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Research Article

Exploring the current status of forest stock in the areas bordering Dinder Biosphere Reserve, Sudan

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Article Info

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Abstract

Dinder Biosphere Reserve (DBR) is one of the first protected areas in Sudan. It hosts diversified populations of plants and animals species ranging from annual plants and grasses to mature and over mature trees, as well as, birds and herbivores to large carnivores. However, with all this diversity, information about the current status of forest resources around the reserve is lacking. Therefore, the objective of the study was to explore the current status of forest stock in the study areas surrounding the DBR, in order to bridge the current information gap for attaining sustainable management of natural resources. Six forest reserves were selected for data collection due to their nearest position and importance to the DBR. For data collection, a systematic sampling method was applied with a 10 % as sampling intensity across the six forest reserve sites. Spiegel Relaskop was used for measuring the basal area per hectare in each sample plot in order to determine the tree density per hectare. After determination of tree species within sample plot of a hectare, variables that included number of trees per hectare, diameter at breast height, total tree height were measured. Paired samples T test in Minitab (Version 17) was used to compares between the various growth parameters. The results of the study revealed that the minimum value of tree density per ha was 20 trees in Remila riverine forest reserve while the highest one was 743 trees in Fazara natural forest reserve. The probability value (P) results revealed that growth parameters differed significantly between riverine forest reserves as 0.032 for DBH, 0.012 for Height, 0.024 for Basal Area and 0.011 for volume with no significant differences among natural forests. Fazara natural forest reserve revealed the maximum value of tree density. Badous riverine forest reserve showed the highest mean value for tree density throughout the study area. Besides, the study findings also distinguished Acacia seyal var fistula, Adansonia digitata and Tamarindus indica as rare tree species in all six-forest reserves. It is that urgent protection measures are needed in the study areas in order to conserve these rare tree species before they disappear from their natural ranges.

Keywords: Biosphere reserve; natural forest; rare species; riverine forest; species density

1 Introduction

Sustainably managed forests have multiple environmental and socio-economic functions at global, regional, and local scales (Fox 2000; Ruddell et al. 2007; Virah-Sawmy 2009). Natural forests and protected areas play a vital role in sustainable development and poverty alleviation in many developing countries across the world (Brockington 2007; Gustafsson et al. 2012; Pfeifer et al. 2012). FAO estimated that 1.6 billion people depend on forest resources for at least part of their livelihood (FAO 2001). For example, in Viet Nam in 2002, the national assessment confirmed that more than 25% of Vietnamese were living in or around the natural forests and protected areas (de Jong. et al. 2006). There are more than 60 million indigenous communities of Latin America, Southeast Asia, and West Africa who are heavily dependent on forests and forest resources (Ennals et al. 2003).

Therefore, to fulfil the requirements of sustainable management of forest resources in a given forested area, it is very important to assess the status of the present stock the exiting forest. An accurate assessment of forest resources is essential for formulating sound forest management strategies and decision-making (Mati and Dawaki 2015). Forest inventory is a key component for this process through which we can gather reliable information for planning, conservation and protection processes (Bohn and Huth 2017). Reliable and up-to-date information about the growing stock, wood and non-wood products, change in vegetation cover, biodiversity, and recreation value, are mainly achievable through forest inventory (Mati and Dawaki 2015; Romijn et al. 2015). DBR is one of the oldest protected areas in Sudan which is of great importance to the country, particularly for local communities in and around the reserve (Ahmed 2005; Elmekki 2008; Mahgoub 2014). However, information about the status of existing forest stock in this area is lacking; therefore, this study is also intended to provide the needed information that will contribute to the sustainable management of forest resources in the study area.

The main aim of this study was to investigate the current status of forest stock in the areas surrounding the DBR, explore the characteristics of growth parameters for different tree species, determine the tree density for each surveyed reserve forest and to identify the rare tree species in the study areas for further conservation.

2 Material and methods

2.1 Study area

DBR was established in 1935 as a national park. It was declared as a biosphere reserve in 1978 and as a Ramsar site in 2002 (known as 'The Rasar Convention on Wetlands 1993'cited by Elmekki 2008). Its area is currently expanded to 10292 Km². It has three ecosystems: Riverine, Meadows (Mayas) and woodland ecosystems (Mahgoub 2014). The biosphere management is the mandate of Wildlife Conservation General Administration (WCGA). For protection and easier management, the reserve was divided into three zones, which included; transition, buffer and core zones. Most human activities are carried out in transition zone, while most carnivores are in core zone (Elmekki 2008; Elmoghraby and Abdu 1985; Mahgoub 2014). Moreover, the buffer zone acted like a barrier between transition and core zones (Fig. 1). For the purpose of this study, three forest reserves were selected within each bordering state depending on their proximity and importance to the DBR. These forests reserves are; Fazara natural forest reserve and Remila riverine forest reserve in Gedaref state border, Wad Ayies natural forest reserve and Okalma natural forest reserve in Sinnar state border as well as, Abu Gadaf natural forest reserve and Badous riverine forest reserve in Blue Nile state border.

