Floristic composition and diversity of Homegarden Agroforestry systems in the Lowlands of Tigray, North-Ethiopia

Abstract

To reverse the challenges of land degradation, through improved vegetation composition and access to feed and wood, communities in northern Ethiopia started to establish homegarden agroforestry decades ago. However, there was information gap on the floristic composition and diversity of the homegarden agroforestry systems in northern Ethiopia, particularly in the lowlands of Tigray region. Hence, this study aimed at filling the gap. Fifteen homegarden agroforestry farms from fifteen farming households (One homegarden agroforestry farm from each household) were selected purposely. Floristic composition and diversity and were estimated through Shannon diversity index, richness, evenness and density estimations. Twenty eight (28) woody species which belong to 17 families were recorded on the home-garden Agroforestry. Fabaceae and Combretaceae were found to the most dominant families whereas 10 of the 17 families represented each by only one species. The density of the woody species in the homegarden agroforestry was 201 stems ha^{-1} from which 56.8% was contributed by *Cordia africana, Ziziphus spina-christi* and *Anogeisusleiocarpus.* The Shannon diversity index and evenness of the homegarden farms were 2.52 and 0.75 respectively. In terms of the importance value index (IVI) of the species in the homegarden agroforestry, *Cordia africana* (64.76%) and *Ziziphus spina-christi* (45.30%) were the top ranking species. Generally, the present study revealed that the homegarden agroforestry systems are comparable to other homegardenagroforestry systems in Ethiopia in terms of floristic composition and diversity. Hence, both governmental and private sectors should play their role for the promotion of homegarden agroforestry systems in the study area, and in areas with similar biophysical and social setup. Moreover, afforestation and reforestation programs have to be continued for those species with low density, frequency and dominance in the study area.

Key words: Homegarden Agroforestry, floristic composition, diversity, Lowlands

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1. Introduction

Land degradation, accelerated soil erosion and deforestation are serious problems in Ethiopia (Haregeweyn et al., 2012; Teka, 2017; Teka et al., 2014). Tigray (north Ethiopia) where the study area is located is one of the regions in Ethiopia is characterized by severely degraded soils, low productivity and loss of biodiversity (Birhane et al., 2006; Teka, 2017; Teka et al., 2014). To overcome the problem, various environmental rehabilitation efforts have been promoted and implemented in the last decades. Establishment of Agroforestry systems such as home-garden agroforestry are among many interventions (Guyassa and Raj, 2013).

Different researchers defined home-garden agroforestry a land use system involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably livestock within the compounds of individual houses, the whole tree-crop, and animal unit is being intensively managed by family labor (Gautam et al., 2004; Kumar and Nair, 2006; Weerahewa et al., 2012). Studies from different locations of the globe such as Dixon (1995), Pandey (2002), Marland (2004), Lemma et al. (2006), Jose (2009), Alem (2013), Duguma et al. (2010), Negash et al. (2015) and Kim et al. (2016), indicated positive impacts of home garden agroforestry on plant diversity restoration, carbon sequestration and soil fertility improvement.

Agroforestry is also found to enhance biodiversity by providing habitats for species (Jose, 2009; Guyassa and Raj, 2013; Negash et al., 2013; Bajigo and Tadesse, 2015), and conserving native species (Harvey and Villalobos, 2007). More than 3000 tree species have been documented in tropical Agroforestry systems (Simons and Leakey, 2004). Agroforestry also provides many ecosystem services such as soil and water conservation, and watershed protection (Pandey, 2002; Jose, 2009), and soil fertility improvement (Negash, 2013).

In north Ethiopia (Tigray) where the study is located, few studies (e.g. Darcha et al., 2015; Guyassa and Raj, 2013; Haileselasie and Hiwot, 2012) on the contribution of home-garden Agroforestry systems to ecological restoration were conducted in different sites. However, the focus of these studies was on the mid to highland areas (elevation greater than 1500 m a.s.l) with less intention to the lowlands (elevation less than 1500 m a.s.l.). The socio-economic conditions, political and historical contexts, and level of management are different in these different agro-ecologies (Guyassa and Raj, 2013). Moreover, the effect of land use conversion is variable, and depends on soil type, land-use history and topography. However, the homegardens in north-Ethiopian lowlands were not adequately evaluated and documented. Furthermore,Quantifying the role of home-garden Agroforestry systems for ecological restoration is critical to help decide whether additional home-garden Agroforestry systems should be established in the area, and areas with similar biophysical and socio-economic setup. Hence, this study aimed at inventorying the woody species composition and diversity of homegarden agroforestry systems in Tselemti district, Northern Ethiopia.

