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Human Disturbance, Plant Species Composition, Diversity and Community Types of Kafta-Sheraro National Park, Tigray Region, Ethiopia

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Abstract

Background: Ethiopia is rich in woodland natural forest although of increasingly subjected to deforestation and forest degradation with extensive expansion of settlement and agricultural practices. In developing countries like Ethiopia forest is one of the vital resources that determine the livelihood of the local communities. Consequently, woodlands' of the country's are under heavy pressure by shifting cultivation and charcoal production. Kafta-sheraro national park is newly established woodland area which lacks documented vegetation diversity and human disturbance on the forest. The study was conducted to quantify plant species richness and diversity along altitude; and identify anthropogenic disturbance on vegetation composition and community diversity of the park.

Methods: a Systematic sampling method was used to determine species composition, abundance, and diversity. 161 quadrats each (400 m^2) lying 200 m far apart for trees and shrubs while sub-plots (1 m^2) for herbs and grasses along transects were established over an altitudinal gradient of 539-1111 m.a.s.l. All vascular plant species were collected and brought to National Herbarium, Addis Ababa University for identification.The degree of disturbance data as (low, moderate and heavy) were visually estimated for each plot.

Result: a total of 182 plant species: 63 (34.6%) herbs,46 (25.3%) trees, 38 (20.9%) grasses, 18(9.89%) shrubs, 11 climbers (6.04%), and 6 (3.3%) tree/ shrub), belonging to 142 genera and 53 families, were identified. Fabaceae was represented by the highest number of species (37 species; 20.3%) followed by Poaceae (36 species; 19.8%) and Asteraceae, 10 species (5.49%). Three plant communities' types were identified: *Acacia mellifera-Balanites aegyptiaca (*1); *Hyphaene thebaica-Ziziphus spina-christi* (2); *Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera* (3). Species richness was highest in community 1 (mid-altitude: 607-640 m.a.s.l.).The highest Shannon-Wiener diversity index (H`=2.82) for the forest was in community 2 (low altitude: 539-610 m.a.s.l.) while evenness (J=0.72) was highest in community 3 (high altitude: 674-1111 m.a.s.l.) There was a significant correlation between species richness ($p=0.024$) and altitude per plot while species diversity was non significant ($p>0.05$) over altitude. Human activities also strongly correlated with species richness and diversity of specific community type.

Conclusion: the site has pronounced floristic composition and diversity. Altitudinal difference and the degree of human disturbance determine variation in species composition and richness among communities. Altitude is significantly correlated with species richness of all community types while it is more strongly correlated with community type1.Crop cultivation, illegal fire, and overpopulation of livestock grazing are the main threats in community types 2 and 3. However, this document is a baseline to vegetation information of the park. detailed study on conservation challenges (anthropogenic disturbance) of the park vegetation and prioritize their mitigation measures should be arranged.

Key words: Species composition, plant community, species diversity, human interference

1. Background

Ethiopia is known as the eastern Afro-montane and the Horn of Africa biodiversity hotspot (World conservation Monitoring Centre, 1994; Conservation International, 2011), with a high level of endemism, center of origin and diversification for a significant number of animals, plants and their wild relatives due to its dramatic geological history, broad latitudinal spread and immense altitudinal range. This variety led to the emergence of habitats that are suitable for the evolution and survival of various plants and animal species, which are contribute to the overall biodiversity existence of the country (Tewoldebirhan, 1989; Tamene *et al*., 2011).

The vegetation classification of Africa lay into 21 floristic regional centers of endemism. Ethiopia is dominantly part of Somalia-Masai, and Sudanian regional center of endemism (White, 1983). The diverse topographic factors coupled with the diverse climatic factors have created diverse vegetation types in the country. Consequently, the potential vegetation of Ethiopia is systematically classified into 12 vegetation types. Based on this vegetation classification the study area dominantly classified under Acacia-Comiphora woodland and bushland, and Combretum-Terminalia woodland. Acacia-Comiphora woodland ecosystem: is characterized by drought-resistant trees and shrubs, either deciduous or with small, evergreen leaves, and most of the National Parks in the country are found in this ecosystem. While Combretum-Terminalia woodland ecosystem: is characterized by small to moderate-sized trees with large deciduous leaves (Friis et al., 2010).

The biodiversity-rich resources of Ethiopia are vanishing at an alarming rate due to extensive deforestation. Although several factors drive natural forest destruction in Ethiopia, agricultural land expansion triggered the increasing human population is probably the dominant force (Motuma et al., 2010; Mulugeta and Demel, 2006). Ethiopia is also known as one of the richest in biodiversity and hot spot of species endemism in the world (World conservation Monitoring Centre, 1994) despite the degradation crisis increasingly continues. Because most of the biological resources of the country are degrading and has faced serious challenges from illegal settlement, illegal poaching of wildlife, deforestation, and degradation, illegal agricultural expansion, conflicts on competing park resources, habitat destruction and loss, grazing of livestock, soil degradation, bush fire by the investors and farmers around the park, charcoal production that threaten their existence and sustainability and over-exploitation of natural resources (Getachew and Weldemariam, 2016; Malede and Girma, 2015).

