Floristic diversity and vegetation structure of Zege Peninsula forest, Northwest Ethiopia

Beyene Belay[a], Solomon Zewdie[b], Tadesse Woldemariam[c]

[a]Amhara Region Agricultural Research Institute, P.O.Box 527, Bahir Dar, Ethiopia; [b]Wondo Genet College of Forestry and Natural Resources, Hawassa University, Ethiopia; [c] Environment and Coffee Forest Forum, Addis Ababa.

Abstract

This study was conducted in 2011/12 to investigate the vegetation composition, regeneration status, and farmers' coffee and tree management practices of Zege peninsula forest. A range of biophysical data were collected from 67 circular sample plots (53 in coffee-based and 14 in non-coffee forest patches) laid along the transect lines across. Data were analyzed for species diversity, basal area and Important Value Index. Socio-economic information was collected from 40 interviewed households. A total of 115 plant species (57 trees, 35 shrubs, 9 climbers, 13 herbs, and 1 Epiphytes) were recorded. Accordingly, the Shannon diversity index (H) of coffee based forest was 2.06 and the Evenness (E) 0.23 and that of the non-coffee forest was 3.28 and 0.43 respectively. The total basal area and density of woody species in coffee-based forest were 25.21m^2 ha^{-1} and 5930 ha^{-1} respectively, and that of the non-coffee forest were 13.49 m^2 ha^{-1} and 4659 ha^{-1} respectively. The local people preferred *Ehretia cymosa*, *Albizia schimperiana* and *Millettia ferruginea* as best coffee shade tree species in descending order. Destruction of forests to obtain wood for market and sheep free grazing were found to be the two major threats for zege peninsula forest.

Key words: Basal area, coffee, regeneration, shade, value index.

Introduction

Ethiopia is one of the tropical countries which comprise the major part of the eastern African highland mass (Tesfaye Awas, 2007) and over 50% of the African Afromontane vegetation (Tamrat Bekele, 1993) of which dry Afromontane forests make the largest part (Demel Teketay, 1996). Eastern Africa Afromontane including the Ethiopian highlands constitute vivid examples of tropical forest ecosystems that have exceptional species richness and high concentrations of endemic species. Particularly, Afromontane rainforests are known as centers of origin and genetic diversity of *Coffea arabica* and still harbor wild coffee species (Schmitt *et al*., 2010) and internationally recognized as the Eastern Afromontane biodiversity hotspot (Mittermeier *et al*., 2004).

Despite their unparalleled advantages, nowadays, most of these natural forests are fragmented, modified or changed into other land use system as a result of settlements, and extensive farming and grazing (Demel Teketay, 1992; EFAP, 1994; Demel Teketay, 2005; Schmitt *et al*., 2007). Reusing (1998) reported that 60% of the Ethiopian forest area has been modified

The vegetation of the study site is classified as undifferentiated Afromontane forest (Aalbaek and Kide, 1993) or dry Afromontane vegetation type (Alemnew Alelign, 2002). It contains two forest patches: the first one is coffee-based forest, which is under the hand of the community which depends on coffee as income source and the second one is non-coffee based forest which is administered by the Kebele. The Zege peninsula forest comprises two Kebeles namely Yiganda and Ura Kidane Mihiret, with a total human population of 7489 (3456 female and 4033 male). Landholding ranges from 2 to 2.5 hectares per household. Lake Tana is everything for the Zege people as they use it for drinking, washing, swimming, fishing, coffee seed raising etc.

Data collection

A reconnaissance survey was made on January 9 and 10, 2011 to have an impression of the forest condition and settlement in general and the study site in particular. The actual field data collection was conducted from January 14 to March 04, 2011. Vegetation data were recorded on circular sample plots laid along the transect lines with 500 m interval in coffee-based forest patch and 200 m interval in non-coffee forest patch. Along each transect, sample plots were laid systematically at 400m interval in coffee-based forest and 150 m interval in non-coffee forest. A total of 67 plots (53 in coffee-based and 14 in non-coffee forest patch) were taken.

Each sample plot contains three circles overlaid each other with different diameter size. Number of woody seedlings, DBH< 2.5 cm, or with height less than 1m (Thang and Dung, 2009) and the ground cover percentage of herbs were recorded in a central plot with 1m radius (3.14 m^2). Woody saplings and shrubs (DBH >2.5 cm and <10 cm) were recorded in the middle circle with a radius of 3 m whereas trees and woody climbers (DBH >10 cm) in the outer circle of 10 m radius.