2.2 Remila riverine forest reserve

It is a riverine forest reserve found in Gedaref State, Rahad locality, between latitudes $12°57'30''$ N and $12°59'0''$ N, and longitudes $35°01'0''$ E and $35°02'0''$ E, with a total area of 86.19 ha (Fig.2A). The main tree species in this forest is *Acacia nilotica*, and the topography is flat with clay to silt soil. Administratively and technically, the forest belongs to federal forests management (Hassan, 2015).

2.3 Badous riverine forest reserve

Badous forest is a riverine reserved forest located in Blue Nile State, Rosaries locality bordering Badous village, between $12°00'00''$ N and $12°10'00''$ N, and $34°15'00''$ E and $34°20'00''$ E. The total area of the forest is 76.98 ha (Fig. **??**). The main tree species in Maya (the bottom of the flood basin characterized by dark cracking clays and flooded for a period of 6 months or more each year) and Geref (the flood basin slopes that separate the Maya from the river) are *Acacia nilotica*, while the Karab area (the flood basin slopes between the Maya and the vast clay plains of the central Sudan) is dominated by *Azadirachta indica* and *Sterculia africana*. Other scattered tree species in Karab were *Combretum aculeatum*, *Grewia tenax*, *Grewia mollis*, *Capparis decidua*, *Acacia senegal*, *Acacia seyal*, *Acacia oerfota*, *Acacia mellifera*, *Hyphaene thebaica*, and *Lonchocarpus laxiflorus*. Soil types in this reserve are clay soil in Geref and Maya, while in the Karab area the soil type is a mixed sandy clay soil (Ibrahim, 2018; Ibrahim, 2019).

2.3.1 Fazara natural forest reserve

It is located in Gedaref State, Basonda locality, at latitudes 12º 41 0 N and 12º 48 0 N and longitudes 35º 37 0 E and 35º 44 0 E, with a total area of 7,095.76 ha (Fig. 3A). The dominant tree species in the flatlands are Acacia seyal var seyal, Acacia senegal, and Combretum

