This may be due to human induced disturbance. Regeneration of the matured woody species as seedling ranges from 60% at Agama PFM to 52% at Matapa PFM forest patches and as saplings range from 80% at Wacha PFM to 57% at Matapa PFM. In both seedling and sapling cases, the representation of matured trees was less in Matapa PFM forest patches even from Non-PFM forest patches.

Comparison result of the current regeneration status of the forest patches with the reference data showed that the regeneration of forest under PFM has improved, i.e. the number of seedling and sapling exhibited an increment in all forests under different forest user groups (Table 3) and the increment was significant at p<0.05.

Table 3: Density of seedling and saplings in different PFM sites in 2004 & 2017

Characteristics	Wacha		Matapa		Agama		F-value	P-value
Year	2004	2017	2004	2017	2004	2017		
Density of seedling	3527.8	59062	6155.6	67292	391.6	71458	244.153	0.00
Density of sapling	1147.2	18100	2663.8	16100	326.2	26633	32.758	0.005

3.4. Forest Structure

3.4.1. Diameter Class Distribution

The forest structure in both PFM and free access forests showed an inverted "J" shape for tree diameter distribution. In both forest patches, small-sized individuals are present in a large amount (Figure 2). But relatively PFM forest block has more individuals across different diameter classes compared to Non-PFM forest patches. The distribution of tree/shrub species in different DBH size classes indicates that 610 (91%) of individuals was found in DBH class 2.5–10 cm forest with PFM and 568 (92.1%) for forest in Non-PFM. The density of individuals of woody plant species with DBH 10.1–30 cm was found to be 78 (5.8%) for forest with PFM and 58 (4.7%) for forest without PFM and only 15 (1.1%) of individuals has found with DBH greater than 70cm in PFM forest than 6 (0.5%) in Non-PFM forests. Even so the difference is not significant, more number of individuals were found in the higher DBH class in PFM forest than compared to Non-PFM forests. This indicates that the forest structure of the PFM forest is more stable in average than Non-PFM forest patches.

3.4.2. Density, Basal area and Frequency

Density of a given species is expressed as number of stems per hectare. All most similar average stem density was recorded in both PFM and Non-PFM forest patches each has recorded 358 stems per hectare. *Coffea arabica L* (4400 stems/ha), *Maytenus undata* (3250 stems/ha), *Chionanthus mildbraedii* (2187 stems/ha) and *Rothmannia urcelliformis* (1616 stems/ha) are the top densely populated woody species in PFM forest patches, whereas, *Coffea arabica L* (6833 stems/ha), *Maytenus undata* (1520 stems/ha) and *Dracaena afromontana* (1516 stems/ha) are densely populated woody species in Non-PFM forest patches. Based on their density the most and least tree species under different forest patches were indicated under table 4.

The average basal area of all woody species in forest with PFM was about 28.9 m^2 ha^{-1} while in the Non-PFM forest was about 30.46 m^2 ha^{-1}, but the variation was not significant ($p > .05$) (Table 2). The highest proportion of basal area in forest with PFM was contributed by *Schefflera abyssinica* (36%), *Olea welwitschi* (39.9%), *Sapim ellipticum* (14.3%), *Phoenix reclinata* (9.39%) and *Coffea arabica L. (10.3%).* In the Non-PFM forest the highest basal area was contributed by *Coffea arabica L. (50.56%)*, followed by *Olea welwitschi* (18.08%), *Syzygium guineense* (3.6%), *Schefflera abyssinica* (2.85%) and *Maytenus undata* (2.7%). The lower basal area observed in the PFM forest may be resulted from very low stocking among the mid-size classes despite the presence of some very large trees. However the difference was not statistically significant ($p > .05$). This result was in line with Solomon *et al*. (2016)'s study which reported not significant impact of PFM on basal area. Similarly Tsegaye *et al*. (2009) also reported more basal area in Non-PFM (19.6 m²/ha) forest than PFM (17.4 m²/ha) forest patches.

