Asian Journal of Geographical Research

Volume 7, Issue 3, Page 36-45, 2024; Article no.AJGR.120999
ISSN: 2582-2985

Floristic Composition and Diversity of Homegarden Agroforestry Systems in the Lowlands of Tigray, North-Ethiopia

Kiros Abay [a*]

[a] *Shire-Maitsebri Agricultural Research Center, Tigray Agricultural Research Institute, Ethiopia.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: https://doi.org/10.9734/ajgr/2024/v7i3241

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/120999

Original Research Article

Received: 02/06/2024
Accepted: 04/08/2024
Published: 10/08/2024

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 was calculated by summing all the species recorded in all plots. In addition, Shannon diversity index, richness, and evenness were used to assess the diversity of the land use. Density was computed by summing up all the individuals from all sample plots and translated to hectare base for all the species. 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

**Corresponding author: E-mail: kirosabay01@gmail.com;*

Cite as: *Abay, Kiros. 2024. "Floristic Composition and Diversity of Homegarden Agroforestry Systems in the Lowlands of Tigray, North-Ethiopia". Asian Journal of Geographical Research 7 (3):36-45. https://doi.org/10.9734/ajgr/2024/v7i3241.*

Anogeisus leiocarpus. 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. The present study revealed that the homegarden agroforestry systems are comparable to other homegarden agroforestry 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.

Keywords: Homegarden agroforestry; floristic composition; diversity; lowlands.

1. INTRODUCTION

Land degradation, accelerated soil erosion and deforestation are serious problems in Ethiopia [1,2,3]. 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 [4,2,3]. 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 [5].

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 [6-13]. Studies from different locations of the globe such as Pandey [14], Marland [15], McNeely & Schroth [16], Lemma et al. [17], Jose [18], Duguma et al. [19], Alem [20], Negash et al. [21] Kim et al. [22], and Udawatta [23] 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 [18,5,21,24], and conserving native species [25]. More than 3000 tree species have been documented in tropical Agroforestry systems [26]. Agroforestry also provides many ecosystem services such as soil and water conservation, and watershed protection [14,18], and soil fertility improvement [21,27,28].

In north Ethiopia (Tigray) where the study is located, few studies [29,5,30] 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 [5,31-33]. 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 [34-38]. 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 [39-43]. 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 (Fig. 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*' [44].

The study area is characterized by dry semi-arid lowland plains [45]. 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 [46].

