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Research article

Characterizing the existing woodland forest to determine forest habitat management options in Gamogofa zone, southern Ethiopia

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Abstract: Ethiopian woodlands are vital for the conservation of plant diversity, including genetic pools of Combretum-Terminalia woodland. However, the woodlands are continuously shrinking and need empirical scientific studies for their effective conservation and sustainable management. These studies was, therefore, conducted to characterizing the existing woodland forest and synthesize literature to determine forest habitat management options in Gamogofa zone, southern parts of Ethiopia. A total of 30 (20 m × 20 m) quadrants for tree/shrubs and 5 m × 5 m for sapling and seedlings were sampled to identify and describe composition, population structure, species diversity, regeneration status, and importance value index (IVI) of woodland forest species. The analysis was done by excel, and results show that a total of 57 woody plant species were recorded. The study site woodland species, were 327 (11.36%) trees/shrubs, 2344 (81.45%) saplings, and 207 (7.19%) seedlings. The value of the Shannon diversity index and evenness were recorded 2.66 and 0.87, respectively. *Combretum adenogonium* had the highest IVI followed by *Acacia mellifera*, *Euclea divinorum*, *Cadaba farinosa*, *Balanites aegyptiaca* and accounted for 44% of the total species. *Combretum paniculatum*, *Ficus ovata*, *Strychnos innocua*, *Grewia bicolor* and *Cordia africana* were species with lower IVI. The ratio of seedlings and saplings to mature individuals was 0.7:3, respectively. The entire woodlands are good, fair and poor regeneration was recorded 0, 67%, and 33% respectively. 18% of the species had neither seedlings nor saplings. The forest has no good regeneration of species, so it needs immediate management intervention to conserve biodiversity and protect the ecosystem services.

Keywords: Conservation, Diversity, Forest habitat, Management, Regeneration.

INTRODUCTION

Ethiopia is well known for its tropical floral diversity. Its complex topography and environmental heterogeneity with a wide range of terrestrial and aquatic ecosystems offer suitable environments for numerous life forms (Friis & Demissew, 2001; Soromessa *et al*., 2004). Vegetation types range from tropical rain and cloud forests in the southwest to desert scrublands in the east and north (Teketay *et al*., 2010). Woodlands forests are the major forest fragments remaining in the country (Atmadja *et al*., 2019.). Woodlands are mostly a phytogeographic subset of forests generally composed of low-density, short-statured trees found in climates that are growth limited by temperature, precipitation, or evaporative demand (Woodward, 1987). It serves as a potential habitat for specialized wildlife species due to the large extent of edge that provides broad-scale ecotones (Barrett *et al*., 1994). These forests are diverse in composition and are sources of a wide variety of products that contribute to the domestic and national economy. Forest characterization (forest composition, diversity, IVI, regeneration) of the existing forests have given a chance to determine the management options of woodland forests (Foster, 2000; Sitzia *et al*., 2010), as well as the realistic and accurate insight of the type of ecosystems (Grabherr & Kojima, 1993).

The importance of characterizing the existing forest and the review-related literature are to determine the appropriate habitat management options of woodland forests. The concept of forest habitat management is a recent idea, which has done in conservation forests for ecological values or improves ecosystem service, with four proposed alternatives in the synthesis by Götmark (2013), including (1) Minimal intervention; the most common form of management usually allows continued succession and disturbances in the forests. It should be developed as old-growth and act as ecological baselines. (2) Traditional management; based on historical reference, is used to create other forest structures that favor biodiversity (e.g. red-listed taxa) related to past cultural landscapes. (3) Non-traditional management is an action to produce old-growth characteristics or specific forest composition or to favor one or a few tree species which may or may not have been abundant in the past. (4) Species management; for threatened, indicator and other species, and rewilding are based on one or a small set of species that is valuable or can shape the forest. Depending on forest area and management aim, combinations of these management types may be used. If the concept

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of ecological restoration is used, which assumes one ‘‘best’’ forest habitat, researchers risk overlooking the importance of evaluating all the alternatives 1 to 4. There are many options to correct habitat for conservation forests. Many more studies of the management alternatives are needed particularly long-term experiments. Besides, management plans, decisions, and actions in the practical management of conservation forests need to be studied, to clarify choices and present conditions.

