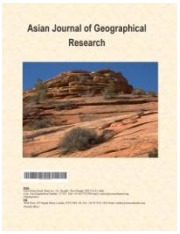

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Regeneration Status and Importance of *Hyphaene thebaica* L. (Doum Palm) and Associated Species in Tekeze Riverine Vegetation of the North Western Zone of Tigray, Northern Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Author KA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors KA and KG collected the data. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of the study was to investigate the regeneration status and importance of *Hypahene thebaica L.* and associated species in Tekeze riparian vegetation of the North western zone of Tigray, Northern Ethiopia.
Study Design: Systematic sampling technique.
Place and Duration of Study: The study was carried out along Tekeze riverine vegetation, northern Ethiopia between January 2015 and March 2015.
Methodology: Three transects (one and two transects on the right and left side of the Tekeze River, respectively) were laid. The distance between the two transects on the left side of the river was 200 m. Along the transects, 30 plots were established systematically at intervals of 100 m to collect vegetation data.
Results: Eighteen plant species belonging to 12 families were recorded. Fabaceae was found to be the dominant family in the study area and were represented by five species, which contributed to

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27.7% of the total species documented, whereas nine families were represented by one species each. The overall density of the study area was 70.97 individuals/ha. *Hyphaene thebaica* was the second abundant species with 16.13 individuals/ha, and contributed 22.7% to the total density of the riparian vegetation. The total basal area of plants was 1.03 m^2 $ha^{-1.}$ *Hyphaene thebaica* was ranked third and accounts for 12.6% of the total basal area with 0.13 m^2 ha^{-1}. The species was the most frequent with 17.02%, followed by *Ricinus communis* and *Balanites aegyptiaca. Balanites aegyptiaca* (53.52%), *H. thebaica* (52.37%) and *Ricinus communis* (51.76%) were the three most important species.

Conclusion: More mature trees were documented than saplings and seedlings, indicating "poor'' re generation status for the riparian vegetation. *Hyphaene thebaica* has shown "fair'', while most species were found to have "poorly'' or "no'' regenerating. Hence a sound management plan is urgently required to sustainably utilize and conserve the riverine vegetation.

Keywords: Associated species; Hyphaene thebaica; importance value index; regeneration; riverine.

1. INTRODUCTION

Palms are an important commodity to most of the population in warmer areas of the world as providers of food and fodder [1]. *Hyphaene thebaica*, commonly known as 'doum palm', is a type of palm tree that is an extremely useful multipurpose tree in arid and semi arid regions. The trunk of the palm is used as parts of the manufacture of domestic utensils, leaves are widely used for weaving mats, bags, baskets, and coarse textiles, amongst other, while its fruits are edible [2]. In the recent years, there has been growing commercial interest in this species. Due to its many uses, it has been over exploited, and is listed by the International Union for Conservati on of Nature as an endangered species [3].

Investigating the regeneration status of a species can reveal important insights regarding vegetation dynamics [4], which is important for sustainable biodiversity conservation, not only depicts the current status, but also hints about the possible changes of the species about the future, determines the geographical distribution of the species.

The few studies that have been carried out on Hyphaene thebaica have mostly focused on antimicrobial studies and phytochemical screening of extracts [5]; physical properties [6] and seed scarification requirement of the species [7]. Because of the severe exploitation of this species in the North western zone of Tigray, Northern Ethiopia, there is an urgent need to investigate its regeneration status to draft sustainable use management policies. For this reason, this study attempts to assess the regeneration status and importance of Hyphaene thebaica in the Northwestern zone of Tigray, Northern Ethiopia. In addition, for comparison purpose and to show the relative regeneration status and importance of Hyphaene thebaica, all associated species were also investi-gated.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Tahtay Adiabo District, Adi-Aser peasant association, along the Tekeze River, northern Ethiopia between January 2015 and March 2015. The district is located between 37021'13"E to 38010'33"E longitude and 14031'34"N to 14051'42"N latitude at an elevation of 800-1500 masl [8]. It is bounded by the districts of Laelay Adyabo to the east, Kafta Humera to the west, Asgede Tsimbla to the south and Eritrea to the north. The district has area coverage of 253,655 ha, out of which 60,017 ha is cropland. 42,778 ha is covered by forest and the rest is homestead and wasteland [9]. The study area was once covered with natural forest, but because of various human activities like cultivation, grazing, and wood cutting the natural vegetation have been reduced to a few scattered clumps of Acacia-Balanites-Ziziphus-Combretum trees/bushes [10]. The district is divided in to three major agroecological zones, hot to warm semi arid low lands, hot to warm sub moist low lands and tepid to cool moist mid highlands. The weather of the district is generally hot with a mean annual temperature of 28.5°C. The mean annual maximum temperature and the mean annual minimum temperature are 37.6 and 20.2°C, respectively [8].

