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Analysis of Composition and Diversity of Natural Regeneration of Woody Species in Jebel El Gerrie Dry Land Forest East of Blue Nile State, Sudan

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Abstract

The study aims to assess composition, diversity and population indices of natural regeneration of woody species in Jebel El Gerrie forest reserve, Blue Nile State, Sudan. We conducted field work between December 2018 and January 2019. We used random sampling to collect vegetation data in the forest where we made a total of 90 circular sample plots (radius 17.84 m) and distributed them proportionally to the area of each of the four density-based vegetation classes of the forest i.e. high density (C1), medium density (C2), low density (C3) and crop land (C4). In each sample plot we identified all regenerating tree species and counted their regeneration frequencies. We calculated ecological metrics of regeneration frequency, density, abundance, richness, evenness, diversity and importance value index (IVI) and drew abundance rank curve. Results revealed that out of fifteen mature tree species present, natural regeneration of 8 species, which belong to 6 families, was observed. The relatively most frequently naturally regenerating and abundant species were *Anogeissus leiocarpa* and *Combretum hartmannianum*. Richness, evenness and diversity of regenerating species were 1.33, 0.82 and 1.7, respectively. One-way ANOVA (α=0.05) of mean regeneration densities disclosed that there were significant differences ($F_{3,86}$=16.77, p=0.000) between C2 & C3 (p=0.000) and C2 & C4 (p=0.000). While regeneration of seven tree species were absent, two, two and four species were of good, poor and fair regeneration status, respectively. A comparison of mean density of natural regeneration with that of parent trees reflects a poor regeneration status of the forest. The study provides empirical results on the regeneration status of species and signifies the need for management interventions for species conservation and restoration, maintenance of biodiversity and sustainable production.

Key Words: Sudan, natural regeneration, diversity, dry land forest

Introduction

Germination, growth and survival of any species are confined to a particular range of habitat conditions and the extent of those conditions is a major determinant of its geographic distribution. Both climatic and biotic factors interference influences the regeneration of different species in the forest (Grubb 1977; Ogbazghi 2001). The population

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of the forest ecosystems and its' future health is dependent on the tree regeneration potential in the form of the presence of sufficient population of different life stages in the plants (Saxena and Singh 1984; Pokhriyal et al. 2010) and on the potential regenerative status of tree species within a forest stand in space and time (Henle et al. 2004). High anthropogenic pressure can disturb the population dynamics of trees by eliminating their regeneration and the removal of mature trees (Mohammed et al. 2021), while use practices of different forests can generate disturbances that can alter critical components and processes of a forest (FAO 2015). Presence of different natural regeneration structures in a forest reflects their ecotone nature and past anthropic impacts (Ávila et al. 2021).

Natural regeneration is a cost-effective, nature-based tool for restoration that enhances resilience, supports local biodiversity and supplies multiple ecosystem goods and services (Chazdon et al. 2020) and helps to preserve genetic identity and diversity (Yang et al. 2014). Good and Good (1972) consider three major components which cause the successful regeneration of tree species: the ability to initiate new seedlings, ability of seedlings and saplings to survive, and ability of seedlings and saplings to grow. While the higher number of seedlings per unit area indicates better regeneration and proper regeneration conditions, the lower number of seedlings per unit area indicates the inefficient environmental conditions, which need to be improved by artificial regeneration in some cases (Karami et al. 2017). A community is said to have a high species diversity if many equally or nearly equally abundant species are present and of low species diversity if it is composed of a very few species, or if only a few species are abundant (Brower and Zar 1977). Species diversity index starts from 1 when there is only one individual of one species, the value reaches to a maximum with the increase of species number (Odum 1971; Gotelli and Ellison 2012).

Tree species inventory and diversity studies help to understand the species composition and diversity status of forests which also determine the information for forest conservation (Yakubu et al. 2020) and helps in developing management options and setting priorities (Zegeye et al. 2011; Mishra et al. 2013; Haider et al. 2018; Siddig 2019). The examination of regeneration status of forest trees has significant consequences for the management of natural forests, and is one of the primary goals of forestry (Malik et al. 2017). The regeneration status of a tree species in a forest community can be accessed from their population counts in different life phages (Shankar 2001; Pokhriyal et al. 2010; Gebeyehu et al. 2019) and the presence of saplings under the canopies of adult trees also indicates the future composition of a community (Austin 1977; Pokhriyal et al. 2010).

