Floristic, Structure, and Regeneration of Woody Species in Bola Wanche Forest of Humbo Carbon Project, Wolaita, Ethiopia

Markos Kuma[1]* & Simon Shibru[2]
[1]Department of Biology, Wolaita Sodo University, Ethiopia, P.O., Woliata Sodo, Ethiopia
[2]Department of Biology, Arba Minch University, Ethiopia; P. O. Arba Minch, Ethiopia
*Corresponding Author: **Markos Kuma**

Abstract
Our present study was carried out to investigate regeneration status and dynamics of populations of woody species in Bola Wanche forest of Humbo Carbon Project Woliata zone, Ethiopia. Thirty two (20m x 20m) plots were laid at an interval of 100m to collect vegetation data. In each plot, five 1m² quadrats were laid to assess regeneration status. DBH (Diameter at Breast Height) of each woody species with DBH ≥2.5cm was measured. Altitude, aspect and slope of each plot were recorded. Among 61 woody species representing 56 genera and 35 families, Syzygium guineense and Dodonaea angustifolia were the most dominant. There was significant difference in the dominance (p < 0.0001) of species between plots. Inverted J-shape and bell-shape population distribution patterns were recognized. The regeneration phase was dominated by D. angustifolia. Only 36% of the species in matured vegetation was represented in seedling phase. Environmental factors considered in this study were not influenced abundance of species and individuals between plots. But when dominant species evaluated separately, altitude had significant influence on abundance of S. guineense and Combretum molle while aspect on C. molle and Terminalia schimperiana. But no factor had influenced abundance of D. angustifolia. The study revealed abundance and dominance of few families and species, prevalence of small size populations and fair regeneration of forest. This may indicate that the forest is in its early secondary successional stage.

Keywords: *Floristics, Bola Wanche Forest, Humbo Carbon Project, Regeneration, Structure*

Introduction

Forests play a significant role in the global carbon cycle absorbing significant proportion of anthropogenic emissions of CO_2. Besides, they provide many important ecosystem services such as watersheds protection and habitats provision for a number of animals (Nune *et al*., 2010; SCBD, 2001). They are also sources of food, household energy, construction and agricultural material, and medicines for both people and livestock (Kuma and Shibru, 2015; Vivero *et al*., 2005; Bekele, 1994). However, human activities, primarily tropic deforestation have been known source of carbon emission to the atmosphere. Clearance of natural vegetation to meet the demands of an ever increasing human population has been an ongoing process in Ethiopia (Tesfaye *et al*., 2013; Hundera *et al*., 2007; Senbeta *et al*., 2007; Shibru & Balcha, 2004; Senbeta & Teketay, 2003). Besides, the increasing livestock population resulted in overgrazing, and demand for fire wood and charcoal resulted in exploitation of existing forests (Tesfaye *et al*., 2013; Soromessa *et al*., 2004; Senbeta and Teketay, 2003). The forest resources of the Humbo Carbon Project have also experienced the same problem (Kuma and Shibru, 2015; Deshmukh, *et al*., 2013; Gurmu, 2006). Ecological and environmental problems such as soil degradation, soil erosion and alteration of natural resources are some of the negative effects resulting from the destruction of forests (Hundera *et al*., 2007; Bekele, 2000). Furthermore, biodiversity resources along with their habitats are rapidly disappearing in the country (Woldemariam & Teketay, 2001; Woldemariam, 2003; Senbeta & Denich, 2006). Loss of such forest resources would have great implication for the environment, biological diversity and socio-economic setup of the communities (Kuma and Shibru, 2015). However, recovery of forest vegetation in drier areas of central rift valley system of Ethiopia is likely if appropriate land use systems and participatory area closure approach are applied (Deshmukh *et al*., 2013; Kaboré, 2013; Shibru & Woldu, 2006).

As the world mobilizes to address the issue of climate change, proper forest management is an alternative option to increase sequestration of carbon in the biosphere. This has increased the demand for detailed knowledge of forest functioning and adequate information about the status of the forests. Hence, developing better understanding on composition, structure, and regeneration of certain forest habitat is essential to maximize the role of forests in carbon cycle, sequestration and storage (Kuma and Shibru, 2015). Information on population structure of a tree species for example, indicates the disturbance history in the environment and its consequence on species. This information in turn can be used to forecast the future trend of the population of species (Peters, 1996). Besides, study on regeneration status of woody plants is not only important to give information on reproductive role but also for ensuring the replacement of any member of a community that dies off after completing life cycle (Fatubarin, 1987; Saxena *et al.,* 1984). To sustain regeneration, the presence of sufficient population of seedlings, saplings and young trees are crucial and indicate a successful regeneration status of forest species (Shibru & Balcha, 2004; Saxena *et al.,* 1984). The information obtained through demographic studies could also be used in restoration of degraded lands (Bekele, 2000).

