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Research Article

Exploring the Contribution of Participatory Forest Management to Maintain Structure and Composition of Dry Forest Resources in the Lowlands of Northwest Ethiopia

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Participatory forest management (PFM) approach has been promoted widely as a mechanism to conserve forest resources while contributing to local livelihoods. However, most PFM evaluations focused on livelihood contributions with less attention to the conservation effects of PFM. The present study examines the contributions of PFM in maintaining the diversity, structure, and composition of the dry forest resources in northwestern lowlands of Ethiopia. Vegetation data were collected from three forest sites managed under PFM and their adjacent open-access dry forests for comparison. Woody vegetation data were collected from 216 sample plots of size 20×20 m laid in systematic random sampling in the PFM forest and adjacent open-access forests. Standard woody vegetation analysis indices followed by an independent t test were employed to investigate the variations in woody species diversity, structure, and composition between forests under PFM and open-access conditions. The dry forests under PFM harbor 23%–62% more woody plant species, 15%–45% more genera, and 30%–40% more families than their adjacent open-access forests. Moreover, PFM-managed forests exhibit significantly higher densities of trees ($p < 0.01$) and seedlings ($p < 0.01$) than the adjacent open-access forests. The mean cumulative basal areas of the PFM forests (24.4 m^2 ha^{-1}) are also significantly higher ($p < 0.01$) than those of the non-PFM forest (9.4 m^2 ha^{-1}) counterparts. The overall importance value index (IVI) analysis also indicates the better conservation status of high-value and locally demanded tree species such as *Boswellia papyrifera*, *Anogeissus leiocarpa*, and *Pterocarpus lucens* in the PFM forests. On the other hand, locally lesser economically demanded tree species constituted the highest IVI values in the non-PFM forests. Overall, the empirical evidence demonstrated the significant contribution of PFM in dry forest resource conservation demonstrated by maintaining the structure and composition of the forest resources. Our findings highlighted that promoting PFM can address conservation objectives while contributing to local livelihoods through local empowerment.

Keywords: conservation; dryforest; forest conditions; open access forest; PFM; woodland

1. Introduction

Comanagement strategy has been widely recognized in forest management aiming the participation of local stakeholders in the management endeavors and sharing associated benefits of forest conservation [1, 2]. Co-management is conceptualized as a functional natural resource governance system that engages networks of actors such as the state, the community, and other relevant actors, in decision-making processes of resource management [1]. It is a decentralized forest governance targeting sustainable forest management with the consideration of social dimension through livelihood improvement as well as ecological aspect in improving forest resources [3]. Thus, such a forest governance system has attracted attention due to the multifaceted role in achieving conservation and livelihoods outcomes [4], alleviating poverty [5] and improving local forest governance [6]. Participatory forest management

(PFM) has emerged as a potential framework and forest management scheme for collaborative forest management between forest adjacent communities and government forestry agencies on the basis of predefined responsibilities and benefit sharing mechanisms [7–9].

In Ethiopia, centralized forest management approaches undermined the potential of local communities to beneficially harness sustainable forest management [10, 11]. Consequently, the exclusion of local communities in the traditional centralized forest governance has resulted in a *de facto* open-access condition. Forest adjacent communities lost interest and commitment to forest conservation, and consequently, forest resources were exposed to an open-access situation, leading to the exploitation of the resource without considering future generations [10]. Hence, the forest resources of Ethiopia have been continuously declining in the alarming rate in both size and quality [12]. Increasing human and livestock population, lack of clear forest policy, and associated factors also contributed to the rapid deforestation and degradation of the country's forest resource [13]. Cognizant to this, comanagement approaches including PFM have been adopted over the last 3 decades by the Ethiopian government for the sustainable management of forest resources [8, 11, 14] with a positive livelihood impacts [15, 16].

Since the introduction of PFM in the mid-1990s [8], the geographical coverage and the extent of the forest area under PFM have increased substantially across Ethiopia with the help of local and international NGO's as well as government sectors [17]. However, majority of the PFM intervention sites are concentrated in Afromontane and moist forests of Oromia and Southern Nations Nationalities and Peoples (SNNP) regions [8, 10]. Recently, PFM approaches have been scaling up to woodland resources in the lowlands of the country facilitated by government and nongovernmental organizations (NGOs) [8]. Likewise, PFM implementation has been introduced to the *Combretum–Terminalia* dry forest of northwestern Ethiopia in 2011 by NGOs and the government.

Despite the general expectation of the PFM approach in achieving sustainable forest management, there are rather divergent results on the contribution of PFM in forest conservation [10, 15, 16, 18, 19]. This could be associated with the diverse and varying nature of the approach as well as the biophysical conditions across regions [20]. As to Agrawal [21] and Girma and Beyene [13], the simultaneous livelihood and conservation outcomes of collective action in the forest management is rather context specific. Hence, answering the research questions "under what condition and to what extent PFM approaches contribute to forest conservation?" remains open and demands context-specific empirical studies [7, 22]. Studies evaluating the performance of PFMs in the Afromontane and moist forests of Oromia and SNNP regions reported the improvement of forest conditions and reduction of forest disturbance [9, 10, 23, 24].

Despite the expansion of PFM in the lowland woodland, their performance in achieving conservation outcomes has not yet been evaluated in a comprehensive manner with due consideration of their livelihood and conservation outcomes [15, 16]. Hence, the objective of the present study is to examine the contribution of PFM in forest conservation through the maintenance of forest conditions. It evaluates the performance of PFM in improving forest conditions in the dry C*ombretum–Terminalia* woodland context in which PFMs mainly target high-value nontimber forest products such as frankincense for local livelihood improvement [16, 25]. The investigation compared the forest structure and composition indicators from three forests managed under PFM with that of adjacent state forests in a *de facto* open-access condition.

2. Materials and Methods

2.1. Description of the Study Area. The study was conducted in the northwest lowlands of Amhara National Regional State, Metema district (Figure 1). The district was purposively selected given the recent piloting of PFM approaches over the last one and a half decade with the aim of sustainable utilization of commercial NTFPs from dry forest resources with the engagement of local communities. Specifically, the study was conducted in three kebeles, the lowest administrative unit, namely, Delello, Gundo, and Meshiha (Figure 1), where PFM-managed forests and their adjacent open-access forests were available.

Metema district is located between 12°19′19″ and 13°27′08″N latitude, and 35°51′20″ and 36°49′44″E longitude. It is one of the largest districts in the region, covering an area of 399,500 ha, and its altitude ranges from 550 to 1608 m.a.s.l. The area receives unimodal rainfall, which extends from June to September, with an annual average of 955 mm. The annual mean minimum and maximum temperatures are 19.1°C and 35.6°C, respectively. Based on the 2007 National Census conducted by the Central Statistics of Ethiopia, the district has a total population of 110, 252 [26].