Scientific name of recorded species were identified with the help of plant identification manuals such as Honey Bee Flora of Ethiopia (Fichtl and Admasu, 1994) and Flora of Ethiopia and Eritrea (Edwards *et al*., 1995; Hedberg and Edwards, 1995; Edwards *et al*., 2000; Hedberg *et al*., 2006). Those which were difficult to identify using the manuals were taken to Addis Ababa University National Herbarium for further identification. Samples of 40 households were interviewed using a checklist to assess parameters such as tree and coffee management practices, coffee shade tree species preferences, off-farm livelihood sources and their main income source.

Data analysis

Shannon-Wiener diversity index, species richness and Shannon's evenness were computed to describe plant species diversity of the two forest patches (Magurran, 2004). Sorensen's similarity coefficient was used to determine the pattern of species turnover among the two forest patches (Magurran, 1988). The formulas of the parameters described above are as follows.

Shannon-Weiner Index (H')

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where, H' = Shannon Diversity Index, *Pi* = Proportion of individuals found in the i^{th} species expressed as a proportion of total cover, S = Total number of species (1, 2, 3…..n).

Shannon evenness (E)

$$E = \frac{H'}{H'_{max.}} = \frac{\sum_{i=1}^{S} p_i \ln p_i}{\ln s}$$

Where, E = Equitability (evenness) index, H' = Shannon Diversity Index, H'_{max} = Maximum level of diversity possible within a given population.

Sorensen's similarity Index (Ss)

$$S_s = \frac{2C}{(2C + A + B)}$$

Where, Ss = Sorensen's similarity index, A = Number of species in coffee-based forest, B = Number of species in non-coffee forest), C = Number of species common to both forest patches.

Population structure

Frequency of a species = $\frac{\text{Number of plots in which a species occurs}}{\text{Total number of plots}} \text{X } 100$

Relative frequency = $\frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \text{X } 100$

Density of species = $\frac{\text{Number of individuals of that species}}{\text{Area sampled}}$

Relative density = $\frac{\text{Density of a species}}{\text{Total density of all species}} \text{X } 100$

Basal area (m^2) = $(DBH/200)^2 \pi$ or $BA = \frac{\pi * DBH^2}{4}$, Where π = 3.14 and DBH= diameter at breast height (cm) for woody species with DBH>2.5

Dominance = $\frac{\text{Total basal area}}{\text{Area sampled}}$

Relative dominance = $\frac{\text{Dominance of a species}}{\text{Total dominance of all species}} \text{X } 100$

Importance Value Index (IVI) = Relative density + Relative frequency + Relative dominance.

Results and discussion

Species diversity and species richness

A total of 115 plant species (57 trees, 35 shrubs, 9 climbers, 13 herbs, and one Epiphytes) were recorded in the studied plots and along the transect lines within the Zege forest. These species belong to 55 families (34 in coffee-based and 38 in non-coffee forest patches and 7 undetermined species). Fabaceae was the most species-rich family comprising 9 (8.3%) of the total plant species identified in Zege forest. A similar result has also been observed in Belete forest (Kitessa Hundera and Tsegaye Gadissa, 2008) and Hugumburda forest (Ermias Aynekulu, 2011). This might be due to agro-ecology similarity of the forests or the adaptation potential of Fabaceae families to wider agro-ecologies.

In considering the two forest patches separately, 56 plant species were recorded in the coffee-based forest patch and 69 in the non-coffee forest patch. Still Fabaceae was the most species-rich family represented by 5 species (in the coffee-based forest) and 7 species (in the non-coffee forest) followed by Euphorbiaceae with 4 species in each forest patch. The coffee-based forest patch had lower values of species richness, evenness and diversity than non-coffee forest patch (Table 1) which agrees with Tripathi and Singh (2009) where the diversity value of plantation forest with intensive management were found to be lower (H = 1.46) than in natural forest (H = 2.05). Of course, forest management highly affects diversity in favoring the selected plant species while suppressing the undesirable ones. The Sorensen's floristic similarity index (S_S = 30.8%) showed that the two forest patches share very few plant species in common.