2. Materials and Methods

2.1. The Study Area

The study was conducted at Sekota-mariam peasant association (PA) in Tselemti District, North Western Zone of Tigray, north-Ethiopia (Figure 1).The study site was purposely selected based on the availability of homegarden agroforestry system and accessibility of the peasant association (PA) for the study. It is located at $13^{0}05$’ latitude and $38^{0}18$’longitude, and has an altitude of 1350 meter above sea level (m a.s.l). Areas characterized by an elevation less than 1500 but greater than 500 m a.s.l are classified as lowland or locally called ‘*Kolla*’ (*Hurni et al.,* 2016).

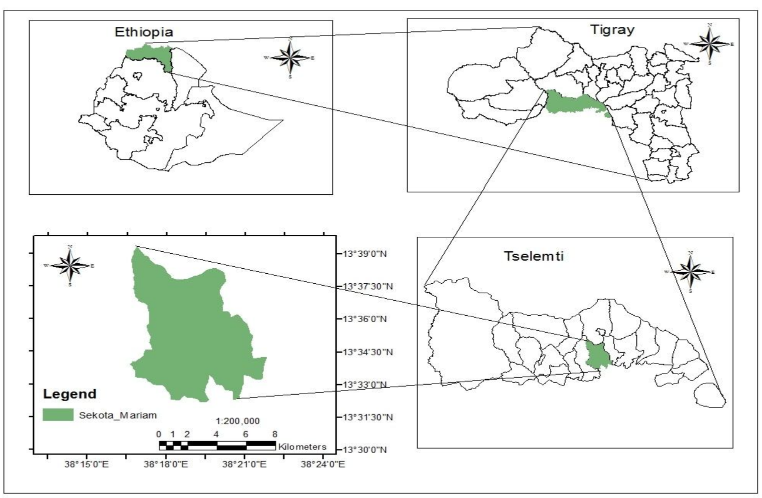

Figure1. Location map of the study area

The study area is characterized by dry semi-arid lowland plains (MOA, 2000). The mean temperature ranges from 15.6 ^{O}C in January to 38.6 ^{O}C in April. While, the annual rainfall ranges from 350 to 750 mm per year and falls from mid-June to early September (*Livelihood Profile, Tigray Region, Ethiopia*, 2007).

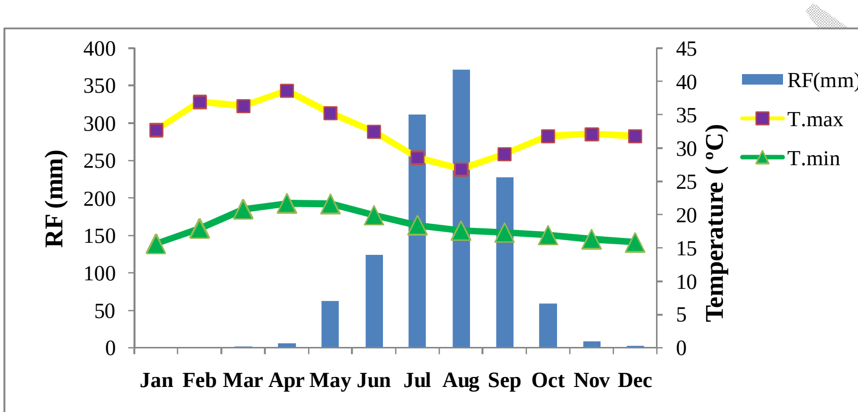

Figure 2.Mean monthly temperature (Years in range) of the study area (Source: Tigray meteorological services center).

The major reference soil groups in the area are Nitosols, Cambisols and Vertisols (TARI, 2002). The area is within a mixed farming zone that produces both food and cash crops along with livestock production. The main crops grown for consumption are sorghum (Sorghum bicolor), finger millet (*Eleusine coracana*) and maize (*Zea mays*). Livestock production is a major component of the livelihood system. The main livestock types are cattle, goats and sheep. Livestock are important for draft power and as an income source. The district has a total land size of 717, 000 ha. From this, 80% is planted in cereals, 4% in oil seeds, 2% in pulses and the remaining with vegetables and fruit trees (OOARD, 2014).The district has a total population of 138,858; of which 68750 are women and 70,108 are men (CSA, 2008). The population density is 36 people km^{-2}.

