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Research Article

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Population Status of *Boswellia papyrifera* dominated woodland in North West Ethiopia

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ABSTRACT

The three main genera that produce gum and resin in Ethiopia's lowland forests are *Acacia*, *Boswellia*, and *Commiphora*. *Boswellia papyrifera* is mainly found in the degraded drylands that are dispersed across many regions of Ethiopia. The purpose of the study was to evaluate the resource status of the northern Ethiopian area of Burie Zuria, which is home to woods dominated by *Boswellia papyrifera*. Determining the district's *Boswellia papyrifera*-dominated woodland's regeneration status and quantifying the population structure of the existing species are among the objectives of the study. From 25mx25m, 5mx5m and 1mx1m size plots, tree, sapling and seedling were collected respectively and the collected data was analyzed through a descriptive statistics. According to the findings, the target species, *Boswellia papyrifera*, had a bell-shaped population structure and a fair regeneration status. Its population structure dominated woods in both the DBH and height class distribution, exhibiting an inverted "J" form. Some species such as *Boswellia papyrifera* (51.2%), *Lannea schimperi* (18.06%), and *Erythroxylum fischeri* (17.6%) had large important value index. The results conclude that the regeneration status and population structures of majority species indicate there is disturbances effect within the area. The finding showed that the population structure of large IVI species was bell-shaped so to sustain such species regular monitoring and conservation activities should be implemented and the finding revealed that the regeneration status of majority species within woodland were fair means there is an anthropogenic disturbance so to minimize such disturbances effect participatory forest management activities should be implement.

Keywords: *Boswellia papyrifera*, dryland species, multi-purpose tree

1. INTRODUCTION

Ethiopia is a country in East Africa in which it is one of the most important centers of biodiversity, that include high forests, woodlands, bush lands, plantations and trees outside forests [1]. The diversity of its vegetation ranges from the high altitude Afroalpine highlands in the central highlands to the arid lowlands in the east and the rainforests in the west [2]. Forests show different structure and composition due to the great variations in environmental conditions and human interactions [3]. [4] found that, natural forests of Ethiopia decreased from 19.26 million ha in 1990 to 17.1 million ha in 2020. This indicates a loss of 73,000 ha per year over the previous 30 years, with more than 90% of deforestation was occurred in the tropical domains [4]. Dry forests are half of the world's tropical and sub-tropical forests and are among the most threatened and least studied forests in worldwide [5]. Ethiopia dry tropical woodlands are comprised of the major gum and resin producing genera of *Acacia*, *Boswellia* and *Commiphora* [6]. But due to deforestation and forest degradation, there have been significant

changes in the population structure and regeneration status of woody species in the country's natural vegetation [7].

Boswellia papyrifera (*B. papyrifera*) is a deciduous dry-land tree that belongs to the family Burseraceae [8]. “The family is distinguished by the production of aromatic oils and resins and the presence of resin ducts in the bark” [[8] cited in [9]]. The tree had thick branches, a maximum DBH of 51.5 cm, a maximum height of 12-16 m, and sweet-smelling flowers on its compound leave to entice honeybees to pollinate it. A drupe is a fruit; that usually has three tapered seeds and is about 2 cm long [10–13]. The species is mainly found in the degraded drylands of Ethiopia within an altitudinal range of 950–1800 m a.s.l with an annual rainfall less than 900 mm and average temperature between 20-27⁰ C [11, 14]. It provides several economic and ecological benefits to the country [10]. Many regions of Ethiopia use this species for household furniture, fences, medicines, apiculture, soil and water conservation, animal feed, frankincense production, and other purposes in addition to coping with the effects of climate change [10, 15, 16].

The population of *B. papyrifera* faces several challenges, evidenced by the decline in Ethiopia and other growing areas [11, 14, 15, 17]. The cause of its degradation were mainly due to its multiple uses [15]. It is an important woody species that are highly endangered [10]. [12] also projected that due to disturbance the current populations of the species are expected to decline by 93% in 50 years for untapped populations and 87% for tapped populations. The *B. papyrifera* dominated forest and woodlands area of Ethiopia are under severe threat owing to the agricultural expansion, uncontrolled livestock grazing, valueless fire and recurrent droughts [11, 12, 14, 18]. In addition to all of them, [14] revealed that due to lack of responsible body for management and conservation practice the population of *B. papyrifera* decreased from time to time. Despite the fact that *B. papyrifera* occurs under open area multiple stakeholders with competing interests are present in the utilization of the woodland, so it promoting its deforestation and degradation [17, 19].

In Ethiopia, the species *B. papyrifera* is scattered throughout the nation; the Tigray, Amhara, Oromia, Benshangul Gumz, and Afar regions are the most dominant [6]. Compared to the other areas, the Amhara region is placed second and the Tigray region first [11]. The reason why Amhara region placed second is due to its several dry land areas where the specie existence. These areas are Metema, Jawi, Adi-Arkay, Abergelle, Debre Elias, Womberma and Burie Zuria districts, while the species existed in this area its resource status does not clearly known in some districts. According to the above-mentioned different scholars, nowadays, due to its multi-function *B. papyrifera* become degraded in our country and they get different population status: in the Benshangul Gumz region both the regeneration and population structure of *B. papyrifera* tree showed normal status [20] but in Metema, Tigray, Abergelle and Jawi districts the status showed abnormal [10, 11, 14, 18]. The study district is one of the existence areas of the species however limited information is available about the resource status of the study species. Further studies on the remaining forest or to restore deforested and degraded area require understanding for implementing appropriate management activities, sustainable utilization and conservation strategies. Therefore, this study tries to examine the current population status of *B. papyrifera* dominated woodland to better understand the natural dynamics, suggest appropriate conservation strategies and to guarantee their sustainable use. The general objective of the study was to examine the population status of *B. papyrifera* dominated woodland in general and *B. papyrifera*

in particular in the district. Whereas the specific objectives were to quantifying the population structure and to determine the regeneration status of *B. papyrifera* dominated woodland in the district.