2.2 Vegetation Data Collection

Vegetation data were collected using a systematic sampling technique on both sides of

Tekeze river bank. Three transect lines, one transect right and two transects left-side of the main river of Tekeze were laid parallel to the direction of the Tekeze river. Ten (right side of river), nine and eleven (left side of river) plots (a total of 30 plots), measuring 20 m x 20 m (400 m^2) [11,12] were placed at 100 m intervals. The distance between the two transects on the left-side of the river was 200 m. Thus, the length of the transects on the right side was 900 m and the length of the transects on the left side of the river was 800 m and 1 km. The transects and plots were about 10 m far from the edge of the river. The number of transects on each side of the river was dependent on the size of the vegetation from the edge of the river to the adjoining upland and the number of plots per transect was dependent on the length of the transect. In each plot, individuals of *Hyphaene thebaica* were counted. All associated species were also identified and recorded by their local name.

2.3 Data Analysis

The status of populations of *H. thebaica* and associated species was examined by estimating dominance, density, frequency, importance value index (IVI) and counting the number of seedlings, saplings, and mature trees.

Density: This refers to the total number of individ uals of a species/ha was computed by summing up all the individuals from all sample plots and translated to a hectare base for all the species. Two sets of density were calculated: density/ha of each species and relative density, calculated as the ratio of the density of a given species to the sum total of the density of all species (Eq. 1).

$$\text{Relative density} = \frac{\text{Density of species A in hectare base}}{\text{Density of all species in hectare base}} * 100 \quad (1)$$

Frequency: It shows the presence or absence of a given species in each sample quadrat. Two sets of frequency were calculated, absolute frequency, which refers to the number of plots in which the species encountered and relative frequency, calculated as the ratio of the absolute frequency of a given species to the sum total of the frequency of all species (Eq. 2).

$$\text{Relative frequency} = \frac{\text{Freqency of species A}}{\text{Frequency of all species}} * 100 \quad (2)$$

Dominance: It refers to the degree of coverage of a given species expressed by a space it occupied in a given area. Two sets of dominance were calculated: absolute dominance (the sum of basal areas of the stems in m^2/ha), and relative dominance: the ratio of the total basal area of a given species to the sum of total stem basal areas of all species.

$$\text{Relative dominance} = \frac{Dominance of species A}{Dominance of all species} * 100 \quad (3)$$

Basal area (BA) was computed using the formula (Eq 4):-

$$BA = \frac{\pi d^2}{4} \quad (4)$$

Where BA = basal area in m^2; π=3.14; D = diameter.

Importance Value Index (IVI): The IVI refers to the relative ecological importance of each species in a given area. It was calculated by summing up the relative dominance, relative density and relative frequency of the species [13] as follows:

$$IVI = Rd + RD + RF \quad (5)$$

Where Rd is relative density, RD is relative dominance and RF is relative frequency.

Regeneration status: To assess the regeneratio n status, seedlings, saplings and mature trees of the species encountered in the sample plots were counted. Species having a height of < 0.5 m, 0.5-3 m and > 3 m were counted as seedlings, saplings and trees respec-tively.

3. RESULTS AND DISCUSSION

3.1 Floristic Composition

Eighteen woody plants belonging to 12 families were recorded, out of which 12, 5 and 1 were trees, shrubs and a grass species respectively. In other words, 11 tree species, 5 shrub species and 1 grass species were encountered in association with the study species, *Hyphaene thebaica* (Table 1). Species composition found in this study is very low compared to a study conducted by Belachew [11] in Beschillo and Abay (Blue Nile) riverine vegetation, Ethiopia (205 species and 53 families) and Meragiaw et al. [14] in riparian vegetation along the Walga River, Southwestern Ethiopia (99 plant species belonging to 45 families). This may be due to envronmental limitations su-ch as low and erratic rainfall and human intervention in the area. Nonetheless, it was higher than reported by Gebrehiwot [15], in selectedareas of northern Ethiopia woodlands (13 species) and Idrissa et

al. [16], in parkland agroforests in western Niger (13 species and 7 families), where Hyp-haene thebaica was reported as one of the dominant species. This variation in species composition among different study areas may be due differences in the level of human disturbance and agroecology.