The forests of the East Africa region account for 21% of the forest area of Africa continent. However, the annual rate of deforestation in the region has increased from 0.7% during the period 1981-1990 (FAO, 1993) to 1% between of 1990-2000 (FAO, 2001). Ethiopia is one of the countries in this region an annual deforestation rate of 0.8% (FAO, 2001). About 65% of Ethiopian land mass is located in dry land areas and they are associated with tropical dry forest (National Conservation Strategy Secretariat, 1993). Woodland's of Combretum-Terminalia and Acacia-Commiphora are the two dominant vegetation types that cover large parts of the dry land areas (Abeje et al., 2011). Woodlands' of the country's are under heavy pressure and shrinking overtime for extracting fuel and construction wood, for expansion of cash crops (e.g., Sesame). Additionally, population growth and government induced resettlement programs aggravate deforestation (Abeje et al., 2012**;** Garedew et al., 2009). Forests, woodlots, and grazing lands have been predominantly common-pool resources or open access resources in the region. Deforestation due to cutting trees for fuel, timber and agricultural implements, and clearing forests and woodlands to expand agricultural lands is common practices (Fujisawa, 2004; Berhanu et al., 2000) and mainly contribute to an increased pressure on remnant forest stands. Although significant area is used for grazing, shortage of feed sources in dry season is the major livestock production problem which increases pressure on batches of forest stands (Berhanu et al., 2000).

Kafta-sheraro national park is a dryland protected area in the border of Eritrea and transvers by Tekeze River. However, Kafta Sheraro National Park (KSNP) is a newly established which was recognized as a park in 2007; now it is one of the 21 known national parks in Ethiopia. Before 2007 the park were found as "Shire wildlife reserve" managed by Tigray national regional state (Blanc et al., 2003). The area has scarcely populated and relatively better natural vegetation cover as compared to other part of the region. The park has great wildlife resources, thus, preliminary wildlife survey of the park indicates that 318 African elephants *(Loxodonta africana),* 500 Greater kudu *(Tragelaphus stoep sicores),* 50 Red Fronted gazelle *(Gazella rufi fronts),* 60 Orbi *(Ourebia ourebia),* 1000 Anubis Baboon *(Papio anubis),* 180 Common Bushbuck *(Tragelaphus imberbis),* 40 Warthog *(Phacochoerus africanus),*500 Grey duiker *(Sylvicapra grimmia),* 141 Soemmerings *(Gazella soemmeringi),* 50 Ground squirrel *(Xerus rutilus)* (KSNPCL, 2008). The hydrology of Tekeze River together with high wildlife resources and natural vegetation makes the park an important site for conservation purpose.

To aggravate the problems in the past three decades Ethiopia has tried to conserve and manage the biodiversity through establishing protected areas. However, most of the protected areas of the countries have lack scientific documented and relevant periodic baseline ecological information; consequently, their management intervention makes a challenge. Kafta-sheraro national park (KSNP) is one of protected areas in the country which is home of African elephant (*Loxodonta Africana* L.); lacks primary data of vegetation composition, diversity and the effects of human disturbance on vegetation composition and species richness. Thus, studying the current status of the park vegetation contributes for sustainable utilization of vegetation and determines feeding ecology of African elephant and to identify the problems and threats associated with the forest. Furthermore, quantitatively assess the effects of human disturbance and elevation on these woody plant communities and their species richness. Based on a survey of 161 vegetation plots, the specific objectives were: (1) to generate scientific knowledge and documents the baseline data of the park vegetation composition, diversity, plant community type (2) to quantify plant species richness and diversity along altitude and identify indicator species for each community type; and (3) to assess the impacts of human induced disturbance on plant community composition, richness and diversity. This provides the park reliable information for the development of appropriate management plan.

2. Materials and Methods

2.1 Description of study site

Kafta-Sheraro National Park (KSNP) was designated as a park in 2007 (Letter, No: 13/37/82/611) with an area of 2176.43 km^2, while the park was formerly named as "Shire Wildlife (game) Reserve" which was established in 1973 with an estimated area of 750 km^2 governed by the National Regional State of Tigray. Kafta-Shirero national park is located in Kafta-humera and Tahitay adiyabo district of Western and North-western Zones of Tigray region 1356 km far from Addis Ababa and 490 km of Mekelle City, the capital of Tigray National Regional State. The park is situated in the northwest of Ethiopia between latitude 14^{0}05′-14^{0}27′ N and longitude 36^{0}42′-37^{0}39′ E. The park bordered by Eritrea in the north through Tekeze River (Fig.1). The elevation of the park varies from 539 to 1130 meters above sea level (m.a.s.l). The landforms of the areas are heterogeneous in nature and consist of flat plain, undulating to rolling, some isolated hills and ridges, chain of mountains and valleys (Fitsum and Bikila, **2020**).

The mean monthly temperature ranges from 28.35°C to 35.1°C. The coolest temperatures occur from July to September while the warmest temperatures occur from March to May. The maximum mean monthly temperature is in March (33.15°C) and May (34.4°C) while the minimum is both in August (28.35°C) and January (28.65°C) respectively. The rainfall pattern is bimodal with two distinct seasons. The short rains occur during May to mid June and September whereas the long rains occur during July (174 mm) and August (252 mm) (Fig. 2) (Fitsum and Bikila, **2020**).

Based on vegetation classification of Ethiopia (Friis et al., **2010**) Kafta-sheraro national park forest communities broadly categorized as Acacia-Comiphora woodland and bushland proper with dominant *Acacia mellifera* and *Balanites aegyptiaca* species; Combretum-Terminalia woodland and wooded grassland with Terminalia brownii and *Boswellia papyrifera* as frequent species; and Riparian/ riverine forest with *Hyphaen ethebaica* as dominant species. Selected parts of this study were dominated by *Boswellia papyrifera* species which is a Frankincense producing tree (Abeje et al., **2011**). Thus, the severity and vegetation cover decline is higher in these lowland protected areas because they are remote and have a scarcity of resources (Feoli et al., **2002**).