2. MATERIALS AND METHODS

2.1 Description of the study area

Burie Zuria district is one of the districts of West Gojjam zone, Amhara National Regional State, Ethiopia. Agro-Climatic or traditional thermal zones of the district are weyna-dega and Kola. The study was conducted in the kola parts (*Boko-tabo* kebele) of the district. The kebele relative location is between 10° 27' 0" to 10° 67' 14" north latitude and 36° 52' 0" to 37° 02' 11" east longitude [21]. The district capital Burie is located 411 km away from Addis Ababa. The mean annual temperature ranges from 19°C to 26°C, and mean annual rainfall ranges from 1386-1757 mm [21].

This dry land area was dominated by *Combretum Terminalia* and *Acacia Commiphora* species. The dryland areas were co-dominated by one or more gum and resin producing species [22].

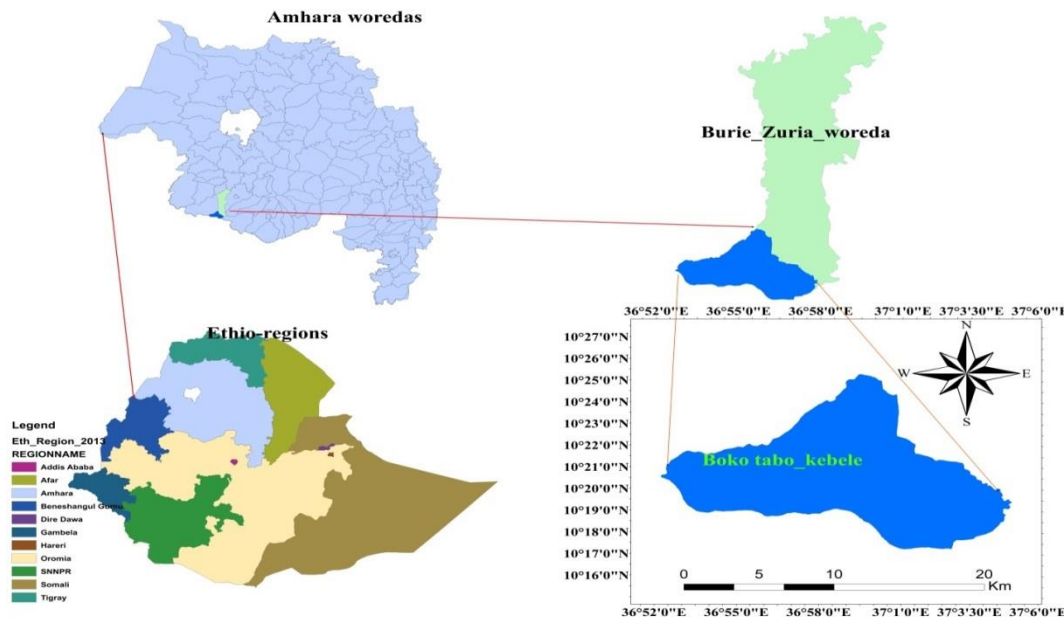


Figure 1 map of the study area

2.2 Methods of data collection

The data was conducted from January 25 to February 28, 2023. In order to examine the status of the resource base, a rapid vegetation assessment survey was conducted. A systematic random

sampling technique was employed to take sample plots. Sample plots were laid along line transects which established horizontally. The first transect line was put randomly at the bottom near the Nile river valley and others systematically with an interval of 500 m between them, following the procedures described by [9]. From 6 parallel transect lines, a total of 48 sample plots with size 20 X 20 m were laid down at regular interval, following the procedures described by [9]. The first sample plot was laid down randomly and the others systematically at 300 m interval. In the main plot, two small plots at the corner and one in the center were laid down for sapling and seedling count respectively, following the procedure of [23]. So the data were collected from the 20 x 20m, 5 x 5m and 2 x 2m trees, saplings and seedlings respectively (Figure 2). In each plot the species were encountered and recorded.

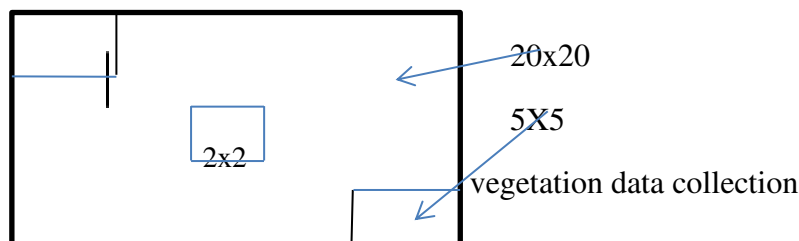


Figure 2: sampling design of the study

For all encountered species its DBH and height were measured. Species diameter was measured using RCD (it's DBH <6 cm) and caliper (it's DBH >6 cm). Woody species diameter was measured at breast height and Shrub diameter was measured at stump height (DSB at 30 cm height from the ground). The species height was measured using hypsometer (large woody species) and marked sticks (small shrubs, seedlings and in some extent saplings). In the case of multi-stemmed shrub each stem was measured, and the diameter equivalent of the plant calculated as the square root of the sum of the diameter of all stems per plant [24].

The diameter equivalent was calculated by using the following formula:

$$de = \sqrt{\sum_x^n dx^2} \dots \dots \dots \text{Eq.1}$$

Where de= diameter equivalent height, dx= diameter of xth stem at the measurement height in cm.

The local name of the species found in the sample plots was identified and recorded with the help of key informants in the field whereas after field inventory it's scientific and family name were identified from Azene Bekele (2007) and Flora of Ethiopia and Eritrea volume 6.