Fabaceae was found to be the dominant family in the study area represented by five species. This shows that the family contributed to 27.7% of the species composition (Fig. 1). This indicates that thestudy area is favorable for the family. Acacia species represented the greatest proportion of the dominant family, Fabaceae, with four species. Palmae (the family in which the study species, *Hyphaene thebaica*, belongs) and Combretaceae were the second diverse families, each represented by two species, while, 9 of the 12 families were represented by only one species each (Fig. 1). This revealed that the vegetation was dominated by a few families. The dominance of Fabaceae was reported from previous studies [16,17].

3.2 Density, Frequency, Dominance and Importance Value Index (IVI)

The overall density of the vegetation was 70.97 individuals/ha (Table 1). Ricinus communis and *Hyphaene thebaica* were the denser species with 22.58 and 16.13 individuals/ha respectively. This indicates that these two species contributed to 54.5% of the total density of the vegetation. The study species, *Hyphaene thebaica*, alone contributed to 22.7% of the total abundance which exhibited nearly as many individuals per hectare (16.13 individuals ha–1) as the sum of the next 5 abundant species (18.55 individuals ha1) (Table 1). The density among other species ranged between 0.86.45 per ha, with most species (72.2%) having density values of less than 3 individuals per ha (Table 1).On the other hand, 16 species (those ranked from 3rd18th) accounted for 45.5% of the total density. The wide range difference of density among species may be due to selective logging and browsing of species. The dominance of *Hyphaene thebaica*, in terms of abundance, in this study agrees with a study conducted by Idrissa et al. [16], who indicated that the species, with a relative density of 11.27%, was found to be the second abundant species in Western Niger.

As shown in Table 1, the total basal area of the plants was 1.03 m^2 ha^{-1} (Table 1), which was found to be lower compared with what was reported from Beschillo and Abay (Blue Nile) riverine vegetation [12.6 m^2/ha] [11]; riverine forest of the Royal Bardia national park, Nepal [19.52 m^2/ha] [18] and riverine forest in Uganda [25.5 m^2/ha] [19]. Nevertheless, it was greater than that of the Hallideghie wildlife reserve, northeast Ethiopia (BA=0.99 m^2/ha [12] and Ylat Forest (BA=1 m^2 ha^{-1} [20]. The three dominant species were Balanites aegyptiaca, Acacia bussei and Hyphaene thebaica with 0.37, 0.17 and 0.13 m^2ha-1 respectively and collectively accounts for 65% of the total basal area. This shows that Hyphaene thebaica was one of the top three species and it accounts for 12.6% of the total basal area of the vegetation.

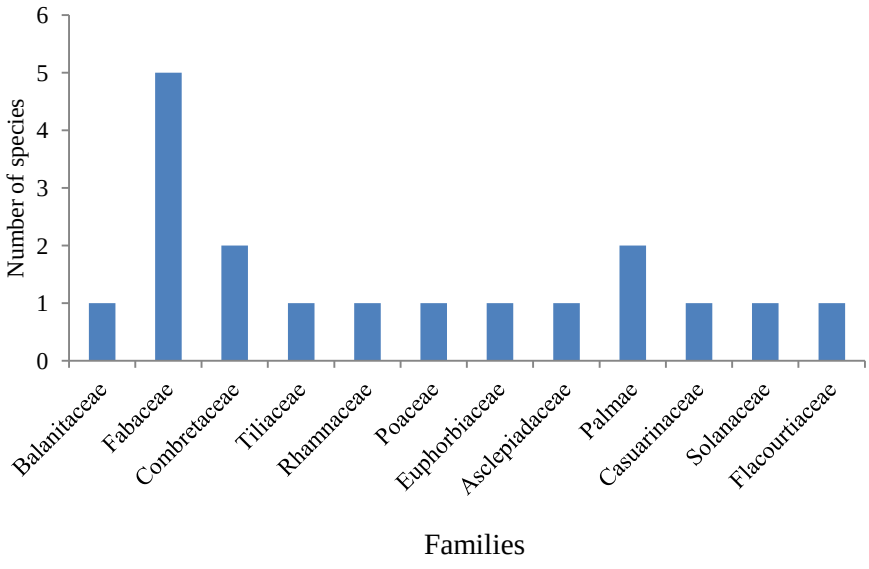

Fig. 1. Proportions of families species composition

Table 1. Abundance (Ab), relative abundance (RA %), density per hectare (den./ha), relative density (R.den(%), dominance per hectare (Dom(m^2/ha), relative dominance (R.Dom(%), frequency (Fre.), relative frequency (R. Fre (%) and Importance Value Index (IVI%) of *Hypahene thebaica* and associated species