The lowlands of Northwest Amhara Region are home to *Combretum–Terminalia* broad-leaved deciduous vegetation, one of the four biomes of Ethiopia that host diverse fauna and flora species [28]. The *Combretum–Terminalia* biome is widely acknowledged for its diverse socioeconomic and ecological services at local, national, and international levels [26, 28]. The vegetation type present in the area provides benefits including the source of income to the rural livelihood and serves as a means to buffer the encroachment of the Sahara desert, biodiversity conservation, protection of wetlands, improvement of soil fertility, and carbon sequestration [28]. This vegetation is also an important source of commercially valuable gums and resins such as frankincense and gum arabic [26]. These forest products play an essential role in the livelihoods of the local communities. Considering their diverse socioeconomic and ecological importance and growing interest of decentralizing the governance of the forest resources, very recently, the local government has transferred forest management rights to local communities. As a result, the dry forests of the area started to be managed under PFM and PFM cooperatives have been established in each village since 2012 with the help of local NGOs, with the objective of addressing rapid

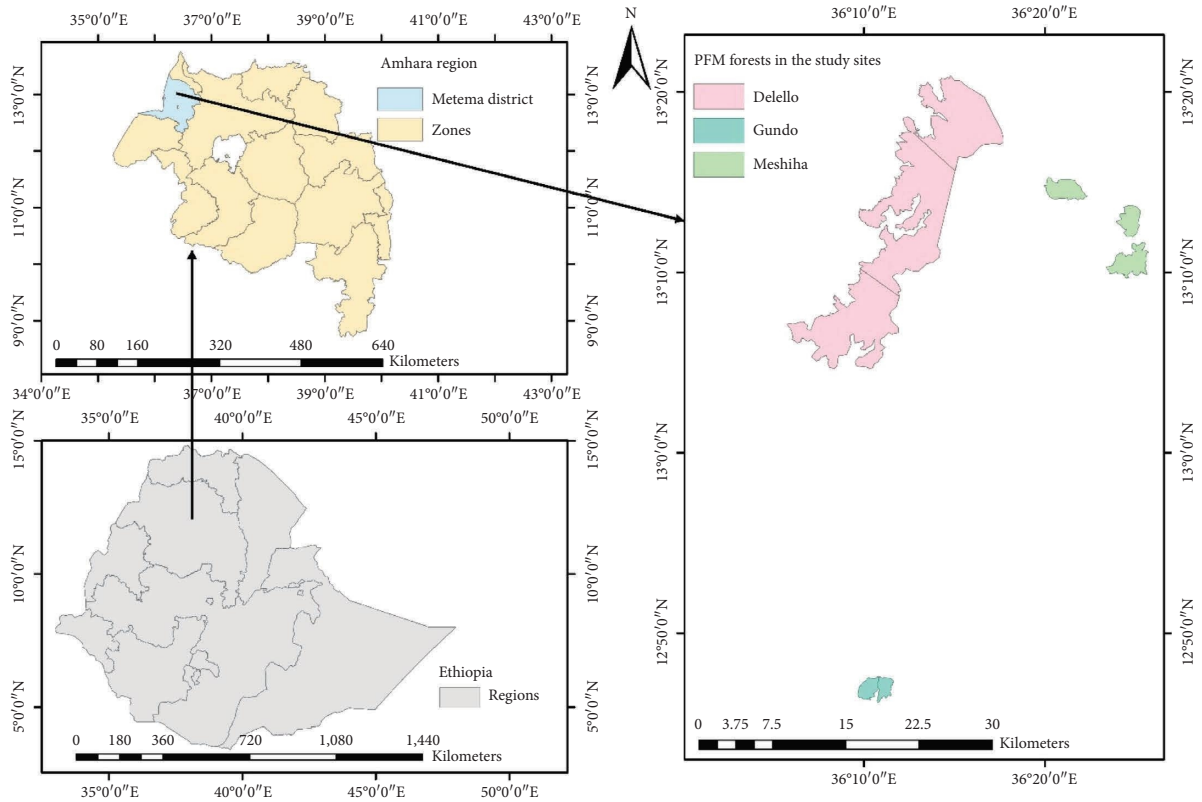


Figure 1: Map of the study area and kebeles in Metema district, Ethiopia.

deforestation and use of the dry forests found in the study area [16].

2.2. Sampling Techniques and Data Collection. To analyze variations in densities of various tree species, species richness, regeneration status, and population structure between forests under participatory management and adjacent non-PFM forests, vegetation inventory data were collected in three PFM forest sites (Delello, Gundo, and Meshiha) in 2023. The detailed description of PFM forests investigated is presented in Table 1. The comparator non-PFM or open-access adjacent forests are extensions of the PFM-designated forests, which share similar environmental conditions except the management approach. Two separate forest patches, one under PFM and the other outside PFM but adjacent to the first, were identified, and an inventory was carried out using systematic line transect sampling [27]. Following the approaches of Eshetie et al. [28], Kent [29], and Wale et al. [30], sample plots of 20 m × 20 m (400 m^2) were systematically laid at intervals of 200 m between plots in the selected forest blocks. The line transects were laid out across the contour at a regular interval of 300 m. Data on adult trees were taken from the larger plots of 400 m^2 area. However, for seedling and sapling inventory, two subquadrats of 2 m × 2 m and 5 × 5 m were nested on the opposite corners of the main plots [30], as illustrated in Figure 2.

A total of 216 plots (116 in the PFM forest [Delello 35, Gundo 41, and Meshiha 40] and 100 in the open-access forest blocks [Delello 34, Gundo 26, and Meshiha 40]) were taken proportional to the size of the sampled forest areas. The growth stages of woody species were defined according to Hundera and Gadissa [31] as adult, sapling, and seedlings. Accordingly, adult trees are those having a diameter at breast height (DBH) ≥ 2 cm and height greater than 2 m, sapling DBH < 2 cm and height less than 2 m, whereas seedlings are those having a DBH < 2 cm but height less than 1 m. For all trees and shrubs, we measured the height and DBH. For regeneration assessment, we counted seedling and sapling numbers by species. To easily identify the names of the species encountered, knowledgeable individuals from the community were involved in the survey and scientific names were identified with flora of Ethiopia [32] and useful trees of Ethiopia [33].

2.3. Data Analysis

2.3.1. Forest Structure and Composition. Standard woody vegetation analysis indices [29] were used to examine the structure and composition of forest blocks under PFM management and their adjacent comparators, which are under open access. Then, independent *t* test was applied to investigate variations in woody species diversity, structure, and composition between forests under PFM and open-access conditions. With and without approach was used to capture the effects of PFM implementations on forests under participatory management (treatment group), which were compared with adjacent non-PFM-managed forests (NPFMs) (control group).

Table 1: Description of the PFM sites selected for this study.

Attributes	Gundo	Meshiha	Delello
Number of members	974	802	101
Year of establishment	2011	2013	2012
Disturbance	Moderately disturbed	Moderately disturbed	Moderately disturbed
Accessibility	Accessible	Limited access	Accessible
Forest area (Ha)	5,090	4,740	18,000
Established and supported by	ORDA*	Government	SRMP**
Distance from nearby town in km	42	79	64
Land use	Dominantly woodland	Dominantly woodland	Dominantly woodland
Altitude	750–823	960–1010	756–820
Terrain	Undulating	Undulating	Undulating

*ORDA, Organization for Rehabilitations and Development in Amhara.
**SRMP, Sustainable natural Resource Management Program [16].

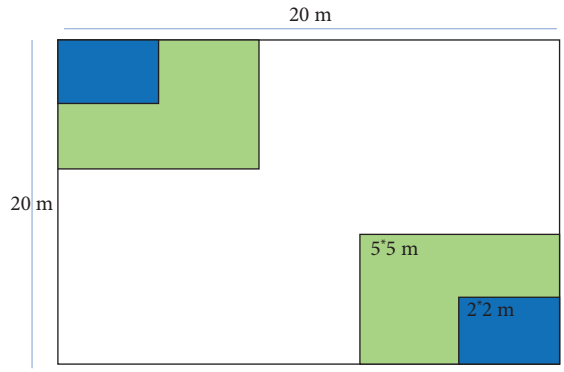


Figure 2: Illustration of the vegetation assessment plots.

