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# Research Article
# Diversity of Woody Species at Different Successional Stages of Disturbed Quinn-Sororo Natural Forest in South-Eastern Ethiopia

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## Abstract

**Background and Objectives:** Agricultural land expansion and the impact of fire are the two main anthropogenic factors that cause the rapid decline of plant species diversity and abundance at tropical dry forest. The study was carried out to compare woody plant species density and diversity at three successional stages each represented by three sites. **Materials and Methods:** A circular plot of a 30m radius was used for the collection of data. In each plot, the identification and enumeration of all woody plants were conducted. Plant density was estimated by quantifying the number of individuals of a species per unit area and converting it into stem density/ha. Shannon-Weaver (H') was used to calculate the diversity while Evenness (E) was calculated by using the Pielou index. Simpson index was calculated taking into account both richness and evenness of species. Plant density and diversity at different successional stages in the forest areas were compared between sites and successional stages. **Results:** A total of 65 species were recorded of which about 81.5 % were found in MS stage forest. The highest number of stem density, H' and E were recorded in MS sites followed by IS site while the highest Simpson index was observed in ES sites indicating the dominance of this successional stage with few species. **Conclusion:** The overall comparison of the number of woody plant species among the successional stages showed that there is a significant difference in the number of woody plant species. The existence of variation in the number of woody species is related to anthropogenic disturbances at the sites.

Key words: Density, disturbance, evenness, richness, successional sites, successional stages, simpson index

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

In succession, there exist over time evolution in structure of plant community[1] involving colonization, establishment and extinction of plant species. The outline of the mechanisms of plant succession at different ecosystems has been investigated by Connell and Slatyer[2]. In an ecosystem, there is a persistent shifting of species within the landscape as a result of the existence of plant succession[3] and this depends on the character and magnitude of disturbance in the area. In such a case there is always variation in plant species richness, diversity and density. It had been suggested by the non-equilibrium hypothesis[4] that the density of species supposed to be higher at intermediate levels of disturbance. However, it had been reported by Collins *et al.*[5] that there could be a chance for species from late stages to occur in the forests at the early of stage succession. On the other hand, local site factors like soil seed banks and the potential of regeneration also affect the diversity, abundance and composition of forests at different stages of succession[6].

Agricultural land expansion and the impact of fire are the two main anthropogenic factors that made tropical forests under the state of secondary seccession[3] resulting in a rapid decline of plant species diversity and abundance at tropical dry Afromontane forests. This case is especially true in Ethiopia a country characterized by diverse ecosystems[7]. Changes in land use mainly through the conversion of natural vegetation to agricultural lands and settlement are the main causes of the rapid deterioration of woody plant species in Afromontane forests in the country[8].

However, there is a lack of information about the status and distribution of woody plant species in Chercher dry Afromontane forests of south-eastern Ethiopia in general and that of Quinn-Sororo in particular in comparison to the number of studies made elsewhere in the country. Early studies conducted in the area were mainly related to the soil and participatory forest management[9,10].

Nevertheless, analysis of changes in Woody Plant species at different successional stages at Quinn-Sororo natural forest of Chercher dry Afromontane was not studied. This study was therefore aimed at identifying and comparing species richness, density and diversity of woody plants under different successional sites at Quinn-Sororo which may be used as a conservation strategy.

## MATERIALS AND METHODS

**Description of the study area:** The study was carried out from April 2018 to February 2019 in Quinn-Sororo Participatory Forest Management (PFM) of Chercher dry Afromontane, south-eastern Ethiopia about 332 km from Addis Ababa. It is located between 34°18'43"-43°04'33" E longitude and 10°09'24"-30°18'43"N latitude. The altitude of the forest ranged from 2,118-3,017 meters above sea level.