For the purpose of this study, the term “seedling”, “sapling” and “tree” are defined as plants with heights up to 150 cm (1.5 m), between 150 and 300 cm (1.5m – 3m) and greater than 300 cm (> 3m), respectively [Demel, 1997a; Getachew *et al.*, 2002 cited in [7]]. To consider the data collection season this methodological approach was selected.

2.3 Data analysis

Structural data analysis: All vegetation data recorded in all plots were entered into Microsoft Excel office, and subsequent analyses of the data were performed. The analysis of population structure was made by comparing both the distribution of diameter classes and height classes with number of individual species.

According to [25], the structural parameter was analyzed using the following formula:

- (a) Density (D): Number of individuals per hectare, of species will be computed by converting the total number of individual of each species to equivalent numbers per hectare

$$\text{Density} = \frac{\text{number of individual trees of a species}}{\text{area of plot}} \dots \text{Eq.2}$$

- (b) Relative density was computed as the ratio of Z specie density and sum of density of all species and multiplied by 100%.

$$\text{Relative density} = \frac{\text{density of z species}}{\text{sum of density of all species}} \times 100\% \dots \text{Eq.3}$$

z= the species occurred in *B. papyrifera dominated* woodlands

- (c) Frequency (F), Frequency is the number of quadrats (expressed as a percentage) in which a given species occurs in the study area over the total plots laid down in the study site [26].

$$\text{Frequency} = \frac{\text{no of plots in which z species is ocured}}{\text{total number plots laid down the study site}} \dots \text{Eq.4}$$

- (d) Relative frequency (RFR) was computed as the ratio of the number of plots in which a species occur and the total occurrences of all species in all plots

$$\text{Relative frequency} = \frac{\text{frequency of z species}}{\text{sum of frequency of all species}} \times 100\% \dots \text{Eq.5}$$

- (e) Dominance was computed as total basal area of z species divided by area of quadrant in hectare

$$\text{Dominance} = \frac{\text{total basal area of z species}}{\text{area of quadrant in hectare}} \dots \text{Eq.6}$$

$$\text{BA} = \frac{\pi \times \text{DBH} \times \text{DBH}}{4} \dots \text{Eq.7}$$

BA= basal area per hectare in m DBH= diameter at breast height and $\pi = 3.13$

Basal area (BA) is the cross-sectional area of all of the stems in a stand at breast height (1.3 m above ground level). It is used to explain the crowdedness of a stand of natural vegetation [26].

- (f) Relative dominance the ratio of dominance of z species and total dominance of all species multiplied by 100%

$$\text{Relative dominance} = \frac{\text{dominance of z species}}{\text{total dominance of all species}} \times 100 \dots \text{Eq.8}$$

- (g) Important value index is the degree of dominance and abundance of a particular species relative to the other species in the area [25], which is the summation of relative density, relative dominance and relative frequency.

$$\text{IVI} = \text{relative density} + \text{relative frequency} + \text{relative dominance} \dots \text{Eq.9}$$

- (h) Diameter class distribution

The pattern of diameter class distribution indicates the general trends in population dynamics and recruitment processes of a particular species [27]. The distribution of trees in different DBH classes was analyzed by classifying them into ten DBH classes: 1) ≤ 5 cm; 2) 5.1-10 cm; 3) 10.1-15 cm; 4) 15.1-20 cm; 5) 20.1-25 cm; 6) 25.1-30 cm; 7) 30.1-35 cm; 8) 35.1-40 cm; 9) 40.1-45 cm; and 10) > 45 by following the procedure described by [13].

(i) Height class distribution

The same to its DBH class distribution the population structure of the species by its height class distribution were analyzed; by following the procedure used by [7], an individual species occurred in the study area was classified into seven height classes: 1) 0- <2 m; 2) 2- <4 m; 3) 4- <6 m; 4) 6- <8 m; 5) 8- <10 m; 6) 10- <12 m; 7) ≥ 12 .

Regeneration data analysis: the status of regeneration of a given species in the forest were analyzed by comparing the density of seedling with sapling and sapling with matured tree data [28]. Accordingly, the regeneration status of the forest was assessed using the following categories.

- (1) "Good" regeneration, if present in seedling $>$ sapling $>$ mature tree
- (2) "Fair" regeneration, if present in seedling $>$ or $\leq$ sapling $\leq$ mature tree
- (3) "Poor" regeneration, if a species survives only in the sapling stage and tree, but not as seedlings (saplings $\leq$ or $\geq$ adults)
- (4) "None," if a species is absent both in sapling and seedling stages, but present as mature
- (5) "New," if a species has no mature, but only sapling and/or seedling stages

Finally, the population structure of the species were depicted or discussed by using bar graph, by following the procedure described by [9, 11] and regeneration status also discussed by using bar graph and frequency table, and the graph were depicted by the help of MS-excel 2010 and the table were depicted by the help of IBM SPSS version 27 software.

3. RESULTS AND DISCUSSION

3.1 Woody species composition

In total 37 woody species belonging to 16 families were identified from 48 plots. The finding of this study was similar to the results in the Metema district [29]. Fabaceae, Combretaceae, and Tiliaceae were the richer families, each represented by 13 (35.1%), 6 (16.2%), and 3 (8.1%) species respectively. Burseraceae 2 (5.4%) and Rhamnaceae 2 (5.4%) existed next to them, and the rest of the families were represented by 1 species or 2.7%. Interims of growth habit, trees were dominants (56.8%) (Fig. 3). At the individual level, the Vegetation of the area was dominated by *B. papyrifera*, *Lannea schimperi*, *Combretum molle*, and *Erythroxylum fischeri* (Table 3).