2.3.2. Measurement of Woody Species Composition, Diversity, and Population Structure. Based on Husch [34], the structure of a stand, that is, the distribution of trees by species and size, is the result of species growth habits, environmental conditions, and management practices done by the different initiatives. Species composition can be examined by estimating the stem density, importance value index (IVI), forest structure, population structure, and diversity patterns [29, 35]. These variables were computed for both PFM-managed and the adjoining non-PFM forests open-access forests using the equations described below.

Stem density in the study forests:

$$\text{Density} = \left(\frac{\text{Number of individuals of a species in all quadrats}}{\text{Total area of quadrats}}\right) \times 100. \quad (1)$$

2.3.2.1. Diversity Analysis. Woody species diversity in the studied forests was analyzed using the Shannon–Wiener diversity index (H') [29]. Species richness is the number of species in a sample of standard size [36]. Species i comprises proportion pi of the total individuals in a community of S species,

$$H' = -\sum_{i=1}^{s} pi * \ln pi, \quad (2)$$

where H' is the Shannon diversity index and pi is the proportion of individuals found in the ith species.

2.3.2.2. Shannon's Equitability (EH) or Evenness

$$\text{EH} = \frac{H}{Hmax} = \frac{H}{ins}, \quad (3)$$

where S is the number of species recorded.

Woody species structure of the studied forests was analyzed using the indicators such as the mean basal area, dominance, and size class distribution. Dominance is described in terms of IVI, which is the sum of the relative basal area, relative density, and relative frequency in the sample plots for each species [29]. Woody species with the highest

value of the IVI were selected for population structure analyses.

Frequency is an indicator of the distribution of the species that measures the probability or chance of finding a plant species in a given sample area or quadrat. Relative frequency is the number of plots in which species A occur divided by the total number of plots computed using the following equation:

$$\text{Relative frequency (RF)} = \frac{\text{Frequency value for species i}}{\text{Total of all frequency values for all species}} * 100. \quad (4)$$

Density of woody species measures the number of plants of a certain species per unit area. In this study, the mean density of woody species was determined by converting the number of individuals of each woody species encountered in all the quadrats and all transects of the study areas in each study site to equivalent number per hectare. The relative density was also computed using the following formula:

$$\text{Relative density (Rd)} = \frac{\text{Number of individuals of species i counted}}{\text{Total number of individuals in the area}} * 100. \quad (5)$$

Relative dominance (RDO) refers to the degree of coverage of a species as an expression of the space it occupies in a given area. Dominance is expressed in terms of the basal area of the species. Then, the RDO is computed as the percentage of the total basal area of a given species out of the total measured stem basal areas of all species,

$$\text{Relative dominance (RDO)} = \frac{\text{Dominance of species i}}{\text{Total dominance of all species}} * 100. \quad (6)$$

The relative ecological importance of each woody species, commonly referred to as IVI, was determined by summing its relative frequency, relative density, and RDO [29]. The IVI is a unitless score calculated by adding the RDO, RD, and RF of a species [29]. The IVI is useful to compare the ecological significance of a species [37] and hence used as an index for summarizing vegetation characteristics and ranking species for management and conservation practices. Later, tree species with higher IVI values and locally demanded tree species were selected for analyses of the population structure. The population structure of the studied forests and selected species was analyzed with eight diameter class distribution patterns. The population structure was depicted using frequency histograms,

$$\text{IVI} = \text{RDO} + \text{Rd} + \text{RF}. \quad (7)$$

In addition, the regeneration status of woody species was summarized based on the total count of seedlings and saplings of each species across all quadrats. The regeneration status of trees, shrubs, and other woody plants was determined by computing density ratios between seedlings and mature individuals, seedlings and saplings, and saplings and mature individuals [38].

Furthermore, the similarity of the studied PFM forests with their counterpart adjacent non-PFM forests was done by computing the Sorensen similarity coefficient. As per Kent [29], similarity coefficient values range from 0 (complete dissimilarity) to 1 (total similarity),

$$\text{Ss} = \frac{2a}{2a + b + c}, \quad (8)$$

where Ss is the Sorensen similarity coefficient, a is the number of species common to both forests, and b and c are the number of species in forests b and c, respectively.

Species diversity, structure, and regeneration data computed for the studied different PFM and non-PFM forests were compared and described, and their statistical variation at $\alpha = 0.05$ was tested using an independent t test with Statistical Package for Social Science (SPSS).

3. Results and Discussion

3.1. Contribution of PFM Interventions in Maintaining Woody Species Composition. Table 2 and Table 3 present the woody plant species encountered in the studied PFM forests and their adjacent forest blocks with de facto open-access conditions. The woodlands under PFM management harbor 23%–62% more woody plant species, 15%–45% more genera, and 30%–40% more families than their adjacent forests. The result illustrates the higher woody plant species composition and diversity in the PFM forests. A total of 45 woody plant species belonging to 21 families were recorded from both PFM and non-PFM forest sites. The highest woody plant species was recorded in PFM forests than in the non-PFM forests. Among the studied PFM forests, Meshiha PFM forest has the highest woody plant species (39 species) followed by Gundo (34 species) and Delello (32 species) forests. Moreover, the recorded woody plant species in PFM

Table 2: Number of woody species in PFM and their adjacent forests.

Woody species composition attributes	Delello		Gundo		Meshiha		Metema forest [30]	Godebe protected area [38]
	PFM	NPFM	PFM	NPFM	PFM	NPFM		
No. of species	32	26	34	26	39	24	36	56
Number of genera	23	20	29	22	29	20	27	43
No. of families	14	10	14	14	17	13	16	29

forests is comparable with the recorded species number a decade ago [30] in Metema and protected forests in the adjacent district [38]. These variations in the species composition among PFM and non-PFM forests are directly associated with the management regime followed and the uncontrolled degradation and extraction of forest products in the open-access forests. Unlike the PFM forests, the non-PFM forests are open to the entire local communities and highly disturbed due to the selective harvesting of timber and other wood products for both subsistence and market uses.

Among the different families recorded in the study PFM forests, *Fabaceae* is by far the dominant family with the highest number of species constituting more than a quarter of all species in the studied forests. Tree species in the *Fabaceae* family account for 26.5%, 32.5%, and 33.3% of the woody species recorded in Gundo, Delello, and Meshiha forests, respectively. *Combretaceae* family is the second most abundant family, following *Fabaceae* with five species (15.62%) in Delello, five (14.7%) in Gundo, and six (15.4%) in Meshiha PFM forests. The rest of the 16 families for the three studied PFM forests comprise different percentages of the woody plant species (Table 3). Like the PFM forests, *Fabaceae* and *Combretaceae* were the dominant families with the highest number of woody plant species. In both Delello and Meshiha PFM, forest highest numbers of families were recorded compared with their non-PFM counterparts, but the same family numbers were recorded in Gundo PFM and non-PFM forests.

The number of woody plant species recorded in Meshiha PFM forests was even higher than a study conducted in the area before a decade by Wale et al. [30], whereas the number of woody species, families, and genera recorded in the study forests were less than the adjacent Godebe protected area forest [39]. This is due to the strict protection of the protected area from human and animal interference, whereas in the studied forests, the PFM members have the right to use the forests with minimum restriction. Only one species (2.2%) encountered in the studied non-PFM forest (Delello) was absent from the entire studied PFM forest. Among the 45 species found in the entire studied forests, 10 (22.2%) species found in the PFM forest were absent in three of the non-PFM forests. Whereas 13 (28.9%) species were shared with the entire PFM and non-PFM studied forests, the rest of 21 (46.6%) of woody plant species were observed in both PFM and non-PFM forests in either one or two of the studied forests.