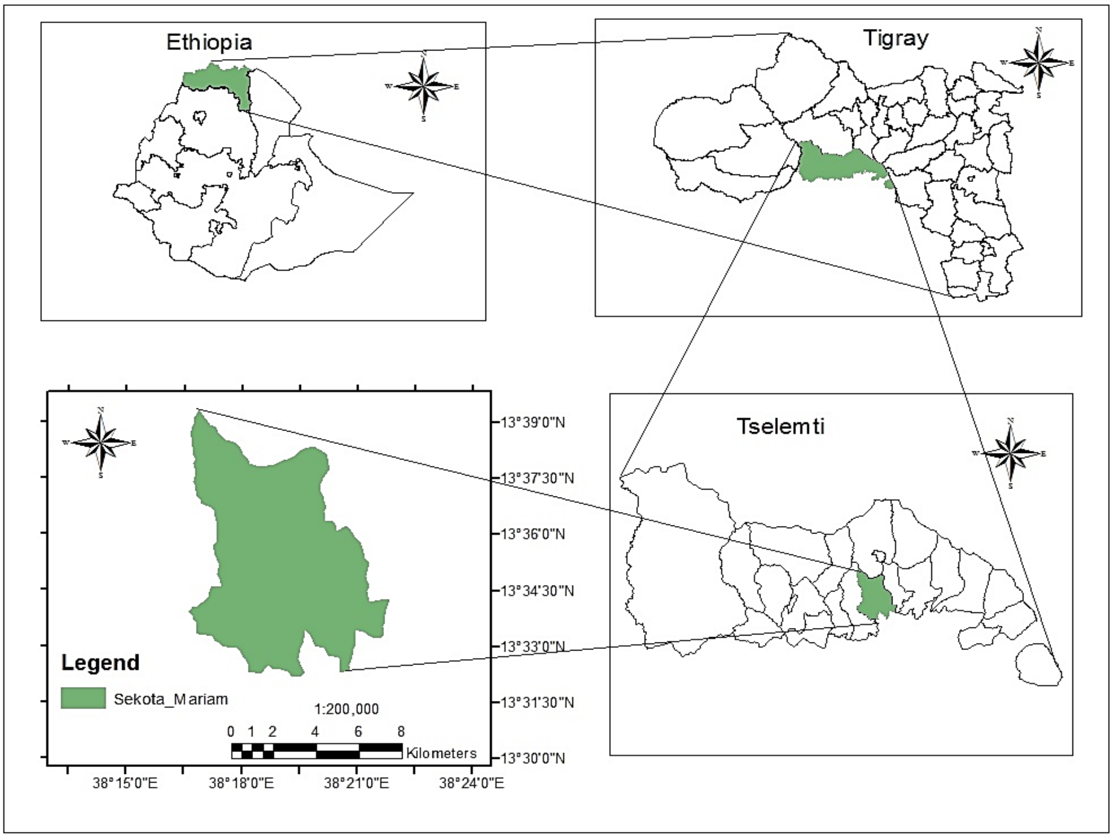

Fig. 1. Location map of the study area

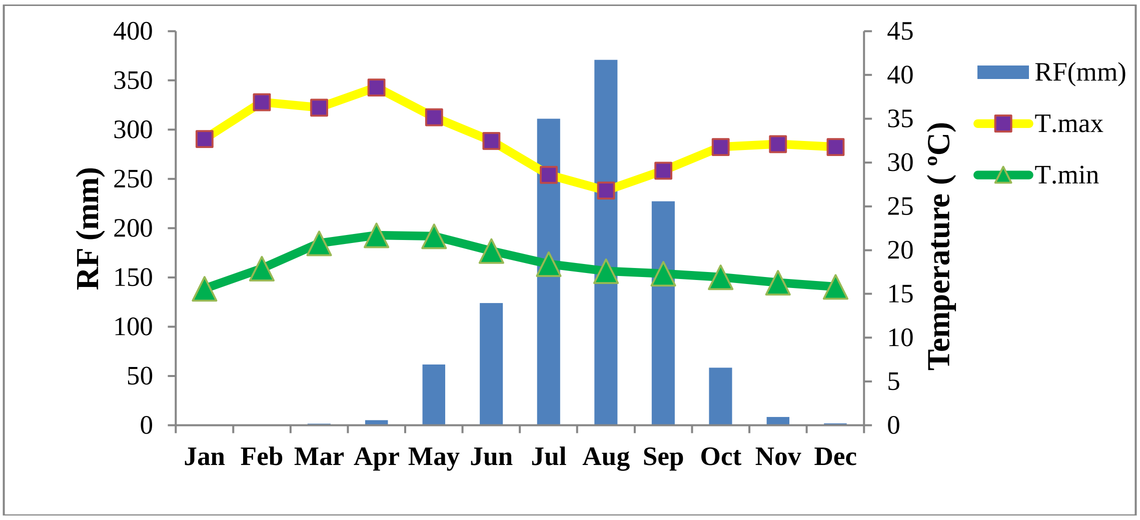

Fig. 2. Mean monthly temperature (Years in range) of the study area (Source: Tigray meteorological services center)

The major reference soil groups in the area are Nitosols, Cambisols and Vertisols [47].

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 [48]. The district has a total population of 138,858; of which 68750 are women and 70,108 are men [49]. 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 homegarden agroforestry farms) from 15 farming households (One homegarden agroforestry 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 [50]. 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 [51].

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 [52,53,54,55], and useful trees and shrubs in Eritrea [56].

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:

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

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:

$$\text{Relativefrequency} = \frac{\text{Freqency of species A}}{\text{Frequency of all species}} \times 100 \quad \text{Eq (2)}$$

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 dominance (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 [57]:

$$\text{Relativedominance} = \frac{Dominanceof speciesA}{Dominanceof allspecies} \times 100 \quad \text{Eq (3)}$$

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

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

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') = $-\sum_{i=1}^{s} \text{pi} \ln \text{pi} / \ln s \ldots$. (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. RESULTS AND DISCUSSION

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 [5] 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 [58] at Dallo Mena District, South-East Ethiopia (15 species), but lower than those reported by Abebe et al. [59] at Sidama Zone of southern Ethiopia (120 species), Haileselasie and Hiwot [30] at home-gardens of Hintalo wagerat district of Tigray region (40 species), and Tolera et.al. [51] 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 Combretaceae were 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.