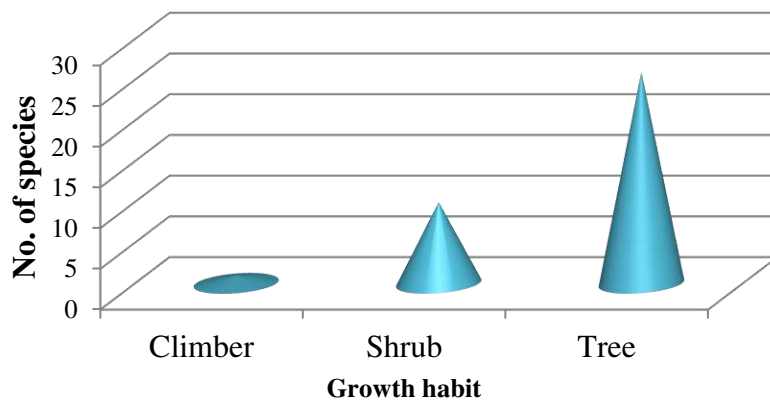


Figure 3: Growth habit of *B. papyrifera* dominated woodland

3.2 Structure of *B. papyrifera* dominated Woodland

Frequency

The most frequent species in the study area were *Combretum molle* (93.75%) followed by *B. papyrifera* (87.5%), *Lannea schimperi* (81.25%), *Erythroxylum fischeri* (75%), *Strereospermum kunthianum* (68.75%), *Ziziphus mucronata* (66.67%), *Strychnos innocua* and *Acacia seyal* (64.58%), *Anogeissus leiocarpus* (62.5%), *Combretum aculeatum* (58.33%), *Terminalia laxiflora* (54.17%) and *Acacia oerfota* (52.08%), while *Acacia seiberiana*, *Grewia villosa*, *Acacia senegal*, *Acacia nilotica*, *Grewia bicolor*, *Calpurnia aurea*, *Albizia amara*, *Commiphora africana*, *Dichrostachys cinerea*, *Maytenus arbutifolia*, *Combretum collinum*, *Carissa spinarum*, *Erythrina brucei*, *Allophylus abyssinicus* and *Diospyros abyssinica* had medium frequent (between 20-50%). But the remaining 8 species were low frequent; they appeared less than 20 % (Table 1). *B. papyrifera* was one of the most frequent species in the study area. Similar results were also reported in the Benshangul-Gumuz region, Abergelle district [13, 30]. They reported that *B. papyrifera* was first frequent species.

Density

The total density of *B. papyrifera* dominated woodland in the study area was 1306.27 stems /ha. This study consistent and comparable with the results studied from other dryland areas such as Metema and Benshangul-Gumuz districts and these results were 911 and 1064 stems/ha respectively [11, 20]. But this study incomparable with the result studied from the dryland areas such as south Omo and Metema districts and these results were 2162 and 3729 respectively [19, 31]. The density of each species was ranges from 5.21-164.58 stems/ha.

B. papyrifera was the most dense species and a density of 164.58 stems/ ha. The result of this study is consistent and comparable with [11]. They reported that the density of *B. papyrifera* were 175 and 87 stems per hectare at Lemlem Terara and Kisha, respectively. *Ziziphus mucronata*, *Strereospermum kunthianum*, *Acacia seiberiana*, *Erythroxylum fischeri*, *Acacia senegal*, *Lannea schimperi*, and *Dichrostachys cinerea* had above 100 individuals and had above

50 stems/ha. The remaining 29 species were less than 100 individuals (in abundance) and 50 stems/ha (Table 1).

Basal area

The total basal area from all plots of Boko-tabo *B. papyrifera* dominated woodland was 36.23 m²/ha. *B. papyrifera* tree contributes the highest total basal area (10.93 m²/ha) followed by *Lannea schimperi* (3.08 m²/ha), *Apodytes dimidiata* (1.99 m²/ha), *Anogeissus leiocarpus* (1.84 m²/ha), *Ziziphus mucronata* (1.56 m²/ha), *Erythroxylum fischeri* (1.37 m²/ha), *Diospyros abyssinica* (1.25 m²/ha), *Acacia senegal* (1.08 m²/ha) and *Acacia seiberiana* (1 m²/ha), and the remaining's 28 species had less than 1 m²/ha total basal area and they contributed 12.13 m²/ha (Table 3). In addition, the total average dominance of the all species was 14.86 m²/ha, from the total *B. papyrifera*, *Lannea schimperi*, *Anogeissus leiocarpus*, *Ziziphus mucronata*, *Erythroxylum fischeri*, *Diospyros abyssinica*, *Acacia senegal*, *Acacia seiberiana*, *Acacia albidia*, and *Dichrostachys cinerea* contributes 10.76 m²/ha and all had 0.5 m²/ha and above. The average dominance of the species ranged between 0.003-4.94 m²/ha, *B. papyrifera* had the highest relative dominance (Table 1). This study was similar to the result reported by [32], they reported that dominance of the species ranges from 0.01-7.1 m²/ha. In addition similar study also reported in Abergelle districts from [29]. These study had large basal area because in this study there was a minimum disturbance in the past, the distance from the forest to the household home is farthest compared to other existence area and the local communities awareness towards the species socio-cultural importance were the main reasons.

Important value index

The total importance value index of all species was 300%. Whereas some species such as *B. papyrifera* (51.2%), *Lannea schimperi* (18.06%), *Erythroxylum fischeri* (17.6%), *Ziziphus mucronata* (13.93%), *Dichrostachys cinerea* (11.73%), *Acacia seiberiana* (11.41%), *Anogeissus leiocarpus* (10.52%), *Combretum molle* (10.32%) and *Acacia senegal* (10.26%) had larger important value index. While the remaining 28 species had less than 10 % important value index and they contributes 144.97% of the total (Table 1). The higher important value index indicates the species have high ecological importance, and needs regular monitoring for the species sustainability. *B. papyrifera* was the first ranked important value index species, this indicates the species were one of a significant ecological importance and the more valued species compared to others. This study was in line with other studies in the drylands of Ethiopia [13, 29, 33, 34].