Since availability of adequate and accurate data on floristics, structural and regeneration of forest is considered to be an essential requirement for forest management (FAO, 2007) and for restoration of degraded lands (Bekele, 2000), this study intended to investigate floristics, structure, and regeneration of woody species in Bola Wanche forest, which is one of the four carbon trading project in East Africa (Deshmukh *et al*., 2013). The project aims at rehabilitating a formerly forested area that had been degraded due to human activities. It is the first of its kind in Ethiopia and is Africa's first large-scale carbon trading forestry project developed under the Kyoto Protocol's Clean Development Mechanism registered under the United Nation Framework Convention on Climate Change (Deshmukh *et al*., 2013; Kaboré, 2013). It is also the first in Africa to generate temporary Certified Emission Reductions, the Kyoto- compliant asset from land use activities, setting an example for similar projects to be scaled up across Africa (Kaboré, 2013).

Materials

Study Site

This study was conducted in Bola Wanche Carbon Project forest. It is located at about 405 km South of Addis Ababa in Bola Wanche kebele of Humbo, Wolaita, SNNPR, Ethiopia (6^0 46' & 6^0 45'N; 37^0 49' & 37^0 50'E) (Fig. 1). With a size of 2728 ha, the area is characterized by a chain of mountains that run from SE to NW mix with small hills, valleys and a rocky ridge (Gurmu, 2006). Its altitude ranges from 1700 to 1800 masl. Nitosol/Vertisol gradient characterizes the soil underlining with Precambrian basement rocks in the plains and calcareous soils at the hill (Gurmu, 2006). Its mean annual rainfall varies from 700-1000 mm (Deshmukh *et al*., 2013, Gurmu, 2006). Before the establishment of Humbo Assisted Natural Resource Project (Carbon trading), the site was described as largely denuded of vegetation where the main activity was digging up remaining tree stumps for charcoal-making. Grazing was also practiced, though forage was low. The area was "closed" to non Humbo Assisted Natural Resources Project use at the end of 2006 (Deshmukh *et al*., 2013; Kaboré, 2013).

Figure 1: Map of study area relative location in the country, region, zone and district, respectively <(Source: Kuma and Shibru, 2015). >>

Data collection

A total of 32 plots of 20 m × 20 m were laid to assess shrubs and trees. In each plot, five 1 m^2 quadrats spread over corners and at the center were established to assess regeneration status. The interval between the main plots was 100 m and transect were thrown based on the aspect of the Mountain. Individuals having DBH < 2.5 cm and height ≤ 0.6 m were counted as seedling whereas individuals with 2.5 cm ≤ DBH ≤ 15 cm and 0.6 ≤ ht ≤3 m were counted as sapling (Kuma and Shibru, 2015). The

DBH was measured at 0.3 m from the ground. Altitude, slope and aspect were measured for each plot using GPS and clinometers.

Data exploration and Analyses

Data were checked for outliers, homogeneity of variances, normality, zero inflation and colinearity as suggested in Zuur *et al*. (2010) and Kindt & Coe (2005).We noticed that the dataset in general violated these assumptions but with no problem of collinearity. We used Shapiro-Wilk test to check for normality and Fligner-Killeen test to explore the homogeneity of variances. The proportion of zero in the dataset was 65.2%. Generalized Linear Models (GLMs) were used to see the effect of environmental factors on the abundance of species and individuals in the study plots. We used Poisson link to evaluate the effect of environmental factors on total abundance of species and individuals whereas quasiPoisson link was used to see the effect on the abundance of dominant species as advised in Zuur *et al*. (2010) and Kindt & Coe (2005). The structural parameters were described adopting the formula from Kuma and Shibru (2015)

Structural characteristics (stem density, basal area & DBH class distributions) were calculated for all individuals. Population structure was analyzed using grouped DBH classes. All individuals of each species encountered were grouped into four arbitrary diameter classes. Then, bar graph were developed using the DBH class versus the density of individuals. Regeneration status of the forest was analyzed by comparing saplings and seedlings with the matured trees according to Dhaulkhandi *et al.* (2008) and Tiwari *et al.* (2010). That is, the forest is at good regeneration status, if seedlings > saplings > adults; the forest is at fair regeneration status, if seedlings > or ≤ saplings ≤ adults; the forest is at poor regeneration status, if the species survives only in sapling stage (saplings may be ≤ or ≥ adults); and if a species is present only in an adult form it is considered as not regenerating. R programs (R core Team, 2015) and XLSTAT version 2015.2.01 were used for data analyses.