The forest faced different types of pressure since the fall of the Derge regime in Ethiopia (1991) to 2004. The major forms of anthropogenic impact have been agricultural land expansion particularly the expansion of *Catha edulis* cultivation as a cash crop, selective logging and illegal settlement as a result of which the forest became fragmented and highly degraded. It was in 2004 that the government of Ethiopia has taken the measure of resettlement of those farmers illegally settled in the forest to other parts of the region (Discussion with key informants) to rehabilitate the forest ecosystem. To sustain the management of the forest, the Oromia Forest and Wildlife enterprise have taken another measure making the forest to be administered under participatory forest management with the formulation of by-laws with local people. Quinn-Sororo forest is the only source of water for irrigation, domestic consumption that supporting the livelihood of the downstream communities and the source of water for the Sororo-Water packaging industry in the area.

**Selection of sites:** Survey of the existing forest was conducted and the forest stand was identified and coded (Table 1) with respect to the time since last major anthropogenic impacts in the forest (agricultural land expansion, illegal logging and illegal settlement) based on information of interviews with key informants.

Finally, nine sites represented by three successional stages were selected[11]. Three disturbed sites (ES1, ES2 and ES3) comprising secondary vegetation were selected from early stage of succession (ES) with age of 16 years. Similarly, three sites (IS1, IS2 and IS3) were selected from stands of forests found to be in transition between early and mature forests known as Intermediate stage forests (IS) with age

Table 1: Estimated ages of fragmented forest stand since its last major anthropogenic disturbance at Quinn-Sororo natural forest

| Site name | Site code | Succession stage | Age since last disturbance |
|---|---|---|---|
| Sororo | ES1 | Early succession | 8 |
| Babu 1 | ES2 | Early succession | 13 |
| Babu 2 | ES3 | Early succession | 16 |
| Tegene 1 | IS1 | Intermediate succession | 20 |
| Tegene 2 | IS2 | Intermediate succession | 25 |
| Gaara Arritti 1 | IS3 | Intermediate succession | 29 |
| Gaara Arritti 2 | MS1 | Mature succession | 35 |
| Gaara Qabanawa 1 | MS2 | Mature succession | 41 |
| Gaara Qabanawa 2 | MS3 | Mature succession | 45 |

years. Finally, three sites (MS1, MS2 and MS3) were selected from Mature stage succession forest stands (MS) with the age of about 45 years since its last major anthropogenic disturbance. Mature stage succession forest was structurally characterized by woody plant species of different types.

**Plot layout and plant species sampling:** For comparative purposes, eight sample plots each with a radius of 30 m were assigned to each of the nine sites under the three successional stage forests. The distance between the consecutive plots was 150 m and the plots were laid along transects that were 400 m apart from each other. In each plot, all woody plants with a diameter at breast height (DBH)>5 cm at 1.3 m above the ground were measured and enumerated. Local Para-taxonomists were involved in the identification of the species and the sample specimens of those species difficult for identification at the site were taken to Addis Ababa University, National Herbarium.

**Data analysis:** Analysis of species richness, density, Shannon index of diversity, species evenness and Simpson index were analyzed and compared among the nine sites and between the three successional stages.

**Species richness:** Species richness is a measure of the number of species found in a sample and was calculated as:

$$S = \Sigma n \quad (1)$$

were, is the total number of species in each site/ successional stages and n is the number of species in each plot.

Chao 2 estimator[12] was conducted to compare the number of species (S) between sites and successional stages. The analysis was performed with biodiversity software EstimateS[13]: http://purl.oclc.org/ estimates.

**Plant density:** The analysis of the plant density of each species was done by converting the average number of individuals of each woody plant species into stem density/ha as shown in Eq. 1. Unbalanced two-way ANOVA was used to compare the density of woody plant species between the nine sites and three successional stages. The differences between means were appraised by Tukey HSD tests:

$$\text{Density} = \frac{\text{The number of individuals of species}}{\text{Area sampled}} \quad (2)$$

**Species diversity:** Shannon's diversity index was calculated for woody plants in each plot. The index takes the assumption that the random sampling of individuals of each woody plant species and all the species are represented by sample plot[14].