2.2.Vegetation data sampling

For vegetation survey in the homegarden agroforestry, 15 plots (in this case homegardenagroforestry farms) from 15 farming households (One homegardenagroforestry farm from each household) were selected purposely. Quadrates were not laid in the homegarden agroforestry, rather the entire area of the homegarden was used as a sampling unit for each farm house hold for vegetation survey (Didita and Mengistu, 2012).The area of the smallest plot, which is 973 m^2 was taken as sampling area for each plot.Complete enumeration of species within each sampling unit was used for vegetation survey (Tolera et al., 2008).

Diameter tape and caliper were used to measure the diameter at breast height (DBH) and diameter at estimated stump height (DSH) of the species. Plant identification was done at the field. The woody species encountered in the plots were identified based on our experience supported by the local residents and district experts. The scientific name of each species was referred from Species list of useful trees and shrubs for Ethiopia (Tesemma, 1993, 2007), and useful trees and shrubs in Eritrea (Bein et al., 1996).

2.3.Vegetation data analysis

The vegetation data were analyzed by computing the density, frequency, dominance, diversity indices and importance value index (IVI).

Density: was computed by summing up all the individuals from all sample plots and translated to hectare base for all the species. Two sets of density were calculated: density/ha of each species and relative density, which was calculated as the ratio of the density of a given species to the sum total of the density of all species:

$$\textbf{Relativedensity} = \frac{\text{Density of species A in hectare base}}{\text{Density of all species in hectare base}} * 100 \ldots\ldots \text{ Eq (1)}$$

Frequency: It shows the presence or absence of a given species in each sample quadrant. Two sets of frequency were calculated, absolute frequency, which refers to the number of plots in which the woody species encountered and relative frequency, calculated as the ratio of the absolute frequency of a given species to the sum total of the frequency of all species:

$$\textbf{Relativefrequency} = \frac{\text{Freqency of species A}}{\text{Frequency of all species}} * 100 \ldots\ldots\ldots\ldots \text{Eq (2)}$$

Dominance: It refers to the degree of coverage of a given species expressed by a space it occupied in a given area. Two sets of dominance were calculated: absolute dominan ce (the sum of basal areas of the stems in m^2/ha), and relative dominance: ratio of the total basal area of a given species to the sum of total stem basal areas of all species. Dominance was calculated for individual stems with diameter > 2.5cm (Worku, 2006):

$$\textbf{Relativedominance} = \frac{DominanceofspeciesA}{Dominanceofallspecies} * 100 \text{ …… Eq (3)}$$

Basal area (BA) was computed using the formula:-

$$BA = \frac{\pi d^2}{4} \text{…………………………Eq (4)}$$

Where BA= basal area in m^2; π=3.14; D=diameter

Importance Value Index (IVI):

It refers to the relative ecological importance of each species in a given area. It was calculated by summing up the relative dominance, relative density and relative frequency of the species as follows:

IVI=Rd+ RD+ RF…………………………… (Eq 5)

Where Rd is relative density, RD is relative dominance and RF is relative frequency.

Diversity indices

Species diversity was estimated using Shannon Wiener Diversity Index and evenness (Kent & Coker 1992):

H'= $-\sum_{i=1}^{s} \text{pi} \ln \text{pi}$……………………………….. (eq. 6)

Where:

H'= Shannon diversity index

s = number of species

Pi=the proportion of individuals or the abundance of the ith species expressed as a proportion of the total

ln= natural logarithm

Evenness: was calculated using the formula:

Evenness (J') = $-\sum_{i=1}^{s} \text{pi} \ln \text{pi} / \ln s$……………….. (Eq 7).

Where: S = number of species and ln is a natural log.

Species richness

Species richness can be expressed as number of species per unit area. The sum of all woody species encountered in the plots of the land use systems was used to determine the species richness.