Tropical forests face serious problems, including the irreversible loss of diversity due to deforestation and fragmentation (Lyaruu *et al*., 2000). Likewise, Ethiopia’s forests are continuously shrinking and are only intact in limited areas (Senbeta *et al*., 2005; Friis *et al*., 2010). Still, the problem is continuing because most researchers focus on the description and comparison of forest research rather than problem-solving. Another challenge is the concept of forest conservation, in which the area of protected and/or exclosure forests is steadily growing (Chape *et al*., 2008; Schmitt *et al*., 2009), and a lack of field experiments have done in the forest to evaluate forest habitat management alternative. Thus, habitat management usually comes after forest protection and reserve selection procedures, and the management largely remains to be developed (Margules & Sarkar, 2007). Consequently, the assessment of woodland resources is necessary for their sustainable use as well as to facilitate the formulation of effective and integrated environmental and economic policies (Nune *et al*., 2013). However, empirical scientific information is lacking on the current status of the forest, and which type of forest management option is a need. The objective of the study are; (1) the existing woodland forest characterization (floristic composition, diversity, IVI, endemicity, structure, regeneration), (2) Based on the characterizing the existing woodland forest and literature synthesis, select appropriate forest habitat management options for improving the ecosystem service, (3) to recommend which type of issue address in the future study.

MATERIALS AND METHODS

Description of the study area

The study was conducted in the Combretum-Terminalia woodland or dry forest of the Mierab Abaya district located in the Gamogofa Zone, Southern Nations, Nationalities and People’s Regional (SNNPR) State of Ethiopia (Fig. 1). The area is situated approximately 660 km southwest of Addis Ababa, Ethiopia’s capital city and eastern landscape parts of Aribaminch town. The district is located between 6º 13'35" to 6º 21'21" N and 37º 2142'40"to 37º 43'52"E. Elevation ranges from 1311 to 1495 m.a.s.l. with a monthly average temperature of 22ºC and annual rainfall of1200-1300 mm.

Mierab Abaya natural vegetation accounts for the major vegetation cover of the Wereda, which was designed to conserve long-lasted unique natural features, unique scenery, historical interests, and other natural values with legal and administrative supports on the upper part of Aribaminch town. The protected part of Mierab Abaya natural vegetation was considered as an important pillar for future local development and it is adjacent to Nechisar national park of protected natural vegetation.

Figure 1. Map of three sampled Combrutem Terminalia woodland in Mierab Abaya District.

Sampling and data collection methods

A reconnaissance survey was made to have a general impression of physiognomic vegetation types of the study area. Then the number of sample site (three representative site), transect lines and the plot were determined. In each transects lines were laid 4.5 km interval that lies parallel to the slope of the stand. To avoid the effect of disturbances the first and the last line transects were laid at a distance of 50 m from the edges. Along the transect lines, a total of 30 plots and the size of the observational sample plots were designed 20 m × 20 m. These plots were established following elevation. Plant species identification was done in the field and specimens were collected for herbarium identification in the National Herbarium of Ethiopia.

Methods of literature review and synthesis to determine the forest habitat management option

This research assessment was focus directly relevant to the practical management of conservation forests. Literature that fulfilled all of the following three criteria/categories was selected for the review: (1) empirical ecological studies published 1991-2019; (2) conservation forests in the woodland; and (3) studies of forest structure and composition. Works of literature were collected from different websites. Then, review and screening related to the forest habitat management option. Overall, 700 listed publications of potential interest were collected, and 28 publications were selected, but other studies did not meet my criteria. To develop the criteria of the forest habitat management option, first define each term (minimal intervention, traditional, nontraditional, species management, combinations) then, selecting five ecological reasons to apply the intervention.

Table 1. Definition of forest management alternatives terms.

