

Population status of *Adansonia digitata* L. and associated species in a different land use type of Quara district, northwest Ethiopia

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1 **Population status of *Adansonia digitata* L. and associated species in a different**
2 **land use type of Quara district, northwest Ethiopia**

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10 **Abstract**

11 **Background:** *Adansonia digitata* is one of the most important Non-timber forest products and a
12 key species that have ecological and socio-economic significance in the lowland area of Ethiopia.
13 However, the population of the species is decreasing from time to time due to different natural and
14 anthropogenic factors. The study important to generate information on the current existing
15 population status of *Adansonia digitata* across three land use types and will provide a scientific
16 recommendation on further management of a species.

17 **Methodology:** About six plots in each forest and agricultural land use type and five plots in
18 homestead were selected randomly from the topography map. Populations of a species were
19 determined using analysis of variance.

20 **Results:** The result showed that homestead and agricultural land use type had higher *Adansonia*
21 *digitata* density than forest land use type but statically it was not significantly different. More
22 *Adansonia digitata* populations were distributed in the middle diameter and height size classes.

23 **Conclusion:** The study concludes that *Adansonia digitata* highly associated with *Combretum-*
24 *Terminalia*, *Ziziphus* and *Acacia* tree species in the study area. This species is dominant and key
25 ecological importance in the woodland vegetation however; *Adansonia digitata* has a very low
26 importance value index in the study area, so it needs further management and conservation.

27 **Keywords:** *Adansonia digitata* L., Density, Land use, Population structure, Woodland

28 **Introduction**

29 The woodlands in Ethiopia cover an estimated area of 26 million hectares from the total 56.76-
30 million-hectare forest resource coverage of the country [1]. These woodland resources are mainly
31 located in the western, eastern and northern parts of Ethiopia especially, in the Amhara region
32 bordering to Sudan. The woodland vegetations are dominated by broad-leaved *Combretum*-
33 *Terminalia* species [2]. The vegetation harbors many economically important species such as
34 *Boswellia papyrifera*, *Acacia* species, *Adansonia digitata* L., (African baobab) *Tamarindus indica*,
35 and *Balanites aegyptiaca* known for their Non-timber forest products used locally and traded to
36 international markets.

37 *A. digitata* L. is one of the most important Non-timber forest products and a key species that have
38 ecological and socio-economic significance in the low land area [3]. It is one of the eight global
39 species in the genus *Adansonia* from the family *Malvaceae* and sub-family *Bombacaceae* [4].
40 *A. digitata* L. tree is characterized by its massive size, reaching to a height of 18-25m, producing a
41 rounded crown, and showing a stiff branching habit. It is a very long-lived tree and thought that
42 some trees are over 1000 years old [5].

43 *A. digitata* L. is distributed in belts in low-lying areas across Africa, Madagascar, India, Sri Lanka
44 and Australia [6]. It can be found in most of Sub-Sahara Africa's semi-arid and sub-humid regions
45 as well as in western Madagascar [7]. The species occurs naturally in most countries of Sahara as a
46 scattered tree in the savannah, and also present in human habitation. The tree has been introduced
47 in many countries used as an ornamental plant [8]. In Ethiopia, it grows in Bereha and dry kola
48 agro-climatic zones of Tigray and Gondar (common in Tekeze Valley), growing best in moist and

well-drained soils [9]. *A. digitata* L. has an extensive root system and high water holding capacity [10].

However, currently the tree species has not been promoted and therefore remain under-utilized and its population is decreasing from time to time due to different natural and anthropogenic factors [10]. This species is not giving more important as expected; it is rather under-utilized so these types of studies have high values to improve the livelihood and use of resources effectively and properly. Due to human-induced factors and lack of promotion, the species are declining in the district.

Limited works carried out so far on *A. digitata* L. in Eastern Africa [11,12,10,13] have shown a variety of population of a species.

However, there is a lack of empirical studies about the population status of a species in the North West lowland of Ethiopia. Also, population status and regeneration are poorly documented and the species is largely neglected by research, development and extension institutions in the country.

This study aims to generate information on the distribution, abundance, and regeneration of *A. digitata* L. in Quara district, North West Ethiopia. This also used as baseline information for further domestication and commercialization of *A. digitata* L. products and such types of important tree species.

Results

Density and distribution of *A. digitata* L. across different land use type

Average densities of *A. digitata* L. in the different land use types were presented. The result showed that densities of *A. digitata* L. trees per hectare did not statistically differ between land use type ($P=0.09$).

The higher *A. digitata* L. density of trees was counted in the homestead and agricultural land use type (2.24 ± 2.06 and 1.57 ± 1.27 trees/ha) than forest land use type (0.32 ± 0.41 trees/ha) in Quara district (Table 1). It was suggested that *A. digitata* L. densities were variable in the land use type even if it was not statistically significant.

Table 1: *A. digitata* L. density results for three land use type

Land use type	No. of <i>A. digitata</i> L. recorded	Density (plants/ha)
Homestead	56	2.24 ± 2.06
Agricultural land	94	1.57 ± 1.27
Forest land	19	0.32 ± 0.41



Figure 1: Sampled *A. digitata* L. trees in three land use types (Source: Own)

Population structure of *A. digitata* L. across different land use type

Population structure of *A. digitata* L. in the study area across different land uses was presented (Figure 2). The largest *A. digitata* L. trees about 360cm wide girths were recorded at homestead land use type. Relatively many sub-adult trees (1-50cm) were encountered 15.80% in forest land-use type, the second 10.60% in agricultural land use type and the lowest 3.57% in homestead land use type. In all land use types, many *A. digitata* L. trees were recorded at 101-150cm and 51-100cm diameter size classes. The lowest *A. digitata* L. trees were recorded at a 301-350 cm diameter size class that is 0.37% trees. The skewness of the data was distributed along the right side of the mean (0.71) which is moderately skewed.

The current survey showed that highest *A. digitata* L. trees were distributed at 14.1-16 m height size class in all land use type. The tallest trees (about 1%) were observed in the agricultural land use type that was recorded in the size class of 22.1-24 m. In addition, most maximum young trees were recorded in agricultural land use type about at the size class of 2.1-4 m and the majority of trees had laid in the middle height size classes.

Trees were laid in the range of 14.1-16 m about 26% proportion of trees. The skewness of data was distributed along the right side of the mean proportion of trees that is positively skewed. Large height size classes of *A. digitata* L. were recorded in agricultural land use type and the highest average proportion of trees was found in medium height size classes. The significant differences displayed in diameter at breast height and height size-classes between different land use types (Figures 2 and 3).