3. Result and Discussions

3.1. Floristic composition

As shown in Table 1, twenty eight (28) woody species which belong to 17 families were recorded on the home-garden Agroforestry. This result corresponds with the findings of Guyassa and Raj (2013) for Abreha we Atsbeha watershed (northern Ethiopia) who reported 28 species in home-gardens. However, this was higher than the number of species reported by Mengistu and Asfaw (2016) at Dallo Mena District, South-East Ethiopia (15 species), but lower than those reported by Abebe et al. (2013) at Sidama Zone of southern Ethiopia (120 species), Haileselasie and Hiwot (2012) at home-gardens of Hintalowagerat district of Tigray region (40 species), and Tolera et.al. (2008) at Arsi Negelle district in central Ethiopia (64 species). These differences may be attributed to the variations in environmental conditions and farmers management.

Fabaceae and Combretaceaewere the most dominant families at the home-garden Agroforestry system represented by 5 and 3 species respectively and contributed 28.5% of the species composition of the system. However, 10 of the 17 families represented each by only one species. This revealed that the system was dominated by few species.

Table1: Tree species in home garden Agroforestry

Species name	Family name	Number of species per Family
Citrus lemon	Rutaceae	Rutaceae=2 species
Cordia africana	Boraginaceae	Boraginaceae=1
Jacaranda mimosifilia	Bignoniaceae	Bignoniaceae=2
Carica papaya	Caricaceae	caricaceae=1
Mangifera indica	Anacardiaceae	Anacardiaceae=1
Psidium gaujava	Myrtaceae	Myrtaceae=1
Acacia polyacantha	Fabaceae	Fabaceae=5
Ziziphus spina-christi	Rhamnaceae	Rhamnaceae=2
Croton macrostachyus	Euphorbiaceae	Euphorbiaceae=1
Citrus aurantifolia	Rutaceae	Rubiaceae=2
Acacia persiciflora	Fabaceae	Combretaceae=2
Gardenia lutea	Rubiaceae	Moraceae=3
Anogeisusleiocarpus	Combretaceae	Meliaceae=1
Fehiderbia albida	Fabaceae	Ebenaceae=1
Ficus vasta	Moraceae	Caesalpinioideae=1
Melia azedarach	Meliaceae	Tiliaceae=1
Acacia seyal	Fabaceae	Burseraceae=1
Terminalia brownii	Combretaceae	
Diospyros mespiliformis	Ebenaceae	
Sterospermumkunthianum	Bignoniaceae	
Ficus ingens	Moraceae	
Cassia singueanea	*Caesalpinioideae*	
Ziziphus jujube	Rhamnaceae	
Ficus sycomorus	Moraceae	
Grewia ferruginea	Tiliaceae	
Commiphora africana	Burseraceae	
Dichrostachyscinearea	Fabaceae	
Vangueria edulis	Rubiaceae	

3.2.Density, diversity indices and richness

The overall density of the woody species in the homegarden agroforestry was 201 stems ha^{-1}(Table 2). Density of species in the homegarden varied among species. *Cordia africana, Ziziphus spina-christi* and *Anogeisusleiocarpus* were the denser species with 52.7, 37 and 24.6 stems ha^{-1} respectively and contributed to 56.8% of the total density in the homegarden agroforestry while 9 species were found to be the least abundant with 0.7 stem ha^{-1} each(Table 2). The density on the homegarden agroforestry was found to be higher than that reported by Yakob et al. (2014), 113 stems ha^{-1}, for Gimbo district (south west Ethiopia), but lower than that reported by Abebe et al. (2013) which was 475 stems ha^{-1} for agroforestry homegarden of Sidama zone, Southern Ethiopia. This difference could be due to difference in planting pattern of the woody species. According to Abebe et al. (2013) for home-gardens in Sidama, and Molla and Kewessa (2015) for home-gardens in Bale zone, woody species abundance largely depends on the planting pattern of the woody species.