Dry forests are half of the world's tropical and sub-tropical forests and are among the most threatened and least studied forest ecosystems in the world (Aide et al. 2013). The area of naturally regenerating forest in Sudan declined from 23.45 to 18.23 million ha between 1990 and 2020 (FAO 2020). Despite high human and livestock pressures, information on the status of the tree species and data of natural regeneration, the ratio of regeneration to adult trees in natural forests are scarce and Jebel El Gerrie dry forest reserve is not an exception. This study aims to examine ecology and quantify the population indices and status of naturally regenerating tree species in Jebel El Gerrie dry forest reserve, Blue Nile State, Sudan.

Materials and Methods

Location and description of the study area

Blue Nile State is located in the south-eastern part of the Sudan lying between latitudes 9° 30' and 12° 30' N and longitudes 33° 5' and 35° 3' E (Musa et al. 2011). It is classified below a tropical sub-humid zone with rainfall of 300-800 mm/annum (Salih et al. 2002). The major land uses in the state are agriculture, forests, pastoralism and residence (Omer 2013). The main forest ecosystems in the state are riparian and dry forests with an estimated total area of 1.07 out of a total state area of 4.22 million ha (FAO 2015). The state has been for centuries a theatre of land use change where forests have been cleared to pave the way for crop production encouraged by national polices that aim at food security and export earnings. The remaining forests are under pressure as they constitute main source of fodder for a livestock population of 15.28 million (MoAARF 2014) and a source of livelihood from cash crop production, collection of wood and non-wood forest products for human communities from within and outside the state.

This study was carried out in Jebel El Gerrie forest reserve which lies between longitudes 34° 36' & 34° 42' and altitudes 11° 46' & 11° 50' (Fig. 1), with an estimated area of about 5040 ha. The topography of forest is a mixture of a series of mountains and plateaus. Abuelbashar (2020) identified fifteen mature tree species that belong to 14 Genera and 10 families in the tree woody vegetation layer of the forest. The relatively most common family in the forest was Combertaceae followed by Malvacea, Bignoniaceae, and Fabaceae. Mature species composition of the forest includes *Acacia seyal, Adansonia digitata, Anogeissus leiocarpa, Azadirechta indica, Balanites aegyptiaca Boswellia papyrifera, Cassia arereh, Combretum hartmannianum, Ficus sycomorus, Lannea fruticosa, Pterocarpus lucens, Sterculia setigera, Stereospermum kunthianum, Terminalia brownii,* and *Ziziphus spina-christi.* Mean density (trees/ha) in the forest was 47 (±5) for matures and 21 (±3) for regeneration.

The Blue Nile State is one of the most important areas in the Sudan where *B. papyrifera* trees are abundant and resin tapping is practiced at large scale (Nour 2008). *B. papyrifera* produces a pale-yellow, clear frankincense resin as a result of tapping (Sommerlatte and Wyk 2022). *B. papyrifera* resin differs from other types of frankincense due to the presence of two unusual and unique chemical markers: incensole and incensole acetate (Rehman et al. 2020).

Boswellia papyrifera (Del.) Hochst. is native to Sudan and Ethiopia and is recognized to be of high medicinal as well as economic importance (Haile et al. 2011; Rehman et al. 2020). Frankincense is chiefly produced by five *Boswellia* species, distributed from West Africa to India, with highest diversity in the Horn of Africa. Frankincense production differs widely among species: *B. papyrifera* is the main producing species at present (Bongers et al. 2019). Tapping of *B. papyrifera* has long been practiced for the production of frankincense constituting an important source of household income. Cash income from gum and resin in rural household in Sudan contributes for reduction poverty with about 23% (Abtew et al. 2014). The current practice of tapping is carried out by shaving a thin layer of the bark, starting about 50cm above ground level, using special tool termed "*Mengaf*" which resemble a double scalped knife. Tapping of trees usually starts immediately after the rainy season, when trees shed their leaves during