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 *Anogeisus leiocarpus* 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. [60], 113 stems ha^{-1}, for Gimbo district (south west Ethiopia), but lower than that reported by Abebe et al. [59] 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. [59] for home-gardens in Sidama, and Molla and Kewessa [61] 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 [61], at Kerala garden in India, ranging from 1.12 to 3 [62], and home-gardens of Thailand, ranging from 1.9 to 2.7 [63]. However, it was found to be higher than those reported by Guyassa and Raj [5] for Abreha-we-Atsbeha (H = 1.31), Bajigo and Tadesse [24] for Gununo in Wolayitta Zone (H=2.02) and Tolera [30] 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 [51] for Arsi Negelle in Ethiopia (0.64) and Mengistu [58] at homegarden of western Amhara of Ethiopia(H=0.69)). However, it was lower compared to the values reported by Molla and Kewessa [60] for Bale zone, evenness ranging from 0.91 to 0.99.

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.

Table 1. 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	

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

Species	Abundance	Density (trees/ha)	Dominance (cm^2/ha)	Freq.	IVI%
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	

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.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

ACKNOWLEDGEMENTS

The author would like to the village administrations and inhabitants of the study area.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Haregeweyn N, Berhe A, Tsunekawa A, Tsubo M, Meshesha DT. Integrated watershed management as an effective approach to curb land degradation: A case study of the enabered Watershed in Northern Ethiopia. Environmental Management. 2012;50:1219–1233.
2. Teka K. Identification of erosion prone areas at macro-watershed level for regional development planning in Northern Ethiopia. Journal of the Drylands. 2017; 7(1):598 – 609.
3. Teka K, Van Rompaey A, Poesen J, Van Bruyssel S, Deckers J, Amare A. Spatial Analysis of Land Cover Changes in Eastern Tigray (Ethiopia) from 1965 till 2007: Are there Signs of a Forest Transition? Land Degrad. Develop; 2014. DOI: 10.1002/ldr.2275
4. Birhane E, Teketay D, Barklund P. Actual and potential contribution of exclosures to enhance biodiversity of woody species in the drylands of Eastern Tigray. Journal of Drylands. 2006;1(2):134-147.
5. Guyassa E, Raj AJ. Assessment of biodiversity in cropland agroforestry and its role in livelihood development in dryland areas: A case study from Tigray region, Ethiopia. Journal of Agricultural Technology. 2013;9(4):829-844.
6. Gautam R, Sthapit B, Shrestha P. Home gardens in Nepal. Proceedings of a national workshop, Local Initiatives for Biodiversity, Research and Development (LI-BIRD). Pokhara, Nepal; 2004.
7. Kumar BM, Nair PKR. Tropical home gardens: A time-tested example of sustainable agroforestry. Environmental Experts, India; 2006.
8. Weerahewa J, Pushpa kumara G, Silva P, Daulagala C, Punyawardena R, Premalal S, Miah G, Roy J, Jana S, Marambe B. Are home garden ecosystems resilient to climate change? An analysis of the adaptation strategies of homegardeners in