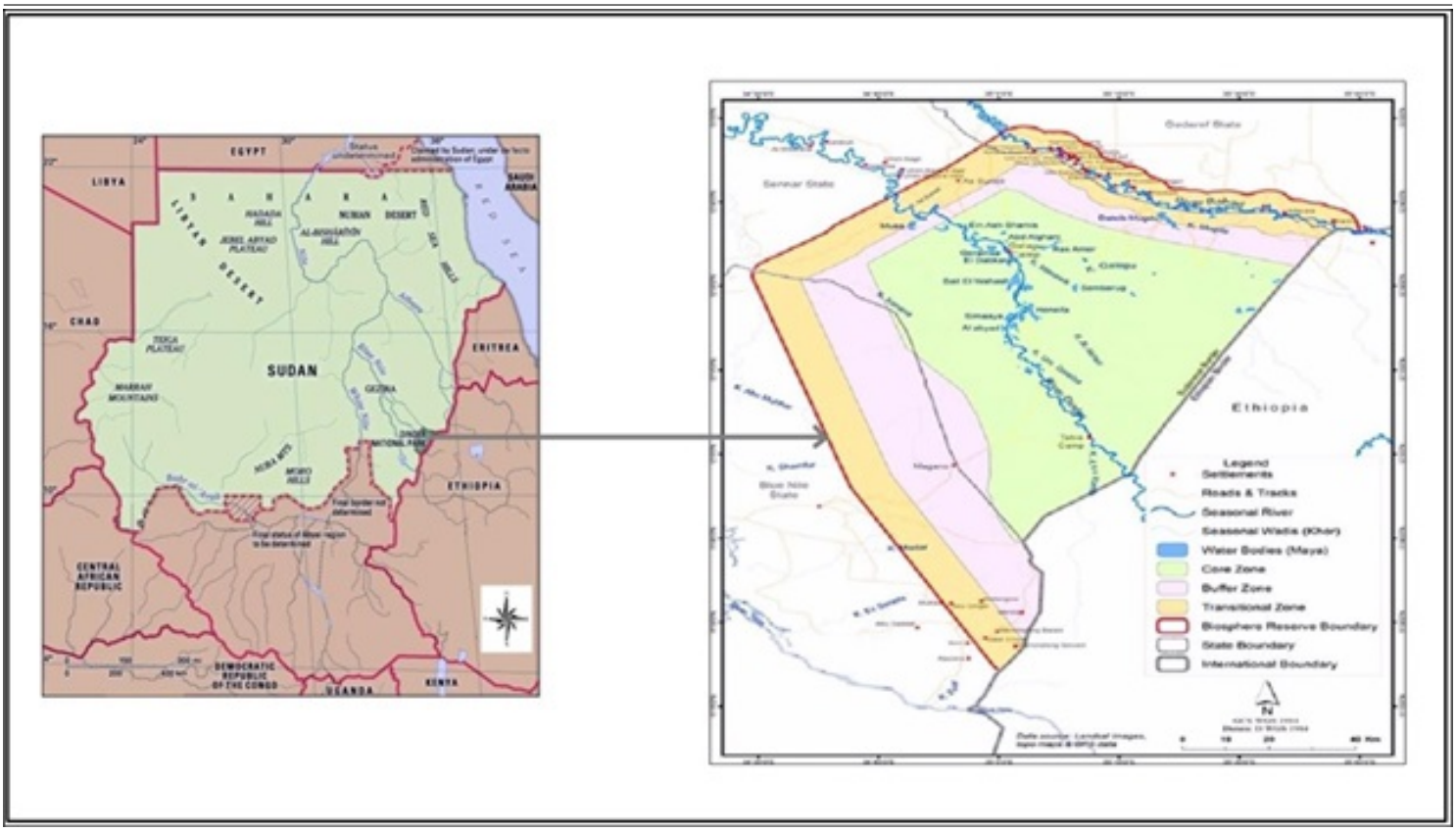

Figure 1: Map of the Dinder Biosphere Reserve in Sudan, including three zones of different protection status and some villages inside and around the reserve. Sources: https://en.unesco.org/biosphere/arab-states/dinder (Last updated: May 2019)

hartmannianum. While the common tree species on mountainous areas are Anogeissus leiocarpus, Terminalia brownii, Terminalia laxiflora, Lannea fruticosa, Sterculia africana, Lonchocarpus laxiflorus, Sclerocarya birrea, Ziziphus spina-christi, Maerua angolensis, and Pterocarpus lucens. The general topography of the forest is flat except in the western area of the reserve around the Fazara Mountain. The elevation of Fazara Mountain is 561 m above sea level with fine and coarse sandy soil. The soil types are crack dark clay soil in the northern and southern parts, and sandy clay in the mid area of the forest (Ibrahim 2019).

2.3.2 Abu Gadaf natural forest reserve

Abu Gadaf forest is the last reserved forest in the eastern part of Wad Almahi locality, Blue Nile State, at Kadalow area near the international boundary between Sudan and Ethiopia. It is located between latitudes 11º 25 00 N and 11º 31 00 N, and longitudes 34º 50 00 E and 34º 55 00 E, with a total area of 4413.78 ha (Fig. 3B). The forest is characterized by high diversity in tree species, soil types and topography. It hosts more than 46 tree species ranging from those of gum production and edible fruits to that of building construction materials and fuel wood. Gum producing species in the forest include; Acacia senegal, Acacia seyal var seyal, Acacia polycantha, Boswellia papyrifera, Commiphora africana, Sterculia africana and Sterculia setigera; while the tree of edible fruits are Balanites aegyptiaca, Diospyros mespiliformis, Grewia bicolor, Grewia flavescuns, Grewia mollis, Grewia tenax, Hyphaene thebaica, Lannea fruticosa, Sclerocarya birrea,Tamarindus indica, Ziziphus abyssinica, and Ziziphus spina-christi. For building/construction purposes the preferable tree species by local communities include Anogeissus leiocarpus, Dalbergia melanoxylon, Acacia seyal var seyal, Combretum hartmannianum, Lannea fruticosa, Lannea schempri, Pterocarpus lucens, and Lonchocarpus laxiflorus. All tree species are used as firewood; however, the preferable one for charcoal production is Acacia seyal var seyal.

Other tree species are: Boscia senegalensis, Combretum aculeatum, Combretum ghazalense, Combretum glutinosum, Combretum micranthum, Combretum molle, Crateva adansonii, Dichrostachys cinerea, Entada africana, Ficus sycomorus, Gardenia lutea, Lannea kerstignii, Maerua angolensis, Piliostigma reticulatum, Pseudocedreca kotschyi, Stereospermum kunthianum, Strychnos innocua, Syzygium guineense, Terminalia brownii, Terminalia laxiflora, Terminalia macroptera, Xeromphis nilotica, and Ximenia Americana (Hassan 2019).

The topography of the forest varies from mountainous one in the northern, north eastern and north western parts to the semi flat in eastern and western parts, and flat one in southern part. The soil types are coarse sand in north western, sandy in north eastern, sandy-clay in northern and crackly-clay soils in southern parts (Ibrahim et al. 2018; Ibrahim and Hassan 2015).