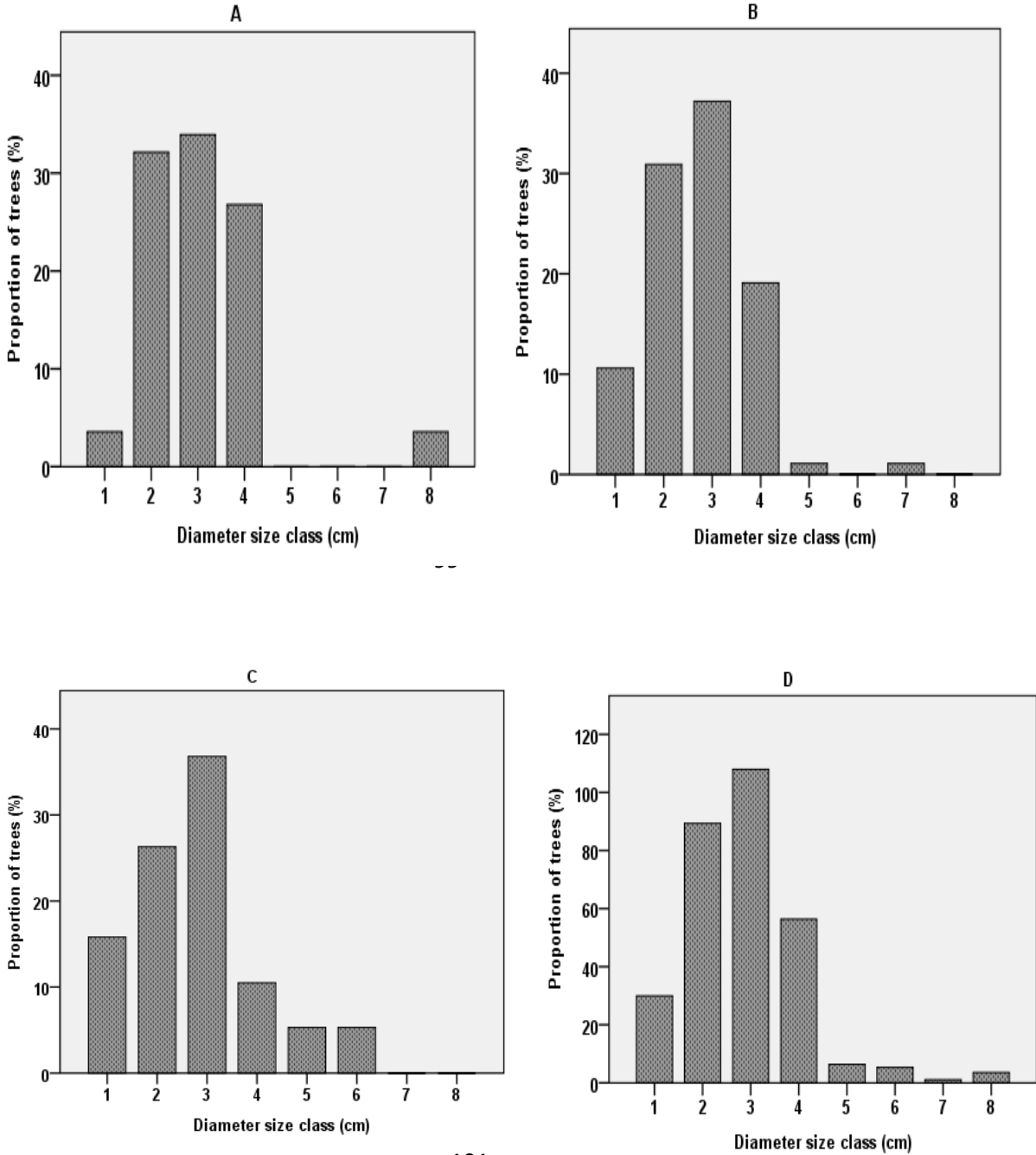


Figure 2: Proportion of *A. digitata* L. trees in the different diameter size classes of homestead land use (A), Proportion of trees in agricultural land use (B), Proportion of trees in forest land use (C) and the total proportion of trees in different diameter size classes (D). Diameter size class (DSC) in cm; 1=1-50, 2=51-100, 3=101-150, 4=151-200, 5=201-250, 6=251-300, 7=301-350 and 8=351-400.

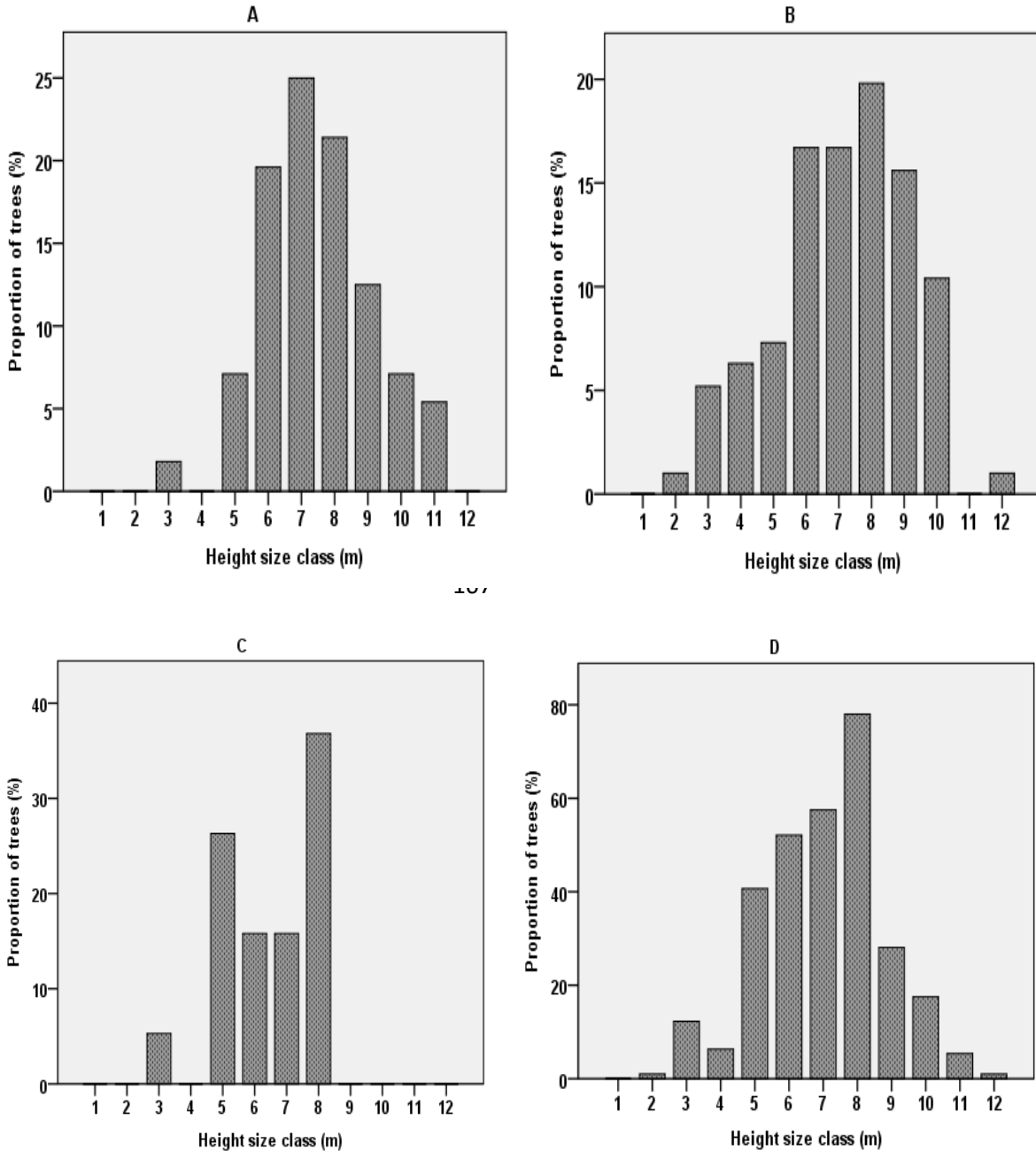


Figure 3: Proportion of *A. digitata* L. trees in different height size class of homestead land use (A), Proportion of trees in agricultural land (B), Proportion of trees in forest land (C) and total proportion of trees (D) in different height size classes. Height size class (m); 1= 0-2, 2=2.1-4, 3=4.1-6, 4=6.1-8, 5=8.1-10, 6=10.1-12, 7=12.1-14, 8=14.1-16, 9=16.1-18, 10=18.1-20, 11=20.1-22 and 12= 22.1-24.

Diversity, evenness, and richness of woody species in forest and agricultural land use type

Forest land use type had higher diversity and evenness than agricultural land use type. In forest and agricultural land use type, 30 and 21 types of species were encountered respectively. The diversity and evenness of woody species in forest land use type were 2.37 and 0.70, and in agricultural land use type 1.98 and 0.65 respectively (Table 2).

Table 1: Diversity, evenness, and richness of woody species

Characteristics	Land use type	
	Forest land	Agricultural land
Species richness	30	21
Evenness	0.70	0.65
Shannon diversity index	2.37	1.98

Density, frequency, dominance and importance value index of woody species among forest and agricultural land use type

Density, frequency, dominance and importance value index of species in forest and agricultural land use type categories based on the degree of disturbances (Table 3 and 4). The density of woody species in forest and agricultural land use type was 1890.66 stems/ha and 2607.46 stems/ha respectively (Table 3 and 4).