S.N.	Type of forest management alternative	Description /definition each forest management terminology
1	Minimal intervention	The most common form of management usually allows continued succession and disturbances in the forests. They should develop as old-growth and act as ecological baselines or human influence and change of the habitat are minimized, to the low level (Parviainen *et al.,* 2000; Chape *et al*., 2008; Feldman, 2010).
2	Traditional	Based on historical reference, it is used to create other forest structures that favor biodiversity related to past cultural landscapes (Honnay *et al*., 2004; Parrotta & Agnoletti, 2007; Bobrovskii, 2010).
3	Nontraditional	Management is an action to produce old-growth characteristics or specific forest composition or to favor one or a few tree species which may or may not have been abundant in the past (Coates & Burton, 1997; Peterken, 2001; Keeton, 2006; Ausden, 2007; Götmark, 2007, 2009).
4	Species management	Species management, for under risk , flag and importance species, and rewilding, is based on one or a small set of species that is valuable or can shape the forest (rewilding may be included in option one , but emphasizes large predators). Manipulation/ treatment of habitat and /or species (Martin & Klein, 1984; Vera, 2000; Willers, 2002; Donlan *et al*., 2005; Caro, 2007; Soulé, 2003, 2010).

Table 2. Each ecological reason /criteria to apply the habitat management option.

S.N.	Type of forest management alternative	Criteria (Ecological reason) for selecting management options in protected forest	Reference
1	Minimal intervention	1.old growth forests are rare (>250 years)	Götmark (2013)
		2.old growth forest with their associated process favor many taxa	Hunter (1999), Moning & Landres (2010), Paillet *et al*. (2010)
		3.forest under minimum intervention serve as reference or baseline information for direct human impact	Arcese & Sinclair (1997)
2	Traditional	1. many species that occur in these human-created habitats are threatened (red-listed) due to lack of suitable habitat and may need active management	Ausden (2007), Prevosto *et al*. (2011)
		2. Many second-growth forests have more-or-less closed canopies (although this is not well quantified).	Götmark (2013)
		3. It should be increase heterogeneity of forest habitat types, and different forms of land use may be incorporated in the management of an area or property	Lindbladh *et al*. (2007)
3	Non-traditional	1. It is dynamic and not fixed by minimal intervention or historical reference.	Callicott et al. (1999), Davis *et al*. (2011)
		2 It can create old-growth structure faster than is normally possible under continued succession in second-growth even-aged forests	Singer & Lorimer (1997)
		3. Certain tree species are important for associated wildlife or maybe favored by e.g. partial cutting or other conservation actions	Götmark (2007, 2009), Brudvig *et al*. (2011)

4	Species management	1. If the extinction risk is high for a forest species that are judged as especially valuable and for which we have good knowledge, specific management action for that species and its habitats should be justified. 2. If a keystone species low abundance in a community, but disproportionately well strong influence on the ecosystem can control overabundant species or improve the ecological function of a forest, it may be favored, re-established or introduced.	Götmark (2013) Soulé (2010), Kauffman *et al*. (2010)
5	Combinations	Based on the nature, role and the size of forest	Götmark (2013)

Data analysis

Species composition, structure, diversity, importance value index (IVI), and regeneration status were analyzed using the Microsoft Excel program. To assess the population structure of woody plants, all plans measure in each plots were grouped into height classes and diameter classes. Shannon's diversity index, Simpson's diversity index (1-D), and Shannon's evenness for diversity analysis were computed as given in Magurran (2004). The status of native and endemic woody species was determined based on the International Union for Conservation of Nature (IUCN) red list category (Vivero *et al*., 2005), rarity (Magurran, 2004), and local criteria (Bekele *et al*., 1999). Importance Value Indices (IVI) was analyzed for woodland species based on relative dominance, relative density, and relative frequency (Kent & Coker, 1992).