Sri Lanka. APN Science Bulletin. 2012; 2:22–27.
9. November E, Aerts R, Behailu M, Muys B. Species list Tigrinya – Scientific. Technical note 2002/4. Forest Rehabilitation Project, Mekelle University, Ethiopia and K.U. Leuven, Belgium. 2002;10.
10. Olsen SR, Sommers LE. Phosphorus. In: Page AL, Miller LH, Keeney DR. (Eds.), Methods of Soil Analysis. Part 2. Chemical and microbiological properties. Agronomy Monograph, second ed., American Society of Agronomy, Madison, WI. 1982;9:403-430.
11. Pearson TR, Brown SL, Birdsey RA. Measurement guidelines for the sequestration of forest carbon. General Technical Report NRS-18.Northern Research Station. United States Department of Agriculture; 2007.
12. Pinho RC, Alfaia SS, Miller RP, Uguen K, Magalha˜es LD, Ayres M, Freitas V, Trancoso R. Islands of fertility: Soil improvement under indigenous home gardens in the savannas of Roraima, Brazil. Agroforestry Systems. 2011;81(3): 235–247.
13. Radersma S, Grierson PF. Phosphorus mobilization in agroforestry: Organic anions, phosphatase activity and phosphorus fractions in the rhizosphere. Plant and Soil. 2004;259(1-2):209-219.
14. Pandey DN. Carbon sequestration in agroforestry systems. Climate Policy. 2002;2(4):367-377.
15. Marland G, Garten CT, Post WM, West TO. Studies on enhancing carbon sequestration in soils. Energy. 2004;29(9): 1643-1650.
16. McNeely JA, Schroth G. Agroforestry and biodiversity conservation–traditional practices, present dynamics, and lessons for the future. Biodiversity and Conservation. 2006;15:549-554.
17. Lemma B, Kleja DB, Nilsson I, Olsson M. Soil carbon sequestration under different exotic tree species in the southwestern highlands of Ethiopia. Geoderma. 2006 ;136(3):886-898.
18. Jose S. Agroforestry for ecosystem services and environmental benefits: An overview. Agroforestry Systems. 2009; 76(1):1-10.
19. Duguma LA, Hager H, Sieghardt M. Effects of land use types on soil chemical properties in smallholder farmers of central highland Ethiopia. Ekológia (Bratislava), Ekológia (Bratislava). 2010;29(1):1-14.
20. Alem SM. Effect of Plantation forests on soil chemical properties, soil temperature and regeneration of woody plants: A comparative analysis. PhD Dissertation. Mendel University in Brno, Czech Republic; 2013.
21. Negash M, Starr M. Biomass and soil carbon stocks of indigenous agroforestry systems on the south-eastern Rift Valley escarpment, Ethiopia. Plant and Soil. 2015;393(1-2):95-107.
22. Kim DG, Terefe B, Girma S, Kedir H, Morkie N, Woldie TM. Conversion of home garden agroforestry to crop fields reduced soil carbon and nitrogen stocks in Southern Ethiopia. Agroforestry Systems. 2016;90(2):251-264.
23. Udawatta RP, Rankoth LM, Jose S. Agroforestry and biodiversity. Sustainability. 2019;11(10):2879
24. Bajigo A, Tadesse M. Woody species diversity of traditional agroforestry practices in Gununo watershed in Wolayitta Zone, Ethiopia. Forest Res. 2015;4(155):2.
25. Harvey CA, Villalobos JAG. Agroforestry systems conserve species-rich but modified assemblages of tropical birds and bats. Biodiversity and Conservation. 2007;16(8):2257-2292.
26. Simons AJ, Leakey RRB. Tree domestication in tropical agroforestry. Agroforestry Systems. 2004;61:167-181.
27. Shannon CE, Weaver W. The mathematical theory of communication. Urbana: University of Illinois Press; 1963.
28. Singh BR, Wele AD, Lal R. Soil carbon sequestration under chronosequences of agroforestry and agricultural lands in Southern Ethiopia. 19th World Congress of Soil Science. Norwegian University of Life Sciences; 2010.
29. Darcha G, Birhane E, Abadi N. Woody species diversity in Oxytenantheraabyssinica based homestead agroforestry systems of Serako, Northern Ethiopia. Journal of Natural Sciences Research. 2015;5(9):18 – 26.
30. Haileselasie TH, Hiwot MT. Agroforestry practices and flora composition in backyards in Hiwane, HintaloWejerat of Tigray, Northern Ethiopia. International Journal of Biodiversity and Conservation. 2012;4(7):294-303.