In terms of species density, *Terminalia laxiflora* is the species with highest species density 416 stems/ha, and the lowest species density is *Millettia ferruginea*, *Ficus thonningii* and *A. digitata* L. (0.27 stems/ha) in forest land use type (Table 3). In agricultural land type, the highest and lowest

species densities are *Ziziphus mucronata* (1032 stems/ha) and *Balanites aegyptiaca* (0.53 stems/ha) (Table 4). Those species can resist low human disturbances. From observation, during wintertime *Ziziphus* and *Acacia* species coppicing were extremely encroached the crop land. It is an additional cost for farmers to remove this coppicing each year but important to help rehabilitate the area by a short time.

Based on field observation, *Balanites aegyptiaca* species dominantly distributed in agricultural land use type of the district but unlikely other *Ziziphus* and *Acacia* species it has rarely distributed in the habitat of *A. digitata* L. population. This is maybe due to species soil type preferences.

A few species of trees saplings and seedlings were found to pre-dominate the density of vegetation in the study areas. For instance, five species *Terminalia laxiflora*, *Combretum adenogonium*, *Acacia brevispica*, *Terminalia brownie*, and *Combretum molle* were contributed 74% of the total density at forest land use type (Table 3). Similarly, five species such as *Ziziphus mucronata*, *Acacia plicata*, *Clutia lanceolata*, *Piliostigma thonningii* and *Acacia brevispica* were contributed to 82% of the total density of woody plant species at agricultural land use type (Table 4). Some species have occurred relatively more than half of the total sample quadrant at forest land use types such as *Terminalia laxiflora* (78.33%) and *Combretum molle* (56.67%) (Table 3). In agricultural lands, type *Ziziphus mucronata* have occurred more than half of the total sample quadrants (86.67%) species. In contrast, *A. digitata* L. and *Millettia ferruginea*, *Ximenia americana* and *Combretum collinum* Fr species in forest land use type had a relatively low frequency (1.67%), and also *Balanites aegyptiaca*, *Terminalia laxiflora*, and *Combretum adenogonium* were lowest frequent species relatively (3.33%) at the total quadrant of agricultural land use type (Table 4).

152 More dominant associated species with *A. digitata* L. species in Quara woodland or forest land use
153 type are *Anogeissus leiocarrpa*, *Pterocarpus lucense*, *Combretum molle*, and *Terminalia laxiflora*
154 descendinglly. *A. digitata* L. is the second dominant tree in forest land use type. In addition,
155 *Terminalia laxiflora*, *Combretum molle*, *Anogeissus leiocarrpa*, *Pterocarpus lucense*, and *Acacia*
156 *brevispica* are the highest five ecological importance species descendingly in forest land use type.
157 On the other hand, *Ziziphus mucronata* and *Acacia pollicantia* are more ecologically important tree
158 species in agricultural land use type. Those species had ecological importance mainly in Quara
159 district woodland.

160 **Table 2: Density, relative abundance, frequency, dominance, relative dominance and IVI in**
161 **forest land use type**

No.	Species	D	F	RF (%)	RA (%)	D	RD (%)	IVI
1	<i>Combretum molle</i>	166.67	34	56.67	8.86	1.141	11.497	77.03
2	<i>Ziziphus abyssinicus</i>	82.93	11	18.33	4.41	0.031	0.315	23.06
3	<i>Millettia ferruginea</i>	0.27	1	1.67	0.01	0.024	0.245	1.93
4	<i>Terminalia laxiflora</i>	416.00	47	78.33	22.12	0.811	8.172	108.62
5	<i>Pterocarpus lucense</i>	15.47	29	48.33	0.82	1.360	13.712	62.87
6	<i>Stricullia stegera</i>	2.67	7	11.67	0.14	0.269	2.712	14.52
7	<i>Piliostigma thonningii</i>	0.53	2	3.33	0.03	0.006	0.062	3.42
8	<i>Lannea fruticosa</i>	12.00	19	31.67	0.64	0.583	5.876	38.18
9	<i>Adansonia digitata L.</i>	0.27	1	13.33	0.01	1.453	14.651	4.00
10	<i>Ximenia americana</i>	7.73	1	1.67	0.41	0.008	0.078	2.16
11	<i>Combretum adenogonium</i>	225.33	18	30.00	11.98	0.263	2.653	44.63
12	<i>Combretum collinum</i>	5.60	9	15.00	0.30	0.150	1.516	16.81
13	<i>Acacia seyal</i>	15.20	7	11.67	0.81	0.029	0.296	12.77

14	<i>Combretum collinum</i> <i>Fr.</i>	0.53	1	1.67	0.03	0.008	0.083	1.78
15	<i>Anogeissus leiocarrpa</i>	100.27	28	46.67	5.33	2.470	24.903	76.90
16	<i>Tamarindus indica</i>	2.40	4	6.67	0.13	0.120	1.210	8.00
17	<i>Strychnos innocua Del</i>	20.53	2	3.33	1.09	0.015	0.148	4.57
18	<i>Balanites aegyptiaca</i>	56.00	5	8.33	2.98	0.168	1.694	13.00
19	<i>Acacia sieberiana(DC)</i>	14.13	4	6.67	0.75	0.039	0.395	7.81
20	<i>Ziziphus mucronata</i>	1.33	2	3.33	0.07	0.050	0.508	3.91
21	<i>Gardenia volkensii</i>	8.00	4	6.67	0.43	0.027	0.274	7.37
22	<i>Acacia brevispica</i>	306.40	21	35.00	16.29	0.015	0.148	51.44
23	<i>Acacia pollicanta</i>	77.87	8	13.33	4.14	0.083	0.833	18.31
24	<i>Diospyros</i> <i>mespiliformis</i>	7.20	3	5.00	0.38	0.001	0.005	5.39
25	<i>Boswellia papyrifera</i>	1.87	3	5.00	0.10	0.083	0.833	5.93
26	<i>Terminalia brownie</i>	282.93	11	18.33	15.04	0.532	5.363	38.74
27	<i>Ficus thonningii</i>	0.27	1	1.67	0.01	0.002	0.022	1.70

28	<i>Stereospermum kuntbium</i>	2.40	6	10.00	0.13	0.121	1.220	11.35
29	<i>Dalbergia melanoxylon</i>	28.00	6	10.00	1.49	0.057	0.573	12.06
30	<i>Erythrina brucei</i>	20.00	1	1.67	1.06	-	-	-

Table 3: Density, relative abundance, frequency, relative frequency, dominance, relative dominance and IVI in agricultural land use type