The difference in the number of woody plant species and families is associated with the implementations of PFM in the studied forests. Similar findings reported the positive contributions of PFM toward forest conditions; for example, Tadesse et al. [19] reported the highest number of woody plant species in PFM forests compared to the non-PFM forests in the Gebradima forest, southwest Ethiopia. Similarly, a study conducted on the role of PFMCs in forest resource conservation revealed that the formation of community-initiated or NGO-initiated PFMCs has improved the status of the forest [40] and the state of the forest is perceived to have improved with the introduction of PFM [24].

3.2. Similarity of PFM and Adjacent Open-Access Forests. Sorenson's similarity coefficient for all woody plant species between the studied PFM forests and their respective adjacent non-PFM forests was found below 0.5 (Table 4), indicating higher species heterogeneity. Despite the similar biophysical conditions in the PFM and their adjacent non-PFM forests, the species heterogeneity and variation between the studied forests could mainly be explained by the expected disturbance in the non-PFM forests. The overextraction of timber and other wood products of the non-PFM forests might result in the emergency of other woody plant species. The emerging species in the non-PFM forests are mainly of light demanding and agro-forestry type of plant species like *Balanites aegyptiaca,* and this in turn decreases the similarities of the woody species compositions of the PFM and non-PFM forests. Similarly, the non-PFM forests show lower similarity of species composition than that of protected forests in Godebe National Park [41] located nearby the present study forests. However, the highest similarity of species composition of the PFM and non-PFM forests was reported elsewhere [19].

3.3. Contribution of PFM Intervention to Woody Plant Species Diversity. Table 5 presents the variation in woody species diversity, richness, and evenness of the studied PFM and non-PFM forests. Considering the pooled data, PFM forests show significantly higher woody species diversity ($p \leq 0.05$), seedling ($p \leq 0.001$), and adult density ($p \leq 0.001$), as well as basal area ($p \leq 0.001$), Like the species composition, the studied forests exhibited different woody plant species diversity values and the PFM forest had a higher Shannon–Wiener diversity (H') index than the non-PFM forests. This variation demonstrates the importance of PFM in maintaining species diversity and biodiversity conservation in the studied forest blocks through decreasing disturbance. Consistent with our findings, similar evidence in the forests of southwest Ethiopia [42, 43] reported an increase in plant species richness as a result of PFM interventions.

Table 3: Plant species recorded from PFM and non-PFM forests.

Scientific name	Family name	Species common name (Amharic)	Growth habit	Studied forest site					
				Delello		Gundo		Meshiha	
				PFM	Non-PFM	PFM	Non-PFM	PFM	Non-PFM
Ziziphus abyssinica	*Rhamnaceae*	Abetere	S/T	−	+	+	+	+	+
Commiphora africana	*Burseraceae*	Aden/Kerbe	T	−	−	+	+	+	+
Dichrostachys cinerea	*Fabaceae*	Ader/Gorgoro	S/T	−	+	−	+	+	+
Cissus populnea	*Vitaceae*	Alke hareg	C	+	+	+	+	+	+
Combretum collinum	*Fabaceae*	Askir	T	+	+	+	+	+	+
Ficus sycomorus	*Moraceae*	Bamba	T	−	+	+	−	+	−
Combretum hartmannianum	*Combretaceae*	Chamda	T	+	+	+	+	+	+
Pterocarpus lucens	*Fabaceae*	Charia	T	+	+	+	+	+	+
Ficus thonningii Blume	*Moraceae*	Chibha		+	−	−	+	+	−
Sterculia setigera	*Sterculiaceae*	Darlie	T	+	+	+	+	+	+
Strychnos innocua	*Loganiaceae*	Dibulbule/Kokoba	T	+	+	+	+	+	+
Adansonia digitata	*Bombacaceae*	Diza	T	−	−	−	−	−	+
Lannea fruticosa	*Anacardiaceae*	Dugundugi/Duduna	T	+	+	+	+	+	+
Ximenia Americana	*Olacaceae*	Enkoy	S/T	−	−	+	+	+	+
Boscia mossambicensis	*Capparidaceae*	Etsemanahi	T	+	−	+	+	+	−
Gardenia ternifolia	*Rubiaceae*	Gambillo	S/T	+	+	+	+	+	+
Albizia malacophylla	*Fabaceae*	Gebso	T	−	−	−	−	+	−
Ziziphus spina-christi	*Rhamnaceae*	Geva	S/T	+	+	+	+	+	−
Acacia polyacantha	*Fabaceae*	Giramda Girar	T	+	+	+	+	+	−
Acacia seyal Del.	*Fabaceae*	Key Girar	T	+	+	+	−	+	−
Anogeissus leiocarpa	*Combretaceae*	Kirkira	T	+	+	+	+	+	+
Entada abyssinica	*Fabaceae*	Kontir	S/T	−	−	−	−	+	−
Erythrina abyssinica	*Fabaceae*	Kuara	T	−	−	−	−	+	−
Tamarindus indica	*Fabaceae*	Kumer	T	+	+	+	−	+	−
Grewia ferruginea	*Tiliaceae*	Lenkuata	−	−	+	−	−	−	
Balanites aegyptiaca	*Balanitaceae*	Lalo	T	+	+	+	−	+	−
Grewia villosa	*Tiliaceae*	Lenkuata	T	−	−	+	−	−	−
Lonchocarpus laxiflorus	*Fabaceae*	Mebrat enchet	T	+	−	+	−	+	−
Combretum molle	*Combretaceae*	Nech Abalo	T	+	+	+	+	+	+
Acacia sieberiana Dc.	*Fabaceae*	Nech girar/Ameshegure	T	+	+	+	−	+	+
Grewia bicolor	*Tiliaceae*	Sefa	T	+	−	+	−	+	−
Acacia Senegal	*Fabaceae*	Senegal girar	T	+	−	+	−	−	−
Arecaceae		Senel/Leha	S	+	−	−	−		
Diospyros abyssinica	*Ebenaceae*	Serkin	T	+	+	+	−	+	+
Flueggea virosa	*Euphorbiaceae*	Shasaha	S/T	+	−	+	+	+	+
Oxytenanthera abyssinica	*Poaceae*	Shimel	H	+	−	+	−	+	−
Ficus thonningii	*Moraceae*	Shola	T	+	−	+	+	+	−
Combretum adenogonium	*Combretaceae*	Tikur Abalo	T	+	+	+	+	+	+
Boswellia papyrifera	*Burseraceae*	Walia Meker	T	+	+	+	+	+	+
Terminalia brownii	*Combretaceae*	Woiba	T	+	−	−	−	+	+

Table 3: Continued.

Scientific name	Family name	Species common name (Amharic)	Growth habit	Studied forest site					
				Delello		Gundo		Meshiha	
				PFM	Non-PFM	PFM	Non-PFM	PFM	Non-PFM
Terminalia laxiflora	*Combretaceae*	Wombella	T	−	−	+	+	+	+
Maytenus undata	*Celastraceae*	Yebreha atat	S/T	−	−	−	−	−	−
Piliostigma thonningii	*Fabaceae*	Yekola Wanza	T	+	+	+	+	+	−
Stereospermum kunthianum	*Bignoniaceae*	Zana	T	+	+	+	+	+	+
Dalbergia melanoxylon	*Fabaceae*	Zobi	S/T	+	+	−	+	+	+

Note: (+) indicates the presence, and (−) indicates the absence.