Shannon index o f diversity was calculated by Eq. 3:

$$H = \Sigma \, Pi \ln Pi \quad (3)$$

where, i, is the proportion of the species relative to the total number of species (Pi) and ln is a natural logarithm proportion of the species i.

**Species evenness (E):** Species evenness is a measure of the relative abundance of the different species making up the richness of an area. It was calculated using Eq. 4:

$$E = \frac{H}{\ln S} \quad (4)$$

Where, H is Shannon-Weaver index of diversity and lnS is the natural logarithm of the number of species.

**Simpson index:** Simpson dominance index (D) was calculated as:

$$D = \frac{\sum ni(ni-1)}{N(N-1)} \quad (5)$$

where, ni is the total number of each species i and N is the total number of all the species counted.

## RESULT AND DISCUSSION

**Species richness:** In this study, a total of 65 woody species were recorded. The number of woody plant species recorded ranged from the least of 16 species (ES1) and to the highest of 53 species (MS2) with the overall mean number of woody plant species per site being 36 (Fig. 1). Sites of MS2 were found to contribute 81.5% of all the species and more than twice the mean number of species from ES stage forests. With respect to the mean number of species at successional stages, the MS were found to have the highest number of species (62) followed by IS (46) and ES (36) stages forests respectively. The number of woody species recorded in this study is about 60.2% of the total number of the plants reported by Yirga *et al.*[15] for Wof-Washa forest and about 36% of the total number plant species reported by Ergua *et al.*[16] from Entoto Mountain and the Surrounding forests Ethiopia.

In ES stage forests, no significant difference was observed in the number of woody plant species between ES1 and ES3 sites but sites of ES2 were significantly different in their

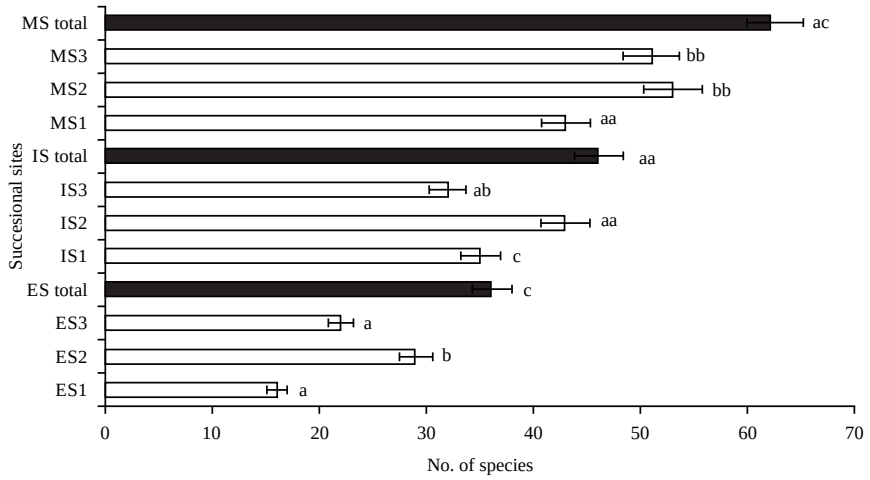


Fig. 1: The number of woody plant species observed at nine successional sites (open bars) and three successional stages (shaded bars)

Different letters show significant differences in the number of woody plant species among the nine sites ($p<0.05$)