Species scientific name	Local name	Family	den./ha	R. den (%)	Dom.(m^2/ha)	R. Dom (%)	Fre.	R. Fre (%)	IVI (%)
Balanites aegyptiaca	Mekie	Balanitaceae	6.45	9.09	0.37	35.92	4.00	8.51	53.52
Acacia abyssinica	Chea	Fabaceae	4.03	5.68	0.08	8.16	3.00	6.38	20.22
Acacia etbaica	Seraw	Fabaceae	1.61	2.27	0.12	11.65	2.00	4.26	18.18
Combretum fragrans	Tenkeliba	Combretaceae	0.81	1.14	0.02	1.55	1.00	2.13	4.82
Grewia villosa	Habeney	Tiliaceae	0.81	1.14	0.00	0.39	1.00	2.13	3.65
Ziziphus spina- christi	Gaba	Rhamnaceae	3.23	4.55	0.01	0.68	4.00	8.51	13.74
Anogeisus leocarpus	Hanse	Combretaceae	0.81	1.14	0.00	0.29	1.00	2.13	3.56
Oxytenanthera abyssinica	Arqay	Poaceae	0.81	1.14	0.00	0.29	1.00	2.13	3.56
Ricinus communis	Gulie	Euphorbiaceae	22.58	31.82	0.05	5.05	7.00	14.89	51.76
Calotropis procera	Gindae	Asclepiadaceae	1.61	2.27	0.00	0.29	2.00	4.26	6.82
Hyphaene thebaica	Arkobkobay	Palmae	16.13	22.73	0.13	12.62	8.00	17.02	52.37
Phoenix reclinata	Sye	Palmae	2.42	3.41	0.01	0.78	1.00	2.13	6.31
Acacia bussei	Gomoro	Fabaceae	2.42	3.41	0.17	16.50	3.00	6.38	26.30
Casuarina equisetifolia	Shewshewe	Casuarinaceae	0.81	1.14	0.06	5.83	1.00	2.13	9.09
Dichrostachys cinearea	Gonoq	Fabaceae	2.42	3.41	0.00	0.00	3.00	6.38	9.79
Solanum incanum	Solanaceae	Engule	0.81	1.14	0.00	0.00	1.00	2.13	3.26
Acacia senegal	Qenteb	Fabaceae	1.61	2.27	0.00	0.00	2.00	4.26	6.53
Dovyalis abyssinica	Harmazo	Flacourtiaceae	1.61	2.27	0.00	0.00	2.00	4.26	6.53
Total			70.97	100	1.03	100	47	100	300

Table 2. Density/ha of seedlings, saplings, mature trees and regeneration status of *Hyphaene thebaica* and associated species in the study area

Plant species	Density/ha			Regeneration status
	Seedlings	Saplings	Mature trees	
Balanites aegyptica	0.81	0.81	4.84	Fair
Acacia abyssinica	0.81	1.61	1.61	Poor
Acacia etbaica	-	-	1.61	None
Combretum fragrans	-	-	0.81	None
Grewia villosa	-	-	0.81	None
Ziziphus spina- christi	-	1.61	1.61	Poor
Anogeisus leocarpus	-	-	0.81	None
Oxytenanthera abyssinica	-	-	0.81	None
Ricinus communis	0.81	1.61	20.16	Poor
Calotropis procera	-	0.81	0.81	Poor
Hyphaene thebaica	5.65	9.68	0.81	Fair
Phoenix reclinata	-	-	2.42	None
Acacia bussei	-	-	2.42	None
Casuarina equisetifolia	-	-	0.81	None
Dichrostachys cinearea	-	2.42	-	New
Solanum incanum	-	0.81	-	New
Acacia senegal	-	1.61	-	New
Dovyalis abyssinica	-	1.61	-	New
Overall	8.06	22.58	40.32	Poor

The relative basal area of the species in this study (12.6%) was far higher than that of western Niger [0.35%] [16]. Hence, *Hyphaene thebaica* can be seen as ecologically significant and pathogen resistance in the study area [21].