Population structure and regeneration

The diameter size distribution of all woody species in the two forest patches showed more or less inverted J-shape (Figure 1), greater numbers of individuals in the lower diameter size class. This indicates that there was excessive felling of large trees in the past to meet the demand of firewood and timber, or they were at secondary stage of forest succession (Abayneh Derero *et al*., 2003). Moreover, the large numbers of individuals in the lower diameter size class might be shrubs particularly coffee plant in the coffee-based forest. In the coffee-based forest, 65.6% and in the non-coffee forest, 66.4% of individuals were concentrated in the first lower diameter size class (2.5 cm-10 cm).

Table 1. Comparison of richness, Shannon diversity (H'), Simpson's diversity (D) and evenness (E) of woody species in coffee-based and non-coffee forest patches.

		Diversity	
Forest patches	Richness	H	E
Coffee-based forest	48	2.06	0.23
Non-coffee forest	60	3.28	0.43
Zege forest in total	74	2.76	0.64

The Sorensen's similarity index of the two forests patches = 30.8%.

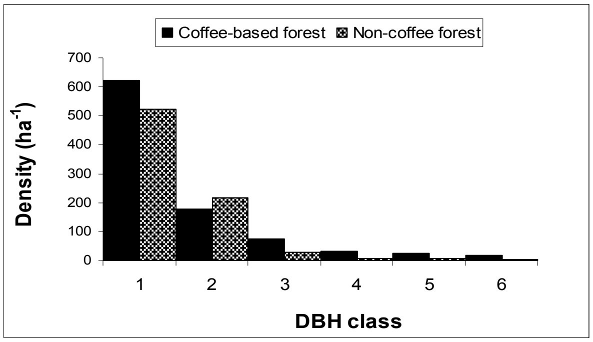

Figure 1. Diameter size distribution of all woody plants within coffee-based and non-coffee forest patches. DBH class: 1 = 2.5-10 cm, 2 = 10-20 cm, 3 = 20-30 cm, 4= 30-40 cm, 5 = 40-50 cm, 6 = >50 cm.

However, 17 (38.6 %) species in the coffee-based forest such as *Bersama abyssinica* and *Ficus thonningii* were not represented by seedling stage. Other 10 species (22.7%) for example *Dracaena steudneri* and *Ficus vasta* were without sapling stage. The rest 7 (15.9%) e.g. *Combertum molle* and *Phytolacca dodecandra* were still losing their tree stage. In the non-coffee forest patch, 9 (15.8%) species, for example *Millettia ferruginea* and *Ficus vasta* were without seedling, whereas 17 (39.8%) and 33 (57.8%) species were without sapling and tree stages respectively. *Ficus vasta* with 183.1 cm and *Celtis africana with* 111.5 cm were the first and the second highest DBH size in the coffee-based forest patch. Similarly, in the non-coffee forest patch, *Ficus vasta* was with the highest DBH size (165.6 cm) while *Cupressus lusitanica (*51.0 cm), was the second. Figure 2 displays the structure of some of the above mentioned tree species.