African elephant (*Loxodonta africana* L.), Roan antelope (*Hippotragus equinus*), Demoiselle crane (*Anthropoides virgo)*, Oribi (*Ourebia ourebi*), Spotted hyena (*Crocuta crocuta*), Greater kudus (*Tragelaphus strepsiceros*), warthog (*Phacochoerus africanus*), Anubis baboon (*Papio anubis*), Grivet monkey (*Chlorocebus aethiops*), Fish species and crocodile species along Tekeze River were some of fauna species observed during the field work of 2018/2019. However, the management practices of KSNP is good relative to other protected areas; the home range of the wild animals specifically elephants is collapsed and limited to specific area of *Acacia mellifera-*

Balanites aegyptiaca community. Because most part of Tekeze riverside of the park area is practiced cultivation of vegetables, fruit crops and under risk by temporary human settlements (Fig. 3).

2.2 Unique features of Kafta-Sheraro National Park

Migratory bird species: a Wintering site of Demoiselle crane (*Anthropoides virgo)* which is the only avifauna species found from the Ethiopian bird sites. This bird species seasonally exists in Tekeze river sides and usually arrive in the park in the middle of December and leave from the area in April (Berihun et al., **2009**). Generally, including the crane, the total bird species of the park were 158 as reported by 2020 (Teklay et al., **2020**).

Gum and raisin sources: Some of the species of Kafta-sheraro national park (KSNP) were *Boswellia papyrifera*, *Acacia Senegal*, *Acacia seyal*, *Acacia polyacantha*, *Commiphora boranensis* and *Sterculia Africana*. For example, Yetan zaf (*Boswellia papyrifera*) is the dominant plant species inside and outside the south part of the park. This plant is potential sources of job opportunity and income generation in the region.

Permanent River: half part in the north and northeast of the park enclosed and traversed in the east part by the Tekeze River (F.g.1) and its many tributary rivers which is basic environmental factor for the life of existing wildlife particularly African elephant (*Loxodonta africana* L.) and Demoiselle crane (*Anthropoides virgo*).

Non renewable natural resources: the area naturally has high deposition of quality gold, sandstone (Marble) and expensive other stone minerals. This creates a good source of incom for the whole Tigray region young peoples.

Wild honey: the area is also a potential source of honey for the nearby communities.The communities are collected wild honey for house hold consumption.

2.3 Sampling design

A reconnaissance survey was taken from August 18 to 25, 2018 in order to have an impression of the forest sites and was performed to assess the variation in plant composition and woody vegetation structure. The survey was concluded with the preliminary identification of three physiognomically distinct vegetation types (strata) namely; Acacia-Comiphora woodland and bushland, Combretum terminalia woodland and Riparian/riverine forest. Following the reconnaissance systematic sampling design was applied (Fitsum and Bikila, **2020**). a quadrats size of 20 m × 20m (400 m^2) were established along a line. In the three vegetation type (strata) a total of 161 plots and adjacent 32 transects were placed at a distance of 200 m and 300 m apart respectively. All transects and plots located on the ground using compass and GPS navigation system (Fitsum and Bikila, **2020**).