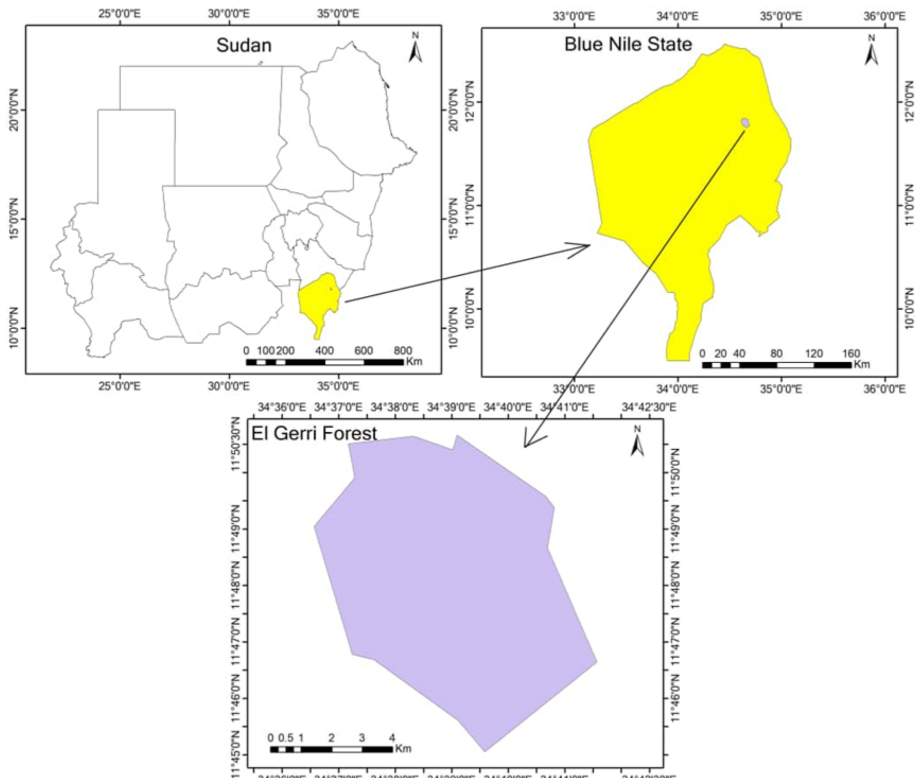

Fig. 1. Study area.

September-October, repeated in sequence and lasts for about four months. Over-tapping, which involves making too deep or too many tapping spots, carried out too frequently than is traditionally practiced for sustainable harvesting, severely weakens the trees (Sommerlatte and Wyk 2022). Jebel El Gerrie forest is one of the very few dry land mountainous forests in east south Sudan where tapping of *B. papyrifera* for production of frankincense is practiced. However, basic data on regeneration composition and structure that could provide valuable information for possible conservation measures is lacking.

Field survey

The data of natural regeneration of tree species was collected between December 2018 and January 2019. The estimated total gazzetted area of Jebel Elgarrie Forest Reserve is 5805.1 ha (Glen 1996). According to growing stock density the forest consists of high density class (C1) at high elevation, medium density class (C2) at low elevation, low density class (C3) at the mountain foot and flat bare farm land (C4). Mean densities (trees/ha) in C1, C2, C3 and C4 were 100, 74, 11, and 0.0, respectively. Their respective estimated areas were 818.8, 2241.1, 1687.6 and 1057.6 ha. A total of 90 circular sample plots (radius 17.84 m) were made and distributed proportionally to the area of the four tree density-based vegetation classes of the forest i.e. 14 in high density (C1), 29 in medium density (C2), 29 in low density (C3) and 18 in crop land (C4). In each sample plot all regenerating species were identified to the species level following the published volumes of Flora of Sudan (El Amin 1983, 1990; Darbyshire et al. 2015) and authenticated specimens in the Forestry Research Centre Herbarium of the Agricultural Research Corporation (ARC) at Soba (Khartoum) and Department of Silviculture, Faculty of Forestry, University of Khartoum. Individuals $<$10 cm DBH were considered as tree regenerations (Saxena et al. 1984; Sundriyal et al. 1994; FAO 2004). Number of identified regenerations for each species in the plot were counted and recorded. Vernacular names were compiled from the knowledge of the local people within the study area and available literature (Gibreel 2008; Gibreel et al. 2013; Ismail and Elawad 2015).