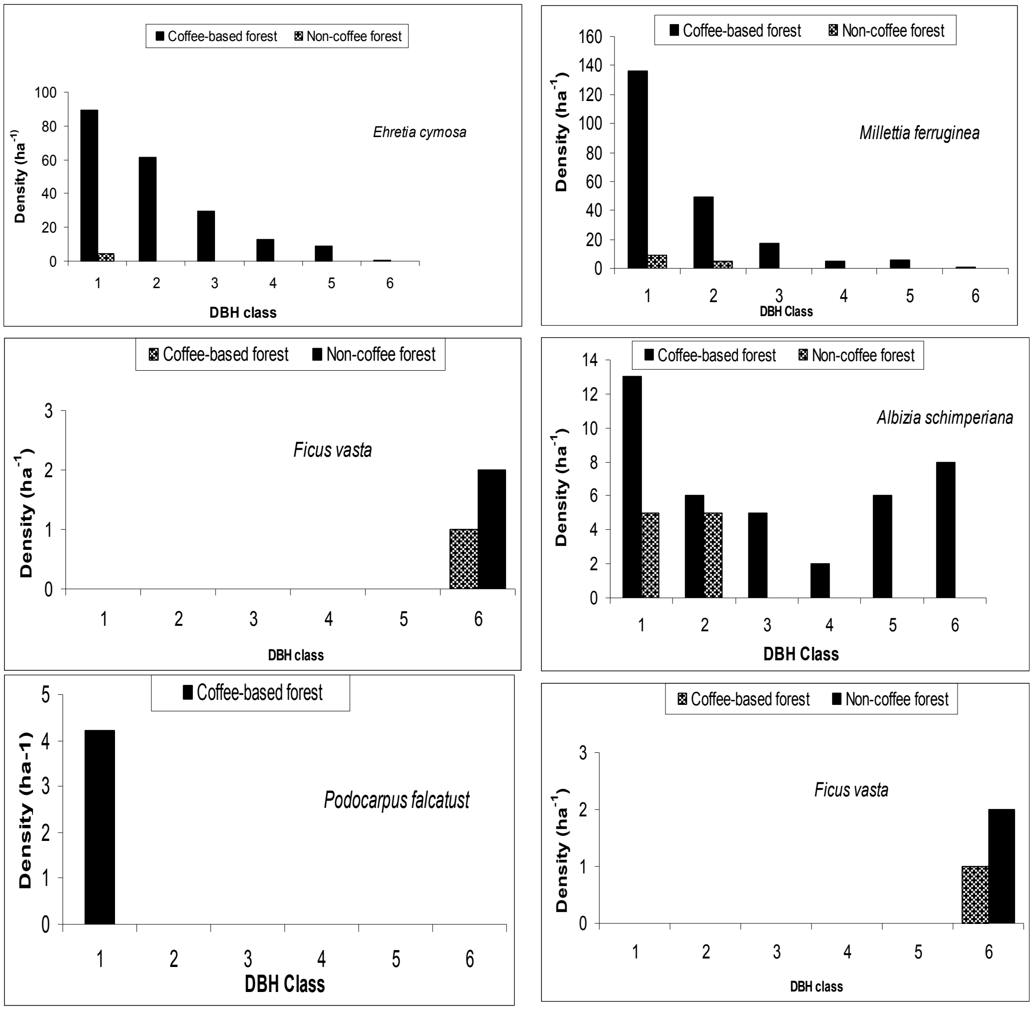

Figure 2. Diameter size of selected woody species in the coffee-based and non-coffee forest patches. DBH class: 1 = 2.5-10 cm, 2 = 10-20 cm, 3 = 20-30 cm, 4 = 30-40 cm, 5 = 40-50 cm, 6 = >50 cm.

The height class distribution of woody species revealed that 54.6% of individual trees in the coffee-based forest were found at the lowest height class (1-5 m) and only 0.3% of individuals were recorded at the highest height class (>30 m) (Figure 3). In the coffee-based forest, *Ficus vasta* was the tallest tree with 34m height and followed by *Celtis africana* with 32 m. Similarly, in the non-coffee forest patch, *Ficus vasta* was the tallest tree with 30 m height and *Cupressus lusitanica* with 25 m.

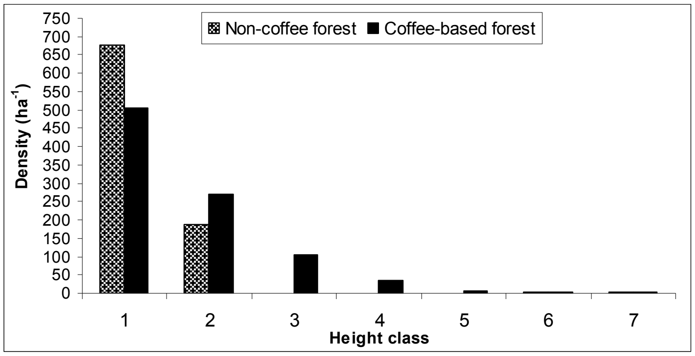

Figure 3. Height distribution of woody species in the coffee-based and non-coffee forest patches. Height class: 1 = 1-5 m, 2 = 6-10 m, 3 = 11-15 m, 4 = 16-20 m, 5 = 22-25 m, 6 = >26 m.

Importance value index (IVI)

Importance value index is a measure of the relative importance of a species in an area (Van Andel, 2003) or an important parameter that reveals the ecological significance of species in a given ecosystem (Lamprecht, 1989). Species with high IVI values are considered more important than those with low IVI value. The IVI values can also be used to prioritize species for conservation, and species with high IVI value need less conservation efforts, whereas, those having low IVI value need high conservation effort. Accordingly, the importance value indices of woody plant species were analyzed (Table 2). *Coffea arbica* had the highest IVI of 54.86 (18.3%) in the coffee-based forest followed by *Millettia ferruginea* with 41.44 (13.9%) and *Ehretia cymosa* with 36.33 (12.1%). In the non-coffee forest *Ficus vasta* with IVI of 36.60 (12.3%) was the first followed by *Rhus glutinosa* with 24.63 (8.25%).