Results

Species composition

A total of 61 woody species representing 55 genera and 35 families were recorded in the forest. *Syzygium guineense* and *Dodonaea angustifolia* were the most abundant species as they represented 35.6% of the species in the matured vegetation. On the other hand, 75% of seedling and 38.4% of saplings were covered by *D. angustifolia.* Some species were rarely represented in the forest with the importance value of less than 1%. A total of 21 species representing 33.3% were classified under this group. Species like *Rhamnus prinoides*, *Ficus sur*, *Teclea nobilis*, *Ozoroa pulcherrima*, *Podocarpus falcatus*, *Ficus ingens*, *Piliostigma thonningii* and *Ziziphus mauritiana* belonged to this group. Fabaceae (9 species), Oleaceae (4 species), Celastraceae, Combretaceae and Euphorbiaceae (3 species each) were species-rich families. Out of the total number of families, 57.1% were represented by single species. Some of the families included under this category were Asteraceae, Araliaceae, Bignoniaceae, Myrsinaceae and Podocarpaceae. Nine families (25.7%) were represented by two species each, and 3 (8.5%) were represented by three species each. In terms of growth habit a cumulative percentage of 93.4 were shrubs and trees, whereas lianas and succulent constituted only 6.5%. List of species with their structural measurements including standard error (SE) are presented in Table 1.

Vegetation Structure

The total density of woody species in the Bola Wanche forest was 1412.4 ± 5.22 SE stems ha^{-1}. *D. angustifolia* had the highest density (142.2 ± 0.49 SE stems ha^{-1}) followed by *S. guineense (*119.5 ± 0.7 SE ha^{-1}) *Terminalia Schimperi, Euclea scimperiana* and *Combretum molle* with a density of 89.8, 87.5 and 82 individuals ha^{-1}, respectively. On the other hand, species like *Podocarpus falcatus*, *Ficus sur*, *Bersama abyssinica, Piliostigma thonningii*, *Polyscias fulva*, *Gardenia ternifolia*, *Maesa lanceolata* and *Ziziphus mauritiana* had a density of less than five individuals per ha^{-1}. There was strong significant difference in density between species in the study areas ($p < 0.0001$). The most frequent woody species was *Allophylus abyssinicus* (96.9%) followed by *D. angustifolia* (93.8%) and *Combretum molle* (81.3%). On the other hand, the least frequent species were *Ozoroa pulcherrima, Ziziphus mauritiana, Capparis fascicularis, Ocimum gratissmum* and *Lippia adoensis* (3.1%) each. The generalized linear model showed that environmental factors considered in this study were not influenced abundance of species and individuals between plots. But when dominant species evaluated separately, we found that altitude had strong influence on abundance of *S. guineense*&*Combretum molle* and, aspect had significant effect on the abundance of *C. molle* and *Terminalia schimperiana*. No factor was influential on the abundance of the most abundant species i.e. *D. angustifolia*.

The total mean dominance was 2047.6 ± 916.3 SE. The most dominate species in the forest in terms of basal area was *S. guineense* (28.1%) followed by *D. angustifolia* (10%) and *C. molle* (9.8%) contributing to 47.9%. There was significant difference in the dominance ($p < 0.0001$) of species between plots. Species with the highest IVI were *S. guineense* (45.1%), *D. angustifolia* (42.4%), *C. molle* (18.9%), *T. schimperiana* (17.4%) and *Euclea schimperi* (14.1%).

Population structure of the forest and selected woody species

The distribution of species density by the DBH classes showed an inverted J-shaped pattern (Fig. 2) for the entire study area. The number of individuals in DBH class >15 cm is almost nil and represented only by *Garcinia buchananii*. From the selected woody species, *S. guineense*, *Acokanthera schimperi, C. molle* and *T. schimperiana* formed a bell shaped structure where number of individuals in the middle diameter classes was higher than the lower and higher diameter classes. *D. angustifolia* and *E. schimperi* represented by inverted J-shape pattern. It showed a pattern where species frequency distribution has the highest in the lower diameter classes and a gradual decrease towards the higher classes. All of the selected species revealed absence of individuals in DBH class >15 cm. Besides, there were no individuals in DBH class 10.1-15 cm of *D. angustifolia, Acokanthera schimperi* and *E. schimperi* but the rest of selected species had very few numbers of individual in this DBH class (Fig. 3). Most of the selected woody species of the forest indicated that the presence of disturbance in lower (DBH class <5 cm) and higher (DBH class >15 cm) classes. But, these DBH classes were the most hampered classes due to anthropogenic activities like charcoal production, fuelwood collection, cutting of trees for construction of houses and fences occurred in previous periods. This unsustainable and unwise use of forest for different purposes is related with lack of awareness, knowledge and intervention of government in conservation and management of forest resources in those periods. The disturbance in upper DBH class (matured trees) decreases seeds in the seed bank, habitat for different wild animals, soil fertility, water shade protection, climate stability and carbon sequestration. As the result, the functioning of the ecosystem may disrupt and in turn it may leads to harming of life on the earth.

<<Figure 2: Population structure of Bola Wanche forest for pooled species data>>

<<Figure 3: Population structure of selected woody species in Bola Wanche forest>>

Regeneration status

In general, the regeneration phase of the study area was represented by 22 and 52 species of seedling and sapling, respectively. Of the total species recorded in the matured stand, 41 had no representation in the seedling stage and 11 had no representation in the sapling stage. On the other hand, four species were encountered in the regeneration phase, which were absent in the matured stand. The abundant species in the regeneration phase was *D. angustifolia* accounting for 75% of the seedling and 38.4% of the sapling. All the rest species were accounted for 25% of the seedling and 61.6% of the sapling. The number of individuals in seedling, sapling and the matured stage accounted 7.3%, 34.8% and 57.9%, respectively of the species composition of the forest.