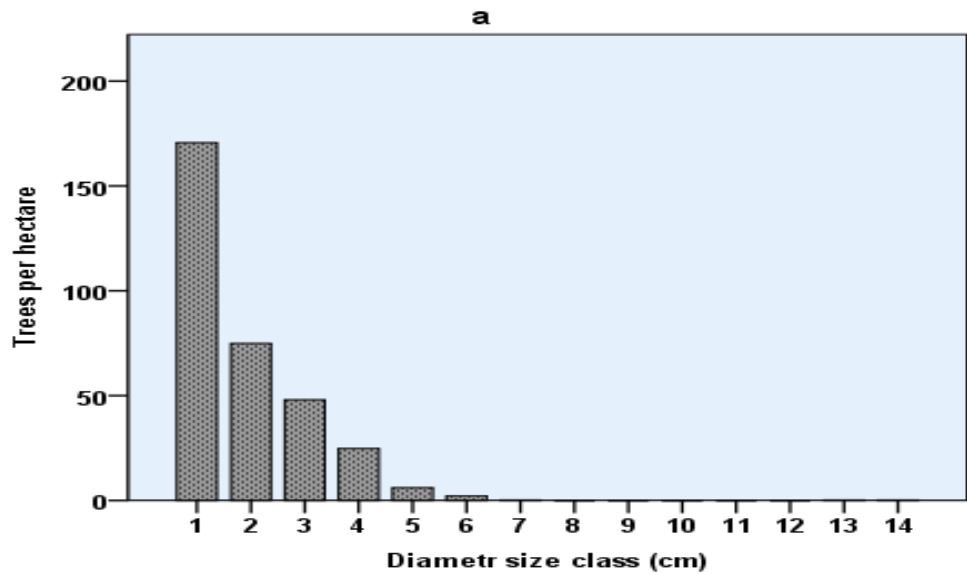
No.	Species	D	F	RF (%)	RA (%)	D	RD (%)	IVI
1	<i>Ziziphus abyssinicus</i>	54.4	4	13.33	2.12	0.005	0.039	15.49
2	<i>Ficus sycomorusl</i>	4.8	5	16.67	0.19	2.187	17.948	34.80
3	<i>Pterocarpus lucense</i>	3.2	6	20.00	0.12	1.126	9.239	29.36
4	<i>Stricullia stegera</i>	1.6	2	6.67	0.06	0.613	5.033	11.76
5	<i>Piliostigma thonningii</i>	149.87	7	23.33	5.83	0.109	0.893	30.06
6	<i>Lannea fruticosa</i>	1.6	2	6.67	0.06	0.024	0.197	6.93
7	<i>Adansonia digitata L.</i>	38.93	7	23.33	0.06	6.841	56.134	18.24
8	<i>Acacia seyal</i>	96.53	7	23.33	3.76	0.133	1.090	28.18

9	<i>Anogeissus leiocarpa</i>	3.73	4	13.33	0.15	0.151	1.243	14.72
10	<i>Balanites aegyptiaca</i>	0.53	1	3.33	0.02	0.020	0.166	3.52
11	<i>Acacia sieberiana (DC.)</i>	56	5	16.67	2.18	0.092	0.753	19.60
12	<i>Ziziphus mucronata</i>	1032	26	86.67	40.15	0.153	1.256	128.08
13	<i>Acacia brevispica</i>	135.47	3	10.00	5.27	0.002	0.018	15.29
14	<i>Acacia pollicanta</i>	511.47	14	46.67	19.90	0.336	2.757	69.32
15	<i>Cordia africana</i>	30.4	3	10.00	1.18	0.076	0.621	11.80
16	<i>Terminalia brownie</i>	3.2	5	16.67	0.12	0.214	1.755	18.55
17	<i>Stereospermum kuntbium</i>	43.73	6	20.00	1.70	0.105	0.858	22.56
18	<i>Terminalia laxiflora</i>	13.33	1	3.33	0.52	-	-	-
19	<i>Clutia lanceolata</i>	280	7	23.33	10.89	-	-	-
20	<i>Combretum adenogonium</i>	26.67	1	3.33	1.04	-	-	-
21	<i>Grewia villosa</i>	120	3	10.00	4.67	-	-	-

Population structure of woody plant species among different diameter size classes

The diameter size class distribution of total woody plant species in forest land use type showed that inverted "J" shape distribution. There are high numbers of individuals in the lower with gradually decreases along the middle and higher diameter size classes (Figure 4a). Similarly, the diameter size class distribution of total woody plant species in agricultural land use type showed that inverted "J" shape distribution with the high deviation between lower size class and others (Figure 4b). In both land use type higher numbers of individuals were recorded in the lowest and middle diameter size classes. The patterns of size class distribution of woody plants were inversely distributed with increasing diameter size classes in forest and agricultural land use type. Generally, the graph showed that vegetation in both land use types had a healthy growth status.

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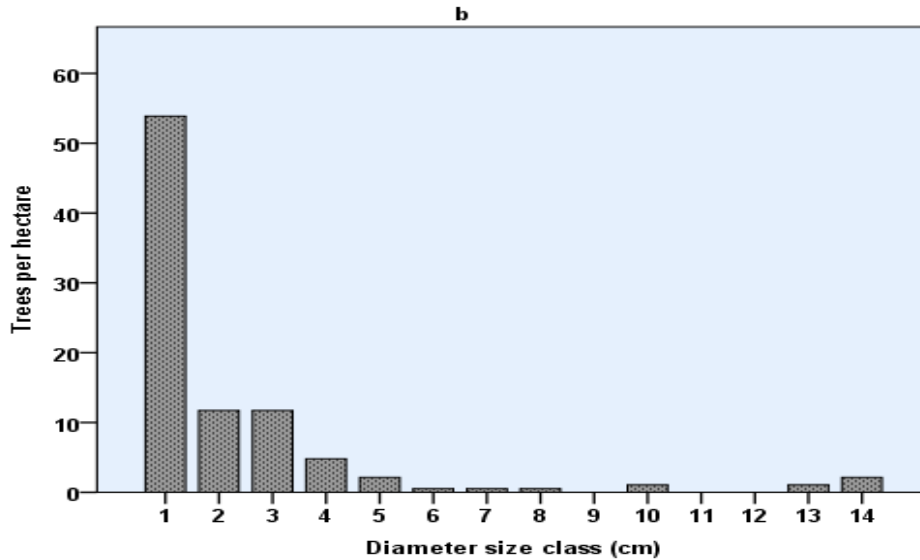


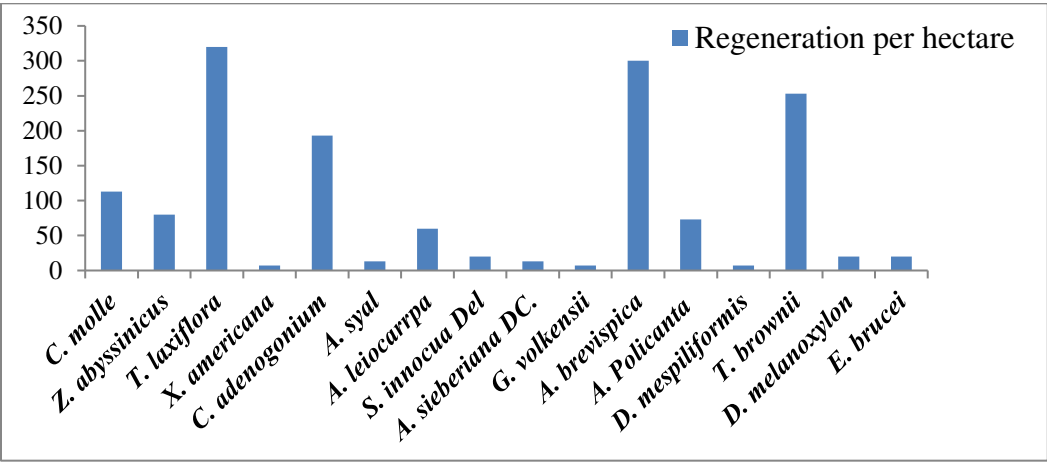
Figure 4: Diameter size class distribution of forest land use type vegetation (a) and agricultural land use type vegetation (b). Diameter size class (cm); 1=1-10, 2=11-20, 3=21-30, 4=31-40, 5=41-50, 6=51-60, 7=61-70, 8=71-80, 9=81-90, 10=91-100, 11=101-110, 12= 111-120, 13=121-130 and 14 >130.

Regeneration status of a species among forest and agricultural land use type

Regeneration status of all encountered species in forest and agricultural land use type was showed (Figure 5). *Terminalia laxiflora*, *Acacia brevispica*, *Terminalia brownie*, *Combretum adenogonium*, and *Combretum molle* have good regeneration status species in forest land use type (Figure 5a) whereas in agricultural land use type (Figure 5b) *Ziziphus mucronata*, *Acacia pollicanta*, *Clutia lanceolata*, *Piliostigma thonningii* and *Acacia brevispica* species have good regeneration status.