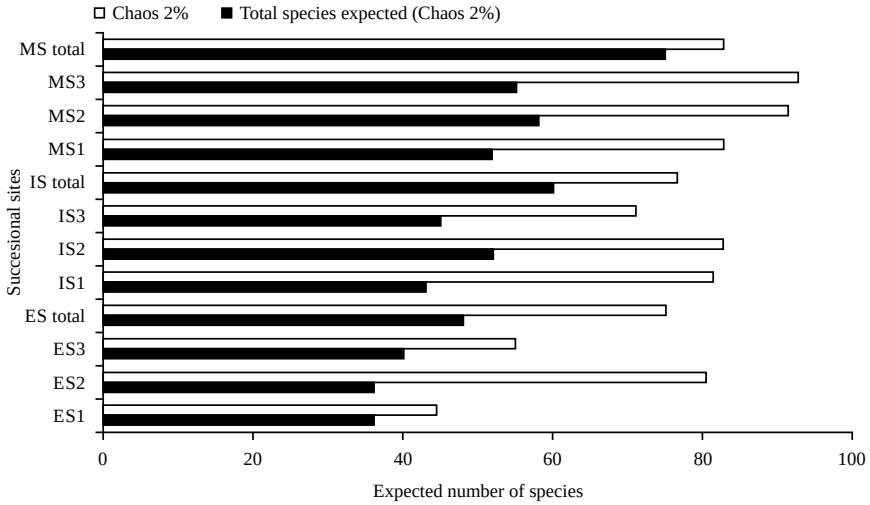


Fig. 2: Expected number of woody plants for nine sites and three successional stages

number of woody plant species from both ES1 and ES3. In the case of IS succession, there were significant differences in the number of woody plant species among the sites of IS1, IS2 and IS3. However, no significant difference was attained between IS2 sites and the total number of all species in IS stages (Fig. 1). Comparison within sites of MS succession showed that no significant variation was observed between MS2 and MS3 sites while MS1 was significantly different from MS2 and MS3 sites. The overall comparison of the number of woody plant species among the successional stages showed that there is a significant difference in the number of woody plant species (Fig. 1).

With respect to the expected number of Woody plants for the three successional stage forests about 75, 76.7 and 82.67% of the species were found in ES, IS and MS stages forests respectively according to the analysis of Chaos2 estimator (Fig. 2). Analysis of Chaos2 also showed that the expected number of species for each site ranged from 44.4% for ES1 sites to 92.73 for MS3 forest sites. In general, is can be seen from this study that about 78.11% of the expected species were found in each of the successional sites indicating that the observed and expected number of woody plant species were closer to each other which is in line with other similar study reported from northern Chiloé Island[17].

The variation in the number of species richness among the sites recorded in this study is related to the anthropogenic factors. The existence of variation in the number of woody species as a result of anthropogenic impacts within the

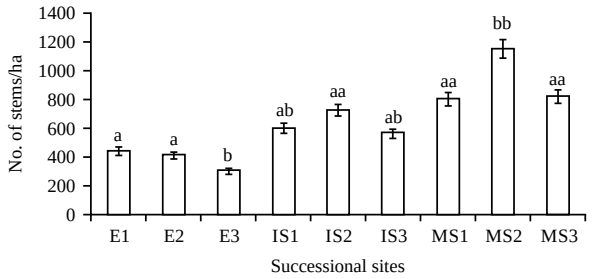


Fig. 3: The density of woody plant species at the nine successional sites

NB: Different letters show significant differences in the density of woody plant species (p<0.05)

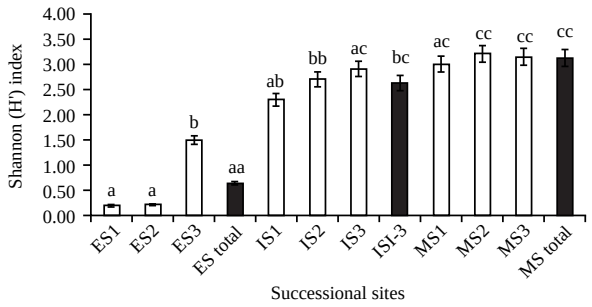


Fig. 4: Shannon index of woody species at nine successional sites (open bars) and three successional stages (shaded bars)

Afromontane forests of Ethiopia was reported by different scholars[18,19,20]. The low number of plant species in ES stage forests could also be related to the limited dispersal and migration of plant species associated for the south-east Afromontane forests[16]. Besides this, the presence of a lower number of species with higher potential to inhabit sites under stress situations could also be the other reason for the lower number of woody plant species in ES stage forests[21].