Discussion

Forest and woodland resources in Ethiopia, like any other developing countries, provide socio-economic and ecological services such as fuelwood, fodder, timber and non-timber products, traditional medicine, wildlife habitats, watershed regulations, soil protection, and carbon sequestration and storage, both at local and global scales. These provisions are important to support livelihoods of the local communities in particular and that of the Nation in general. Therefore, their sustainable conservation and management is crucial (Kuma and Shibru, 2015; Neelo, *et al*., 2013). Bola Wanche forest (Deshmukh *et al*., 2013; Kaboré, 2013; Biryahwaho *et al*., 2012) and Oda forest (Kuma and Shibru, 2015; Deshmukh *et al*., 2013; Kaboré, 2013; Biryahwaho *et al*., 2012) under Humbo Assisted Natural Resource Project is a live example where these have been recently proven. Although the Bola Wanche forest in the past had been degraded due to tree cutting, charcoal production and livestock grazing, now the area is restoring because of appropriate participatory interventions. Following the inclusion of the forest in the Humbo Assisted Natural Resource Project, efforts have been made to foster natural regeneration as is also true in Oda forest in the same project (Kuma and Shibru, 2015). Our study witnessed that progressive changes were recorded in terms of composition, structure and regeneration of woody species in support of the results of Kuma and Shibru (2015) in Oda forest. Pohjonen (1989) stated that succession of bushy vegetation of pioneer species like *Dodonaea* and *Acacia* may lead to mature Afromontane forests. The abundance of *D. angustifolia* in both matured and regeneration stages showed that the forest of Bola Wanche was in its early successional stage, a result which is consistent with previous report elsewhere (e.g. Bekele, 2000). This is also true for Oda forest (Kuma and Shibru, 2015).

S. guineense followed by *D. angustifolia* and *C. molle* were the most abundant specie in terms of basal area, contributing to 47.9%. These species also had the highest IVI values. This indicated the highest dominance was contributed only by three species. The species with the largest contribution in basal area and IVI value can be considered ecologically important woody species in the forest (Fatubarin, 1987).

The population structure for the pooled data showed an Inverted J-shaped pattern. Generally, the number of stems with big DBH classes was very low or absent. This shows that the status of the small size class is not large enough to attain more stable population dynamics. However, vegetation type and protection time were found to have a significant effect on the population structure (Saxena *et al*., 1984). Species–wise, two population patterns were observed in the forest. One of them was an inverted J-shaped distribution. This is a general pattern of regular population structure where the majority of the species had the highest number of individuals at lower DBH classes with gradual reduction toward high DBH classes. This suggests good reproduction and healthy recruitment potential of woody species. *D. angustifolia* was one of the species which showed this pattern in our study area.

Similar results were reported by Kuma and Shibru (2015), Shibru & Balcha (2004), Bekele (2000), and Bekele (1994).

The second type was a Gauss-type (bell-shaped) distribution pattern, with the first and second DBH classes having a low number of individuals, a gradual increase in the number of individuals towards the medium classes, and subsequent decrease in number towards the higher DBH classes. Examples of the species which showed this type of distribution were *Syzygium guineense*, *Combretum molle*, *Acokanthera schimperi* and *T. schimperiana.* Various studies (e.g. Kuma and Shibru, 2015; Senbeta *et al.* 2007; Shibru & Balch, 2004; Tesfaye *et al*., 2013; Bekele, 1994) reported that a bell shaped pattern indicates a poor reproduction and recruitment of species in the forest. This may be associated with either intense competition from the surrounding trees or influence of anthropogenic activity (Bekele, 2000).

D. angustifolia dominated the regeneration phase, followed by few species, especially in the seedling phase. This is also true in Oda forest (Kuma and Shibru, 2015). There was low correspondence between species composition of the seedling phase and that of the standing vegetation. Dhaulkhandi *et al.* (2008) and Tiwari *et al*. (2010) classified forest regeneration status based on the proportion of seedlings, saplings and matured tree/shrubs. According to this approach, the forest of Bola Wanche was categorized under fair regeneration status. But species wise the case might be different. For example *D. angustifolia* had good regeneration potential whereas *Syzygium* had not. This urges and encourages keeping the momentum so that the regeneration status could change progressively in the coming times for most of the species and for the forest. This is important to attain the objectives envisaged by Humbo Assisted Natural Resource Project, so that it directly contributes to the improvement of the livelihood of the local community at local scale and to the region and country at large.

Although there were positive conservation and management efforts, there are still human driven activities such as overgrazing, tree cutting, grass harvesting and fire in and around the forest. As it was observed in the field, mowing of grasses and fire decrease the seeds return into seed bank of the forest. But cutting of trees and grazing reduces production of seeds by reducing twig development. A researchers' personal communication with some local informants confirmed that some of the local community members were affecting the forest due to lack of awareness and knowledge.