Diversity indices of natural regeneration of tree species

The field data was compiled and analyzed for abundance (A'), relative abundance (REA'), mean density (MDE) (No./ha), relative density (RDE), richness (R), evenness (E), diversity (H'), of the entire species composition using Shannon-Weiner diversity index, regeneration percentages (RP), regeneration status (RS) and importance value index (IVI). Natural regeneration indices per vegetation classes of the forest were analyzed too.

Frequency (FR) displays the presence or absence of a given species in each sample plot. Absolute frequency of a species (FR_{abs}) refers to the number of plots in which the species encountered, was calculated using Count Function of MS Excel. RFR of a species was calculated as equal the percentage of the division of the frequency of a species over frequency of all species.

Density refers to the total number of individuals of a species and of all other species occurring per land unit area. Mean density (MDE) of woody species was determined by converting the total number of individuals of each woody species encountered in all the sample plots of all classes to equivalent number per hectare. Relative density (RDE) of a species was calculated as the percentage of the division of the density of a species over density of all species (Neelo et al. 2013).

Abundance refers to density of individuals of a species in those sampling units only, in which a given species occurs (Saha et al. 2016; Maua et al. 2020). Relative abundance was calculated as equal the division of total number of individuals of a species in all sampling units over total number of sampling units in which a species occurred. We ranked natural regenerating species from highest to lowest relative abundance and drew a rank abundance curve.

Shannon-Wiener diversity index (H') was calculated using equation (1) according to Yeom and Kim (2011) and Frerebeau (2019). The index takes into account the species richness and proportion of each species in all sample plots (Neelo et al. 2015).

$$\mathrm{H}' = -\sum_{\mathrm{i}=1}^{\mathrm{S}} \mathrm{p_i} \ln p_i, but\, p_i = \frac{n_i}{N} \quad (1)$$

Where:
H'=Shannon-Wiener diversity index (Shannon 1948)
n_i=number observed from the i^{th} species,
N=total number of individuals of all species
S=number of observed species
p_i=relative proportion of the i^{th} species in the population

Species richness (S) is the total number of different woody species present in a particular community. It does not take into account the proportion and distribution of each species (Yeom and Kim 2011, Neelo et al. 2013). Following Jannat et al. (2020) we calculated Margalef's index of species richness using equation 2.

$$R=\frac{(S-1)}{\operatorname{Ln} N} \quad (2)$$

Where
R=species richness index
S=total no. of species
N=total no. of individuals of all species

Species evenness (E) is the relative abundance of the different species present in a particular community (Yeom and Kim 2011). Pielous's measure of evenness was calculated using equation 3 (Okpiliya 2012)

$$E=\frac{H'}{\operatorname{Ln} S} \quad (3)$$

Where
E=species evenness
H'=the Shannon-Weiner Index of Diversity
S=total No. of species

Natural regeneration percentage and status

Regeneration status can be assessed as equal the number of seedlings/saplings relative to the number of parent trees per unit area (Dhaulkhandi et al. 2008; Tiwari et al. 2010; Mishra et al. 2013; Yakubu et al. 2020). We calculated regeneration percentages (RP) using equation 4 (Mishra et al. 2013; Yakubu et al. 2020). We followed Yakubu et al. (2020) scale that rates the regeneration status of species as Good (RP=1-12%), Fair (RP=0.4-0.99%), Poor (RP=0.01-0.39% and not regenerating (RP=0.00%).

$$RP=\frac{\text{Number of seedlings/saplings per hectare}}{\text{Number of parent trees per}} \quad (4)$$

Importance value index (IVI) of species belonging to tree and other communities should be evaluated based on dominance and abundance respectively (Bhadra and Pattanayak 2016). The IVI of any species indicates the dominance of species in a mixed population (Misra 1968; Shukla and Chandel 2000; Rahman et al. 2011; Rahman et al. 2020). IVI was calculated as equal the sum of relative density, relative frequency and relative abundance of species (Rahman et al. 2020).