The Shannon diversity index value and species evenness of the homegarden agroforestry were found to be 2.52. This was comparable to the findings at Bale zone home garden in Ethiopia ranging from 2.53 to 2.73 (Molla and Kewessa, 2015), at Kerala garden in India, ranging from 1.12 to 3 (Kumar et al., 1994), and home-gardens of Thailand, ranging from 1.9 to 2.7 (Gajaseni and Gajaseni, 1999). However, it was found to be higher than those reported by Guyassa and Raj (2013) for Abreha-we-Atsbeha (H = 1.31), Bajigo and Tadesse (2015) for Gununo in Wolayitta Zone (H=2.02)and Tolera (2008) for Arsi Negelle in Ethiopia (H = 2.22). The richness of the species in the land use system was found to be 5. Moreover, the evenness of homegarden in the study area (0.75) was higher compared to what was reported by Tolera (2008) for Arsi Negelle in Ethiopia (0.64) and Mengistu (2008) at homegarden of western Amhara of Ethiopia(H=0.69)). However, it was lower compared to the values reported by Molla and Kewessa (2015) for Bale zone, evenness ranging from 0.91 to 0.99.

Table 2: Species abundance, density, dominance, frequency and importance value index

Species	Abundance	Density (trees/ha)	Dominance (cm^2/ha)	Freq.	IVI%
Citrus lemon	15	10.3	1395.1	2	9.7
Cordia africana	77	52.7	16286.2	12	64.8
Jacaranda mimosifilia	1	0.7	110.4	1	1.8
Carica papaya	11	7.5	1512.6	2	8.5
Mangifera indica	8	5.5	875	2	6.6
Psidium gaujava	3	2.1	2829.6	1	6.3
Acacia polyacantha	7	4.8	2590.3	4	11.3
Ziziphus spina-christi	54	37	10789.7	9	45.3
Croton macrostachyus	12	8.2	1891	2	9.4
Citrus aurantifolia	1	0.7	223.4	1	2
Acacia persiciflora	5	3.4	468	1	3.7
Gardenia lutea	2	1.4	394.8	2	3.9
Anogeisusleiocarpus	36	24.7	8218.8	6	31.6
Fehiderbia albida	8	5.5	2753.1	3	10.5
Ficus vasta	1	0.7	950.2	1	3
Melia azedarach	1	0.7	115.4	1	1.8
Acacia seyal	16	11	9230.8	3	22.3
Terminalia brownii	1	0.7	502.6	1	2.4
Diospyros mespiliformis	1	0.7	110.5	1	1.8
Sterospermumkunthianum	5	3.4	2475.9	1	6.5
Ficus ingens	6	4.1	2001	1	6.2
Cassia singueanea	1	0.7	42.8	1	1.7
Ziziphus jujube	4	2.7	507.5	2	4.7
Ficus sycomorus	5	3.4	3439.4	2	9.1
Grewia ferruginea	1	0.7	105.6	1	1.8
Commiphora africana	5	3.4	283.2	1	3.4
Dichrostachyscinearea	6	4.1	1346.6	2	6.6
Vangueria edulis	1	0.7	36.9	1	1.7
Total	294	201	71486	67	

3.3.Frequency, dominance and importance value index (IVI)

In homegarden agroforestry, *Cordia africana* and *Ziziphus spina-christi* were the most frequent species encountered in 12 and 9 plots respectively out of the 15 plots, while 14 species were recorded in only one quadrat (Table 2). The two most dominant species were *Cordia africana* (22.78%) and *Ziziphus spina-christi* (15.09%) with 1.63 m^2/ha and 1.08 m^2/ha respectively (Table 2). In terms of the importance value index of the species in homegarden agroforestry, *Cordia africana* (64.76%) and *Ziziphus spina-christi* (45.30%) were the top ranking species

(Table 2). This can show us only few species hold the largest value of IVI and so higher difference in ecological importance of each species at the study area.

4. Conclusion

The results of this study elucidated that the floristic composition, density, diversity indices in the homegarden agroforestry systems of in the lowlands of Tigray region, northern Ethiopia are comparable to many other homegardens of the country. Most of the families were founded to be represented by a single species which shows that the system was dominated by few species and families. The study also revealed that only three species contributed to more than half of the total density in the homegarden agroforestry. In addition, half (14) of the total species were recorded in only one plot where one species was recorded in almost all of the plots. On top of that, the study showed that only few species hold the largest value of Importance Value Index (IVI) and so higher difference in ecological importance of each species at the study area. Both governmental and private sectors should play their role for the promotion of homegarden agroforestry systems in the study area, and in areas with similar biophysical and social setup. Moreover, afforestation and reforestation programs have to be continued for those species with low density, frequency and dominance in the study area.

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