Conclusion

Humbo Carbon Project is one of the four carbon trading projects in East Africa which is Africa's first large-scale carbon trading forestry project developed under the Kyoto Protocol's Clean Development Mechanism. It consisted of 61 woody species belonging to 55 genera and 35 families. *D. angustifolia* and *S. guineense* were ecologically significant species being most abundant and dominant in terms of density, basal area and IVI. Analysis of population structure of the pooled woody species showed inverted J-shape Pattern and some selected species showed Gauss-type distribution pattern. Only about 36% of the species were represented in the seedling phase, indicating lack of adequate regeneration in most of the species. But the preponderance of small size population especially the domination of the early successional stage species, *Dodonaea angustifolia* in the study area may have indicated that the forest was in its early secondary successional stage. Therefore, sustaining participatory conservation practices started by Humbo Assisted Natural Resource Project in line with Carbon trading should be encouraged. In collaboration with government and NGO, local community should take the lead in the conservation and management of the forest. Awareness creation workshops are important to maintain progressive changes observed in the study area. We recommend further investigations on socioeconomic, edaphic and herbaceous including grass vegetation of the study area. The site being under rehabilitation program could be an ideal place to study ecological succession to observe vegetation dynamics in the long term as well.

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Table 1: Floristic composition with their structural measurements (Den= density, SE = standard Error, R. Den= Relative density, R.Freq=Relative frequency, R.Dom= Relative Dominance, IVI= Importance Value Index)

Species	**Den ha^{-1}**	**SE**	**R.Den**	**R.Freq**	**R.Dom**	**IVI**
Acacia hockii De Wild.	6	0.08	0.44	1.18	0.05	1.7
Acokanthera schimperi (A.DC.) Scheweinf.	29	0.39	2.05	1.77	3.61	7.4
Albizia schimperiana Oliv.	6	0.12	0.44	0.74	0.28	1.5
Allophylus abyssinicus (Hochst.)Radlk	52	0.29	3.65	4.57	1.55	9.8
Aloe gilbertii Sebsebe & Brandham	2	0.04	0.11	0.29	0.03	0.4
Bersema abyssinica Fresen	3	0.06	0.22	0.59	0.34	1.2
Calpurnia aurea (Ait.) Benth.	32	0.3	2.27	2.65	1.6	6.6

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Capparis fascicularis DC.	2	0.06	0.11	0.15	0.01	0.3
Carissa edulis (Forssk.) Vahl	60	0.44	4.26	3.39	2.4	10.0
Clutia abyssinica Jaub. & Spach	22	0.12	1.55	3.53	0.24	5.3
Clutia lanceolata Forssk.	11	0.09	0.77	2.06	0.05	2.9
Combretum collinum Fresen.spp.Binderianum(Kotschy) Okafor	43	0.39	3.04	2.8	3.47	9.3
Combretum molle R.Br.ex G.	82	0.53	5.81	3.83	9.78	19.4
Crotalaria pallida L.	2	0.05	0.17	1.33	0.01	1.5
Croton macrostachyus Hochst. ex Delile.	16	0.25	1.11	0.44	0.89	2.4
Dichrostachys cinerea (L.) Wight & Arn.	44	0.33	3.1	3.68	1.03	7.8
Dodonaea angustifolia L.f.	142	0.49	10.07	4.42	10.01	24.5
Entada abyssinica Steud, ex A. Rich.	8	0.11	0.55	1.18	0.31	2.1
Euclea schimperi (A. DC.) Dandy	88	0.61	6.19	3.09	5.05	14.3
Fagaropsis angolensis (Engl.) Milne-Redh.	7	0.09	0.5	1.18	0.25	1.9
Ficus ingens (Miq.) Miq.	8	0.28	0.55	0.29	0.01	0.9
Ficus sur Forssk.	4	0.11	0.28	0.29	0.33	0.9
Flacourtia indica (Burm. f.) Merr.	8	0.11	0.55	1.18	0.12	1.9
Garcinia buchananii Baker	7	0.18	0.5	0.44	1.99	2.9
Gardenia ternifolia Schumach. & Thonn.	2	0.04	0.11	0.29	0.03	0.4