Frequency is the number of quadrats in which a given species occurred in the study area. Frequency is the indication of homogeneity and heterogeneity of given vegetation in which the higher number of species in higher frequency classes and low number of species in lower frequency classes show similar species composition while large number of species in lower frequency classes and small number of species in higher frequency classes indicates higher heterogeneity (Lamprecht, 1989). *Maytenus undata*, *Phoenix reclinata Jacq.*, *Olea welwitschi*, *Lepidotrichilia volkensii* and *Coffea arabica L.* are the most frequently observed species in PFM forest, while, *Olea welwitschi, Coffea arabica L., Dracaena afromontana* and *Maytenus undata* are the top frequently observed species in Non-PFM forest patches.
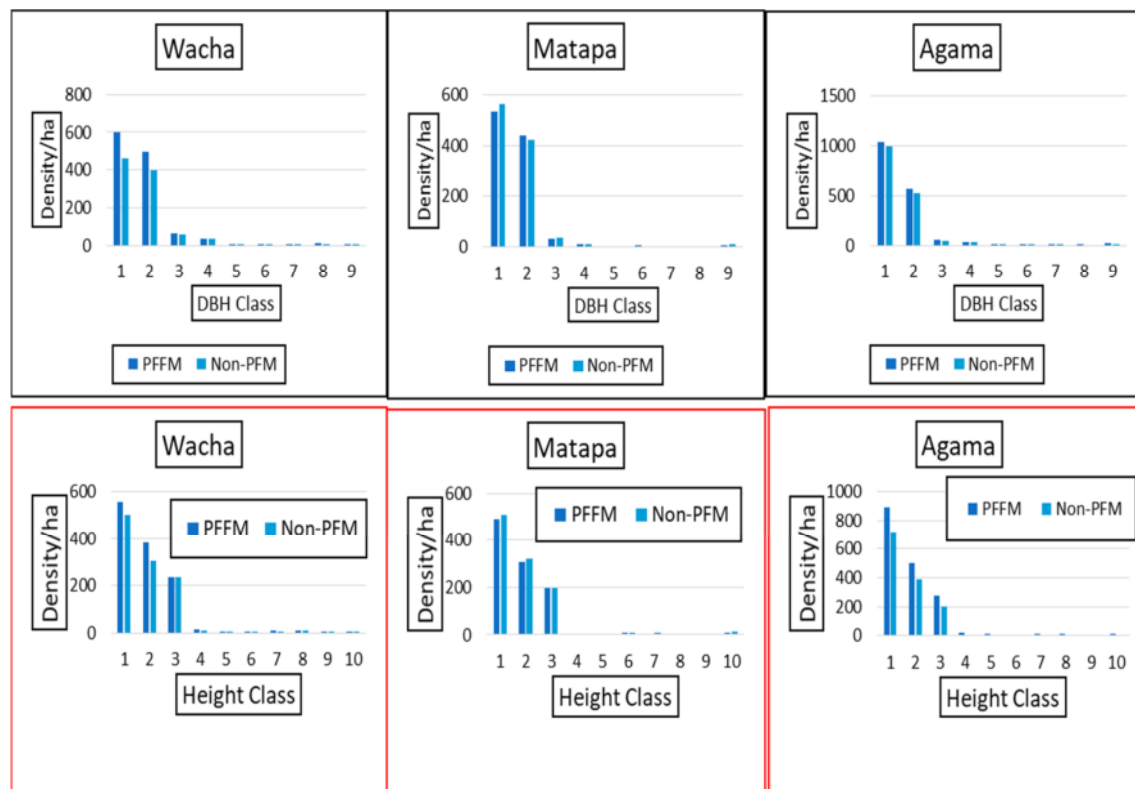
Figure 2: DBH Class Distribution of Woody Species in Different Forest Patches
(DBH Class: 1=2.5-5cm, 2=5.01-10cm, 3=10.01-20cm, 4=20.01-30cm, 5=30.01-40cm, 6=40.01-50cm, 7=50.01-60cm, 8=60.01-70cm, 9=>70cm) and (Height class: 1=<5m, 2=5.0-10m, 3=10.0-15m, 4=15-20m, 5=20-25m, 6=25-30m, 7=30-35m, 8=35-40m, 9=40-45m, 10=>45m)

Table 4: Five most and least tree species based on their density.