Table 4: Similarities of the studied forests.

Studied forest	Delello PFM	Delello NPFM	Meshiha PFM	Meshiha NPFM	Gundo PFM	Gundo NPFM
Delello PFM	1					
Delello NPFM	0.43	1				
Meshiha PFM	0.45	0.43	1			
Meshiha NPFM	0.41	0.41	0.43	1		
Gundo PFM	0.45	0.43	0.46	0.42	1	
Gundo NPFM	0.42	0.42	0.44	0.44	0.43	1
Godebe National Park	0.4	0.37	0.42	0.36	0.27	0.36

According to Engida [9], forests with low levels of disturbance have a high species diversity compared to the disturbed forest. Similar findings were reported on the positive contributions of PFM in other parts of the country on species diversity and evenness [10, 19, 42, 44]. However, the present results were even lower than those of a study done on dry forests of northwestern Ethiopia [30] and Godebe protected area, which is found adjacent to the studied forest [39]. The low level of diversity of the woody plant species for the PFM-managed forests is associated with the intention of PFM. While PFM was initiated in the study area, its prime target was to save the ever-declining *Boswellia* forest and to use the forest for frankincense production and only *Boswellia*-dominated forests were demarcated, but for the non-PFM forests, it was directly related to the human disturbance.

3.4. Contribution of PFM Intervention in Maintaining Woody Species Stocking and Enhancing Regeneration. A visible variation was observed in the tree, sapling, and seedling densities of individual species per hectare in the studied PFM and non-PFM forests (Appendix 1). The tree, sapling, and seedling densities in the PFM forests are higher than their non-PFM counterparts. The overall mean density of mature trees/shrubs per hectare was 1,003, 810, and 693 for Delello, Gundo, and Meshiha PFM forests, respectively, whereas the lowest number of individual mature trees/shrubs ha $^{-1}$ was recorded for the non-PFM forests. The overall mean density of mature tree/shrub ha^{-1} for the two management categories had also shown a considerable difference ranging from 872 individuals ha^{-1} for PFM-managed forests to 179 individuals ha^{-1} for forests without PFM. PFM implementations in the studied forests have significantly influenced the mature tree density (Table 5).

The lowest number of mature trees/shrubs recorded in the non-PFM forests is associated with the selective logging of valuable trees for subsistence consumption and cash income of households in the area. Unlike the non-PFM forests, PFM forests are better protected by bylaws from illegal logging where local communities are only allowed to collect nontimber forest products, frankincense, that might have created an incentive for better protection of the forests. The investigated PFM forests had a larger number of user members compared with other related PFM groups functioning in the study area, and larger PFM groups are expected to have a positive contribution to forest condition improvement [15, 40].

The densities and basal areas of particular species for each of the studied PFM and non-PFM forests had also shown variation (Table 6, Appendix 1). In the PFM-managed forests, high-value and economically demanded tree species such as *Boswellia papyrifera*, *Dalbergia melanoxylon, Oxytenanthera abyssinica* had the highest density. On the other hand, locally lesser economically demanded tree species such as *Ba. aegyptiaca*, *Anogeissus leiocarpa*, and *Sterculia setigera* constituted the highest mature tree/shrub density in the non-PFM forests. The lowest number of individual mature trees/shrubs ha^{-1} on the non-PFM forests might also be associated with the presence of the leakage effect. While restrictions were made on the PFM-managed forests, local communities might be forced to extract forest products found on the non-PFM forests for their HH consumption and commercial purposes.

The aggregated sapling densities ha^{-1} for PFM-managed forests and non-PFM forests were not statistically significant. However, the sapling density was highest in forests managed under PFM. This clearly indicated that sapling densities in both forest management regimes had not shown a difference and this is widely attributed to the recurrent forest fire happening in both PFM and non-PFM forests. As a result, there are poor recruitment and succession of seedlings to sapling stages.

The average seedling densities ha^{-1} calculated for the respective studied forests had shown great variations; comparatively, forests managed under PFM had the largest number of seedlings ha^{-1} than the adjacent non-PFM forests, and this difference was statistically significant. The highest seedling density was recorded in Delello PFM forests (964 individuals ha^{-1}), and among the species, the highly demanded frankincense-bearing tree *B. papyrifera* constituted the highest seedling density (414 individuals ha $^{-1}$). Contrary to this Meshiha, non-PFM forest had the lowest seedling density per hectare (154 individuals ha $^{-1}$). The variation in the seedlings recorded in the two forest management strategies is a clear indication of the positive impact of PFM interventions in the dry forest resources of the area primarily by reducing human and animal disturbance. Several similar studies on the contribution of PFM intervention on regeneration status mainly of seedling density enhancement reported in different forest types. Mengist et al. [42] noted that more seedlings and saplings were recorded in PFM-managed forests than the forests without PFM. The number of seedlings reported on the entire studied PFM-managed forests is greater than the previous report of the study district [30]; however, the number of individual

Table 5: Summary statistics for PFM-managed forests and non-PFM forests.

Diversity attributes	Delello PFM	Delello NPFM	p value	Meshiha PFM	Meshiha NPFM	p value	Gundo PFM	Gundo NPFM	p value	Polled PFM	Polled NPFM	p value
Species evenness (E)	0.81 ± 0.005	0.72 ± 0.008	NS	0.82 ± 0.005	0.75 ± 0.005	NS	0.83 ± 0.005	0.76 ± 0.042	***	1.99 ± 0.03	1.38 ± 0.04	***
Species diversity (H)	1.81 ± 0.055	1.19 ± 0.072	NS	2.09 ± 0.05	1.53 ± 0.05	NS	2.066 ± 0.055	1.4 ± 0.11	*	0.82 ± 0.00	1.38 ± 0.04	**
Tree density ha^{-1}	1002.85 ± 81.39	179.41 ± 14.79	***	816.25 ± 74.14	165.38 ± 8.88	***	810.38 ± 65.85	195.18 ± 26.93	***	872.82 ± 42.89	179.84 ± 9.28	***
Sapling density ha^{-1}	248.57 ± 52.6	184.58 ± 47.34	NS	274.24 ± 41.89	188.12 ± 16.93	***	384.78 ± 42.94	457.67 ± 102.18	*	337 ± 26.51	273.13 ± 34.09	NS
Seedling density ha^{-1}	964.28 ± 170.20	211.76 ± 33.68	***	631.25 ± 73.66	154.54 ± 17.28	***	735.99 ± 82.06	324.9 ± 65.12	NS	777.19 ± 64.18	235.79 ± 23.57	***
Basal area (m^2/ha)	28.70 ± 2.61	7.83 ± 1.03	***	20.08 ± 1.24	8.44 ± 0.749	***	25.05 ± 2.69	12.94 ± 1.99	***	24.44 ± 1.33	9.40 ± 0.71	***

Note: Levels of significance: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p \leq 0.001$; NS indicates not significant.

Table 6: Species basal area (m^2 ha^{-1}) and their percentage input of the PFM and non-PFM forests.