In this study, there is a linear increment of the number of woody plant species from ES to MS stage forests (p<0.05). The MS stage forests were found to include all the woody plant species from ES and IS stage forests. The result of this study is again in line with Aravena *et al.*[17] but disagrees with the hypothesis explaining that a decrease in woody plant species richness in MS stage forests following an increase in species richness through IS stage forests[22,23,24].

**The density of woody plants in succession sites:** In terms of the density of woody plants, sites of ES were found to have the lowest density ranging from 302 in ES3 to 439 in ES1 while the highest density was recorded in MS sites that ranged from 799 in MS1 to 1148 in MS2 sites (Fig. 3) followed by IS sites. The total density from all ES stages was less than the total number of woody plants/ha recorded in only MS2 sites. A comparison of the total number of woody plants/ha from MS sites was twice more than the total number of woody plants/ha recorded in ES sites. It had been observed from this study that there was a significant difference in the density of woody plants among the three successional stages (p<0.05). There was a significant increment in the density of woody plants from ES succession to MS succession.

Comparison of density between sites and successional stages with unbalanced two-way ANOVA also showed that the IS and MS stages forests were found to have a higher number of individuals/ha than the ES stage forests (Fig. 3) (p<0.05). With regard to comparison within sites from similar successional stage forests showed that no significant difference was observed in the number of individuals/ha between most sites (ES1 vs. ES2, IS1 vs. IS3, MS1 vs. MS) from ES, IS and MS stages forests respectively. Similarly, analysis for the existence of variation in density of woody plants for forest sites from different successional stage showed no significant difference among IS2, MS1 and MS3 forest sites (Fig. 3).

The higher number of individuals /ha in the MS forests in this study was due to the fact that the MS forests were situated an altitudinal range far away from contact by the local community. The presence of a large number of individuals /ha in the MS stage forests due to its lower anthropogenic impacts was also reported elsewhere[21, 25] for other similar studies. The number of individuals/ha recorded in each successional stage in this study was higher than similar studies reported from other dry tropical montane forests[25] but lower than the number of individuals/ha of plant species recorded for Oda Forest at Humbo[26].

The higher density of woody plant species in this study in MS stage forests disagrees with the findings of Rogers *et al.*[27] where he found a higher density of woody plant species in the ES stage forest but it is in line with similar studies reported from Chile[17]. An asymptotical increment in the density of large-sized individuals with an increase in maturity of the forest has been reported from south-eastern Brazilian forest[28].

**Shannon index of diversity:** The variation in diversity indices among the nine successional sites shows the status of the forest under different levels of disturbance. The Shannon index of diversity for the nine sites showed that highest value was recorded for MS2 sites (3.21) followed by MS3 (3.15) and MS1 (3.01) sites while sites from ES stage forests were found to have the lowest values ranging from 0.201 for ES1 sites to 1.5 for ES3 sites (Fig. 4). The lowest and highest Shannon indices for IS sites were found to be 2.3 and 2.9, respectively. The

overall Shannon diversity indices for the nine sites ranged between 0.20 and 3.21 with the lowest and highest indices being observed from ES1 and MS2 sites respectively. The overall mean of the Shannon index of diversity for successional stages showed that 0.64, 2.64 and 3.12 for ES, IS and MS stage forest respectively while the overall mean value for the three successional stages at the study site was found to be 2.13. This makes Quinn-Sororo to be among forest ecosystems belonging to medium to high diversity in terms of its species diversity according to Barbour *et al.*[29].

The study showed that a general increase in Shannon index of diversity from ES to MS stage forests supporting the finding of the study from Chile[17] where he found an increase in diversity of woody plant species consistent with the maturity of successional stages.