Table 1: Frequency, relative frequency, density, relative density, basal area, dominance, relative dominance and important value indices of the species

Scientific Name	FR	RFR	D	RD	BA	DO	RDO	IVI
<i>Boswellia papyrifera</i>	87.5	5.36	164.58	12.6	10.93	4.94	33.24	51.2
<i>Apodytes dimidiata</i>	58.33	3.57	28.13	2.15	1.99	0.49	3.3	9.02
<i>Ziziphus mucronata</i>	66.67	4.08	67.19	5.14	1.56	0.7	4.71	13.93
<i>Strereospermum kunthianum</i>	68.75	4.21	57.29	4.39	0.38	0.17	1.14	9.74
<i>Acacia seiberiana</i>	47.92	2.93	65.1	4.98	1	0.52	3.5	11.41
<i>Acacia albidia</i>	14.58	0.89	13.54	1.04	0.1	0.53	3.57	5.5
<i>Acacia bussei</i>	54.17	3.32	17.19	1.32	0.26	0.05	0.34	4.98

<i>Combretum molle</i>	93.75	5.74	48.44	3.71	0.88	0.13	0.87	10.32
<i>Combretum aculeatum</i>	58.33	3.57	14.06	1.08	0.16	0.03	0.2	4.85
<i>Terminalia laxiflora</i>	54.17	3.32	22.4	1.71	0.54	0.16	1.08	6.11
<i>Erythroxylum fischeri</i>	75	4.59	107.29	8.23	1.37	0.69	4.78	17.6
<i>Grewia villosa</i>	31.25	1.91	17.71	1.36	0.15	0.04	0.27	3.54
<i>Strychnos innocua</i>	64.58	3.95	29.17	2.23	0.63	0.14	0.94	7.12
<i>Acacia senegal</i>	39.58	2.42	53.13	4.07	1.08	0.56	3.77	10.26
<i>Ximennia americana</i>	14.83	0.91	22.4	1.71	0.28	0.14	0.94	3.56
<i>Acacia nilotica</i>	14.83	0.91	46.35	3.55	0.9	0.47	3.16	7.62
<i>Acacia seyal</i>	64.58	3.95	32.81	2.52	0.6	0.1	0.67	7.14
<i>Grewia ferrugineae</i>	10.42	0.64	18.23	1.4	0.38	0.2	1.35	3.39
<i>Ficus sycomorus</i>	18.75	1.15	18.23	1.4	0.39	0.2	1.35	3.9
<i>Grewia bicolor</i>	31.25	1.91	31.77	2.23	0.81	0.42	2.84	6.98
<i>Acacia oerfota</i>	52.08	3.19	17.71	1.4	0.24	0.04	0.27	4.86
<i>Acacia etbaica</i>	56.25	3.44	32.81	2.52	0.85	0.17	1.14	7.1
<i>Calpurnia aurea</i>	22.92	1.4	13.02	1	0.12	0.06	0.4	2.8
<i>Albizia amara</i>	37.5	2.3	11.98	0.92	0.21	0.04	0.27	3.49
<i>Commiphora africana</i>	31.25	1.91	23.96	1.93	0.42	0.23	1.55	5.39
<i>Lannea schimperi</i>	81.25	4.97	84.9	6.5	3.08	0.98	6.59	18.06
<i>Dichrostachys cinerea</i>	41.67	2.55	76.04	5.82	0.96	0.5	3.36	11.73
<i>Rhamnus staddo</i>	14.58	0.89	7.29	0.56	0.02	0.003	0.02	1.47
<i>Maytenus arbutifolia</i>	33.33	2.04	8.33	0.64	0.02	0.01	0.07	2.75
<i>Combretum collinum fresen.</i>	43.75	2.68	24.48	1.87	0.72	0.15	1.01	5.56
<i>Carissa spinarum</i>	43.75	2.68	16.15	1.24	0.06	0.01	0.07	3.99
<i>Erythrina brucei</i>	37.5	2.3	34.9	2.67	0.5	0.2	1.35	6.32
<i>Capparis tomentose</i>	16.67	1.02	5.21	0.4	0.02	0.004	0.03	1.45
<i>Albizia schimpernia</i>	16.67	1.02	9.38	0.72	0.54	0.28	1.89	3.63
<i>Allophylus abyssinicus</i>	45.83	2.81	15.1	1.17	0.99	0.14	0.94	4.92
<i>Anogeissus leiocarpus</i>	62.5	3.81	27.08	2.07	1.84	0.69	4.64	10.52
<i>Diospyros abyssinica</i>	27.08	1.66	22.92	1.75	1.25	0.65	4.38	7.79
Total	1633.82	100	1306.27	100	36.23	14.86	100	300

D =density (stems/ha); RD= relative density (%); F = frequency (%); RF = relative frequency (%); BA= basal area of the tree/ all quadrants (48)
DO= dominance (m²); RDO= relative dominance (%); IVI = importance value index (%)

3.3 Diameter and Height class distribution

Diameter class distribution

Population structure of *B. papyrifera* dominated woodland shows an inverted J-shape or the woodland had normal population structure (their lower DBH class was greater than the middle and higher DBH class, and it indicates their saplings and trees progressively decline).