RESULTS AND DISCUSSION

Characterizing the existing exclosure woodland forest

Species composition and structure

In the floristic analysis, 57 woody plant species were identified. The highest species dominance was recorded for the Fabaceae family, followed by Euphorbiaceae, Asteraceae, and Rubiaceae. This dominance could be attributed to the adaptation potential of leguminous species (Fabaceae) to diverse ecologies of the country (Aynekulu, 2011). The analysis of DBH and height distribution showed that the majority of species had more individuals fall in the lower DBH and height classes (Fig. 2). The diameter and height class had reverse J-shape patterns, and its distribution pattern of species was considered as an indication of a stable population (Tesfaye *et al*., 2010). Furthermore, the population structure of a tree species indicates the history of past disturbance of this species and its environment, which can be used to forecast the future trend of the population of particular species (Girma Shumia *et al*., 2019). Therefore, assessment of the floristic composition and vegetation structure of woody species in the forest is important for their management, conservation, and sustainable utilization (Atomsa & Dibbisa, 2019). Knowing the species composition and structure are a vital role to determine the exact forest habitat management option.

Species diversity and endemicity

The value of the Shannon diversity index and evenness in the woodland were 2.66 and 0.87, respectively. Shannon diversity index is considered as high when the calculated value is 3.0, medium when it is between 2.0 and 3.0, low between 1.0 and 2.0, and very low when it is 1.0 (Cavalcanti & Larrazabal, 2004). Shannon's diversity index places more weight on the rare species in the sample, whereas Simpson's diversity index gives more weight to the most abundant species (Krebs, 1999). There were no recorded woody species that are endemic to Ethiopia.

Importance value index

The IVI of woodland species was calculated from relative density, relative dominance, and relative frequency, and it indicates the ecological status of the tree species in community structure. *Combretum adenogonium* Steud. ex A.Rich. had the highest IVI followed by *Acacia mellifera* (M. Vahl) Benth., *Euclea divinorum* Hiern, *Cadaba farinosa* Forssk., *Balanites aegyptiaca* (L.) Del. and accounted for 44% of the total species. *Combretum paniculatum* Vent., *Ficus ovata* Vahl, *Strychnos innocua* Del., *Grewia bicolor* Juss. and *Cordia africana* Lam. were species with lower IVI (Table 1). The IVI values have been helped to understand the ecological significance of the tree species in community forest structure (Premavani *et al*., 2014). The higher IVI values have been considered as the most ecologically important tree species in vegetation assessments (Balcha *et al*., 2004) whereas the lower IVI may indicate that these tree species are threatened and need immediate conservation measures (Anteneh *et al*., 2011; Temesgen *et al*., 2015). IVI is an indicator of the positive effect of conservation and management interventions for existing forests (Lamprecht, 1989; Gurmessa, 2010). The Importance Value Index can be used for prioritizing species for conservation (Berhanu *et al*., 2017). It is very important to balance the ecologically significant species and endemic or rare species during prioritization for the restoration or rehabilitation of the forest. If we are focused on ecologically significant species, may be lost the rare species. Therefore, immediate action must be taken (like species management) to secure diversification. Other important things will be dealing with the history of ecologically significant species, to know the exact once and with no trouble restore the existing forest.