**Different letters indicate significant differences in the Shannon index of diversity (p<0.05):** The occurrence of the low values of the Shannon diversity index in ES sites due to the dominance of few early successional species was also reported from southern Malawi[30]. The variations in the values of the Shannon index of diversity among the sites also related to the differences in the degree of disturbances as reported from other Afromontane forests of Ethiopia[16]. The differences in the Shannon index of diversity could also be due to the presence of possible physiological variation among the different succession sites[17]. The higher Shannon diversity of the MS sites as compared with the other sites in this study related to the less anthropogenic impact as this site is farther away from local villages.

**Species evenness:** The evenness values (E) showed a similar trend with that of the Shannon index of diversity in which there was a trend of rise in evenness values from ES stage forests to the MS stage forests (Fig. 5) Evenness values varied between 0.065- 0.71. The least uniform composition of woody species with an evenness value of 0.065 was calculated for ES2 sites of ES stage forests where the number of woody species was also lowest. The highest evenness value of 0.71 was recorded for MS2 sites followed by MS3 and MS1 sites respectively. Sites of IS were found to have a mean evenness of value 0.497. The overall mean evenness value for all sites was 0.347. This means that the relative homogeneity of the woody plant species for all sites in the study was 34.7% of the maximum possible even population.

No significant variation in evenness values was recorded between sites of E1 and E2 from ES stage forests. Similarly, sites of IS2 and IS3 from IS stage forests had no significant

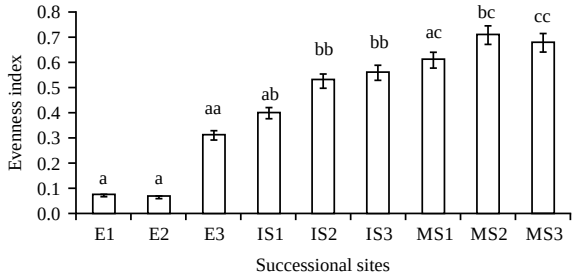


Fig. 5: Evenness values of woody species for nine successional sites

NB: Bars with different letters indicate significant differences in Evenness index (p<0.05)

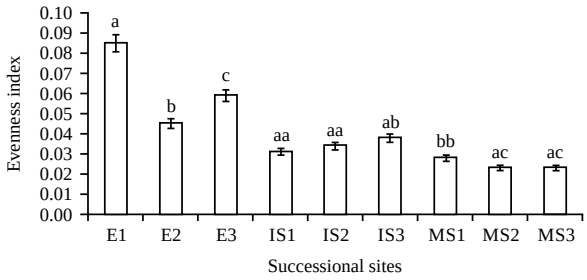


Fig. 6: Simpson index of woody plants species at nine successional sites

NB: Bars with different letters indicate significant differences in Simpson index (P<0.05)

differences in their evenness values while all the sites from MS stage forests were found to be significantly different from each other. Comparison of evenness values among sites from different successional stage forests showed the existence of significant variation in their evenness values. The variations are mainly as a result of the local factors[31,32]. In this study, the low evenness values in the ES sites are as a result of local agricultural land expansion dominated by *Chata edulis* shrubs. The influence of the dominance of few species on the evenness values has been reported elsewhere from Ethiopia[16].

**Simpson index of diversity:** With regard to the Simpson (D) index of diversity, the values ranged from 0.023 to 0.085 (Fig. 6). Sites of ES1 had the highest Simpson index of 0.085 while the sites of MS2 and MS3 were both with the least Simpson diversity index of 0.023. The Sites of MS were richer in plant species than all other sites. The overall mean Simpson diversity index of diversity for the three successional sites in the forest was found to be 0.040.

There was significant variation among the three sites from ES stage forests. With regard to IS stage forests, no significant

difference was observed between IS1 and IS2 while the sites of IS3 were significantly different from both IS1 and IS2. Comparison of sites from MS succession showed that MS1 sites were significantly different from both MS2 and MS3 while MS2 and MS3 had no significant difference in their Simpson index of diversity.