Variation of natural regeneration of species between vegetation classes

One-way ANOVA (α=0.05) was carried out to compare natural regeneration densities and Games-Howell procedure for pair wise comparisons of means (Sauder and DeMars 2019) was used to identify densities of natural regeneration in the four classes of significant differences (α=0.05).

Results

Diversity indices of natural regeneration of tree species

Natural regeneration of eight species, which belong to six families, was observed. *A. leiocarpa*, *C. hartmannianu, L. fruticosa, A. seyal var. seyal, B. aegyptiaca, T. brownii, A. indica* and *Z. spina-christi* were naturally regenerating in the forest. The relatively most frequently naturally regenerating species were *A. leiocarpa* and *C. hartmannianum* (Table 1). Seven other species that lack natural regeneration were *A. digitata*, *B. papyrifera*, *C. arereh*, *F. sycomorus, P. lucens, S. setigera* and *S. kunthianum*.

Species abundance ranged from a maximum of 4.73 for *A. leiocarpa* to a minimum of 1.0 for *A. indica* with intermediate values for other six species (Table 1). Both absolute and relative abundances disclosed that *A. leiocarpa* was the most abundant naturally regenerating species. Diversity index of natural regeneration of species in the forest was 1.7 (Table 1). Richness and evenness of natural regeneration were 1.33 and 0.82, respectively. Fig. 2 displays ranks of relative abundance of naturally regenerating tree species in

Table 1. Frequency, abundance, heterogeneity, density and IVI of natural regeneration of tree species in Jebel El Gerrie forest

Family	Species	Local name	FR	RFR	FR_{abs}	A'	REA'	H'	MDE*	RED	IVI	DE_{par}	RP	RS
Anancardiaceae	*Lannea fruticosa* (Hochst. ex A. Rich.) Engl.	Layoun	22	11.40	8.00	2.75	0.12	0.25	2	0.11	11.63	6	0.41	Fair
Combretaceae	*Anogeissus leiocarpa* (DC.) Guill. & Perr.	Sahab-Silk	71	36.79	15.00	4.73	0.21	0.37	8	0.37	37.37	16	0.50	Fair
Combretaceae	*Combretum hartmannianum* Schweinf.	Habeel Al Gabal	46	23.83	11.00	4.18	0.19	0.34	5	0.24	24.26	5	0.94	Fair
Combretaceae	*Terminalia brownii* Fresen.	Darout	15	7.77	4.00	3.75	0.17	0.20	2	0.08	8.02	1	1.70	Good
Fabaceae: Mimosoideae	*Acacia seyal* Delile var. *seyal*	Talih Ahmer	20	10.36	10.00	2.00	0.09	0.23	2	0.10	10.55	3	0.81	Fair
Meliaceae	*Azadirachta indica* A. Juss.	Neem	1	0.52	1.00	1.00	0.04	0.03	0	0.00	0.57	1	0.17	Poor
Rhamnaceae	*Ziziphus spina-christi* (L.) Desf.	Sidir	8	4.15	5.00	1.60	0.07	0.13	1	0.04	4.26	0	9.00	Good
Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile	Heglig	10	5.18	4.00	2.50	0.11	0.15	1	0.05	5.34	4	0.30	Poor
Malvaceae: Bombacoideae	*Adansonia digitata* L.	Tabldi	0									1		NR
Burseraceae	*Boswellia papyrifera* (Delile) Hochst.	Targ Trag	0									1		NR
Fabaceae: Caesalpion-ioideae	*Cassia arereh* Delile	Al Gaga	0									0		NR
Moraceae	*Ficus sycomorus* L.	Jumaiz	0									0		NR
Fabaceae: Faboideae	*Pterocarpus lucens* Lepr. ex Guill. & Perr.	Taraya	0									3		NR
Malvaceae: Sterculioideae	*Sterculia setigera* Delile	Tartar	0									0		NR
Bignoniaceae	*Stereospermum kunthianum* Cham.	Khash khash Abiad	0									6		NR
	Total		193	100.0	58.00	22.52	1.00	1.70	21	1.00	102.0	47		

*MDE & DEpar are rounded.