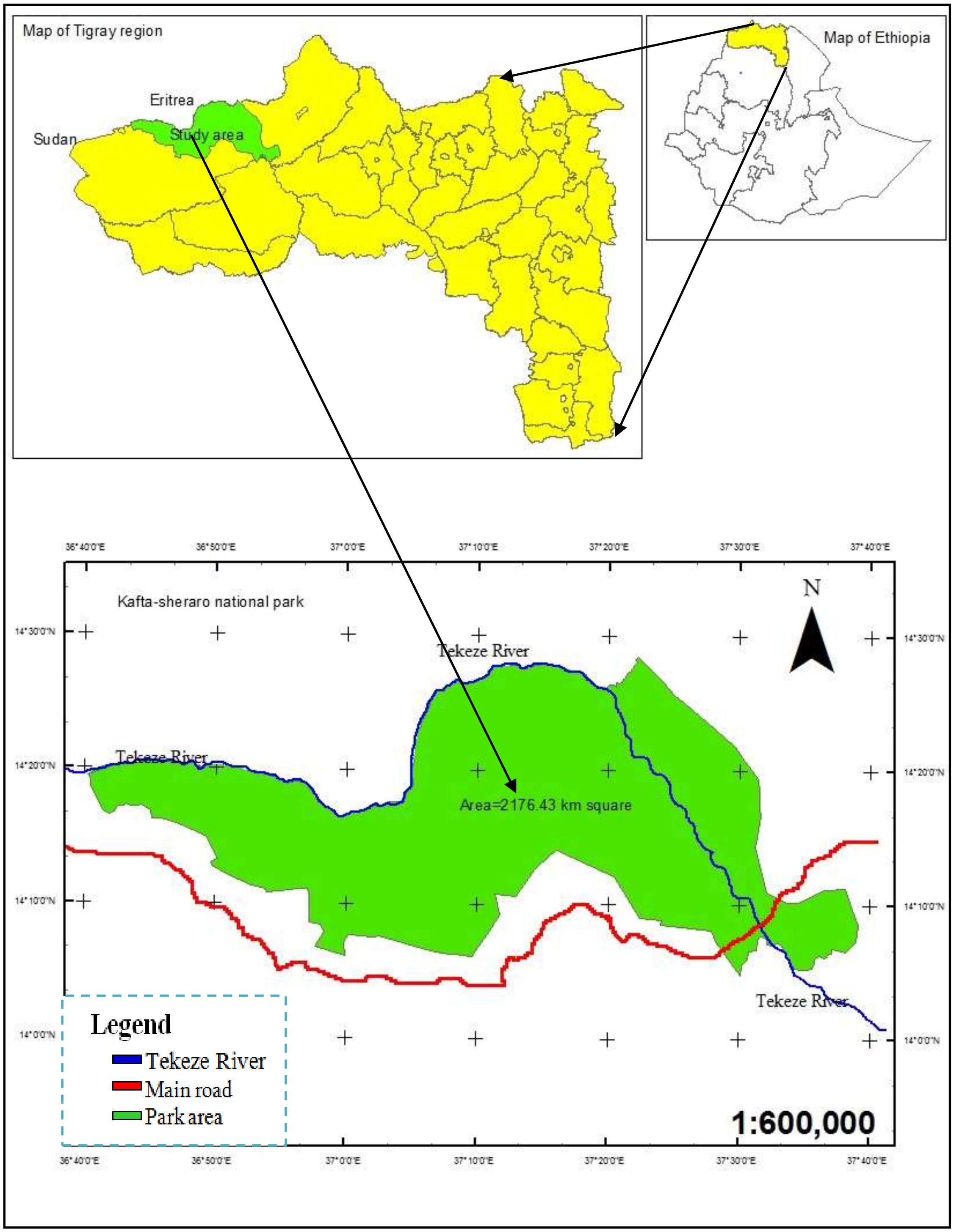

Fig. 1: Location map of the study site (**Source**: Fitsum and Bikila, 2020)

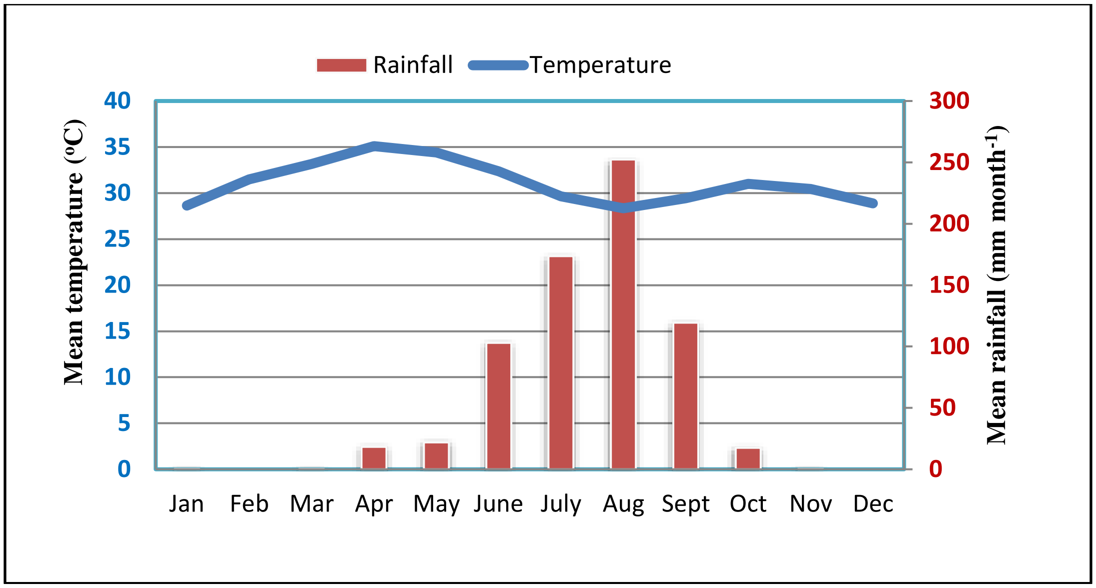

Fig.2: Average Rainfall and Temperature (**Source**: Fitsum and Bikila, **2020**)

Fig. 3: Tekeze riverside irrigated farm land and settlement in side Kafta-sheraro national park

2.4 Data collection

2.4.1 Human impact data (disturbance information)

In addition to recoding the altitude, aspect and geographical coordinate of all quadrates'; anthropogenic disturbances like grazing and other illegal activities (cutting, firewood collection, fire, charcoal production and trampling in the vegetation) were noticed and recorded. Thus following (Kebrom et al., **1997**; Zerihun and Backeus, **1991**) impact of grazing intensity class was estimated as: (3=heavy; 2=moderate; 1=lightly; and 0=not grazed). While the state of illegal human activities was estimated following (Leul et al., **2010**; Kumelachew and Tamrat, **2002**) modified a 0-3 subjective scale to record the degree of the impacts of fire wood collection, charcoal production, and expansion of agriculture by burning of vegetation as: (3= heavy; 2= moderate; 1=low; and 0= nil (absent)). The sum of all scores for each plot provides an overall ranking of Human disturbances index in each community. High ranks lead high levels of anthropogenic disturbance and low ranks indicate low levels of disturbance (Venkateswaran and Parthasarathy, **2003**).

2.4.2 Vegetation data

The detail vegetation data were collected during flowering and fruiting season from August 26-30 December 2018. **Trees and shrubs:** in (400 m^2 plot) individual plants (stems) of all tree and shrub species with diameter at breast height (DBH) ≥2.5 cm abudndance were counted and recorded their circumferance (diameter). Height of individual trees and shrubs ≥2 m were recorded for every woody individual plants having DBH ≥2.5 cm. **Herbs and grasses:** Finally within each 25 m^2 sub-plots, five further 1m × 1m (1 m^2) sub-plot was laid out to collect data on the species diversity and richness of herb and grass species (Fitsum and Bikila, **2020)**.