The occurrence of variations in Simpson index values between sites is attributed to the differences in the history of disturbance impacts of the sites[25]. The high variation in the Simpson index observed between ES and MS succession may be a result of fragmentation as well as the difference in intensity and type of disturbance between the two succession stage forests.

## CONCLUSION

The overall comparison of the number of woody plant species among the successional stages showed that there is a significant difference in the number of woody plant species. The existence of variation in the number of woody species is related to anthropogenic disturbances at the sites. There was a significant increment in the density of woody plants from ES succession to MS succession. The variation in diversity indices among the nine successional sites shows the status of the forest under different levels of disturbance. Maintenance of the different successional plant species must be applied through the formulation of strategies and conservation priorities for the sustainable increment of plant species richness and diversity.

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## SIGNIFICANCE STATEMENT

This study discovered the impact of disturbance on forest lands at different times on woody plants diversity and richness that can be beneficial for planning the conservation strategies for sustainable management of forest resources as: this study will help the researchers to uncover the critical areas of forest stands under various stage of succession that many researchers were not able to explore.

## REFERENCES

1. Prach, K. and L.R. Walker, 2011. Four opportunities for studies of ecological succession. Trends Ecol. Evol., 26: 119-123.
2. Connell, J.H. and R.O. Slatyer, 1977. Mechanisms of succession in natural communities and their role in community stability and organization Am. Nat., 111: 1119-1144.
3. Tansley, A.G., 1935. 1935: The use and abuse of vegetational concepts and terms. Ecol., 31: 284-307.
4. Connell, J.H., 1978. Diversity in tropical rain forests and coral reefs. Sci., 199: 1302-1310.
5. Collins, S.L., S.M. Glenn and D.J. Gibson, 1995. Experimental analysis of intermediate disturbance and initial floristic composition: Decoupling cause and effect. Ecology, 76: 486-492.
6. Kammesheidt, L., 2004. The role of tree sprouts in the restoration of stand structure and species diversity in tropical moist forest after slash-and-burn agriculture in Eastern Paraguay. Plant Ecol., 139: 155-165.
7. Girma, Z., G. Chuyong, P. Evangelista and Y. Mamo, 2018. Vascular plant species composition, relative abundance, distribution and threats in arsi mountains national park, Ethiopia. Mountain Res. Dev., 38: 143-152.
8. Mewded, B., M. Negash and T. Awas, 2019. Woody species composition, structure and environmental determinants in a moist evergreen Afromontane forest, southern Ethiopia. J. For. Res., 10.1007/s11676-019-00894-0
9. Mohammed, A., P.A.L. Le Roux, C.H. Barker and G. Heluf, 2005. Soils of Jelo micro-catchment in the chercher highlands of eastern Ethiopia: I Morphological and physicochemical properties. Ethiop. J. Nat. Resour., 7: 55-81.
10. Murphy, H.F., 1968. A Report on the Fertility Status and Other Data on Some Soils of Ethiopia. Experiment Station bulletin, Addis Ababa, pp: 100-255.
11. Almazán-Núñe R.C., M. Del C. Arizmendi, L.E. Eguiarte and P. Corcuera, 2012. Changes in composition, diversity and structure of woody plants in successional stages of tropical dry forest in southwest Mexico. Revista Mexicana De Biodiversidad, 83: 1096-1109.
12. Colwell, R.K. and J.A. Coddington, 1994. Estimating terrestrial biodiversity through extrapolation. Philos. Trans. R. Soc. London, 345: 101-118.
13. Colwell, R.K. and J.E. Elsensohn, 2014. EstimateS turns 20: statistical estimation of species richness and shared species from samples, with non-parametric extrapolation. Ecography, 37: 609-613.
14. Magurran, A.E. 1988. Ecological Diversity and its Measurements. Princeton University Press, Princeton, New Jersey, Pages: 179.
15. Yirga, F., M. Marie, S. Kassa and M. Haile, 2019. Impact of altitude and anthropogenic disturbance on plant species composition, diversity and structure at the Wof-Washa highlands of Ethiopia. Heliyon, 10.1016/j.heliyon.2019.e02284