FR, frequency; RFR, relative frequency; FR_{abs}, absolute frequency; A', abundance; REA', relative abundance; H', diversity; DE_{abs}, density; RDE, relative density; IVI, importance value index; DE_{par}, density of parent trees; RP, regeneration percentage; RS, regeneration status; NR, non-regenerating.

Jebel El Gerrie forest. Results disclosed that IVI of naturally regenerating species ranged from 37.38 for *A. leiocarpa* to 0.56 for *A. indica*.

Natural regeneration percentage and status

While two, two and four species were of good, poor and fair regeneration status, respectively, seven other species were not regenerating. Highest regeneration percentage was reported for *Z. spina-christi* followed with *T. brownie* (Table 1).

Variation of natural regeneration of species between vegetation classes

The frequency of natural regeneration varies between

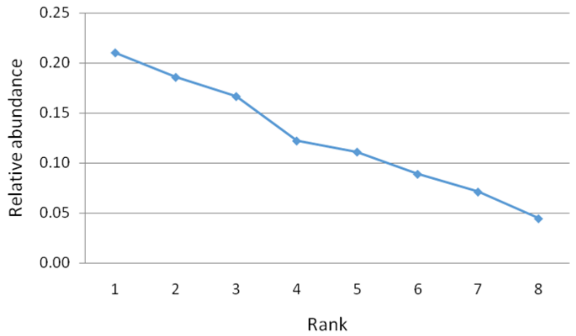

Fig. 2. Relative abundance rank curve of naturally regenerating species.

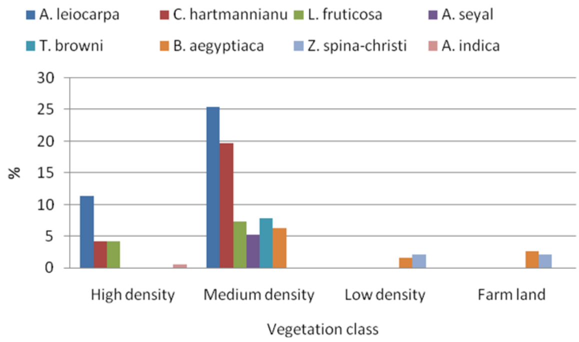

Fig. 3. Richness of natural regeneration of species by vegetation classes.

vegetation classes. It was most prevalent in C2 (71.5%), followed by C1 (20.2%), C4 (4.7%) and lower in C3 (3.6%). Richness of regenerating species follows same trend where 6, 4, 2 and 2 species were present at the four classes, respectively (Fig. 3).

Means of natural regeneration across C1, C2, C3 and C4 were 28, 48, 2 and 5, respectively. One- way ANOVA ($df=_{3,86}$, $F=16.77$, $p=0.000$) revealed a significance difference ($p=0.000$) between at least two means. Results of Games-Howell procedure for pair wise comparisons revealed significant differences in mean regeneration densities between C2 & C3 ($p=0.000$) and C2 & C4 ($p=0.000$) with mean regeneration density higher in C2 than in other vegetation classes. Pool mean density of natural regeneration (No./ha) in the forest was 21 compared to 47 of mature trees.

Discussion

Diversity indices of natural regeneration of tree species

Lacking of natural regeneration of seven species, which were found only as matures, is serious for their continuity as the future composition of the forests depends on the potential regenerative status of tree species within a forest stand (Henle et al. 2004). In addition to ecological importance of all these non-regenerating species, many of them provide important multiple products for human and livestock populations.