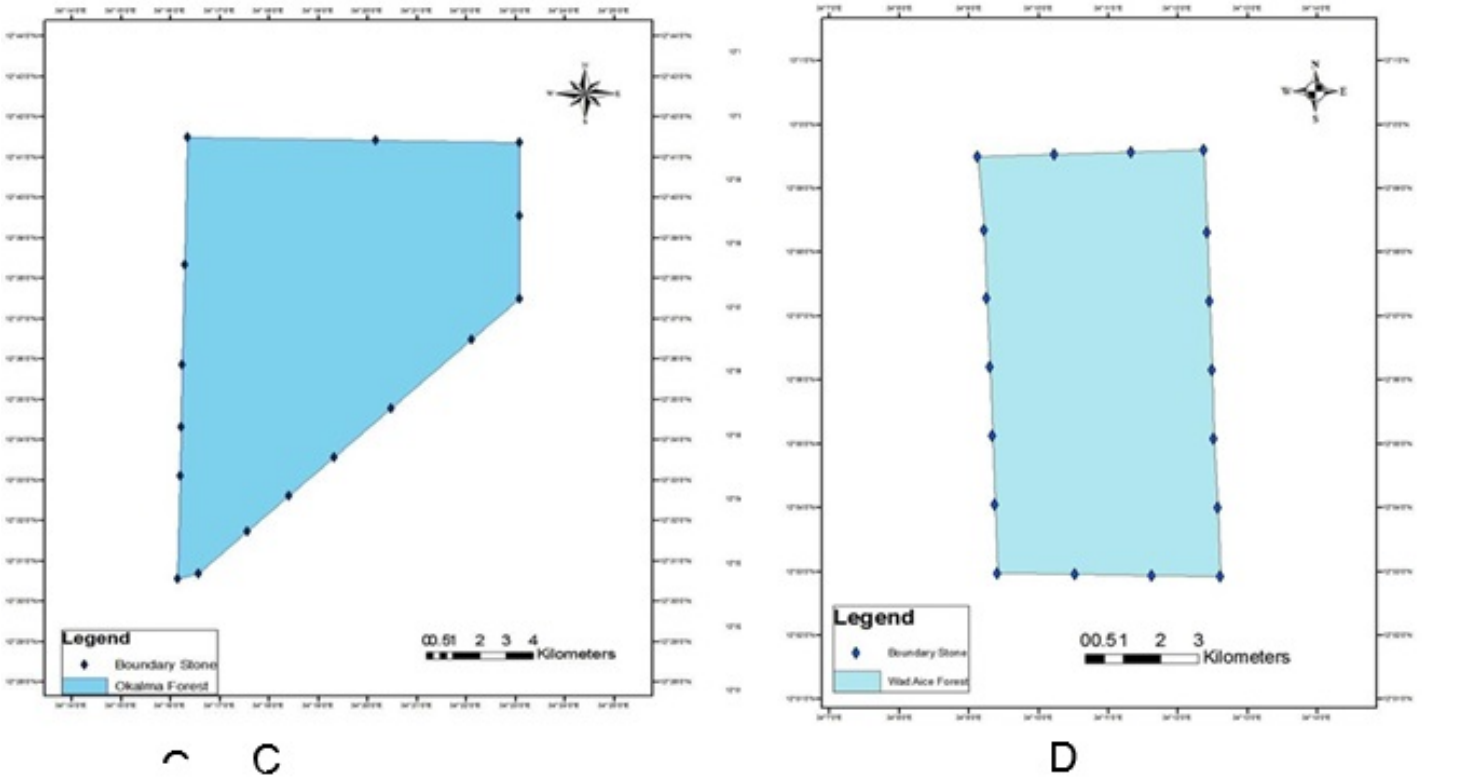

Figure 2: Maps of selected natural forest reserves in the study area (A: Fazara natural forest reserve, B: Abu Gadaf natural forest reserve, C: Okalma natural forest reserve and D: Wad Ayies natural forest reserve

2.3.3 Okalma natural forest reserve

This forest reserve is located in the southern east part of Sinnar State at latitude 12º 30 00 N and 12º 40 00 N, and longitude 34º 16 00 E and 34º 24 00 E (Fig. 3C). It is the largest forest in the State with total area of 17639.65 ha (Hassan 2019). The forest includes different tree species, which are dominated by Acacia senegal, Acacia seyal var seyal, Lannea fruticosa, Ziziphus spina- christi, Acacia mellifera, and Acacia oerfota. Some tree species like Sterculia setigera, Anogeissus leiocarpus, Dalbergia melanoxylon, and Acacia nilotica are present in small quantities. The forest topography is flat to semi flat with crack clay soils alternating with deeply cracked clay soils in the Mayas and sand soil in mountainous and bare land.

2.3.4 Wad Ayies natural forest reserve

This forest located at latitudes 12º 52 00 N and 13º 00 00 N, and longitudes 34º 09 00 E and 34º 13 00 E, with an area of 7160.86 ha (Fig. 3D). It is dominated by Acacia seyal var seyal, Acacia senegal and Balanites aegyptiaca with scatter numbers of Acacia oerfota and Acacia mellifera. Acacia nilotica, Tamarindus indica, and Ziziphus spina-christi are present in small quantities along the valleys and Mayas. Generally, the forest is characterized by flat topography with clay soil in area covered by Acacia seyal, and sandy clay soil in Acacia senegal areas (Mohammed et al. 2021).