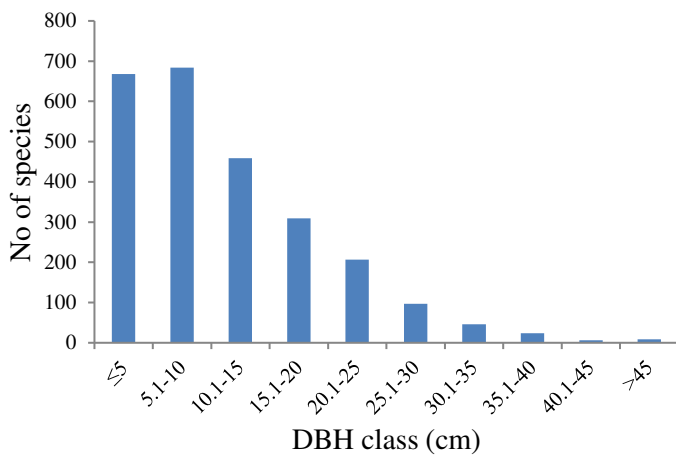


Figure 4: Population structures of *B. papyrifera* dominated woodland based on DBH class

Population structure of each species shows three (an inverted J-shape, J-shape and bell-shaped) general DBH class distribution patterns, the first species such as *Apodytes dimidiata*, *Ziziphus mucronata*, *Strereospermum kunthianum*, *Acacia bussei*, *Combretum molle*, *Terminalia laxiflora*, *Erythroxylum fischeri*, *Strychnos innocua*, *Acacia oerfota*, *Acacia etbaica*, *Lannea schimperi*, *Dichrostachys cinerea*, *Maytenus arbutifolia*, *Combretum collinum*, *Allophylus abyssinicus*, *Anogeissus leiocarpus*, *Lannea schimperi*, *Ximennia americana*, *Ficus sycomorus*, *Grewia bicolor*, *Commiphora africana*, *Rhamnus staddo*, *Erythrina brucei* and *Carissa spinarum* was an inverted J shaped patterns. Only *Capparis tomentose* species shows the second patter (J-shape structure); this indicates the species are at risk of extinction because the species existed in the smaller amount at seedling and sapling stage.

While *Albizia schimpernia*, *Albizia amara*, *Acacia seyal*, *Calpurnia aurea*, *Grewia ferrugineae*, *Acacia nilotica*, *Acacia Senegal*, *Combretum aculeatum*, *Acacia seiberiana*, *Acacia albidia*, *Boswellia papyrifera* and *Diospyros abyssinica* were bell-shaped structure (Figure 4). The bell-shaped diameter distribution indicates that the species' regeneration is under risky and the species is considered to be at high risk for its continued existence [35].

The population structure of *B. papyrifera* based on DBH class distribution in the study area were bell-shaped this implies there was a good regeneration in the past but currently the disturbance effect increases in the area and its regeneration becomes risky. This result similar to several researchers result in Sudan, Eritrea and Ethiopia [9] and [36] in Sudan, [37] in Eritrea, and Ethiopia; [11] in Lemlem and Kisha Terara of Metema district, [38] in Metema district, [30] in Benishangul-Gumz region, [39] in Jawi district, [19] in Metema district, [13] in Abergelle district). However [11] in Lemlem Terara, [9] and [32], [36] did not get lower class DBH. But in this study there have been lower DBH classes (<5 cm) so the result of this study was more in line with the result of [[11] in *kisha terara*; [37, 38, 30, 19]]. In addition, [40], get a normal population structure (there were DBH less than 5 cm) in Benshangul-Gumz region so this result also comparable with he's result, the only difference is amount of seedlings existence.

In this study the DBH of *B. papyrifera* ranges from 1-44 cm (Figure 4), this study was consistence and comparable with [9, 11, 12, 19, 39] and different from [13, 33, 41] because they reported that complete absence of trees with $DBH \geq 35$ cm.