Analysis of species specific frequency of occurrence across the sampling plots showed that *Hyphaene thebaica* was the most frequent species followed by Ricinus communis and Balanites aegyptiaca with the relative frequency of 17.02, 14.89 and 8.51% respectively. The three species together contributed to over 40% of the cumulative relative frequency of the entire species. Whereas, seven species appeared to be disproportionately the least frequent and occurred only in one plot (Table 1). The high distribution of *Hyphaene thebaica* across the plots was consistent with a report from western Niger (relative frequency of 15.2%) [16]. The authors reported that the species was ranked second in parkland agroforests.

The importance value index reflects the extent of the relative dominance, relative frequency and relative density of a given species in relation to other species in an area. In the present study, IVI of species varied from 3.26 (1.08% of the total IVI) to 53.52 (17.84%). Three species contributed over 52.55% of the IVIs: Balanites aegyptiaca (53.52%), *Hyphaene thebaica* (52.37%) and Ricinus communis (51.76%) (Table 1). Over half of all the species [11 (64.7%) species] had IVI of less than 10%. This indicates that the study species, *Hyphaene thebaica* is the second important species in the study area. This coincides to a finding by Idrissa et al. [16], from parkland agro forests of western Niger, who reported that the species is ranked third in its importance value index, next to Balanites aegyptiaca and Faidherbia albida. The higher value of IVI of Balanites aegyptiaca in this study goes well with a study conducted in Niger [16], but contrasts to that of the central rift valley of Ethiopia [22], which demonstrated that the species was among the species with low IVI.

3.3 Regeneration Status

Regeneration status of tree species was analyzed on the basis of population size of seedlings, sapling, and mature trees following Dhaulkhadi et al. [23] in the following categories: If a forest has seedlings >saplings >adults, it is in a good regeneration; if seedlings> or ≤ saplings ≤ adults, fair regeneration; if the species survives only in sapling stage, but no seedlings (saplings may be or = adults), poor regeneration; If a species is present only in an adult form it is considered as not regenerating; species is considered as new if the species has no adults but only seedling or saplings. As shown in Table 1, the total density of plant species in all the 30 sample plots of the

study area was 70.97 individuals/ha, of which, seedlings, saplings, and trees were 8.06, 22.58 and 40.32 individuals/ha respectively (Table 2), which indicates ‘’poor’’ regeneration status. Four species were represented by seedlings, whereas, the remaining 14 species were not found in the seedling stage. In terms of seedlings, the study species, *Hyphaene thebaica*, was the denser species with 5.65 individuals/ha, which accounted for about 70% of the total density of seedlings (Table 2). The sapling stage was composed of 10 species covering 31.8% of the plant species. Similar to seedlings density trend, the denser species, in terms of saplings was *Hyphaene thebaica* with 9.68 individuals/ha accounting for about 42.9% of the total sapling density of the study area. This indicates that the density of saplings and seedlings were dominated by one species. 14 species were found at the mature trees stage, which accounts for 56.8% of the total density, while 4 species were absent at this stage (Table 2).

Analysis of species-specific regeneration status showed that, out of the 18 species, none of them achieved ‘’good’’ regeneration, two (11%) species namely Balanites aegyptiaca and the study species, *Hyphaene thebaica*, had “fair’’ regeneration, four species (22.2%), namely Acacia abyssinica, Ziziphus spina christi, Ricinus communis, and Calotropis procera demonstarated ‘’poor’’ regeneration, eight (44.4%) species lacked regeneration and four (22.2%) were appearing as new re-generating species (Table 2). The reason for the poor and lack of regeneration of most of the tree species may be due to some anthropo-genic disturbances such as fuel wood collection and grazing. According to Singh et al. [24], overgrazing by livestock harms the ground flora and hinders the regeneration of tree species.

4. CONCLUSIONS AND RECOMMENDA-TIONS

The finding of this study elucidated that the study area is low in its species composition, with 18 species belonging to 12 families. *Hyphaene thebaica* was found to be one of the most important tree species. The contribution of mature trees to the total population was highest followed by saplings and seedlings. It shows that the overall regeneration status of tree species in the study area is “poor”, maybe due to human intervention and overgrazing in the study area. Seedlings and sapling’s contributions vary considerably among species. *Hyphaene thebaica* has shown “fair” regeneration status with more individuals were recorded at the saplings stage. While most of the species showed “poor” or “no” regeneration. The growth and reproduction potential of these tree species is at risk in the future. Therefore, a sound management plan must be implemented for sustainable utilization and conservation of the tree species in the riverine vegetation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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