Basal area and density

The total basal area of all the woody species in the Zege forest with DBH >2.5cm was 22.76 m^2 ha^{-1} due to the presence of some large sized trees in the forest (Figure 4). The basal area of all the woody species with DBH>2.5 cm in the coffee-based and non-coffee forest patches was 25.21 m^2 ha^{-1} and 13.49 m^2 ha^{-1} respectively. *Ehretia cymosa with* 5.10 m^2 ha^{-1} attained the largest proportion of the total woody species basal area in the coffee-based forest followed by *Albizia shimperiana* with 4.19 m^2 ha^{-1}. In the non-coffee forest, *Ficus vasta* had the highest basal of 4.89 m^2 ha^{-1} followed by *Rhus glutinosa* with 1.77 m^2 $ha^{-1.}$

Table 2. Importance value index (IVI) of the woody plant species in the coffe-based and non-coffee forests.

Forest patches	Botanical names	RF	RD	RDO	IVI
Coffee-based	*Coffea arabica*	8.99	44.83	1.53	54.86
	Millettia ferruginea	1.08	18.50	14.06	41.44
	Ehretia cymosa	0.18	5.55	21.64	36.33
	Albizia shimperiana	0.90	1.41	17.76	26.54
	Croton macrostachyus	6.29	1.87	5.98	14.24
	Diospyros abyssinica	6.29	0.42	1.48	14.16
	Ritchiea albersii	7.01	3.28	0.56	10.84
	Vangueria volkensii	5.94	3.13	1.71	10.68
	Celtis africana	4.68	1.33	4.23	10.23
	Solanum gigantum	5.40	3.34	0.19	8.91
	Cordia africana	3.06	0.43	3.68	7.17
	Ficus vasta	0.36	0.01	6.71	6.90
	Sub-total	50.18	84.1	79.53	242.3
	Total (including other 36 species)	100.00	100.00	100.00	300.00
Non-coffee based	*Ficus vasta*	0.45	0.05	36.11	36.60
	Rhus glutinosa	5.38	4.44	14.81	24.63
	Stereospermum kunthianum	4.48	9.11	9.46	23.05
	Buddleja polystachya	4.48	14.95	0.07	19.50
	Cordia africana	4.04	2.57	7.66	14.26
	Vernonia amygdalina	5.38	4.53	2.66	12.58
	Grewia ferruginea	3.14	7.20	1.03	11.37
	Clausena anista	3.59	6.21	0.00	9.80
	Dulesa (local name)	2.69	0.93	5.98	9.60
	Croton macrostachyus	3.59	2.15	3.15	8.88
	Vangueria volkensi	4.04	3.74	0.49	8.26
	Bersama abyssinica	1.79	4.39	0.88	7.07
	Sub total	43.05	60.27	82.3	185.6
	Total (including other 48 species)	100.00	100.00	100.00	300.00

RF = Relative frequency; RD = Relative density; RDO = Relative dominance.

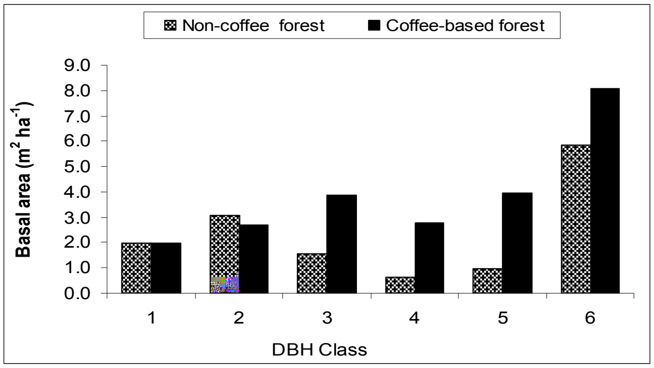

Figure 4. Basal area across diameter classes of all woody species in coffee-based and non-coffee forest patches. DBH class: 1 = 2.5-10 cm, 2 = 10-20 cm, 3 = 20-30 cm, 4 = 30-40cm, 5 = 40-50 cm, 6 = >50cm.