Cover abundance: ground cover percentage was estimated following the procedure of Braun-Blanquet (Mueller-Dombois and Ellenberg, **1974**; Braun-Blanquet, **1965**). The percent cover values, visually estimated in the field, were later converted into 1-9 modified Braun-Blanquet (van der Maarel, **1979**) scales; 1=≤ 0.1%, 2=0.1 to 1%, 3=1 to 2%, 4=2 to 5%, 5=5 to 10%, 6=10 to 25%, 7=25 to 50%, 8=50 to 75%, and 9 >75%.

Plant species identification: The scientific name was identified using Flora of Ethiopia and Eritrea Volume-1 toVolume-8 for trees and shrubs canbe found in (Fitsum and Bikila, **2020**) and for herbs and grasses (Hedberg et al., **2006**; Phillips, **1995**). Specimens of identified and unidentified species were collected, pressed and dried properly, following standard Herbarium procedures, and taken to the National Herbarium (ETH) at Addis Ababa University for further confirmation and identification of specimens which could not be identified in the field (Fitsum and Bikila, **2020**).

2.5 Data analysis

2.5.1 Plant community analysis

The community types of vegetation in the study area were determined by conducting the cluster analysis techniques. The cover abundance data were analyzed and classified using Community Analysis Package version 5.0 (CAP5.0). The Hierarchical Agglomerative Clustering technique (Ward's method) was employed to classify sites and species of the study area. Agglomerative methods of classification have been widely advocated (Sneath and Sokal, **1973**); while Ward's method is the most commonly used and robust method among the hierarchical classification techniques (Ward, **1963**).The raw data contained 161 quadrats and 166 species. However, 182 specimens were collected; sixteen species were collected outside the quadrats for floristic composition only and are not included in other parameters analysis. The plant communities were named after one or two dominant indicator species. A dominating species in this case is a species having a synoptic cover-abundance value (mean frequency * mean cover-abundance) (Kent, **2012**; van der Maarel et al., **1978**) and a characteristic species having a high frequency in the type and a lower frequency in most other types.

Diversity analysis: The diversity of woody species were determined using the Shannon-Wiener Diversity Index (H') and Equitability (evenness) Index (J) (Barnes et al., **1998**; Krebs, **1989**).
Shannon-Wiener Diversity Index (H’)**:** high Wiener index indicates high diversity and often low disturbance whereas low index value shows low diversity and often high disturbance.

$$\mathbf{H' = \sum_{i=1}^{S} (Pi)(lnpi)} \quad (1)$$

Where, H'=the Shannon-Wiener Diversity Index; ∑=sum of species from species 1 to species S, Pi=*ni*/*N* and is the proportion of the total number of all species in a quadrat; S=numbers of species encountered and ln=natural logarithm in base e, Ni= number of individuals of species i; total number of individuals of all species.
Species richness: is the number of species in a given area. It is most often used in conservation studies to determine the sensitivity of ecosystems and their resident species. Species richness was calculated in equation form as:

$$\mathbf{S = \sum_{i=1}^{s} \quad , Si = S} \quad (2)$$

Where, Si is the number of individuals in the i^{th} species
Equitability index (Evenness): is measured the relative abundance of the different species making up the richness of an area;

$$\mathbf{J = H'/H'_{max} = \frac{H'}{lns} = \sum_{i=1}^{S} \frac{(Pi)\,(lnpi)}{lnS}} \quad (3)$$

Where, J=Evenness, H'_{max}= lnS, H’=Shannon Wiener diversity index, lnS =the natural logarithm of the total number of species in each community, S=number of species in each community.
Communities’ similarity**:** Ecological resemblance refers to similarity or dissimilarity between samples in terms of their species composition-two samples sharing the same species in the same abundances show the highest similarity (lowest dissimilarity).
Sorensen’s similarity index: used to evaluate species composition and species distribution among the three plant community of KSNP vegetation following (Kent and Coker, **1992**).

$$Ss = \frac{2a}{(2a+b+c)} \quad (4)$$

Where, Ss=Sorensen’s similarity coefficient; b=number of species in community-1; c=number of species in community-2; a=number of species common to both communities 1 and 2.

2.5.2 Anthropogenic disturbance analysis

The magnitude of the impacts of the disturbance was quantified based on the variables score (level) recorded in each plot (Table 1). The type and degree of anthropogenic disturbance were analyzed for the three community and scores of each type of disturbance obtained from plots were summed and taken the average value. Finally, each community disturbance scores had pointed to indicate the highest disturbance rate and absence of disturbance (Table 5).

Table 1: Anthropogenic disturbance parameters in sample plots

Disturbance types	Scores (levels)			
	0	1	2	3
Grazing	Not grazed	Lightly	Moderate	Heavy
Fire wood collection	Nil	Low	Moderate	Heavy
Crop cultivation	Nil	Low	Moderate	Heavy
Charcoal production	Nil	Low	Moderate	Heavy
Gold mining	Nil	Low	Moderate	Heavy
Illegal fire	Nil	Low	Moderate	Heavy

2.6.3 Statistical analysis

The deviation of species richness, diversity and the eveness of all woody species in response to altitude along sampling plots were estimated by the analysis of variance to measure any significant difference. The species richness of the three plant communities in response to human disturbance intensity (no or low, moderate and heavy disturbance level) were analyzed using regression and Correlation statistical method. All analysis was facilitated using the R-statistical package (R-Development Core Team, **2019**). For qualitative analysis, descriptive statistics were used and these descriptive statistics graphs were performed with the Microsoft Office Excel 2007 software (Fitsum and Bikila, **2020**).