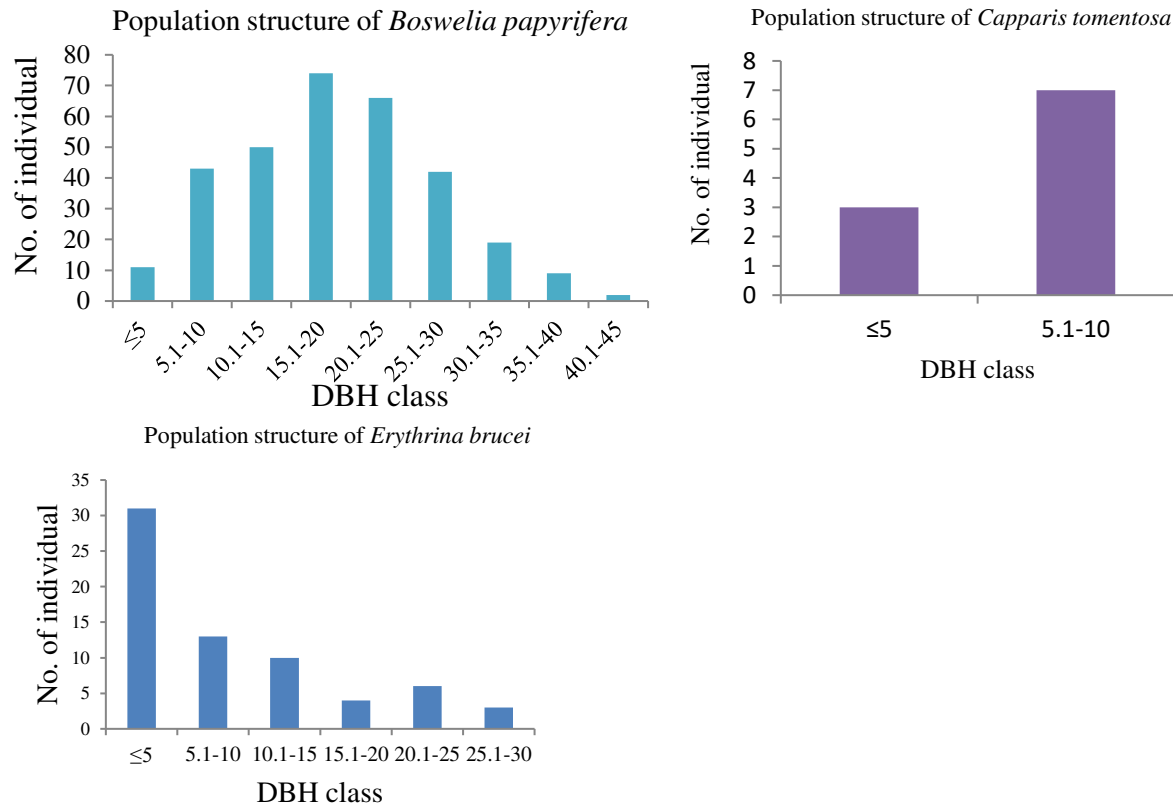


Figure 5: Population structure of the selected species based on DBHs class (cm)

Height class distribution

Based on their height class's *B. papyrifera* dominated woodland shows an inverted J-shape.

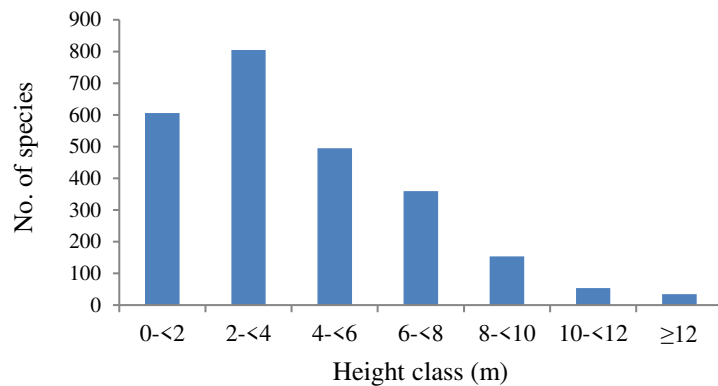


Figure 6: Population structure of *B. papyrifera* dominated woodland based on hieght class

In general, the species *B. papyrifera* dominated woodland shows three patterns; first patterns considered as inverted J shape, second patterns considered as bell-shaped and third patterns also considered as J shape (Figure 5).

The first patterns (an inverted J shape or normal population structure) described by such species; *Apodytes dimidiata*, *Ziziphus mucronata*, *Strereospermum kunthianum*, *Combretum molle*, *Erythroxylum fischeri*, *Lannea schimperi*, *Maytenus arbutifolia*, *Combretum collinum*, *Allophylus abyssinicus*, *Anogeissus leiocarpus*, *Lannea schimperi*, *Ximennia americana*, *Ficus sycomorus*, *Grewia bicolor*, *Commiphora africana*, *Erythrina brucei*, *Acacia seyal*, *Terminalia laxiflora*, *Carissa spinarum*, *Albizia schimpernia* and *Acacia senegal*. As [42] the decrease in the number of each size class towards the highest classes showed that in the forest there was a dominance of small individuals, which was characteristic of the normal forest.

The second pattern (bell-shaped or abnormal population structure) described by some species such as *Albizia amara*, *Rhamnus staddo*, *Acacia bussei*, *Strychnos innocua*, *Acacia oerfota*, *Acacia etbaica*, *Dichrostachys cinerea*, *Calpurnia aurea*, *Grewia ferrugineae*, *Acacia nilotica*, *Acacia seiberiana*, *B. papyrifera*, and *Diospyros abyssinica* and,

The third pattern (J-shape or abnormal population structure) despite by *Capparis tomentose*, *Combretum aculeatum*, *Acacia albidia*, and *Grewia villosa*.

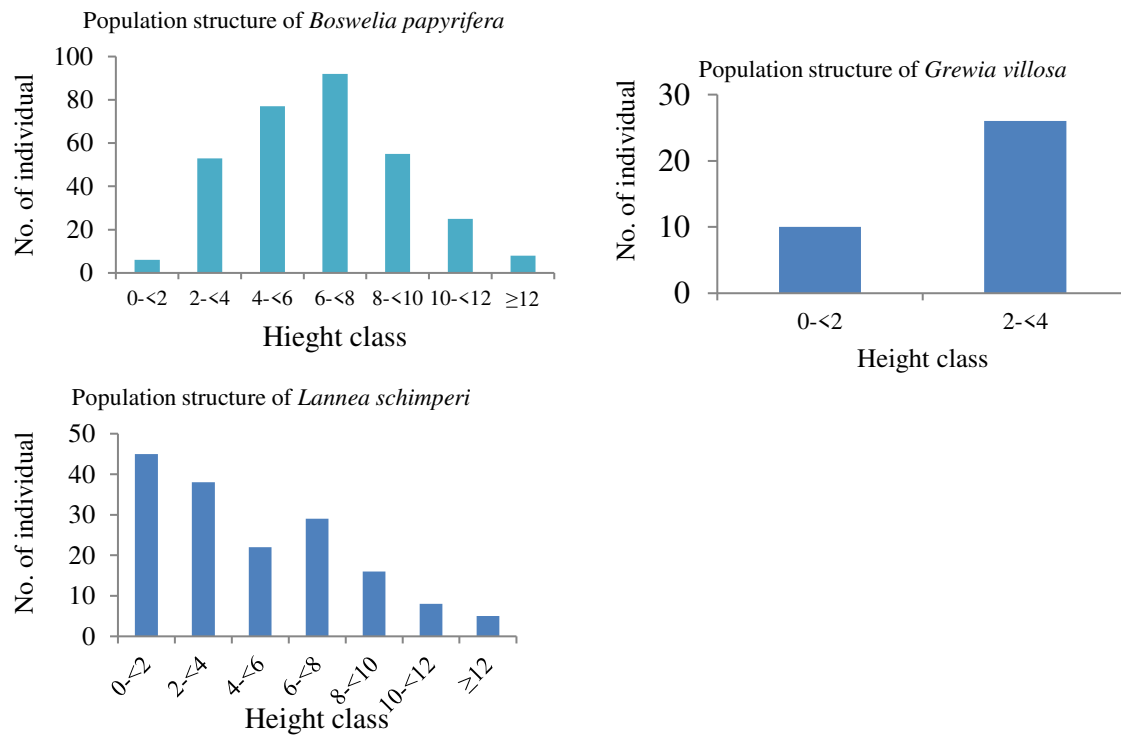


Figure 7: Population structure of the selected species based on height class (m)