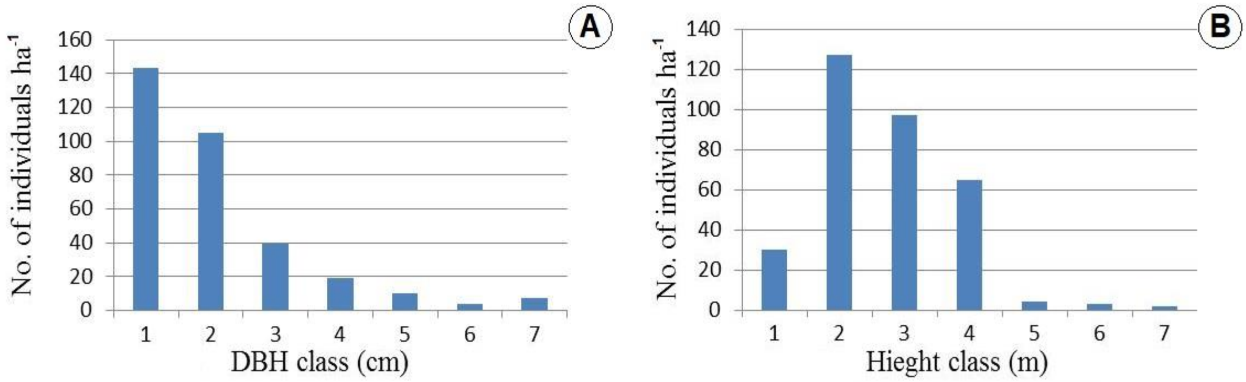

Figure 2. A, DBH classes (cm) (**1**=5-9.17**, 2**=9.18-13.34**, 3**=13.35-17.51**, 4**=17.52-21.68, **5**=21.69-25.85, **6**=25.86-30.02, **7**=30.03-34); **B**, Height classes (**1**=2.6-4.37,**2**=4.38-6.14,**3**=6.15-7.91,**4**=7.92-9.98,**5**=9.99-11.45,**6**=11.46-13.22,**7**=13.23-15) of the existing forest A and B, respectively.

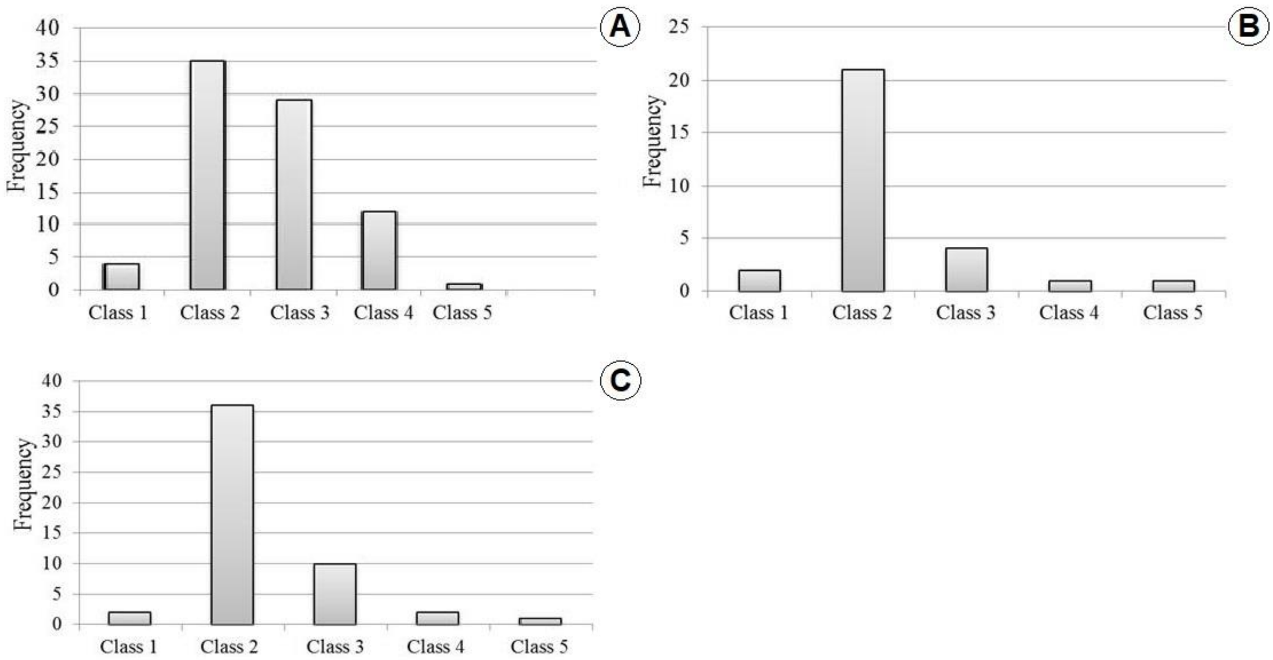

Figure 3. DBH class distribution of three keystone species: **A**, *Combretum adenogonium* Steud. ex A.Rich.; **B**, *Acacia mellifera* (M. Vahl) Benth.; **C**, *Euclea divinorum* Hiern.

Table 3. The importance value index (IVI) of existing woodland forest.