Scientific name	Delello forest			
	PFM		Non-PFM	
	BA (m^2 ha^{-1})	%	BA (m^2 ha^{-1})	%
Boswellia papyrifera	11.69	40.72	0.14	1.71
Sterculia setigera	5.42	18.89	0.47	5.83
Combretum molle	2.09	7.29		
Dalbergia melanoxylon	1.73	6.02	0.16	1.93
Balanites aegyptiaca	1.6	5.58	2.62	32.29
Anogeissus leiocarpa	1.4	4.89	1.24	15.23
Lannea fruticosa	1.24	4.31	1.11	13.72
Pterocarpus lucens	1	3.49	0.6	7.34
Ficus thonningii	0.43	1.51		
Combretum adenogonium	0.38	1.33		
Combretum hartmannianum			0.93	11.44
Commiphora africana			0.38	4.71
Acacia seyal			0.15	1.85
Total of other species	1.71	5.95	0.37	4.5
Total	**28.71**	**100**	**8.16**	**100**
Scientific name	**Gundo forest**			
	PFM		Non-PFM	
	BA (m^2 ha^{-1})	%	BA (m^2 ha^{-1})	%
B. papyrifera Hochst	9.48	37.83	2.029	18.02
Acacia polyacantha Willd.	2.37	9.45	0.201	1.79
Lannea fruticosa	1.9	7.58	0.769	6.83
A. leiocarpa	1.86	7.42	1.036	9.2
P. lucens	1.64	6.56	1.642	14.58
Sterculia setigera	1.5	5.97	1.996	17.72
Ziziphus abyssinica	1.19	4.76		
Combretum molle	1.12	4.46		
Terminalia laxiflora	1	4.01	0.428	3.8
F. thonningii			1.672	14.84
Combretum hartmannianum			0.31	2.75
Combretum adenogonium			0.237	2.1
Combretum collinum	0.78	3.11		
Total of other species	2.22	8.86	1	8
Total	**25.05**	**100**	**11**	**100**
Scientific name	**Meshiha forest**			
	PFM		NPFM	
	BA (m^2 ha^{-1})	%	BA (m^2 ha^{-1})	%
P. lucens	3.68	18.39	0.77	8.38
Lannea fruticosa	2.19	10.92	0.83	8.93
A. leiocarpa	2.05	10.24	1.38	14.92
B. papyrifera	1.9	9.49	1.07	11.57
Sterculia setigera	1.47	7.35	4.08	44.11
Acacia polyacantha	1.39	6.95		
Commiphora africana	1.05	5.24		
Stereospermum kunthianum	0.84	4.21		
Terminalia laxiflora	0.79	3.95		
Combretum hartmannianum	0.61	3.04	0.1	1.12
Strychnos innocua			0.46	5.02
Commiphora africana			0.24	2.59
Flueggea virosa			0.04	0.45
D. melanoxylon			0.04	0.42
Total of other species	4.05	20.22	0.23	2.5
Total	**20.03**	**100**	**9.25**	**100**

Note: Bold values are the total/cumulative of all the species.

seedlings ha^{-1} reported was lower for the non-PFM forests. Furthermore, an overall higher density of mature trees ha^{-1} in PFM forests than in state forests in the Adaba–Dodola forest area of the Oromia region, Ethiopia [44].

Considering the stocking or woody species density, PFM forests have significantly higher woody stocking (Table 5, $p < 0.00$) with a basal area 127%–225% higher than that of their adjacent open-access forests (Table 6). Moreover, the

highly valued species like *Boswellia* are better preserved in the PFM forests constituting the highest RDO in Delello (40%) and Gundo (37%) PFM forests. This is consistent with the objective of the PFM scheme by which incentives are created for the sustainable management of the targeted tree species while contributing to the local livelihood. However, the lower stocking and basal area of woody plant species in non-PFM forests can be explained by the degradation of the open-access forests with the harvesting of timber and other wood products.

In the adjoining open-access forests, lesser economically demanded and agroforestry tree species constituted the highest RDO. In Delello non-PFM forests, *Ba. aegyptiaca* constituted almost one-third of the total RDO followed by *A. leiocarpa* (15.2%), while in Delello adjacent open-access forests, *Ficus thonningii* constituted 14.84% of the total amount. The variation arises because in the non-PFM forests, selective cutting of individual trees having the highest diameter and economic values has been exploited exhaustively and this has hugely reduced the basal areas of these forests. Similar findings were reported on the positive contribution of PFM on basal area improvement by Tadesse et al. [19] who reported that PFM-managed forests had the highest basal areas than the non-PFM forests. However, a contrary finding [10] reported that PFM forests had the lowest basal area than the PFM-managed forests. A higher basal area in the study area was also reported by Wale [30] who reported 42.54 m^2 before a decade.

3.5. Contribution of PFM in Maintaining Population Structure of Major Tree Species. Figure 3 presents the cumulative diameter class frequency distribution for the studied forests and selected tree species. The population structure of the studied forests and selected species was analyzed with eight diameter class distribution patterns following Worku et al. [45]. The diameter class distribution of the selected tree species shows different patterns for PFM and non-PFM forests. Cumulative diameter class distribution for Delello and Gundo PFM-managed forests exhibited an inverted J shape, while Meshiha PFM forests showed a bell shape. Similarly, Delello and Meshiha NPMFs blocks exhibited an inverted J shape, whereas Gundo non-PFM forest block showed a bell shape. This is not close to the inverted J-shape structure of a "healthy" forest [43]. Although PFM interventions are believed to have an impact on the population structure of the species, in the study area the same diameter class distribution irregularities were observed in the PFM-managed forests. This could be attributed to the unfolding recurrent forest fire occurrences, livestock grazing, and trampling happening in both the PFM and non-PFM forests. However, a normal diameter class distribution of individuals was recorded in PFM forests in other parts of the country with different forest types [19, 42, 43].

As the aggregated species population structure might not tell much about the health and distribution patterns of the key species, the population structure of the major tree species was further examined. Based on their IVI, three dominant species selected for diameter class frequency distribution (*B. papyrifera, A. leiocarpa*, and *Pterocarpus lucens*). As illustrated in Figure 3 (C), the diameter class distribution of *B. papyrifera* had not shown any variations between the two management regimes despite the fact that this species is highly demanded for its frankincense production potential. The diameter class distribution shows a bell-shaped pattern with a similar pattern also reported in the study area [30]. This clearly indicates the need for urgent conservation intervention to sustain its existence by PFMCs and stakeholders since the resource is the source of income for PFM cooperatives and local communities. Similar studies in Ethiopia highlighted that *B. papyrifera* population is declining rapidly due to the anthropogenic effects and researchers are calling for immediate actions by the different stakeholders to sustain the resource [46–48]. The diameter class distribution pattern of *A. leiocarpa* showed a bell-shaped pattern in both PFM-managed forests and the adjacent open-access forests where the highest number of individual trees are found in Class 3 as demonstrated in Figure 3(b).

3.6. Stocking and Conservation Status of Major Tree Species in PFM Forests. Table 7 presents the IVI values and conservation status of tree species in the studied PFM and non-PFM forests. Highly valued tree species have a higher conservation status as demonstrated by their high IVI, while other species depict a higher IVI in the non-PFM forests. *B. papyrifera* tree with diverse ecological and economic benefits had the highest value indices of 75.54 and 34.9 for Delello and Gundo PFM-managed forests, respectively. This indicates the better conservation status of the Boswellia tree in the PFM-managed forests unlike the adjacent open-access forests. This is not a surprise since the major motivation for the establishment of PFM cooperative in the study area is to manage and to enhance the socioeconomic importance of gum and frankincense-bearing tree species. On the other hand, economically less demanded tree species such as *Ba. aegyptiaca, A. leiocarpa*, *and S. setigera* constituted the highest IVI values for Delello, Gundo, and Meshiha non-PFM forests, respectively. These tree species have little importance for construction materials and fuel wood for the local population.