3.4 Regeneration Status of *B. papyrifera* dominated woodland

The future composition of forests depends on the potential regeneration status of individual species within a forest stand in space and time [43]. In this study a total of 2508 individuals; from them, 632 seedlings (329.1 stems/ha), 643 saplings (334.9 stems/ha), and 1231 trees (643.1 stems/ha) were counted in the whole plots of the sample site. The regeneration status of the *B.*

papyrifera dominated woodland was fair because seedling $>$ or $\leq$ sapling $<$ tree thus its regeneration was under risk of extinction or hampered (Figure 6). Lower individuals of seedlings and saplings indicated the forest population is unstable and the presences of disturbances within the area. From the group discussion, the major causes of lower individual of seedlings and saplings were indicated that clearance of small trees and shrubs for agricultural activities (they reported that now a days, the nearest communities starts agricultural expansion in some flat areas of the woodland), grazing, infrastructure, fire problem and selective cutting fore fence and fuelwood.

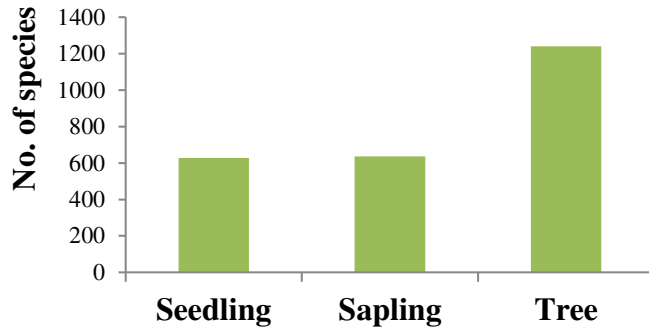


Figure 8: Proportion of seedlinds, saplings and trees of *B. papyrifera* dominated woodland

Accordingly, ten species with the largest contribution to seedling and sapling were *Combretum molle*, *Erythroxylum fischeri*, *Lannea schimperi*, *Strereospermum kunthianum*, *Acacia senegal*, *Erythrina brucei*, *Combretum collinum*, *Dichrostachys cinerea*, *Ziziphus mucronata*, and *B. papyrifera* while *Albizia schimpernia*, *Capparis tomentose*, *Diospyros abyssinica*, *Albizia amara*, *Combretum aculeatum* and *Rhamnus staddo* contributed lower number of seedlings and saplings. The study species had only good and faire regeneration status. An individual species such as *Erythroxylum fischeri*, *Erythrina brucei*, *Strereospermum kunthianum*, and *Rhamnus staddo* had good regeneration status whereas other 33 species had fair regeneration status because their seedling $>$ or $\leq$ sapling $<$ tree.

The target species, *B. papyrifera* have been fair regeneration status. This study was consistent and comparable with [12, 20, 37, 40], contradicts with [9, 11]. Also this study similar with the result of [30], they reported that *B. papyrifera* had a bell-shaped population structure with low densities of individual at the lowest and highest diameter classes and relatively high number of density in the middle classes. The reason why this study get fair regeneration status was due to the low population number of the local communities, distance from *B. papyrifera* existence to household's residences (they were between 1.5- 3.5 km), low tapping activities (investors did not tape from starting of conflict between Tigray region and Ethiopia up to now), local communities had low knowledge on the species importance and they did not want the species for their livelihoods. According to [8] study in Eritrea, seeds collected from untapped trees had 80% germination and seeds collected in tapped tree had less than 6% germination rate.

4. CONCLUSION AND RECOMMENDATIONS

Population structure of *B. papyrifera* woodland illustrates that natural regeneration of the species good in the past but due to disturbance nowadays the status was under risky. The regeneration

status also some species had good status but majorities had fair, it implies the woodland futurity will be under risky so wisely utilization and conservation is needed to sustain the woodland. The species such as *B. papyrifera*, *Allophylus abyssinicus*, and *Acacia species* had large IVI, and their population structure revealed bell-shaped but had fair regeneration status. The higher important value index indicates the species had an ecological importance so regular monitoring activities should be applying for species sustainability.

Individual tree species are the potential stock for future genetic resources, and would have a great implication for the environment, the whole forest population status, and ecological and socio-economic importance. To minimize the effects of anthropogenic disturbance in the forest, and to sustain the benefits of the forest resources in the long term inclusion of local communities in the forest conservation and management activities is the realistic and an evidenced option. Based on the result of the study, the following recommendations were drawn: The finding showed that the population structure of large IVI species was bell-shaped so to sustain such species regular monitoring and conservation activities should be implemented, the finding revealed that the regeneration status of majority species within woodland were fair means there is an anthropogenic disturbance so to minimize the effects of these disturbance participatory forest management activities should be implement, and the finding revealed that all households used more forest products than NTFP so awareness of to use NTFPs and sustainable utilization interventions related to deforestation and forest degradation reduction should be created within each village.

The present study was limited to the population status of *B. papyrifera* dominated woodland, and then further studies on the local communities perception towards *B. papyrifera* dominated woodland is recommended.

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Disclosure statement

No potential conflict of interest will be reported by the authors.

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