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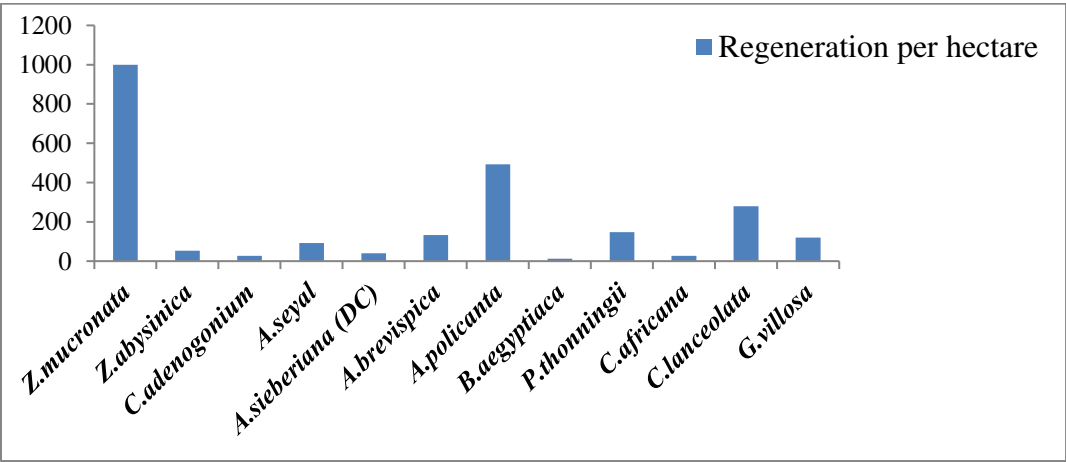
a



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b



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Figure 5: Regeneration status of different species in forest land use type (a) and agricultural land type (b).

198 **Discussions**

199 **Distribution of *A. digitata* L. across different land use type**

200 The distribution of *A. digitata* L. in the study area differs across different land use types. Relatively
201 more *A. digitata* L. tree species were found in homestead and agricultural land use type rather than
202 forest land use type. Population species density is not evenly distributed. This could be related to
203 the solitary nature of the species and protection. As to the distribution in some areas, the
204 population of *A. digitata* L. found in the clustered manner and whereas in most areas it was
205 distributed more sparsely. Based on the vegetation survey population of the species in adjacent
206 river vegetation and abandoned village and church areas were distributed in a clustered pattern.

207 A similar study in South Africa, [13] indicated that villages and fields had higher densities of trees
208 than plains and rocky outcrops in South Africa.

209 Additionally, [14] showed that the *A. digitata* L. population was mainly observed at human
210 settlements in the Omusati region in Northern Namibia. Different crops covered most of the
211 homestead and agricultural land use types in summer and autumn seasons; this is an advantage to
212 protect *A. digitata* L. trees in the district.

213 **Diversity, evenness, and richness of woody species in forest and agricultural land use type**

214 All individual species in forest land use type more equally distributed and highly diversified than
215 agricultural land use type species.

216 Species composition variation in two land use types may be due to a level of disturbance; in
217 agricultural land use, type had practiced extreme clear cultivation in the study area. This practice
218 reduced the species composition in crop land, only existed high coppicing and resistance ability

woody species like *Ziziphus mucronata* and *Acacia pollicanta*. Similarly, [2] at low levels of disturbance superior competitor species monopolize resources and exclude other species, whereas at high disturbance levels only the most resistant species survive. Additionally, the study suggested that wet season length and soil variability were contributed to the variation of species richness. Besides, [15] indicated that species diversity in each forest ecosystem might be varying, due to altitudinal difference, habitat diversity and low human disturbances. In similar agro-ecology of the current study, [16] indicated that woody plant species have more existed in Metema woodland are the most disturbance resistance species.

Density, frequency, dominance and importance value index of woody species among forest and agricultural land use type

Agricultural land use type had higher abundance species than forest land use type. This may be due to farming practices in the district; there are common low plow frequency, zero tillage and long year fallow period. These practices are important to increase the abundance of coppicing and regeneration of light-demanding woody plant species in agricultural land use type.

Similarly, [17] revealed that sites with higher disturbance in open grazing and farmlands were found to own a relatively higher number of tree and shrub species than the less disturbed sites in Rift Valley of Ethiopia.

The importance value index is an important parameter to identify which species more ecological significant and valuable and to sustain those species required to sustainable utilization and management. Low importance value index species like *A. digitata* L. species need to give priority for conservation. Similarly, [18] reported that the importance value index is important to compare

the ecological significance of a given species. The result revealed that importance value is a good index for summarizing vegetation characteristics and ranking species for management and conservation practices. Stands that yield more or less the same importance value index for the characteristic species indicate the existence of the same or at least similar stand composition, structure, site characteristics and comparable dynamics as discussed by [17] .

Regeneration status of a species among forest and agricultural land use type

Regeneration (seedling and sapling stage) of *A. digitata* L. was not found in the study area. According to vegetation survey, *A. digitata* L. leaves are very palatable by different herbivores and could not resist disturbance. The local people suggested that major factors that affected the regeneration of *A. digitata* L. in the district are livestock grazing and clear cultivation. Similarly, [15] indicated that the major reasons for hampered are unfavorable environmental conditions like rocky land and poorly developed soil, and human disturbance particularly grazing.

Besides, [19] indicated that land clearances for small-scale farming usually powerless of a problem as large and *A. digitata* L. individuals are not eliminated in the clearing process but still destroy *A. digitata* especially young individuals.

257 **Conclusions and Recommendations**

258 **Conclusions**

259 *A. digitata* L. population distributions are higher in homestead and agricultural land use type rather
260 than forest land use type.

261 The majority of a species population was distributed in the middle diameter size class and height
262 size classes. There was no found *A. digitata* L. species regeneration in all land use types; these will
263 be challenged on the future *A. digitata* L. population dynamics.

264 *A. digitata* L. was highly associated with *Combretum-Terminalia*, *Ziziphus* and *Acacia* tree species
265 in forest and agricultural land use types. This species is dominant and key ecological importance in
266 the woodland vegetation however; *A. digitata* L. has a very low importance value index.

267 **Recommendations**

268 In the current study, there is no regeneration of *A. digitata* L. species and the dynamics of *the*
269 population are declining. Therefore, domestication and protection should be done before the local
270 extinction of the species.

271 **Further researches also required in the following areas:**

- 272 • Propagation, growth performance and seed pre-treatment methods of *A. digitata* L. species
- 273 • *A. digitata* L. population dynamics for certain consecutive years in Quara district
- 274 • Value chain study of *A. digitata* L. products in Ethiopia

Methodology

Study area

The study was conducted at Quara district (Figure 6), in the West Gondar zone, North West Ethiopia. Quara district is found in the western part of the Amhara regional state at about 1049 km (the town of the district) from Addis Ababa. It covers an area of 858,588 ha. The vegetation type of the study area is *Combretum Terminalia* deciduous dry forests with important woody plant species diversity. The district lies in the range of latitudes 020 39' 47"-110 46' 54"N and longitude 350 15'28"-360 29' 59" E. The mean annual rainfall and temperature of the study area is 400 to 1200mm and 25 to 42^oc respectively. The district has two agro-climatic zones naming Qolla and Woyina dega that cover about 70 and 30% of the district area respectively. The soil type of the district both from two agro-ecology zones is very soil, sandy loam soil and silt loam soil (Quara woreda agricultural office 2018 E.C). According to the Quara government communication affairs office (2010 E.C), the total population of the district is about 137,476 and these populations are settled in 28 kebeles. From the total population, more than 98% lead their lives by the agricultural practice of crop cultivation and animal rearing activities. The rest 2% or less than this figure is merchants.

Quara was selected for this study owing to the abundant resource distribution and production of *A. digitata* L. products. The district is found in the border of Sudan where illegal trading of *A. digitata* L. products is being practiced.