31. Van reeuwijk LP. Procedures for Soil Analysis, 3rd edition. International Soil Reference Centre Wageningen (ISRIC), Netherlands, Wageningen; 1992.
32. Walkley A, Black IA. Chromic acid titration for determination of soil organic matter. Soil Science. 1934;63:239 - 251.
33. Wang G, Welham C, Feng C, Chen L, Cao F. Enhanced soil carbon storage under agroforestry and afforestation in subtropical China. Forests. 2015;6:2307-2323.
34. Araujo AS, Leite LF, De Freitas Iwata B, De Andrade Lira M, Xavier GR, Figueiredo MD. Microbiological process in agroforestry systems. A review. Agronomy for Sustainable Development. 2012;32(1): 215-226.
35. Awasthi KD, Singh BR, Sitaula BK. Profile carbon and nutrient levels and management effect on soil quality indicators in the Mardi watershed of Nepal. Acta Agriculturae Scandinavica Section B-Soil and Plant. 2005;55(3):192-204.
36. CSA. Summary and statistical report of the 2007 population and housing census results. Population size by age and sex. Central Statistical Agency of Ethiopia: Addis Ababa; 2008.
37. Grossman R, Reinsch T. Bulk density and linear extensibility. Methods of Soil Analysis: Part 4 Physical Methods (methods of soil). 2002;201-228.
38. Harcombe R. Soil nutrient loss as a factor in early tropical secondary succession. Biotropica. 1980;12:8±15.
39. Houba V, Vander L, Novazamsky I, Walinga I. Plant and soil analysis procedures. Department of Soil Science and Plant Nutrition Agric. Univ. Wageningen, Netherlands; 1989.
40. Jackson M. Soil Chemical Analysis. 6th ed. Prentice; Halls, Inc., Englewood cliffs: New Jorsey. 1958;498.
41. Jha MN, Gupta MK, Raina AK. Carbon Sequestration: Forest soil and land use management. Annals of Forestry. 2001;9:249-256.
42. Labata MM, Aranico EC, Tabaranza ACE, Patricio JHP, Amparado Jr RF. Carbon stock assessment of three selected agroforestry systems in Bukidnon, Philippines. Advances in Environmental Sciences. 2012;4(1).
43. Moges A, Holden NM. Soil fertility in relation to slope position and agricultural land use: A case study of Umbulo Catchment in Southern Ethiopia. Environmental Management. 2008;42(5): 753-763.
44. Hurni H, Berhe WA, Chadhokar P, Daniel D, Gete Z, Grunder M, Kassaye G. Soil and water conservation in Ethiopia: Guidelines for Development Agents. Second revised edition. Bern, Switzerland: Centre for Development and Environment (CDE), University of Bern, with Bern Open Publishing (BOP). 2016;134.
45. MOA (Ministry of Agriculture). Agro ecological Zones of Ethiopia, Natural Resource Management and Regulatory Department, Addis Ababa; 2000.
46. Livelihood Profile, Tigray Region, Ethiopia. Draft Adiabo Lowland Livelihood Zone. 2007;5. Available:www.heawebsite.org/download/file/fid/357
47. TARI (Tigray Agricultural Research Institute). Spatial stratification of agro ecologies in Tigray, Mekelle; 2002.
48. OOARD (Office of Agriculture and Rural Development). Annual report of Office of the agricultural and rural development of Tselemti Woreda, Tselemti; 2014.
49. Abera G, Wolde-Meskel E. Soil properties, and soil organic carbon stocks of tropical Andosol under different land uses. Open Journal of Soil Science. 2013;3:153-162.
50. Didita M, Mengistu B. The role of homegarden Agroforestry in plant diversity conservation in Bale. Forestry and forest products in Ethiopia. Proceedings of the national work shop on forestry research technologies. Ethiopian Institute Agricultural Research (EIAR). Addis Ababa, Ethiopia; 2012.
51. Tolera M, Asfaw Z, Lemenih M, Karltun E. Woody species diversity in a changing landscape in the south-central highlands of Ethiopia. Agriculture, Ecosystems and Environment. 2008;128(1):52-58.
52. Tesemma A. Useful Trees and Shrubs for Ethiopia. Identification, Propagation and Management for Agricultural and Pastoral Communities. Technical handbook No 5. Regional soil conservation unit. Swedish International Development Authority; 1993.
53. Tesemma A. Useful trees of Ethiopia: Identification, propagation and management in 17 agro ecological zones. Nairobi: RELMA in ICRAF Project. 2007;552.
54. Wei X, Shao M, Gale W, Li L. Global pattern of soil carbon losses due to the

conversion of forests to agricultural land. Sci Rep. 2014;4:40 – 62.

55. Yimer F, Alemu G, Abdelkadir A. Soil property variations in relation to exclosure and open grazing land use types in the Central Rift Valley area of Ethiopia. Environmental Systems Research. 2015;4(1):17.

56. Bein E, Habte B, Jaber A, Birnie A, Tengnas B. Useful Trees and Shrubs in Eritrea. Identification, Propagation and Management for Agricultural and Pastoral Communities. Regional soil conservation unit, RSCU/SIDA, Nairobi; 1996.

57. Worku AG. Population Status and Socio-economic Importance of Gum and Resin Bearing Species in Borana Lowlands, southern Ethiopia.Msc thesis, Addis Ababa University; 2006.

58. Mengistu B, Asfaw Z. Woody species diversity and structure of agroforestry and adjacent land uses in Dallo Mena District, South-East Ethiopia. Natural Resources. 2016;7(10):515-534.

59. Abebe T, Sterck FJ, Wiersum KF, Bongers F. Diversity, composition and density of trees and shrubs in agroforestry home gardens in Southern Ethiopia. Agroforestry Systems. 2013;87(6):1283-1293.

60. Yakob G, Asfaw Z, Zewdie S. Wood production and management of woody species in homegardens agroforestry: The case of smallholder Farmers in Gimbo District, South West Ethiopia. International Journal of Natural Sciences Research. 2014;2(10):165-175.

61. Molla A, Kewessa G. Woody species diversity in traditional agroforestry practices of Dellomenna District, Southeastern Ethiopia: Implication for Maintaining Native Woody Species. International Journal of Biodiversity; 2015.
Available:http://dx.doi.org/10.1155/2015/643031

62. Kumar BM, George SJ, Chinnamani S. Diversity, structure and standing stock of wood in the home gardens of Kerala in peninsular India, Agroforestry Systems. 1994;25(3):243–262.

63. Gajaseni N, Gajaseni J. Ecological rationalities of the traditional home garden system in the Chao Phraya Basin, Thailand. Agroforestry Systems. 1999; 46(1):3–23.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/120999