2.4 Data collection

Point sampling (spot less sampling) design was used for data collection, whereby each forest reserve was systematically divided into survey lines for grid formation from which the sample centers were recorded and entered into a GPS device map 62s GARMIN. To create this grid layout (Fig. 4), Arc GIS version 9.3 was used. The sample plot size was 1 ha and the sampling intensity was 10% throughout the study area [except under topographical circumstances (such as mountain/hills, meadows … etc) where the percent 10 deferred]. Table 1 illustrates the number of samples per forest reserve, survey lines and forest area for each selected forest reserve in the study area. The tree variables measured were: Diameter at Brest Height (DBH at 1.30 m above the ground) and Total Tree Height (TTH), while Basal Area/ha (BA) and Tree Volume (V) were computed from the measured variables. The Spiegel Relaskope was used to count the number of trees/ha as recommended by other researchers (e.g., Ueno 1978). DBH was measured using diameter tape, while, height was measured using Suunto Clinometer as recommended by other scientists (e.g., Ibrahim et al. 2015; Ibrahim and Osman 2014). The total number of measured trees in this study was 8,014 trees from the six forests.

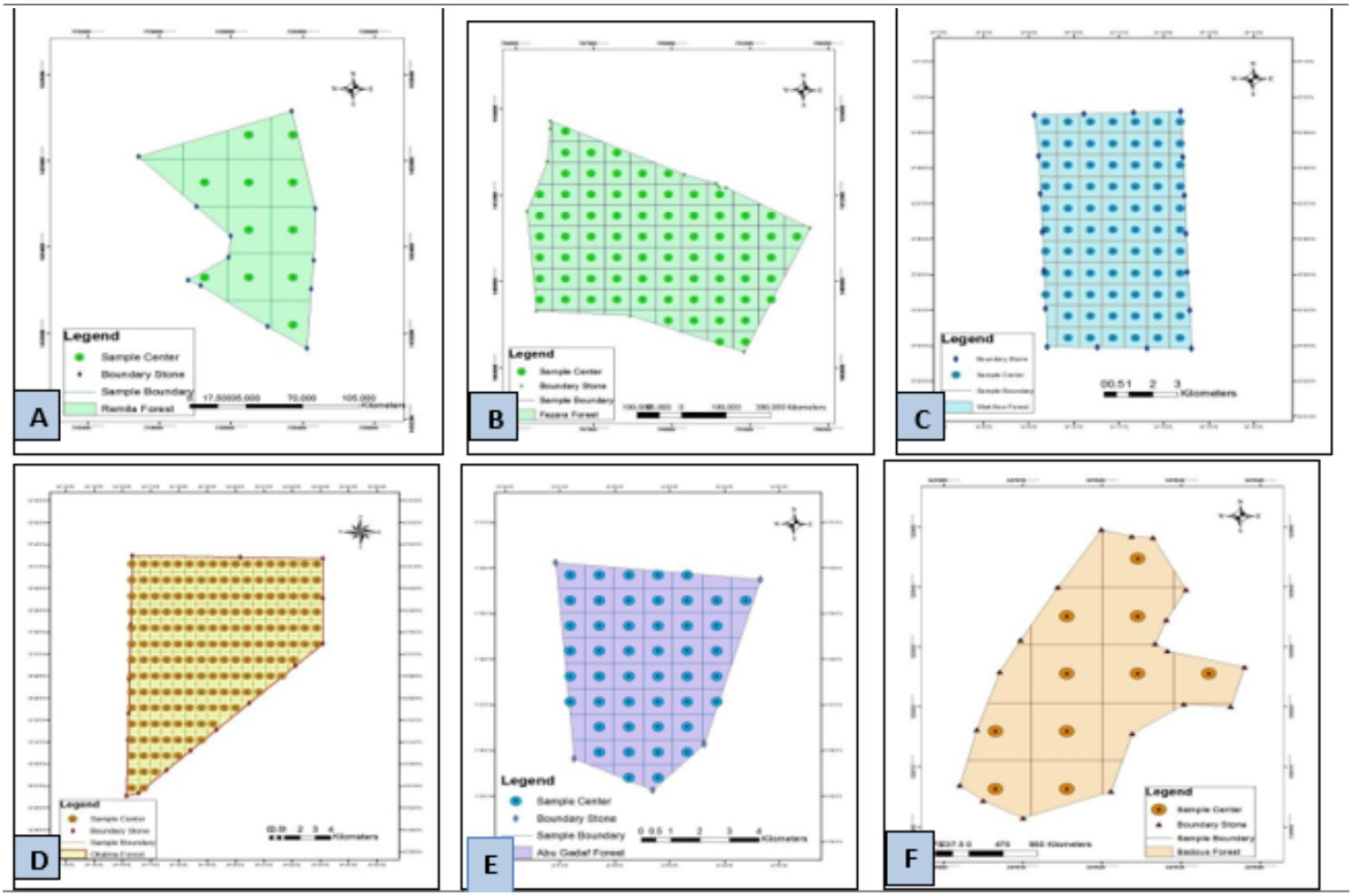

Figure 3: Sampling layout for the six forest reserves (A. Remila, B. Fazara, C. Wad Ayies, D. Okalma, E. Abu Gadaf and F. Badous)

2.5 Data analysis

The following equations were applied to calculate the Tree Basal Area (BA), Volume (V), and Density per ha as recommended by Ibrahim and Hassan (2015).