Gnidia glauca (Fresen.) Gilg.	4	0.07	0.28	0.74	0.01	1.0
Grewia bicolor A. Juss.	2	0.05	0.17	0.44	0.02	0.6
Grewia velutina (Forssk.) Vahl	5	0.09	0.39	0.88	0.15	1.4
Hypericum revolutum Vahl	42	0.37	2.99	3.39	0.8	7.2
Jasminum floribundum R. Br. ex Fresen	21	0.1	1.49	3.53	0.15	5.2
Lippia adoensis Hochst. ex Walp.	1	0.03	0.06	0.15	0	0.2
Maerua oblongifolia (Forssk.) A. Rich,	16	0.29	1.16	0.29	0.21	1.7
Maesa lanceolata Forssk	2	0.04	0.11	1.33	0.05	1.5
Makhamia lutea (Benth.) K.Schum.	23	0.19	1.66	2.95	0.76	5.4
Maytenus gracilipes (Welw. ex Oliv.) Exell	21	0.22	1.49	3.09	0.31	4.9
Maytenus senegalensis (Lam.) Exell.	8	0.16	0.55	0.88	0.17	1.6
Myrtus communis L.	12	0.2	0.83	1.33	0.55	2.7
Ocimum gratissmum L.	1	0.03	0.06	0.15	0	0.2
Olea capensis L.	43	0.42	3.04	2.36	3.04	8.4
Olea europaea L. ssp. Cuspidata (Wall.) ex G. Don) Cif.	33	0.35	2.32	2.65	2.34	7.3
Olinia rochetiana A. Juss.	34	0.36	2.43	2.5	1	5.9
Osyris quadripartita Decn.	5	0.07	0.33	0.88	0.02	1.2
Ozoroa pulcherrima (Schweinf.)R.&A. Fernandes	3	0.13	0.22	0.15	0.32	0.7
Piliostigma thonningii (Schumach.) Milne-Rodh.	3	0.13	0.22	0.15	0.01	0.4

Podocarpus falcatus (Thunb.)	5	0.11	0.33	0.44	0.01	0.8
Polyscias fulva (Hiern) Harms	2	0.05	0.17	0.44	2.49	3.1
Protea gaguedi J. F. Gmel.	35	0.45	2.49	1.77	1.96	6.2
Pterolobium stellatum (Forssk.) Brenan	16	0.28	1.11	1.47	0.39	3.0
Rhamnus prinoides L` Herit	6	0.19	0.44	0.44	0.16	1.1
Rhoicissus revoilii Planch.	16	0.13	1.16	2.5	0.16	3.8
Rhus natalensis Krauss	38	0.36	2.65	2.36	0.16	5.2
Rothmannia urcelliformis (Hiern) Robyns	23	0.22	1.6	2.36	0.78	4.7
Salacia congolensis De Wild. & Th. Dur.	7	0.11	0.5	1.03	0.15	1.7
Schrebera alata (Hochst.) Welw.	45	0.39	3.21	3.39	2.07	8.7
Senna petersiana(Bolle) Lock	4	0.08	0.28	0.59	0.02	0.9
Syzygium guineense (Willd.) DC.	120	0.7	8.46	3.39	28.12	40.0
Teclea nobili Del.	5	0.12	0.39	0.59	0.04	1.0
Terminalia schimperiana Hochst.	90	0.51	6.36	3.83	8.36	18.6
Uvaria schemffieri Diels	35	0.47	2.49	1.77	1.72	6.0
Vernonia filigera Oliv. & Hiern.	2	0.04	0.11	0.29	0.02	0.4
Ziziphus mauritiana Lam.	1	0.03	0.06	0.15	0.01	0.2