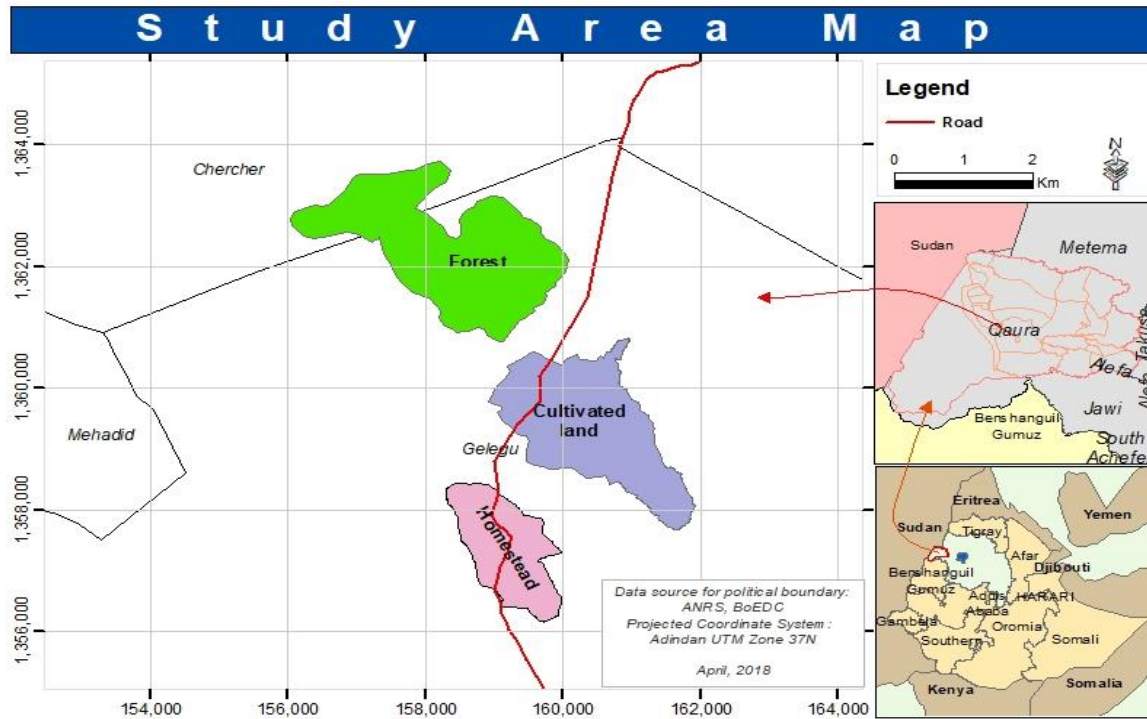


Figure 6: Map of the study area (Source: Own)

Research design

The study was conducted from November up to December. The distribution, abundance, and structure of the species were studied across three land use types such as homestead, agricultural and forest land. Following the preliminary survey, for each land use type study sites were selected and delineated using GPS coordinates and then prepared topographic maps. The delineated forest and agricultural land use area were subdivided into 1km*100m plots, and also homestead land-use or around settlements were sub-divided into 0.5km*100m plots following the methods used by [3]. Ten percent of the total plots in each land use type was employed as a sample plot. Six main plots (60 ha) in each forest and agricultural land use type and five plots (25 ha) in homestead land use type were taken randomly (Table 5).

307 The sample areas were very large enough to obtain meaningful sample trees since *A. digitata* L.
308 species sparsely distributed in the area.

309 Investigation of *A. digitata* L. population status across three land use types, density, frequency,
310 diameter at breast height (DBH), height, crown diameter, and global positioning system (GPS)
311 waypoints or coordinates of all individuals were measured and derived.

312 Based on the preliminary survey, were found more associated tree species in forest and agricultural
313 land use type but homestead only *Ziziphus abyssinicus* and *Azandarica indica* tree species were
314 associated with *A. digitata* L. tree species. Due to this co-existing tree, species parameters were
315 recorded only in forest and agricultural land use type.

316 In each main sample plot of the forest and agricultural land use type, 10 and 5 sub-plots were
317 randomly selected, which measuring 25 X 25m to measure and record associated woody tree
318 species parameter. In each quadrant, the total number of individuals and name of species were
319 counted and recorded to determine the abundance of all species.

320 Finally, a sub-sub sample plot for regeneration count that measuring 5m x 5m was established at
321 each corner and center of the selected sub-plots at forest and agricultural land use type to count
322 seedlings (<1m height) and sapling (≥ 1 m and <2.5cm diameter at breast height).

323

Table 4: Summary of plot design technique

Landuse type	Total no. of plots	Area of each sampled plot (ha)	The total area of the sampled plot (ha)	Total delineated area (ha)	Sampling intensity (%)
Homestead	5	5	25	215.3	10
Agricultural land	6	10	60	559	10
Forest land	6	10	60	566	10

324

Data analysis

326 Based on the collected vegetation data population status of *A. digitata* L. and associated woody
 327 plant species were determined by computing density, abundance, frequency, dominance,
 328 importance value index (IVI) and population structure. Densities of *A. digitata* L. were determined
 329 using analysis of variance.

330 **Density:** which refers to the total number of individuals per hectare in different land use type was
 331 calculated by summing up all the stems across all sample plots (abundance) and translates to
 332 hectare base for the species encounter in the study plots [2].

333 **Density = (Number of individual trees)/ (Per hectare)**

334 **Population structure:** Size class distributions of tree species in different land use types were
 335 analyzed and compared using analysis of variance (ANOVA), correlation and regression analysis.

336 Diversity of the woody plant vegetation in forest and agricultural land use type were also
337 determined using Shannon-wiener diversity and richness indices. Comparisons were also made
338 between the vegetation of the two land use types.

339 **Diversity:** Heterogeneity of the dry land species in forest and agricultural land use type were
340 determined using Shannon-Weiner diversity indices. Shannon-Wiener's diversity index (H) was
341 calculated as follow;

342
$$H' = - \sum_{i=1}^S p_i \ln p_i$$
 Where,

343 Where, H'=Shannon diversity index; S =the number of species; pi= the proportion of individuals
344 or the abundance of the ith species expressed as a proportion of total cover; ln=natural logarithm.

345 **Evenness:** This is a new concept attempting to quantify the unique representation of a given
346 species against a hypothetical community in which all species are equally distributed, such that
347 when all species have equal abundance in the community.

348
$$(Evenness) J = \frac{- \sum_{i=1}^S p_i \ln p_i}{\ln S}$$

349 The composition and structure of the woodland in Forest and Agricultural land use type were
350 analyzed as a proportion in the percentage of the various species encountered concerning the total.
351 Thus, the percentage of contributions of targeted species in various measurable entities compare to
352 the associated species was analyzed as follows.

353 The structure of the vegetation was described using frequency distributions of DBH. Tree or shrub
354 density, which is greater than 1.5cm DBH, and basal area values were computed on a hectare
355 basis.

356 Importance value indices (IVI) were computed to know the dominant woody species based on their
357 relative density (RD), relative dominance (RDO) and relative frequency (RF) to determine their
358 dominance.

359 Importance value indices = Relative Density (abundance) + Relative Dominance (basal area) +
360 Relative Frequency, Where:

361 •RD = the number of all individuals of a species/the total number of all individuals (DBH > 1.5
362 cm) X 100;

363 •RF = the number of plots where a species occurs/ the total occurrence of all species in all of the
364 plots X 100.

365 •RDO= Dominance of a species/dominance of all species X 100 (DBH > 1.5 cm) and

366 •Dominance=Mean basal area/tree X the number of trees of a species

367 •Basal area (BA) was calculated using DBH as follows: $BA = \pi d^2/4$, where, $\pi= 3.14$; d = DBH
368 (m) [18].

369 **Regeneration:** The regeneration status of *A. digitata* L. and other associated species in different
370 land use types were summarized based on the total count of regeneration (seedling and sapling) of
371 species across all sample plots as follows [18].

372 **List of abbreviations**

373 *A. digitata* L.: *Adansonia digitata* L.