Tree Basal Area = $\pi \times \frac{(DBH)^2}{4}$
Basal Area per Sample Plot = $\sum$(Trees Basal Area in a plot)
Basal Area per ha = $\left(\frac{\text{Basal Area per Sample Plot}}{\text{Area of Sample Plot}}\right) \times 10000$
Volume per ha = (Basal Area per ha) $\times FF \times$ Average Height

Where Basal Area is in m^2, Volume is in m^3, and FF is the form factor (a correction factor for the taper of a tree). Paired samples T-test in Minitab 17 (HUSCH 1971) was used to compare between the calculated parameters.

2.6 Results

2.6.1 *Characteristics of the Growth Parameters and Tree Density*

Riverine forest reserves showed better performance than natural forest reserves, where all growth parameters were higher in riverine than natural forest reserves. Growth parameters differed significantly between Badous and Remila riverine forest reserves with probability values (P) of 0.032 for DBH, 0.012 for Height, 0.024 for Basal Area, and 0.011 for Volume (Table 2). However, the same parameters indicated no significant differences between the four natural forest reserves (Table 3).

On the other hand, the minimum value of tree density per ha was 20 trees in Remila riverine forest reserve, while the highest one was 743 trees in Fazara natural forest reserve (Table 4). In terms of average values, riverine forests attained good density values compared to natural forests, where Badous riverine forest reserve has an average density of 356 trees/ha (Table 4).

2.7 Rare tree species in the study areas

Six tree species appeared as rare species in both Badous and Remila riverine forest reserves, beside other four species distinguished independently. Local communities around the two riverine reserves used Adansonia digitata, Balanites aegyptiaca and Ziziphus spina-christi for food, fodder and medicinal uses (Table 5). For natural forest reserves, Abu Gadaf showed the highest number of rare tree species (13) followed by Fazara, Wad Ayies and Okalma forest reserves as 8, 8 and 7, respectively (Tables 5).Species like Acacia seyal var seyal, Adansonia digitata and Tamarindus indica are shared as rare species in all four natural reserves, while others like Acacia

Table 1: Table 1: forest area size No. of survey lines, and sample sizes in the studied area

Forest name	Forest area (ha)	Survey lines (No.)	Samples (No.)
Remila Riverine Forest Reserve	86.186	3	11
Fazara Natural Forest Reserve	7,095.758	11	74
Wad Ayies Natural Forest Reserve	7,163.866	7	75
Okalma Natural Forest Reserve	17,647.059	17	178
Abu Gadaf Natural Forest Reserve	4,413.784	7	46
Badous Riverine Forest Reserve	76.984	4	10
Total	36483.637	49	394

Table 2: Characteristics of the trees parameters in selected riverine forest reserves

Parameter	**Badous Riverine Forest Reserve**					**Remila Riverine Forest Reserve**				
	Min	Mean	Max	SE	CV%	Min	Mean	Max	SE	CV%
DBH (cm)	10.8	28.4	58.2	0.495	35.3	11.2	23.9	58.2	0.376	36.7
Height (m)	12.0	18.1	18.6	0.165	18.3	5.6	10.0	26.1	0.168	39.1
Basal Area (m^2)	0.01	0.071	0.266	0.003	72.1	0.01	0.051	0.266	0.002	76.3
Volume (m^3)	0.05	0.55	2.50	0.023	84.6	0.04	0.24	1.53	0.011	105.

Note: Min, Max, SE, and CV are Minimum, Maximum, Standard Error, and Coefficient of Variation, respectively. P is the probability value.

polyacantha, Dichrostachys cinerea and Sterculia setigera are rare in only three reserves. Reasons that make species in the study areas to be rare were illicit grazing, illegal harvesting trees and growing demand for the NTFPs in the forest reserves.

3 Discussion

Riverine forest reserves characterized by a good management system and well-scheduled plans, that is why they attained good performance of growth parameters particularly in Badous forest. Tree diameter and height are key indicators for healthy growth and fertile stand, which is well recognized in this study. Variation in the stand spacing and density, as well as the site characteristics, guided the observed significant differences between Badous and Remila forest reserves. These findings are similar to (Ibrahim et al. 2018). On the contrary, other natural forest reserves are exposed to a continuous livestock browsing/grazing and illegal harvesting (FNC 2011), which negatively affected the natural regeneration of the tree species and their growth performance. Probably, that is why tree diameter, total height, basal area and volume exhibited no significant differences between natural forest reserves. This finding is supported by the results obtained by other researchers (e.g., Ibrahim and Hassan 2015 and Osman and Idris 2012).