The density of all the woody species in the coffee-based forest with 5930 ha^{-1} was higher than the non-coffee forest with 4659 ha^{-1} (Table 3). In both forest patches saplings with DBH>2.5cm and < 10cm obtained the highest proportion and followed by seedlings with DBH<2.5 cm. Coffea *arabica* with 2659 ha^{-1}, *Millettia ferruginea* with 1097 ha^{-1}, *Diospyros abyssinica* with 380 ha^{-1} and *Ehretia cymosa* with 329 ha^{-1} were the first four species with highest stem density in the coffee-based forest. In the non-coffee forest, *Rhus glutinosa, Solanum gigantum* and *Vernonia amygdalina* were with the highest density of 27 ha^{-1} each.

Table 3. Density (ha^{-1}) of woody species in both the coffee-based and non-coffee forests of the Zege forest.

Growth stages	Coffee-based forest	Non-coffee forest
Seedlings (DBH <2.5 cm and height <1 m)	2424	1824
Sapling (Understorey and shrubs, 2.5 cm >DBH<10 cm)	3031	2473
Trees (DBH >10 cm)	475	362
Total	5930	4659

Farmers' coffee shade preferences and their management practices

Most of the trees and shrubs in the Zege forest regenerated naturally, except coffee and very few fruit trees although the forest is in the hands of the community. An interview made to assess farmers' coffee shade tree preference showed that 82.9% of the respondents preferred *Ehretia cymosa*, *Albizia schimperiana*, *Millettia ferruginea and Celtis africana* in order of importance. Of course, farmers have their own justifications in selecting these species, for example *E. cymosa* is evergreen with medium canopy density so that it gives year round and fair shade, *A. schimperiana* and *M. ferruginea* though deciduous they regenerate at peak dry season to provide shade for coffee. Similar studies carried out in Costa Rica also showed that farmers' follow the same principles of preference (Albertin and Nair, 2004).

Factors affecting forest condition

Wood extraction for fuel wood and timber was found to be the major threat of Zege peninsula forest followed by sheep free grazing. The 111.2 stump ha^{-1} density in the coffee-based forest showed that there was high human interference than the non-coffee forest with 36.4 stump ha^{-1} (Table 4). Moreover, coffee and fruit production is highly challenged by drought and wild animals, respectively.

Table 4. Stump density ha^{-1} of woody species in the two forest patches at Zege.

Species	Coffee-based forest	Non-coffee forest
Millettia ferruginea	35	-
Ehretia cymosa	25	-
Celtis Africana	19	-
Diospyros abyssinica	16	-
Croton macrostachyus	12	-
Ritchiea albersii	11	-
Rothmannia urcelliformis	8	-
Cordia Africana	8	-
Vanguria volkensi	6	-
Albizia schimperiana	5	-
Coffea Arabica	5	-
Eucalyptus camaldulensis	2	-
Rhamnus prinoides	1	-
Unidentified	17	-
Stereospermum kunthianum	-	3
Vernonia amygdalina	-	2
Bersama abyssinica	-	2
Cordia Africana	-	1
Unidentified	-	8
Total stem stamp recorded	170	16

Conclusions and recommendations

Zege Peninsula forest has a healthy population structure of inverted J-shape. However, economically important indigenous species like *Prunus africana, Podocarpus falcatus and Ficus vasta* were highly affected. The traditional coffee forest management has negatively affected woody species diversity by only favoring certain species that are used for coffee shade. In Zege Peninsula forest, there was no proper management to improve coffee production and to install sustainable forest management in place except some routine practices of slashing, coppicing etc. The decline of coffee production and subsequent shift to intensive wood extractions, free sheep grazing in the forest and vertebrate pests are the major factors that adversely affect the Zege Peninsula forest.

Generally, Zege forest offers great economic and social values for the rural communities. Therefore, to reduce the present pressure on the forest and to manage the forest on a sustainable basis, the following recommendations are suggested: Enrichment planting should be done particularly in the open spaces of the non-coffee forest patch for sustainable fuel wood and timber production. Designing irrigation and water harvesting techniques, diversifying livelihood through honey production, organizing existing fishing practices, jewelry selling and tourist guiding should be encouraged as off-farm activities. Fruit production should be promoted and preventive measures against vertebrate pests and fruit disease need to be design.

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