374 DBH: Diameter at breast height

375 DSC: Diameter size class

376 E.C: Ethiopian calendar

377 Ha: Hectare

378 IVI: Importance of value index

379 GPS: Global positioning system

380 **Authors' contributions**

381 This research article is a part of MSc thesis for the partial fulfillment of MSc in University of
382 Gondar, College of Agriculture and Rural Transformation. Dr. Asmamaw Alemu and Dr. Abeje
383 Eshete supervised this work and contributed the study design, statistical analysis and thesis
384 preparation. Both authors read and approved the final manuscript.

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390 **Competing interests**

391 The author declares there are no conflicts in interest.

392 **Availability of data and materials**

393 Please contact the author for data requests.

394 **Consent for publication**

395 Not applicable

396 **Ethics of approval and consent to participate**

397 I was got permission from Quara district management office to done my research in the district. In
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399 their village.

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Figures



Figure 1

Sampled *A. digitata* L. trees in three land use types (Source: Own)

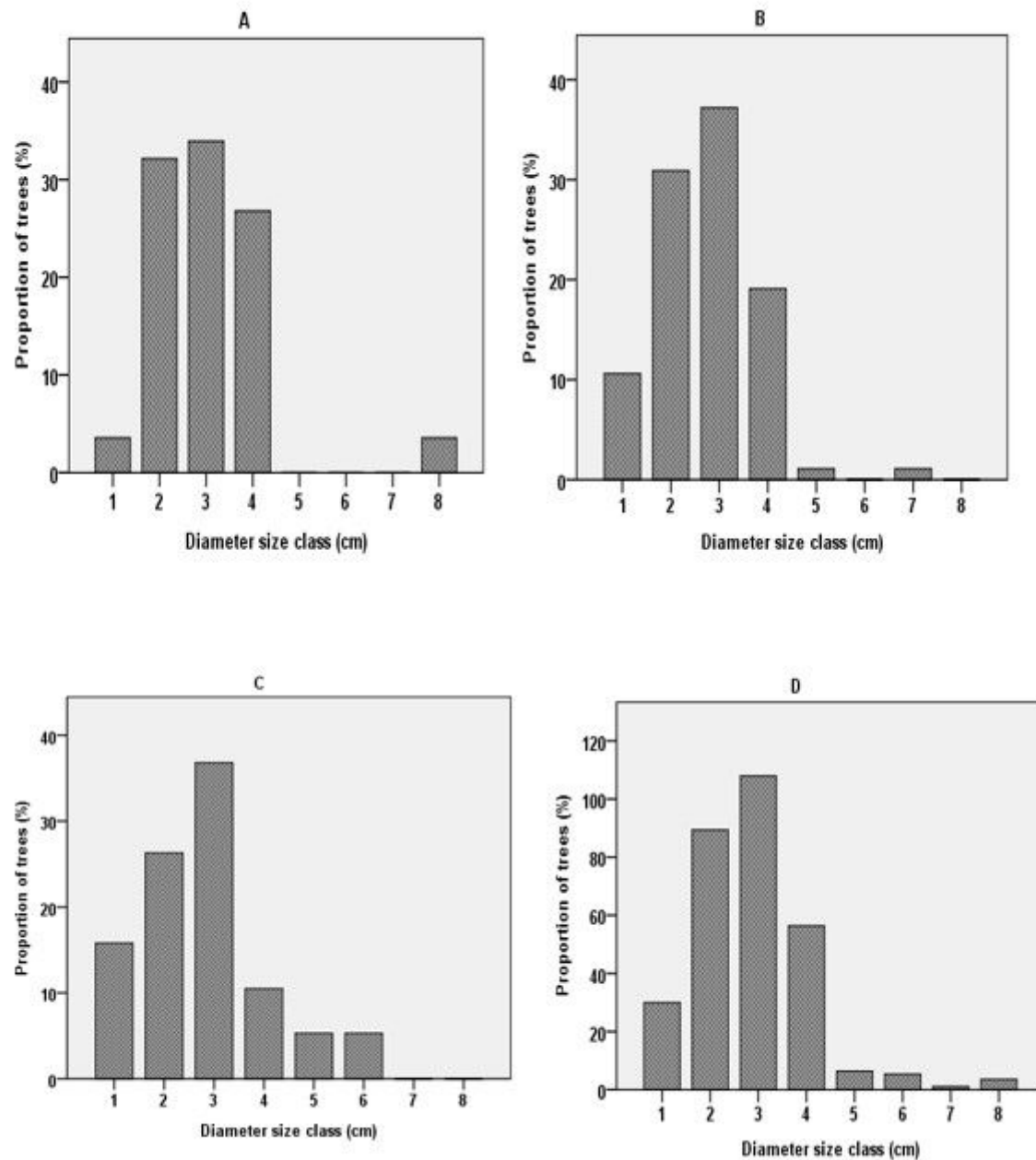


Figure 2

Proportion of *A. digitata* L. trees in the different diameter size classes of homestead land use (A), Proportion of trees in agricultural land use (B), Proportion of trees in forest land use (C) and the total proportion of trees in different diameter size classes (D). Diameter size class (DSC) in cm; 1=1-50, 2=51-100, 3=101-150, 4=151-200, 5=201-250, 6=251-300, 7=301-350 and 8=351-400.

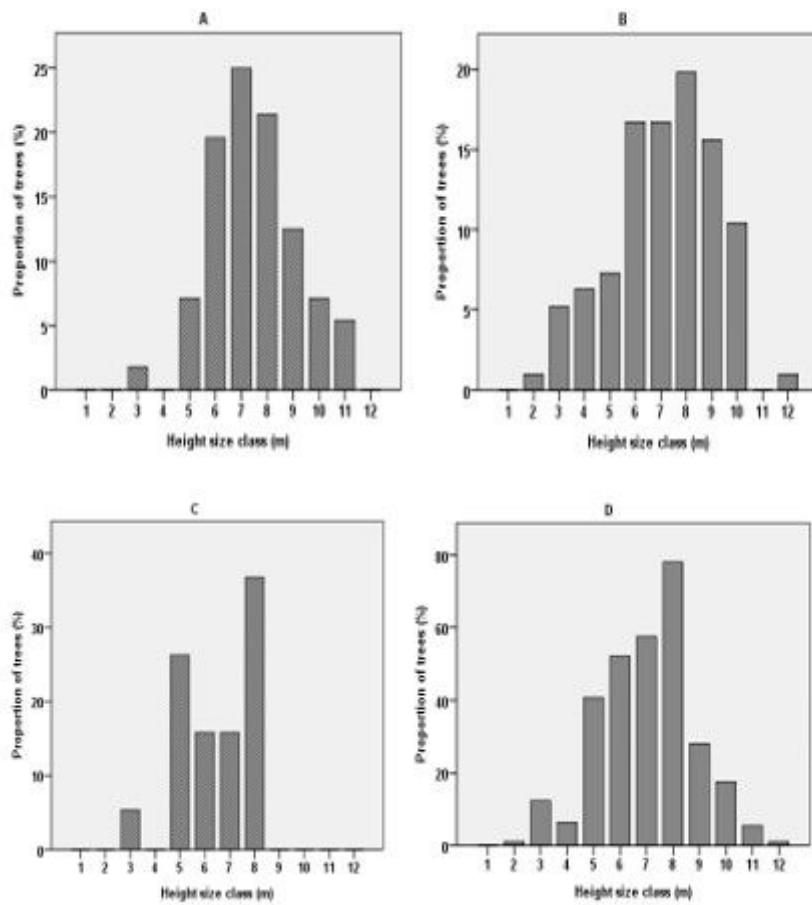


Figure 3

Proportion of *A. digitata* L. trees in different height size class of homestead land use (A), Proportion of trees in agricultural land (B), Proportion of trees in forest land (C) and total proportion of trees (D) in different height size classes. Height size class (m); 1= 0-2, 2=2.1-4, 3=4.1-6, 4=6.1-8, 5=8.1-10, 6=10.1-12, 7=12.1-14, 8=14.1-16, 9=16.1-18, 10=18.1-20, 11=20.1-22 and 12= 22.1-24.