	Wacha		Matapa		Agama	
	PFM	**Non-PFM**	**PFM**	**Non-PFM**	**PFM**	**Non-PFM**
Most	*Maytenus undata*	*Schefllera abyssinica*	*Coffea arabica L.*	*Maytenus undata*	*Coffea arabica L.*	*Coffea arabica L.*
	Coffea arabica L.	*Croton macrostachyus*	*Rothmannia urcelliformis*	*Chionanthus mildbraedii*	*Maytenus undata*	*Maytenus undata*
	Clausena anisata	*Ficus ovata*	*Ocntea kenyensis*	*Dracaena afromontana*	*Chionanthus mildbraedii*	*Dracaena afromontana*
	Lepidotrichilia volkensii	*Olea welwitschi*	*Chionanthus mildbraedii*	*Vepris dainellii*	*Dracaena afromontana*	*Rothmannia urcelliformis*
	Chionanthus mildbraedii	*Syzygium guineense*	*Vepris dainellii*	*Croton macrostachyus*	*Rothmannia urcelliformis*	*Lepidotrichilia volkensii*
Least	*Allophylus abyssinicus*	*Cassipourea malosana*	*Poureria adolfifreiderici*	*Polyscias fulva*	*Poureria adolfifreiderici*	*Ehretia cymosa*
	Celtis africana	*Polyscias*	*Ilex mitis*	*Prunes*	*Ficus palmata*	*Allophylus*

	fulva		*africana*	*L*	*abyssinicus*
Ficus sur	*Ilex mitis*	*Sapium ellipticum*	*Ehretia cymosa*	*Cassipourea malosana*	*Ficus palmata L*
Apodytes dimidiata	*Cordia africana*	*Croton macrostachyus*	*Ficus sur*	*Polyscias fulva*	*Celtis africana*
Poureria adolfifreiderici	*Fagaropsis angolensis*	*Ehretia cymosa*	*Poureria adolfifreiderici*	*Ilex mitis*	*Apodytes dimidiata*

3.4.3.   Importance value index (IVI)

As described by Kent and Coker (1992), importance value index (IVI) is a good index for summarizing vegetation characteristics, ranking species, management and conservation practices. It is also useful to compare the ecological significance of species (Lamprecht, 1989). *Schefllera abyssinica* (39.18%), *Olea welwitschi* (78.04%), *Coffea arabica L.* (42.67%), *Maytenus undata* (24.07%), *Phoenix reclinata* (19.95%) and *Trilepisium madagascariense* (12.3%) are the highest IVI value recorded species in PFM forest. Similarly, *Coffea arabica L.* (83.41%), *Phoenix reclinata* (21.51%), *Dracaena afromontana* (13.63%) and *Maytenus undata* (12.09%) were also the most dominant species in Non-PFM forest patches.

Table 5: The most and least five plant species based on their IVI values

Patches	No.	Most	IVI	Least	IVI
Wacha	PFM	*Schefllera abyssinica*	39.18	*Brucea antidysentricu*	0.6
		Maytenus undata	24.07	*Prunes africana*	0.6
		Phoenix reclinata	19.95	*Diospyros abyssinica*	0.6
		Coffea arabica L.	13.08	*Apodytes dimidiata*	0.6
		Sapium ellipticum	17.73	*Embelia schimperi*	0.7
	Non-PFM	*Coffea arabica L.*	91.75	*Combretum paniculatum*	1.11
		Olea welwitschi	23.66	*Cordia africana*	1.11
		Dracaena afromontana	14.99	*Euphorbia ampliphylla*	1.11
		Maytenus undata	13.30	*Schefflera volkensii*	1.11
		Lepidotrichilia volkensii	12.41	*Cassipourea malosana*	1.05
Matapa	PFM	*Olea welwitschi*	78.04	*Prunes africana*	0.7
		Coffea arabica L.	42.67	*Allophylus rubifolius*	0.7
		Trilepisium madagascariense	12.3	*Brucea antidysentricu*	0.7
		Rothmannia urcelliformis	11.75	*Rhamnus prinoides*	0.7
		Ocntea kenyensis	9.18	*Poureria adolfifreiderici*	0.8
	Non-PFM	*Maytenus undata*	87.58	*Combretum paniculatum*	1.06
		Vepris dainellii	22.59	*Cordia africana*	1.06
		Dracaena afromontana	14.31	*Euphorbia ampliphylla*	1.06
		Coffea arabica L.	12.69	*Schefflera volkensii*	1.06
		Lepidotrichilia volkensii	11.84	*Cassipourea malosana*	1.00
Agama	PFM	*Olea welwitschi*	43.71	*Cassipourea malosana*	0.5
		Coffea arabica L.	23.11	*Cordia africana*	0.5
		Phoenix reclinata	19.53	*Euphorbia ampliphylla*	0.5
		Maytenus undata	14.34	*Ficus palmata L*	0.5
		Schefllera abyssinica	12.13	*Maesa lanceolata*	0.5
	Non-PFM	*Coffea arabica L.*	83.41	*Cassipourea malosana*	1
		Olea welwitschi	21.51	*Cordia africana*	1
		Dracaena afromontana	13.63	*Euphorbia ampliphylla*	1
		Maytenus undata	12.09	*Schefflera volkensii*	1
		Lepidotrichilia volkensii	11.28	*Combretum paniculatum*	1