16. Atinafe, E., E. Assefa, B. Belay, Y. Endale and T. Seta, 2020. Floristic diversity and natural regeneration status of entoto mountain and the surrounding area in Addis Ababa, Ethiopia Int. J. For. Res., 10.1155/2020/4936193
17. Aravena, J.C., M.R. Carmona, C.A. Pérez and J.J. Armesto, 2002. Changes in tree species richness, stand structure and soil properties in a successional chronosequence in northern Chiloé Island, Chile. Rev. Chil. Hist. Nat., 75: 339-360.
18. Berhanu, A., S. Demissew, Z. Woldu and M. Didita, 2017. Woody species composition and structure of Kuandisha afromontane forest fragment in northwestern Ethiopia. J. For. Res., 28: 343-355.
19. Bekele, T., 1994. Studies on remnant Afromontane forests on the central plateau of Shewa, Ethiopia. Acta Phytogeogr. Suec., 79: 1-58.
20. Admassu, A., S. Teshome, K. Ensermu, D. Abyot and K. Alemayhu, 2016. Floristic composition and plant community types of Agama Forest, an Afromontane Forest in Southwest Ethiopia. J. Ecol. Nat. Environ., 8: 55-69.
21. Álvarez-Yépiz, J.C., A. Martinez-Yrizar, A. Burquez and C. Lindquist, 2008. Variation in vegetation structure and soil properties related to land use history of old-growth and secondary tropical dry forests in northwestern Mexico. For. Ecol. Manage., 256: 355-366.
22. Grime, J.P., 1979. Plant Strategies and Vegetation Processes. 1st Edn., Wiley, Chichester, UK.
23. Tilman, 1982. Resource Competition and Community Structure. Monographs in population biology. Princeton University Press, Princeton, New Jersey, USA.
24. Huston, M.A., 1994. Biological Diversity: The Coexistence of Species on Changing Landscapes. Cambridge University Press, Cambridge, UK.
25. Denslow, J.S., 1980. Patterns of plant species diversity during succession under different disturbance regimes. Oecologia, 46: 18-21.
26. Kuma, M. and S. Shibru, 2015. Floristic composition, vegetation structure and regeneration status of woody plant species of oda forest of humbo carbon project, Wolaita, Ethiopia. J. Bot. 10.1155/2015/963816
27. Rogers, P.C., B. O'Connell, J. Mwang'ombe, S. Madoffe and G. Hertel, 2008. Forest health monitoring in the Ngangao forest, Taita hills, Kenya: a five year assessment of change. J. East Afr. Nat. Hist., 97: 3-17.
28. Madeira, B.G., M.M. Espírito-Santo, S.D. Neto, Y.R.F. Nunes, G.A. Sánchez-Azofeita, G. Wilson and M. Quesada. 2009. Changes in tree and liana communities along a successional gradient in a tropical dry forest in south-eastern Brazil. Plant Ecol., 201: 291-304.
29. Barbour M.D., J.H. Burk and W.D. Pitts, 1987. Terrestrial Plant Ecology. 2nd Edn., Benjamin Cummings Inc., Menlo Park, CA, Pages: 634.
30. Bone, R., M. Lawrence and Z Magombo, 1997. The effect of a *Eucalyptus camaldulensis* (Dehn) plantation on native woodland recovery on Ulumba Mountain, southern Malawi. For. Ecol. Manag., 99: 83-99.
31. Dorji, T., S.R. Moe, J.A. Klein and Ø. Totland, 2014. Plant species richness, evenness and composition along environmental gradients in an alpine meadow grazing ecosystem in central Tibet, China. Arctic, Antarctic, Alpine Res., 46: 308-326.
32. Maestre, F.T., 2004. On the importance of patch attributes, environmental factors and past human impacts as determinants of perennial plant species richness and diversity in Mediterranean semiarid steppes. Diversity Distrib., 10: 21-29.