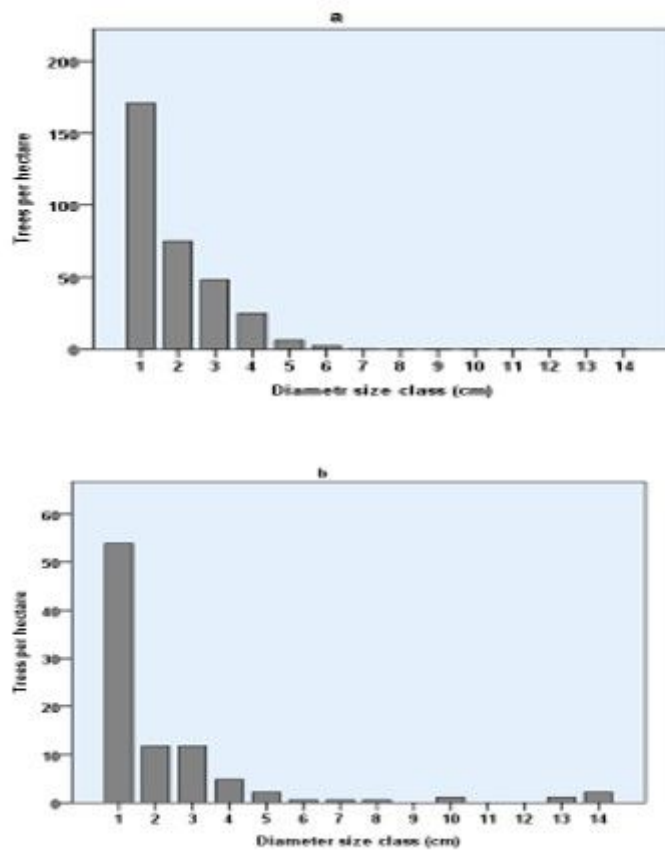


Figure 4

Diameter size class distribution of forest land use type vegetation (a) and agricultural land use type vegetation (b). Diameter size class (cm); 1=1-10, 2=11-20, 3=21-30, 4=31-40, 5=41-50, 6=51-60, 7=61-70, 8=71-80, 9=81-90, 10=91-100, 11=101-110, 12= 111-120, 13=121-130 and 14 >130.

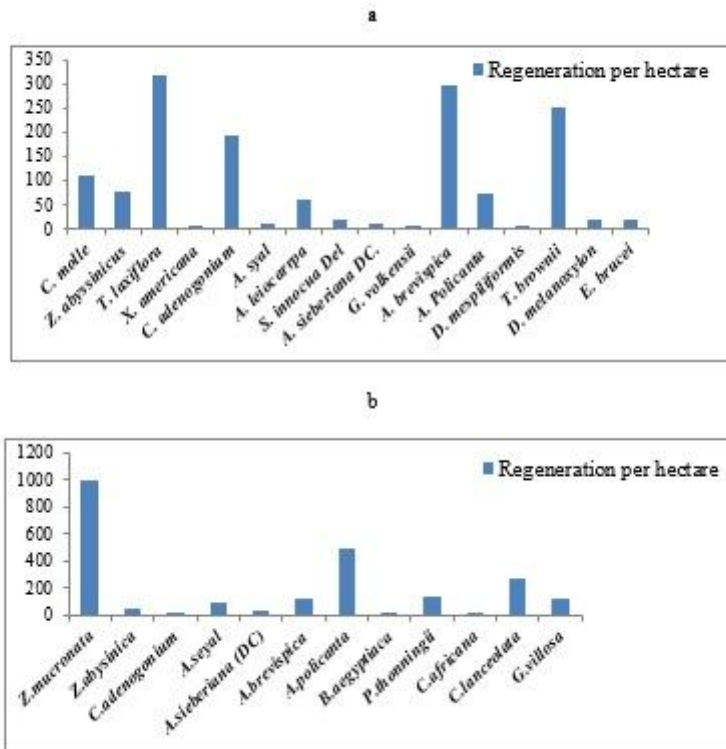


Figure 5

Regeneration status of different species in forest land use type (a) and agricultural land type (b).

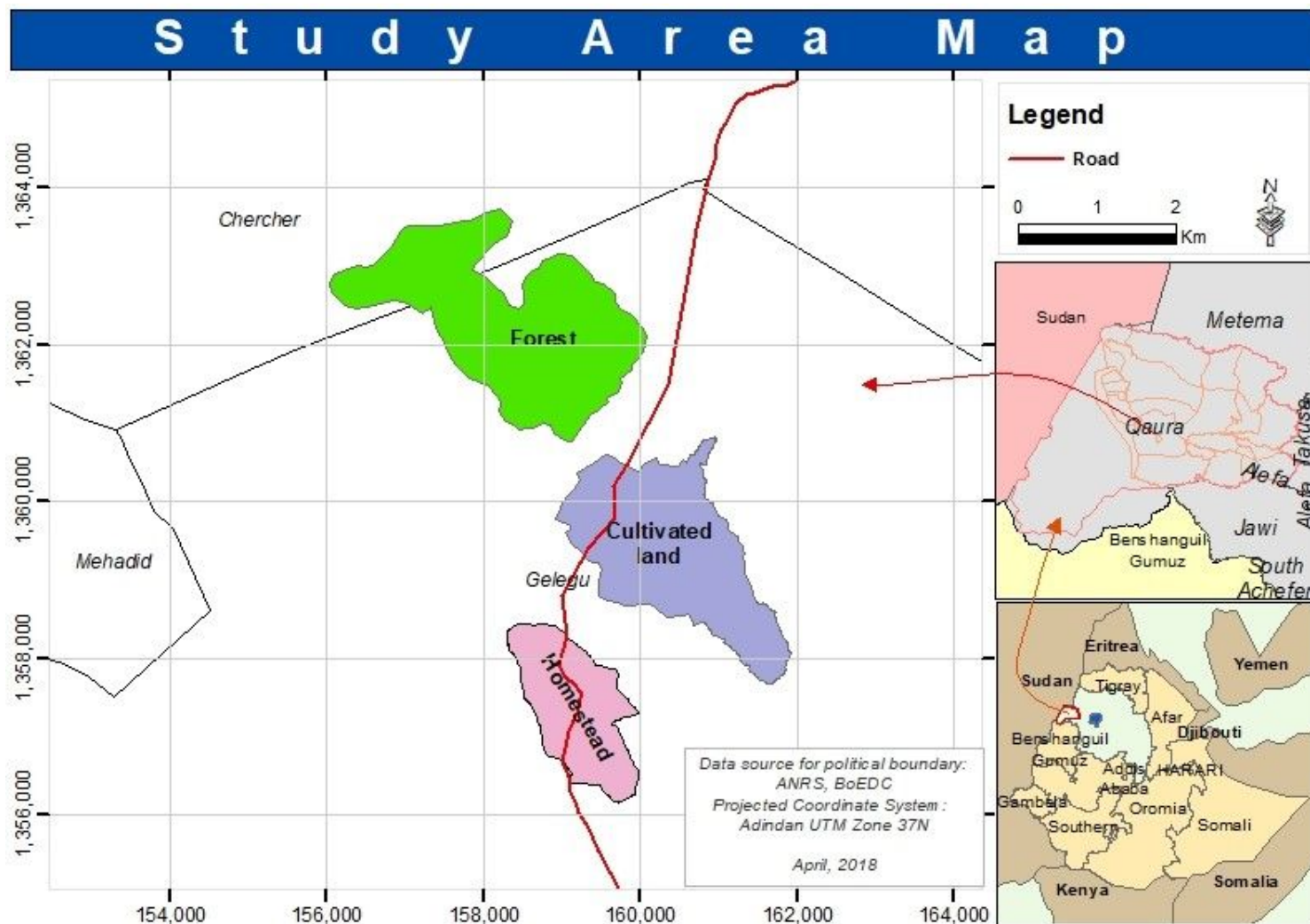


Figure 6

Map of the study area (Source: Own)