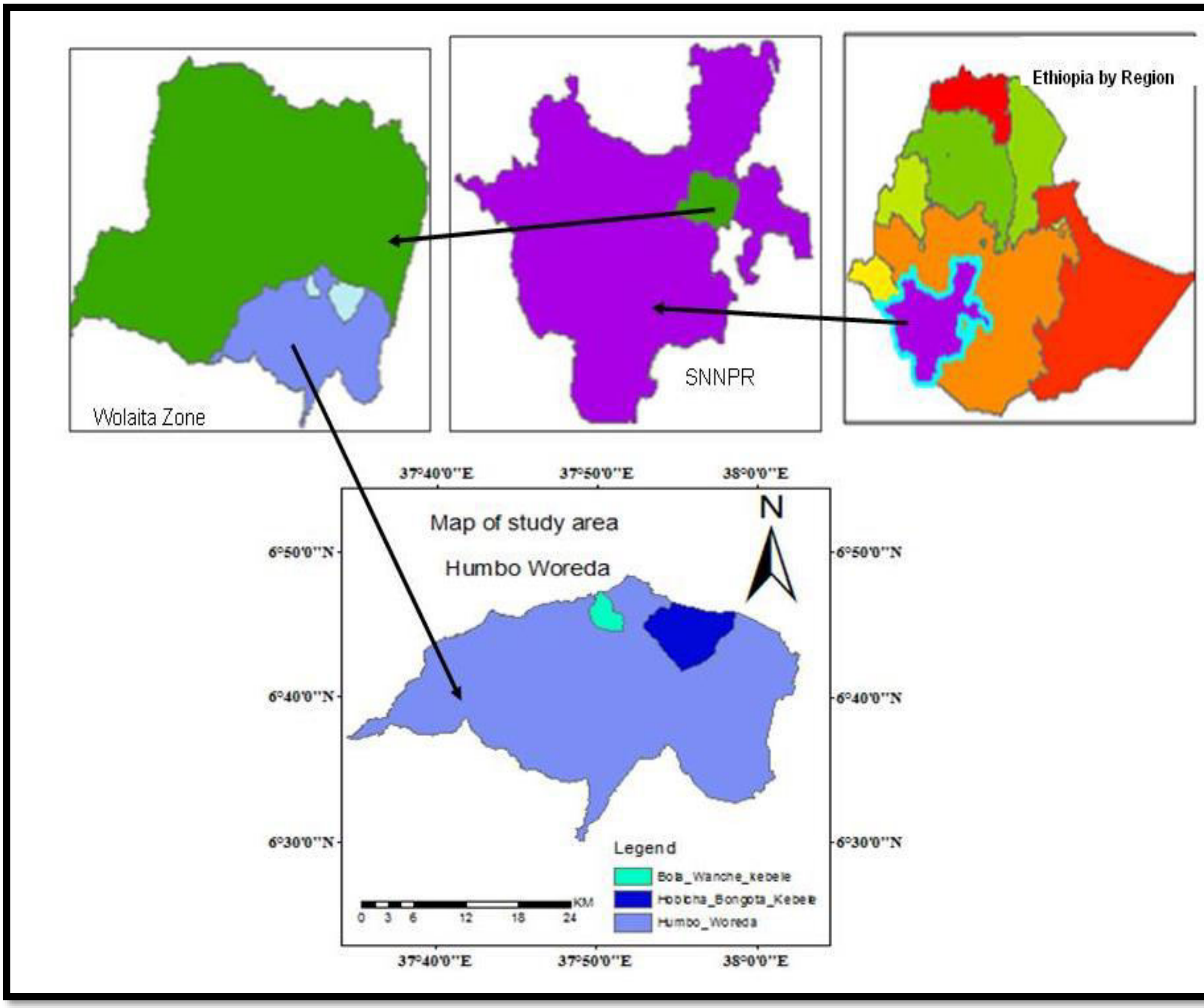

Figure 1: Map of study area relative location in the country, region, zone and district, respectively (Source: Kuma and Shibru, 2015).