3. Result

3.1 Vegetation composition of kafta-sheraro national park

A total of 182 species belonging to 142 genera and 53 families were recorded in Kafta-sheraro national park (Appendix 1). The habit contains 63 (34.6%) herbs, 46 (25.3%) trees, 38 (20.9%) grasses, 18 (9.89%) shrubs, 6 (3.3%) trees/shrubs and 11 (6.04%) herbaceous climbers. In the park herbs occupied the highest proportion followed by trees and grasses (Fig. 4). Out of the total 182 species identified from the study area, 166 species which were collected from the 161 quadrats were used in the floristic analysis. The rest sixteen plant species were collected from outside of the quadrats, and included in the plant composition list only.

The occurrence of the richest families were Fabaceae, which had, 37 species (20.3 %); Poaceae followed by 36 species (19.8%); Asteraceae,10 species (5.49%); Combretaceae and Solanaceae 8 species each (8.8%); Tiliaceae, 5 species (2.75%); Rhamnaceae; Malvaceae; Euphorbiaceae and Lamiaceae, 4 speciecs each (8.8%); Capparaceae, Rubiaceae, Anacardiaceae, Cucurbitaceae, Amaranthaceae, Asclepiadaceae, and Acanthaceae, 3 species each (from total species occupied 11.55%); Cyperaceae, Burseraceae, Ebenaceae, Apocynaceae and Liliaceae, 2 species each (5.5%) and 30 families had each 1 species (16.5%) of from the total family (Fig. 5).

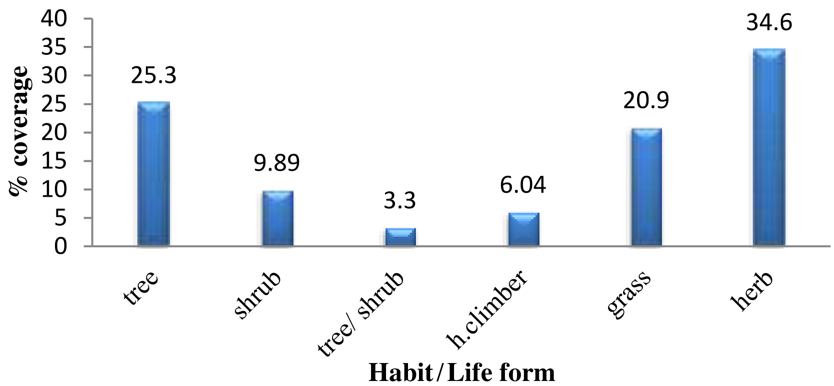

Fig. 4: Life form (habit) distribution of Kafta-Sheraro National Park vegetation

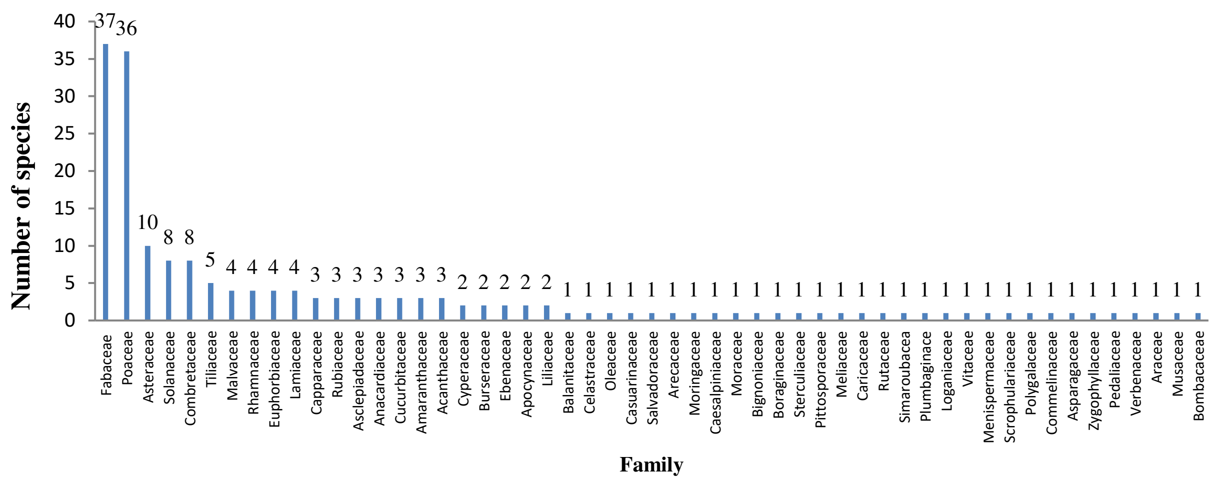

Fig. 5: The number of plant species in each family in Kafta-sheraro national park (KSNP)

3.2 Classification of plant communities in Kafta-sheraro natioanl park vegetation

3.2.1 Plant community types

The vegetation classification was done by using the percent cover abundance value data estimate of each species included in the analysis. Vegetation classification is a powerful tool to summarize the knowledge of vegetation patterns in a given forest areas (Jennings et al., **2003**). In KSNP vegetation three plant community types were identified from the Agglomerative hierarchical cluster analysis program using the Community Analysis Package version 5.0 (CAP5.0). The package for determining the optimal number of clusters was used to decide the number of plant community types. Ward's method and Euclidean distance were used to draw the Dendrogram showing the linkage among the three clusters (Fig. 6). Community names were given after one or two species that had higher species synoptic mean value (Table 2). In all observed plant communities, species with higher indicator values are those that were easily observed repeating themselves in associations. The identified groups are more or less coinciding with the real natural associations while walking through the forest. The identified plant community in the park were; *Acacia mellifera-Balanites aegyptiaca* (Community Type 1); *Hyphaene thebaica- Ziziphus spina-christi* (Community Type 2); *Combretum hartmannianum - Terminalia brownii-Boswellia papyrifera* (Community Type 3).