S.N.	Scientific Name	BA	RF	RDM	RD	IVI
Highest five IVI						
1	*Combretum adenogonium* Steud. ex A.Rich.	0.0096	70.000	2.224	24.695	96.919
2	*Acacia mellifera* (M. Vahl) Benth.	0.0059	53.333	1.368	8.841	63.543
3	*Euclea divinorum* Hiern	0.0069	43.333	1.615	15.549	60.498
4	*Cadaba farinosa* Forssk.	0.0131	30.000	3.057	7.012	40.069
5	*Balanites aegyptiaca* (L.) Del.	0.0117	30.000	2.717	3.049	35.765
Lowest five IVI						
1	*Cordia africana* Lam.	0.0054	3.333	1.259	0.305	4.898
2	*Grewia bicolor* Juss.	0.0050	3.333	1.170	0.305	4.808
3	*Strychnos innocua* Del.	0.0035	3.333	0.821	0.305	4.459
4	*Ficus ovata* Vahl	0.0033	3.333	0.772	0.305	4.411
5	*Combretum paniculatum* Vent.	0.0020	3.333	0.457	0.305	4.095

Note: BA, Basal Area; RF, Relative Frequency; RDM, Relative Dominance; RD, Relative Density.

Regeneration status

From 57 woody species, the number of seedlings, saplings, and mature trees/shrubs were estimated at 327 (11.36%), 2344 (81.45%), and 207 (7.19%) ha^{-1}, respectively. The regeneration of good, fair and poor woody species was recorded 0, 7, and 3 respectively. There is no good regeneration in the forest, and 18% of the species had neither seedlings nor saplings. This confirms that these species have less seedling survival rates in existing woodland forests, and most of the woody species have fair and poor to regenerate, so far need habitat management to ensure the perpetuation of the species (Melese & Ayele, 2017; Goncalves *et al*., 2018). Rare and poor regeneration (like *Ficus ovata*, *Combretum paniculatum*, *Strychnos innocua*) as well as flag or keystone species and faire regeneration (like: *Acacia brevispica* Harms., *Acalypha racemosa* Wall. ex Baill., *Rhus natalensis* Bernh. ex Krauss., *Euclea divinorum* and *Combretum adenogonium*) will be given a priority in forest habitat management.

Synthesis of exclosure woodland forest habitat management option

Woodland forest characterization (diversity, IVI, regeneration status), observation and ecological reasons combined with forest habitat management will be effective to be to improve the ecosystem service in the study area. In this study primarily consider IVI and regeneration status for urgent forest habitat management. The status of currently five keystone species were identified in woodland forest *Acacia brevispica*, *Acalypha racemosa*, *Rhus natalensis*, *Euclea divinorum* and *Combretum adenogonium* species have fair regeneration, and need species management. Species management is the management of conservation forests mainly based upon one or a few species, or a certain set of species, that may be threatened, keystone, umbrella, flagship or otherwise of high conservation value (Caro, 2007). Five lists of IVI species are considered as rare in the study area, and all species are low regeneration. The management options in this cause use specie and traditional management as rewilding or introduction into the systems (Martin & Klein, 1984; Vera, 2000; Willers, 2002; Donlan *et al*., 2005; Soulé, 2003, 2010), and considered manipulation of tree cover and trees (e.g. coppice, pollarding, and forms of selective cutting) influence floristic and habitat conditions (Rackham, 2006). Generally, by characterizing the forest, own observation and review works of literature need a combination habitat management will be applied and for further investigation, minimal intervention is practical, which is the most common approach of the management of conservation forests elsewhere the world and referred to as spontaneous rewilding (Feldman, 2010).

CONCLUSION AND RECOMMENDATION

Overall characterizing (forest composition, population structure, diversity, regeneration status, IVI, and endemicity) the existing forest is crucial for the planning and implementation of appropriate forest habitat management options and conservation activities. The combination of generated information and literature synthesis is enhanced effective management intervention. This study indicates that the combination of habitat management options will be applied to secure biodiversity and improve ecosystem services. The prioritizing of the highest and low IVI as well as the low regeneration of woody species will be considered during the first phase of forest management intervention.

We recommended that this is the time of shifting from description and comparison study into forest habitat management (species level) options to secure our national forest. The forest has no good regeneration of species, so it needs immediate management intervention for those plant species to secure biodiversity and improve the ecosystem services from further degradation. It is important to deal more with each species habitat and characteristics that have determined the exact species intervention.

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