Most prominent is the non-regenerating status of *B. papyrifera* which is the only species in the forest that has long been utilized for economic benefits. The same result was found in different parts of South Kordofan (Badi and Abdel Magid 2013) and in Ethiopia (Gebrehiwot et al. 2003; Abtew et al. 2011). Absence of regeneration is attributed to different interrelated disturbances such as overgrazing, over tapping, pests, agricultural expansion and poor management (Eshete et al. 2005; Gidey et al. 2020), to climatic anomalies (Abtew et al. 2012; Alemu et al. 2015; Khamis et al. 2016) and to stress that could arise during sexual reproduction and establishment (Negussie et al. 2008). Tapped *B. papyrifera* trees produced fewer flowers, fruits and seeds than non-tapped trees, and germination success of the seeds from non-tapped trees was much higher than from tapped trees (Eshete et al., 2012). The present system of intensive annual tapping throughout the dry season leads to low production of non-viable seeds (Ogbazghi 2001). Tapping also reduced foliage production, annual carbon gain and carbon stock of *B. papyrifera* trees (Woldie 2011; Mengistu et al. 2012). Such negative effects could, at least partly, explain the recent lack of regeneration observed for *B. papyrifera* populations in northern Ethiopia (Groenendijk et al. 2012). This result indicates that the population of the species is unstable and under threat due to lack of recruitments through regeneration (Haile et al. 2011; Abtew et al. 2012) and that *B. papyrifera* is really suffering in regeneration to sustain its existence (Gidey et al. 2020). The situation of lacking regeneration has been described in Eritrea (Ogbazghi et al. 2006), Sudan (Khamis (2001) in Jebel Marra and Abtew et al. 2012 in Nuba Mountains) and Ethiopia (Abiyu et al. 2010; Eshete et al. 2011; Alemu et al. 2015; Addisalem et al. 2016). Using tree rings Tolera et al. (2013) estimated that the mature trees in existing *B. papyrifera* forests in Ethiopia established themselves from seeds between 1903 and 1955, but not later. In connection with the regeneration and sustainability problems of the species, its ecological and economical benefits are expected to decrease (Ogbazghi et al. 2006; Negussie et al. 2008; Mekonnen et al. 2013; Lemenih et al. 2014; Khamis et al. 2016). These sustainability problems are also expected to accelerate replacement of *B. papyrifera* by other aggressive woody species (Eshete et al. 2011). Absence of seedlings and saplings of tree species indicates urgent need for targeted forest management plan to enhance regeneration (Abyot et al. 2014; Gebeyehu et al. 2019) and unless appropriate management activities are undertaken, the regeneration status will be threatened in the future (Dereje and Duguma 2019).

However, Addisalem et al. (2016) reported *B. papyrifera* with a high density of seedlings and saplings in western region of Ethiopia which is characterized with fewer agricultural activities and relatively undisturbed forests. As well, Adam and El Tayeb (2008) encountered quite high number of seedlings of the species in the wet environment of Jebel Marra in west Sudan in a survey conducted immediately after the rainy season. The variation in the regeneration results can be taken as an indicator that *Boswellia* has the ability to produce ample quantities of seedlings but these seedlings face difficulties of establishment (Abtew et al. 2012) and lack the components which cause the successful regeneration of tree species (Good and Good 1972). This potential may be sustained and improved with appropriate conservation and management efforts, particularly the control of human induced interventions as seedlings and saplings are usually destroyed by livestock (Ogbazghi 2001), agricultural practices such as plowing, weeding and hilling do not favor the emergence of seedlings or their transition and therefore juveniles (Sabo et al. 2021). Establishment of enclosures in which tapping and grazing is not allowed were found to be an effective measure to promote natural regeneration (Ogbazghi 2001). Chazdon et al. (2020) emphasized use of farmer managed natural regeneration to restock former croplands and grazing lands with trees through productive agroforestry. It is a low-cost practice (Koffi and Worms 2021) that could be integrated into the local economies of rural communities to promote greater local commitment to forest conservation and sustainable forest management (Rayner et al. 2010).