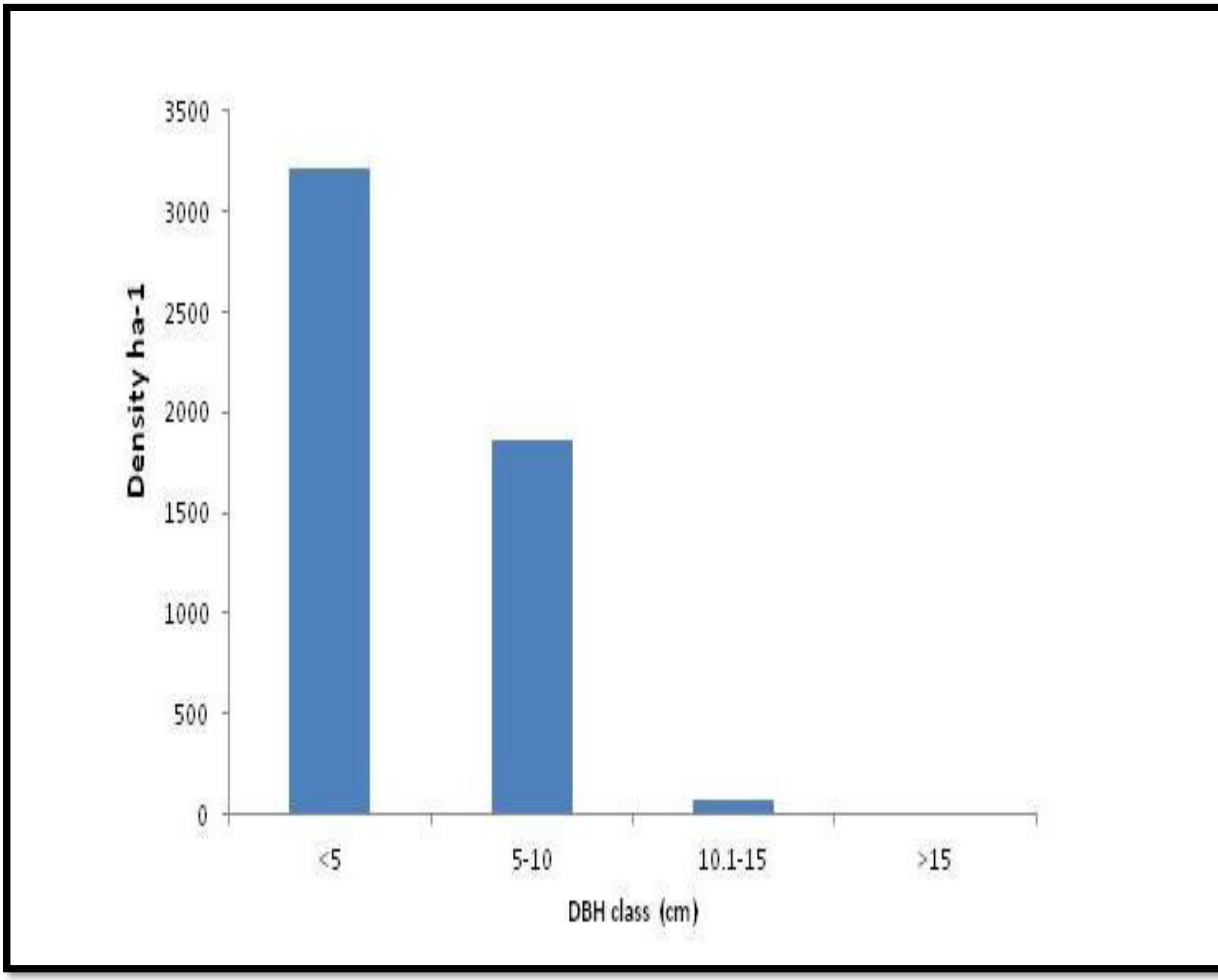

Figure 2: Population structure of Bola Wanche forest for pooled species data

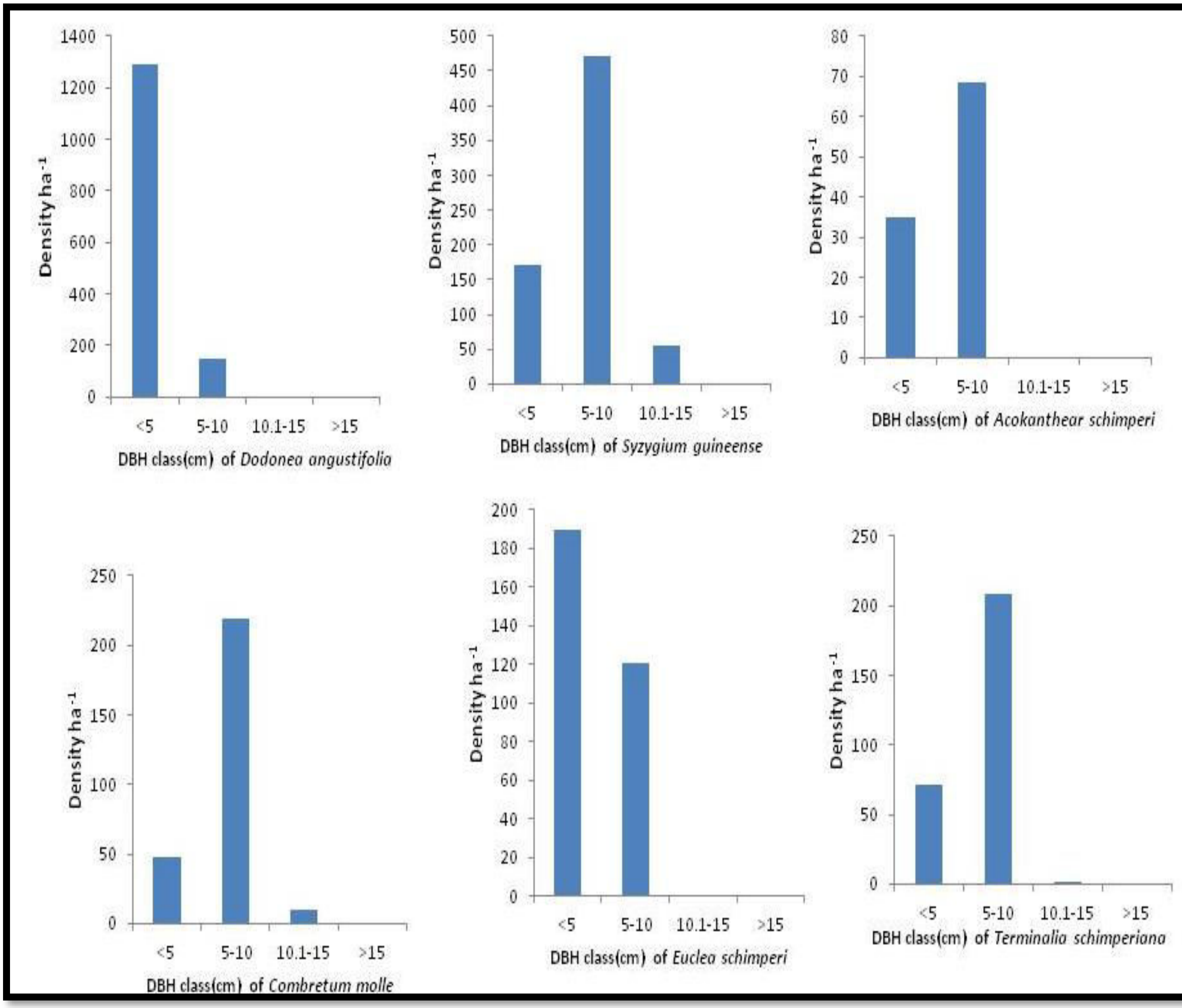

Figure 3: Population Structure of selected species