Similar research findings were reported on woody plant species that had the highest IVI values in the Metema dry forest with *B. papyrifera, A. leiocarpa*, and *P. lucens,* which were the species with the highest IVI values [30]. The present study also found that these species had still retained the highest IVI values despite the intensification of the human disturbance, mainly the extraction of forest products and expansion of agriculture on the expense of the forest. This indicates the potential of PFM or local institutions in improving the forest conditions and contributing for sustainable forest management. Several studies to date have documented the positive impacts of PFM in improving the forest conditions in different parts of the world. For instance, Seymour et al. [49] in their review of the literature studies on community-based forest management concluded that

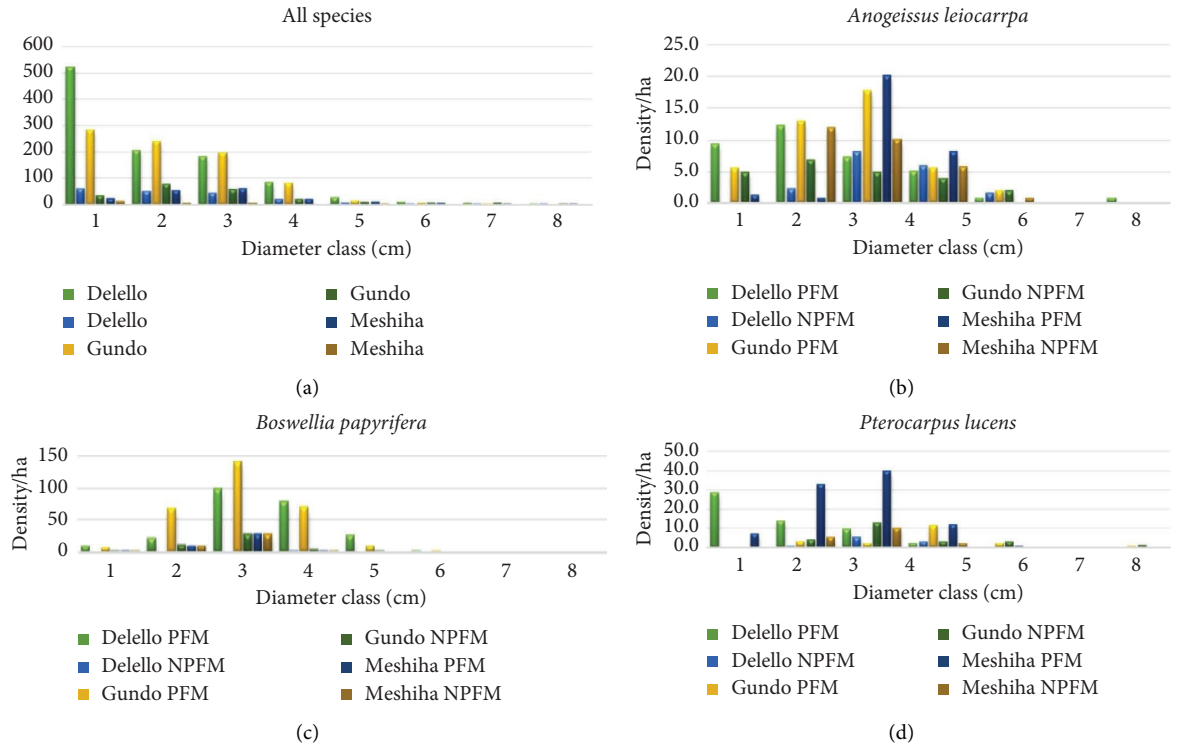


Figure 3: Diameter class frequency distribution for the studied forests and selected tree species. DBH classes versus the number of individuals per hectare in both forests. Diameter class in centimeters: Class 1 = 1–10.6 cm, Class 2 = 10.7–20.3 cm, Class 3 = 20.4–30 cm, Class 4 = 30.1–39.6 cm, Class 5 = 39.7–49.3 cm, Class 6 = 49.4–59 cm, Class 7 = 59.1–68.6 cm, Class 8 > 68.7 cm.

Table 7: Importance value indices for woody species for the studied forests.

Scientific name	Delello PFM forest				Scientific name	Delello NPFM forest			
	RD	RF	RDO	IVI		RD	RF	RDO	IVI
Species with the highest IVI values					Species with the highest IVI values				
Boswellia papyrifera	26.24	8.57	40.73	75.54	*Balanites aegyptiaca*	27.57	14.38	20.96	62.92
Dalbergia melanoxylon	14.28	7.14	6.02	27.44	*Stereospermum kunthianum*	1.15	4.58	25.21	30.93
Sterculia setigera	2.32	6	18.9	27.22	*Combretum hartmannianum*	10.77	12.42	7.43	30.62
Combretum molle	6.48	4.57	7.29	18.34	*Acacia seyal*	15.7	11.11	1.2	28.02
Combretum hartmannianum	7.93	8.29	0.4	16.61	*Anogeissus leiocarpa*	7.91	7.19	9.89	24.99
Lannea fruticosa	3.61	8.29	4.31	16.2	*Lannea fruticosa*	3.19	6.54	8.91	18.63
Dichrostachys cinerea	8.93	6.57	0.31	15.81	*Pterocarpus lucens*	4.47	7.19	4.77	16.42
A. leiocarpa	4.02	5.71	4.89	14.62	*Ziziphus spina-christi*	7.79	7.19	0.15	15.13
B. aegyptiaca	2.44	5.43	5.58	13.45	*Sterculia setigera*	0.51	1.96	12.59	15.06
P. lucens	2.89	5.14	3.49	11.52	*Dichrostachys cinerea*	3.57	5.88	0.13	9.59
Total species with middle IVI values	18.8	28.29	7.51	54.6	Total species with middle IVI values	12.25	12.42	8.08	32.75
Species with least IVI values					Species with least IVI values				
Strychnos innocua	0.27	0.86	0.15	1.28	*Diospyros abyssinica*	1.66	0.65		2.31
Acacia seyal	0.32	0.86	0.01	1.19	*Grewia villosa*	0.77	1.31		2.07
Acacia sieberiana Dc.	0.29	0.86	0	1.15	*Gardenia ternifolia*	0.51	1.31	0.16	1.97
Terminalia laxiflora	0.13	0.57	0.36	1.06	*Ziziphus abyssinica*	0.26	1.31	0.05	1.61
Cissus populnea	0.45	0.57	0	1.02	*Ficus sycomorus*	0.26	1.31	0	1.56
Ficus sycomorus	0.35	0.57	0	0.93	*Combretum adenogonium*	0.38	0.65	0.26	1.3
Tamarindus indica	0.1	0.57	0	0.67	*Piliostigma thonningii*	0.38	0.65	0.2	1.24
Commiphora africana	0.05	0.57	0.02	0.64	*Strychnos innocua*	0.38	0.65	0.02	1.05
Maytenus undata	0.1	0.29		0.38	*Cissus populnea*	0.38	0.65	0	1.04
Combretum collinum	0.03	0.29	0.03	0.35	*Tamarindus indica*	0.13	0.65	0	0.78
Total	**100**	**100**	**100**	**300**	**Total**	**100**	**100**	**100**	**300**

Table 7: Continued.