The forest is composed of a few natural regenerating species to be classified as of low diversity (Brower and Zar 1977). Gibreel (2008, 2013) reported 54 medicinal woody plant species that belong to 36 genera and 18 families in El Nour natural forest reserve, a nearby and 9-10 kilometers northeast Jebel El Gerrie forest.

In terms of relative abundance of natural regeneration *A. leiocarpa* was the single most abundant species in the forest while *A. indica* was least. The steep rank abundance curve indicates low evenness of regenerating species as only a few species are abundant (Brower and Zar 1977) and that the high ranking species have much higher abundances than the low ranking species (Magurran 2004; Yeom and Kim 2011). Although the relative abundance, growth and distribution of seedlings and/or saplings are important in determining species that replace the canopy, abundance of seedlings and/or saplings should not at all considered as an indicator of the ultimate establishment of young individuals. The reason for this is that, the establishment of many indigenous woody plants seedlings and/or saplings is not easy to regenerate because of unfavorable microhabitat (Dereje and Duguma 2019).

Natural regeneration percentage and status

The inventory of the forest reveals smaller mean density of natural regeneration (21) relative to parent trees (47) indicating poor regeneration condition (Tripathi and Khan 2007) and qualifies the forest as of poor regeneration status (Dhaulkhandi et al. 2008; Tiwari et al. 2010; Aliyi et al 2015). Regenerating percentage of the eight naturally regenerating species is variable with *Z. spina-christi* on top. High regeneration percentage of *Z. spina-christi* may be attributed to its common regeneration from seed bank in C4 which is devoid of parent trees and in C3 which is of relative low stocking of parent trees. *B. aegyptiaca* presence in C4 in particular may be attributed to local institutional orders that prohibit cutting mature trees for furniture making or other uses and to farmers' preference to retain some mother trees on crop land. Both species are multi-purpose trees and suitable candidates of agroforestry system.

Variation of natural regeneration of species between vegetation classes

Relatively high richness and frequency of naturally regenerating species in C2 may be attributed to lesser slope, and less canopy cover compared to C1, which is difficult to reach, less accessible to anthropogenic factors and relatively more dense limiting natural regeneration. Various studies show that open canopy might be in favor of seed germination and seedling establishment through increased solar radiation on the forest floor (Khan et al. 1987; Kadavul and Parthasarathy 1999).

Low species richness, mean regeneration and frequency in C3 and C4, relative to C1 and C2, may be attributed to livestock grazing and agricultural practices. Use practices that generate disturbances that alter critical components and processes of a forest (FAO 2015). Trading in forest products, mainly firewood and charcoal, leads to complete destruction of natural forest in Elnour natural forest reserve and around Elgarri natural forest reserve (Osman et al. 2018).

B. aegyptiaca regeneration was present in all classes except C1, *Z. spina-christi* was regenerating in C3 and C4, *A. seyal* and *T. brownii* regeneration was limited to C2, while that of *A. leiocarpa*, *C. hartmannianum* and *L. fruticosa* was limited to C1 and C2. Regeneration of any species is confined to a peculiar range of habitat conditions and the extent of those conditions is a major determinant of its geographic distribution (Grubb 1977).

A. leiocarpa was found to be the most dominant and frequent species with the highest importance value index, and therefore, is considered more important than those with low IVI value (Shibru 2002; Zegeye et al. 2011). *A. seyal*, *Z. spina-christi*, *B. aegyptiaca* and *T. bownii* contribute to household consumption and trade, at local and national levels, improving local economies at present. They are of low IVI and need high conservation effort (Shibru 2002; Gurmessa et al. 2013; Zegeye et al. 2011).

Conclusion

The study provides empirical results on the composition, density and status of regenerating woody tree species in the forest and indicates the shaky future of the forest. It prioritizes species for conservation and provides an evidence for a critical need for management interventions to encourage and sustain natural regeneration in a difficult and dry woodland environment. Particularly for *B. papyrifera* the study highlight the absence of seedlings and saplings as an indicator of unstable population. The study suggests the necessity for anthropogenic disturbance control as it constitutes the major source of seedling destruction and forest degradation in the studied area.

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