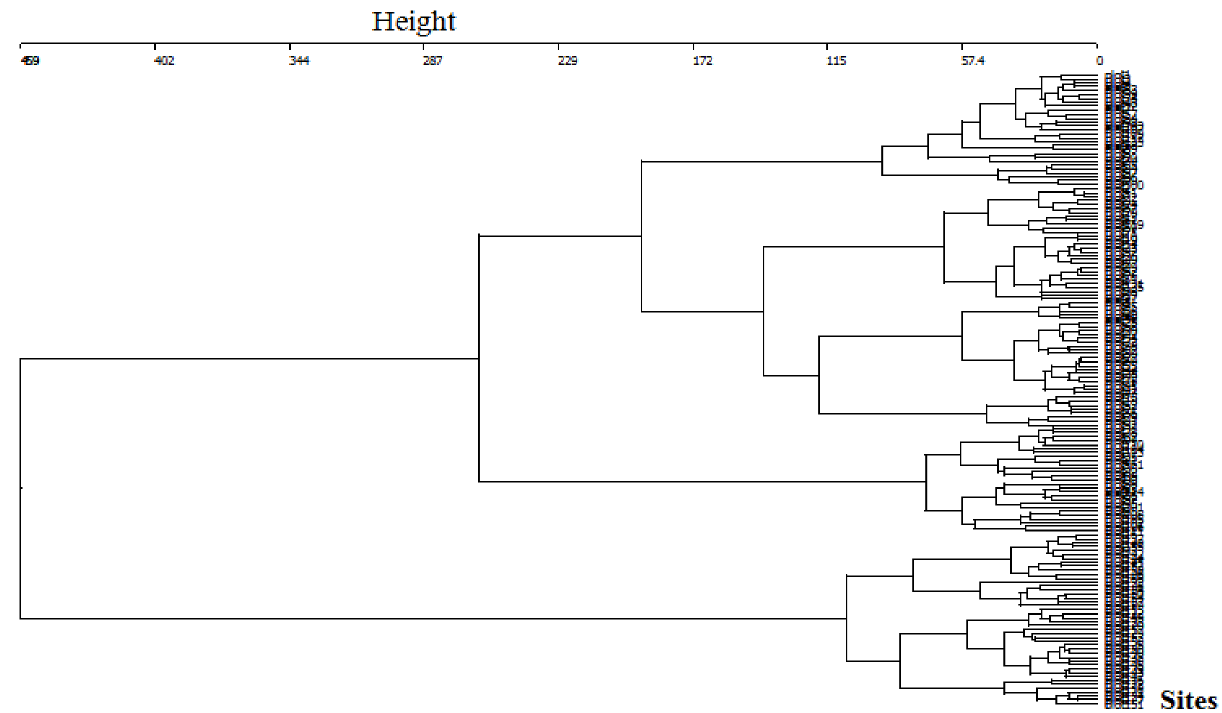

Fig. 6: Dendrogram showing plant communities 'types of Kafta-Sheraro National Park using Agglomerative hierarchical Ward's method and Euclidean distance (**C1plots:**1-30,32,34,37-77, 79,84,88,91,93,96-100,103,107,109,112,119,131,133,135;**C2plots:**31,35,36,78,80-83,85,86,87,89,90,92,94,95,101, 102,104,105,106,108,110,111,113,114,161;**C3plots:**16,33,115-118,120-130,132,134,136,137-160).

Community type 1: *Acacia mellifera-Balanites aegyptiaca* community

Acacia mellifera-Balanites aegyptiaca community type was represented by 90 quadrats (3.6 ha) and 87 species at altitudinal range of 610-640 m.a.s.l. This community had an average plot-level species richness of 4.7 ± 1.6 and Shannon diversity of 1.3 ± 0.3. *Acacia oerfota, Acacia Senegal* and *Dicrostachy scinerea* were the dominant trees and shrubs species. The other associated trees and shrubs of this plant community were: *Dalbergia melanoxylon*, *Grewia bicolor*, *Acacia seyal*, *Sterculia africana*, *Maytenus senegallensis*, *Adansonia digitata, Capparis decidua*, *Grewia villosa*, *Grewia flavescens*, *Acacia lahai*, *Acacia etbaica*, *Acacia tortilis*, *Plumbago zeylanica*, *Cissus guadrangularis*. While the dominant herbs of the community are: *Achyranthes aspera*, *Phyllanthus maderaspatensis*, *Sida acuta*, *Senna obtusifolia*, *Guizotia schimperi*, *Amaranthus spinosus*, *Abelmoschus esculentus*, *Ocimum gratissimum*, *Bidens pachyloma*. Whereas, the dominant grasses layers are; *Stipa tenuissima*, *Phragmites australis*, *Cymbopogon caesius*, *Cenchrus ciliaris*. The African elephant is dominantly concentrated in this community (Fig. 7).