The formal national accounts show a limited contribution of the Sudan forestry sector to the GDP. These accounts register figures of 1- 2% contribution, which equals the value of wood produced from government forest reserves or registered in the format of royalty collection (CBoSTAT 2014). This accounting deficiency attributed to the lack of data on different forest products obtained from different forest areas in addition to the difficulty of assessing the indirect benefits of trees and forests. Excluding Gum Arabic, most of the non-wood forest products not accounted for GDP (FAO 2014 b). Sudan forestry sector differ significantly before and after the separation of South Sudan to form an independent country on 9 July 2011. However, according to the Forest National Corporation (FNC) – Sudan - report for the year 2011 (year of separation/referendum), the percentages of forest cover was 11.60%. Thus, the reduction in percentage was from 29.4% to 11.6% with reduction of 17.8%, which categorizes Sudan as one of the low forest cover countries with deforestation rate of 2.46% annually (FNC 2011).

The various forms of forest destruction was carried out in the form of illegal felling of tree branches and debarking up to complete tree logging. Overgrazing is another key factor that eliminates the forest stock and degrades many rangelands (Chaturvedi et al. 2012; Hassan and Tag 2017; Lempesi et al. 2017; Nicu 2018; Yousif and Mohammed 2012). These two factors (overgrazing and illegal harvesting) are the main reasons for the remarkable reduction of tree species in these natural forests. These results are supported by the findings of different researchers (Alvarez-Aquino and Williams-Linera 2012; Mahgoub 2014; Pour et al. 2012).

Twenty-one NTFPs trees and shrubs species surrounding the two forest reserves in Gadarif state were utilized. However, disappeared and rare species, record a total of 34 and 36, respectively (Hassan 2019). The same study stated that from the tree species that disappeared due to dust bowl, 2013 in Kadalow area was Cordia sinensis. More investigation could be carried out to roadmap forest trees resilient or vulnerable to climate change/climate variability processes. Abu Gadaf natural forest reserve revealed the highest number of rare tree species, which directly related to the high anthropogenic pressure coming from the local communities and firewood traders in these remote areas.

The study results indicated that the number of tree species among the six studied forests ranges from 3 to 49 tree species per forest. The results of the study showed that the average growing stock for one ha (one sample plot) was ranging between 2 m3 ha-1 to 28.6 m3 ha-1 (the overall average was 10.5 m3 ha-1). This was 2% to 26% compared to the global average (110 m3 ha-1). The global average for growing stock is 110 m3 per hectare (11 000 m3 per km2) and has not changed significantly over the last 15 years. Growing stock is a measure of the volume of stem wood in a given area of forest or wooded land, usually measured in solid cubic meters (m3). Forest growing stock has traditionally been a key indicator of wood production and is used as a basis for estimating biomass and carbon stocks in most countries. The results also indicated that the overall average for measured variables: Basal Area (m2); Tree number per ha (No); Form factor (f); Tree height (m) and Volume per ha (m3) between the three states were significantly different (P 0.000). The results revealed that the minimum value of tree density per ha was 20 trees in Remila riverine forest reserve while the highest one was 743 trees in Fazara natural forest reserve. The probability value (P) results revealed that growth parameters differed significantly between riverine forest reserves as 0.032 for DBH, 0.012 for Height, 0.024 for Basal Area

Table 3: Characteristics of the trees parameters in four selected natural Forest Reserves

Parameter	Fazara Natural Forest Reserve					Wad Ayies Natural Forest Reserve					Okalma Natural Forest Reserve				Abu Gadaf N
	Min	Mean	Max	SE	CV%	Min	Mean	Max	SE	CV%	Min	Mean	Max	SE	
Mean	Max	SE	CV%												
DBH (cm)	6.7	23.1	36.6	0.44	23.3	15.5	23.5	38.0	1.09	23.5	17.0	25.6	39.7	1.56	
25.4	42.7	1.47	27.2												
Height (m)	6.2	8.3	11.8	0.43	17.7	6.9	8.6	11.9	0.24	15.0	7.1	9.6	12.7	0.39	
9.1	13.9	0.34	19.3												
Basal Area (m^2)	0.03	0.05	0.12	0.01	48.8	0.03	0.05	0.13	0.01	49.4	0.03	0.06	0.14	0.01	
0.06	0.16	0.01	56.4												
Volume (m^3)	0.07	0.18	0.38	0.03	62.3	0.08	0.20	0.67	0.13	51.5	0.08	0.25	0.77	0.20	
0.22	0.97	0.17	51.7												