4.   CONCLUSION AND RECOMMENDATIONS

4.1. Conclusion

The research findings revealed that the intervention of PFM program was associated with substantial improvements in woody species diversity and forest conditions. This study founded that there is a differences in species composition, diversity, and vegetation structure between the two forest management regimes. More species diversity and richness in Agama and Wacha PFM forest indicated that the PFM approach contributed better forest management than the Non-PFM managed forests. And the lower value of species diversity and species evenness were recorded in Matapa as compared to adjacent Non-PFM forest. The regeneration of woody species was better

in PFM forest compared with adjacent Non-PFM forest. The density of seedling, sapling and matured trees were recorded higher in Agama and Wacha PFM forest as compared to adjacent Non-PFM forests. The density of seedling in Matapa PFM was recorded higher than to the adjacent Non-PFM forest, but lower density of sapling and matured tree as compared to adjacent Non-PFM forest. Wacha and Matapa PFM forest patches recorded slightly lower value of basal area than to the adjacent Non-PFM forest patches, whereas Agama PFM forest revealed better value of basal area than to the Non-PFM forest patch. There is also a difference in the structure of forest vegetation, especially in the first four diameter size classes between the two forest management units with more density of individuals in PFM forest than Non-PFM forest patches. The present study supports previous arguments that compared to other types of forest management regimes, participatory forest management has a potential to improve forest condition. However, its potential in woody species conservation and forest conservation is not consistent in all forest user groups. Illegal grazing, selective cutting and fuel wood harvesting are observed to be the central part of several disturbances reported to take place in almost all forest patches. Therefore, further to its general positive impacts on forest condition improvement, variation in performance of different forest user groups should be given due attention to make all FUGs competitive in all aspects of participatory forest management objectives. And it is important to protect the remaining Non-PFM forests in the study area from further degradation through scaling up of the program.

4.2. Recommendations

From the evaluated impacts of PFM on woody species diversity and forest conservation the following recommendation has been specified for different stakeholders at different level:

Despite the fact that forests under PFM still holds an important proportion of tree species richness, there is a need to prevent further human disturbances within the forest and there is variation in forest conservation within different forest user groups and some of the user groups has low performance than even that of adjacent Non-PFM forests. Therefore it is important to evaluate the internal institutional enforcement on usage of forest products and controlling non-members exploitation. Continuous monitoring and evaluation of the performance of the forest user groups is also an important area to be focused. Tangible benefits what they obtain from being the member of PFM and challenge that hinder from best performance should be examined and further research focused.

Conflict of Interests

Asrat Alemayhu and Yemiru Tesfaye, the authors of the paper, declare that there is no conflict of interests regarding its publication.

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BIOGRAPHICAL SKETCH

Mister Asrat was born in place name Kaffa zone, in southwest, Ethiopia, in 1982. He attended his primary education (1 - 6) in Sheka zone, southwest Ethiopia. He continued his junior secondary education (7 – 8) at Hasho Primary School; secondary education at Deka Secondary School in Gesha district in Kaffa zone southwest, Ethiopia and the preparatory education at Masha Secondary School in Sheka zone southwest Ethiopia. Then he joined Hawassa University, Wondo Genet College of Forestry and Natural Resources in 2009/10 and obtained his B.Sc. degree in Agroforestry in June 2012. Then he has served at Rural and Agriculture Development office in Sayilem district in Kaffa zone southwest, Ethiopia for two years. And Since 2015 he has been working in southern Agricultural Research Institute in Bonga Agricultural Research Centers as a researcher. In September 2016 he joined School of Graduate Studies of Hawassa University, Wondo Genet College of Forestry and Natural Resources and obtained his M.Sc. degree in Production Forestry in 2018 and currently works in southern Agricultural Research Institute in Bonga Agricultural Research Centers as forestry researcher.