Scientific name	Gundo PFM forest				Scientific name	Gundo NPFM forest			
	RD	RF	RDO	IVI		RD	RF	RDO	IVI
Species with the highest IVI values					Species with the highest IVI values				
B. papyrifera	9.60	6.98	18.32	34.90	*A. leiocarpa*	46.12	10.41	9.36	65.89
A. leiocarpa	12.41	5.78	9.36	27.55	*B. papyrifera*	4.33	7.93	18.32	30.59
P. lucens	2.72	5.38	14.83	22.93	*Dichrostachys cinerea*	17.70	10.91	0.28	28.89
Sterculia setigera	0.51	1.79	18.02	20.32	*P. lucens*	2.46	6.94	14.83	24.23
Lannea fruticosa	5.68	7.58	6.95	20.21	*Sterculia setigera*	0.88	3.97	18.03	22.88
Combretum molle	12.41	6.78	1.01	20.20	*Ficus thonningii*	0.88	1.98	15.10	17.97
F. thonningii	0.03	0.20	15.10	15.33	*Lannea fruticosa*	2.65	5.95	6.95	15.55
Dichrostachys cinerea	9.19	5.58	0.28	15.05	*Combretum molle*	5.80	4.96	1.01	11.77
Acacia polyacantha	6.47	6.38	1.82	14.67	*Combretum hartmannianum*	1.18	4.96	2.80	8.93
Combretum collinum	5.56	6.58	1.59	13.73	*Stereospermum kunthianum*	2.06	5.45	0.65	8.17
Total species with middle IVI values	33.85	42.95	12.5	89.27	Total species with middle IVI values	8.75	22.15	10.79	41.69
Species with least IVI values					Species with least IVI values				
Commiphora africana	0.25	0.80	0.00	1.05	*D. melanoxylon*	1.38	3.47	0.09	4.94
Piliostigma thonningii	0.16	0.60	0.25	1.00	*Strychnos innocua*	0.98	3.47	0.16	4.61
Balanites aegyptiaca	0.19	0.60	0.00	0.79	*Commiphora africana*	2.65	0.99	0.00	3.65
Tamarindus indica	0.16	0.60	0.00	0.76	*Cissus populnea*	0.98	1.98	0.00	2.97
Gardenia ternifolia	0.16	0.40	0.00	0.56	*Gardenia ternifolia*	0.29	1.49		1.78
Terminalia brownii	0.06	0.40	0.00	0.46	*Boscia mossambicensis*	0.10	0.50	0.70	1.29
Oxytenanthera abyssinica	0.22	0.20	0.00	0.42	*Ziziphus spina-christi*	0.29	0.99	0.00	1.29
Acacia Senegal	0.28	0.00		0.28	*Flueggea virosa*	0.29	0.99	0.00	1.29
Ficus elastica	0.06	0.20		0.26	*Piliostigma thonningii*	0.10	0.50	0.25	0.84
Acacia sieberiana Dc.	0.03	0.20	0.00	0.23	*Diospyros abyssinica*	0.10		0.70	0.80
Total	**100**	**100**	**100**	**300**	**Total**	**100**	**100**	**100**	**300**
Scientific name	**Meshiha PFM forest**				**Scientific name**	**Meshiha NPFM forest**			
	RD	**RF**	**RDO**	**IVI**		**RD**	**RF**	**RDO**	**IVI**
Species with the highest IVI values					Species with the highest IVI values				
P. lucens	6.11	6.52	18.39	31.02	*Sterculia setigera*	6.11	8.98	44.25	59.35
Oxytenanthera abyssinica	13.75	4.28	0.88	18.91	*Flueggea virosa*	34.20	14.06	0.45	48.71
A. leiocarpa	3.58	4.68	10.24	18.50	*A. leiocarpa*	13.26	10.94	14.97	39.17
Stereospermum kunthianum	7.86	6.11	4.21	18.18	*B. papyrifera*	5.07	5.47	11.61	22.15
Lannea fruticosa	2.68	4.28	10.92	17.88	*Lannea fruticosa*	4.42	7.42	8.96	20.80
Acacia polyacantha	5.92	3.26	6.95	16.13	*P. lucens*	3.51	6.25	8.41	18.17
B. papyrifera	2.65	3.05	9.49	15.19	*Cissus populnea*	7.80	7.81	0.00	15.61
Combretum hartmannianum	5.77	5.70	3.04	14.52	*Dichrostachys cinerea*	6.37	5.47	0.41	12.25
Terminalia laxiflora	3.32	4.68	3.95	11.95	*Strychnos innocua*	2.99	3.52	5.03	11.54
Sterculia setigera	1.49	3.05	7.35	11.89	*Stereospermum kunthianum*	3.25	6.25	0.14	9.64
Total species with middle IVI values	42.4	47.45	22.6	112.40	Total species with middle IVI values	9.62	17.19	4.43	31.24
Species with least IVI values					Species with least IVI values				
Combretum collinum	0.48	1.43	0.35	2.26	*Combretum molle*	0.78	1.56	0.33	2.67
Grewia villosa	0.52	1.63	0.00	2.15	*Acacia sieberiana Dc.*	0.65	1.56	0.00	2.21
F. thonningii	0.04	0.20	1.34	1.58	*Terminalia laxiflora*	0.26	0.78	0.36	1.40
Flueggea virosa	0.75	0.81	0.00	1.56	*Diospyros abyssinica*	0.39	0.78	0.00	1.17
Albizia malacophylla	0.78	0.41	0.00	1.19	*Ximenia Americana*	0.39	0.39	0.33	1.11
Boscia mossambicensis	0.48	0.41	0.29	1.18	*Terminalia brownii*	0.39	0.39	0.00	0.78
B. aegyptiaca	0.41	0.61	0.04	1.07	*Combretum collinum*	0.13	0.39	0.15	0.67
Erythrina abyssinica	0.75	0.20	0.00	0.95	*Combretum adenogonium*	0.26	0.39	0.00	0.65
Tamarindus indica	0.15	0.61	0.00	0.76	*Adansonia digitata*	0.13	0.39		0.52
Terminalia brownii	0.11	0.61	0.00	0.72	*Erythrina abyssinica*	0.00	0.00	0.17	0.17
Total	**100**	**100**	**100**	**300**	**Total**	**100**	**100**	**100**	**300**

Note: Bold values are the total/cumulative values of all woody species.

community-managed forests had a positive impact on forest management outcomes than state-managed forests.

4. Conclusion and Recommendations

PFM is considered a forest management strategy that can help to curve the rate of deforestation and forest degradation. The findings of the current study highlighted the positive impacts of PFM on the forest condition improvement of the dry forest resources as demonstrated by the better structure and composition of PFM-managed forests. Forest conditions and various forest stand parameters under the two forest management strategies showed a significant difference. Forests managed under PFM had

a better forest condition than the forests without PFM. Higher species diversity, richness, better regeneration with higher density of seedlings, saplings, and stocking of trees were recorded in the PFM-managed forests than forests without PFM. This is mainly associated with the uncontrolled extraction of forest products in the adjacent open-access forests. However, the lowest number of trees in the smaller diameter class in the two forest management regimes is an indication of the presence of recruitment problems of the selected high-value species and guided for the relevance of further forest protection. The presence of human disturbance has contributed to the poor regeneration and succession of the seedlings to the sapling stage. The examination of the dynamics in the species composition and structure based on permanent sample plots can give better and detailed understanding on the conservation values of PFM interventions than a cross-sectional study in the present study.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

Disclosure

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

Author Contributions

Asmamaw Alemu and Zemenu Woldie: conceptualization, methodology, drafting and reviewing the manuscript, and fund acquisition. Zemenu Woldie: data collection and analysis. Zemenu Woldie: conceptualization, data collection, and analysis with the guidance of Asmamaw Alemu as part of the PhD research work.

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Supporting Information

Additional supporting information presenting the details of woody plant species seedling, suppling, and adults density encountered in the studied PFM and adjacent non-PFM forests can be found online in the Supporting Information section. *(Supporting Information)*

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