Table 4: Characteristics of the tree density/ha in the studied forest reserves

Forest Reserve	Mean	Min	Max	SE	CV%
Badous Riverine Forest Reserve	356	160	614	3,909	42.53
Remila Riverine Forest Reserve	157.8	20	298	5,182	73.43
Abu Gadaf Natural Forest Reserve	257.2	168	422	2,378	29.24
Fazara Natural Forest Reserve	184.1	16	743	7,519	129.2
Wad Ayies Natural Forest Reserve	219.6	65	424	3,733	53.75
Okahna Natural Forest Reserve	219.6	71	424	3,733	53.75

Note: Min, Max, SE, and CV represent Minimum, Maximum, Standard Error, and Coefficient of Variance, respectively.

and 0.011 for Volume with no significant differences among natural forests. Fazara natural forest reserve revealed the maximum value of tree density, however, Badous riverine forest reserve showed the highest mean value for tree density throughout the study area. Besides that, the study findings also distinguished Acacia seyal var fistula, Adansonia digitata and Tamarindus indica as rare tree species in all six-forest reserves. Hence, urgent protection measures are needed in the study area in order to conserve these rare tree species before they disappear from their natural ranges.

Although, Badous is a riverine forest reserve with good management system and well- scheduled plans, it has a highest percent of the rare species. So, considerable managerial works should take place. The study made in the transitional zone of DBR has shown that the highest number of disappeared tree and shrub species were 21 species in Sinnar side followed by Blue Nile 11 species and Gedaref 9 species (El-Mugheira 2019). The lowest number of rare species was 12 in Sinnar while the highest one was 20 species in Gedaref side. These findings indicate that the over utilization is very apparent in Sinnar forest reserve compared with Blue Nile and Gedaref where disappeared species were observed in the area. The highly affected area by agricultural expansion was that part of transitional zone bordering Sinnar State followed by Gedaref State and Blue Nile State, while for reserved forests; the worse situation was in Blue Nile followed by Gedaref and Sinnar. The results of the study have revealed that the inadequate stocking density and growing stock per ha in the study area. The above mentioned finding was in line with e.g. Badi and Abdel Magid (2013) for Blue Nile (Sunt) and Hassan (2015) assessment of the forest resources in the transitional zone of the DBR and the forest reserves around the zone.

4 Conclusion

Stocking density and growing stock per ha in the study area was poor (only 9.5% as compared to the global average). The study concludes that riverine forest reserves are well stocked compared to natural forest reserves. However, all forest reserves have a significant number of rare tree species that need urgent intervention to conserve and protect these vulnerable species. Acacia seyal var fistula, Adansonia digitata and Tamarindus indica were documented as rare tree species throughout the study area, while Acacia seyal var seyal and Acacia nilotica were dominant in all natural forests and riverine forests, respectively. Special attention should be devoted to the planting and conservation of Balanites aegyptiaca, Tamarindus indica and Adansonia digitata, which have growing importance within the climate change context and multi-utilizations throughout the country. The study recommends increasing the stocking density to increase the quantity and quality of forest reserves to fulfil the environmental and socio- economical requirements in order to improve livelihoods of the communities and sustain the DBR.

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Conflict of interest

The authors declare no conflict of interest

Table 5: Rare tree species in the studied riverine and natural forests reserves

Species	Uses	Forests Reserves
Acacia mellifera	Fodder, building materials, and firewood	B; R
Acacia polyacantha	Fodder and firewood	Abu; Wada
Acacia seyal var fictula	Fodder and charcoal	B; R; Abu; Fazara; Wada; O
Acacia sieberiana	Fodder and firewood	R
Adamsonia digitata	Food, fodder, and medicine	B; R; Abu; Fazara; Wada; O
Balanites aegyptiaca	Food, fodder, medicine, firewood, and furniture	B; R; Fazara; O
Combretum aculeatum	Fodder and firewood	B; Wada
Combretum microtratum	Fodder, building materials, and firewood	Fazara
Commiphora africana	Medicine and fodder	Fazara
Dalbergia melanoxylon	Furniture and building materials	Abu
Dichrostachys cinerea	Fodder and firewood	B; R; Abu; Wada; O
Grewia bicolor	Food and fodder	Abu
Grewia flavescens	Food and fodder	Abu
Grewia mollis	Food and fodder	Abu
Grewia tenax	Food and fodder	Abu
Hyphaene thebaica	Food and building materials	O
Pseudocedrela kotschyi	Building materials, furniture, and firewood	Abu
Stereospermum kunthianum	Medicine and fodder	B; Fazara; Wada; O
Tamarindus indica	Food, fodder, and firewood	B; R; Abu; Fazara; Wada; O
Terminalia macroptera	Firewood, furniture, and building materials	Abu; Fazara
Ziziphus spina-christi	Fodder, furniture, food, medicine, and firewood	B; Abu; Wada

Note: B for Badous; R for Remila; **Abu** for Abu Gadaf; F for Fazara; **Wada** for Wada Ayies; and O for Okahna.

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