Fig. 7: Some floras of *Acacia mellifera-Balanites aegyptiaca* community type

Community type 2: *Hyphaene thebaica- Ziziphus spina-christi*

Hyphaene thebaica-Ziziphus spina-christi community type was located along Tekeze river side and tributary streams of the park (Fig. 8). This community type was distributed at altitudinal ranges between 539-607 m.a.s.l. and is comprised of 27 quadrats (1.08 ha) and 50 species. Have an average species richness of 5.5 ± 2.0 and Shannon diversity of 1.4 ± 0.3 per plot. *Anogeissus leiocarpus*, *Tamarindus indica* and *Casuarina equisetifolia* are dominant tree species of this community next to *Hyphaene thebaica* and *Ziziphus spina-christi* species. *Other associated trees include: Diospyros mespiliformis*, *Burkea africana*, *Jasminum abyssinicum*, *Salvadora persica*, *Ziziphus mauritiana*, *Feretia arodanthera*, *Diospyros abyssinica*. Common grass species of the commuity were *Cyperus rotundus* and *Cyperus scariosus*.

Fig. 8: *Hyphaene thebaica- Ziziphus spina-christi* community type

Community type 3: *Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera*

Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera community type comprised of 44 quadrats (1.76 ha) and 66 species with an average of species richness and

Shannon diversity of 4.7 ± 1.7, 1.3 ± 0.4 per plot respectively. The community is located between 674-1111 m.a.s.l altitudinal ranges (Fig. 9). *Boswellia papyrifera* is next dominant characteristics of the community. *Combretum molle*, *Commiphora boranensis*, *Ziziphus mucronata*, *Stereospermum kunthianum*, *Pittosporum viridiflorum*, *Boscia angustifolia*, *Acacia polyacantha* were other associated tree species. The common herb species were *Scorpiurus muricatus*, *Ocimum gratissimum* and *Nicandra physaloids* while dominant grass layers were *Oxytenanthera abyssinica*, *Pennisetum typhoideum* and *Heteropogon contortus*.

Fig. 9: *Combretum hartmannianum -Terminalia brownii* dominated community type

Table 2: Indicator species (Mean cover abundance estimates) in each communities and the bold values indicate the name of the representative plant community

Species name	C_1	C_2	C_3
Acacia mellifera	**6.96**	0.93	0.00
Balanites aegyptiaca	**3.70**	0.20	0.02
Acacia oerfota	1.79	0.16	0.00
Acacia senegal	1.54	0.57	0.00
Dicrostachy scinerea	0.43	0.11	0.05
Dalbergia melanoxylon	0.36	0.15	0.00
Adansonia digitata	0.26	0.20	0.01
Sterculia africana	0.22	0.00	0.06
Hyphaene thebaica	0.15	**8.66**	0.03
Ziziphus spina-christi	0.27	**6.46**	0.05
Tamarindus indica	0.02	3.03	0.03
Anogeissus leiocarpus	0.17	2.23	0.08
Casuarina equisetifolia	0.00	1.70	0.00
Diospyros mespiliformis	0.00	1.11	0.00
Combretum hartmannianum	0.03	0.16	**9.37**
Terminalia brownii	0.02	1.01	**5.24**
Boswellia papyrifera	0.01	0.00	**4.84**
Combretum molle	0.00	0.00	3.90
Lannea microcarpa	0.00	0.00	0.45
Commiphora boranensis	0.00	0.00	0.33

Note: C_1=*Acacia mellifera-Balanites aegyptiaca*, C_2= *Hyphaene thebaica- Ziziphus spina-christi* and C_3= *Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera*

3.2.2 Similarity between the communities

The highest similarity was calculated between communities one and three (CC=0.46) followed by community one and two (CC=0.43) while the least similarity was calculated between communities two and three (CC=0.41). Community one commonly shared 52 species with community two and 65 species with community three whereas community two shared 41 species with community three (Table 3).

Table 3: Similarity between the three plant communities types (C1, C2, and C3) in Kafta-sheraro national park vegetation

Plant communities	C 1	C2	C3
C1		0.43	0.46
C2	CC^a=2*52/2*52+87+50		0.41
C3	CC^a=2*65/2*65+87+66	CC^a=2*41/2*41+50+66	

Note: C1: *Acacia mellifera-Balanites aegyptiaca*; C2: *Hyphaene thebaica- Ziziphus spina-christi*
C3: *Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera*
CC^a= Sorensen's similarity Coefficient, the formula is given in the upper-left hand the calculated results are presented in the bottom-right sides of the table

3.2.3 Richness, Diversity, and Evenness of the plant communities

Based on the analysis of Shannon-Wiener diversity index the three plant communities' diversity and equitability index value of Kafta-sheraro national park (KSNP) vegetation was computed. The clusters are ranking in increasing order of total number of species in the community richness of 1> 3> 2 and diversity of 2>1>3.Thus, community type 2 has the highest species diversity and lowest species richness whereas community type 3 has the least species diversity and intermidiate species richness. Both highest diversity index (H'=2.82) and evenness (J=0.720) was observed in community 2 though it has the smallest number of sampled quadrats (27plots=1.08 ha). While lowest value was in community 3 (H'=2.750 and J=0.656 respectively). Species richness is relatively higher in community 1 (87 species) at mid-altitude (610-640 m a.s.l.).Whereas lowest in community 2 (50 species) at lower altitude (539-607 m.a.s.l) of riparian (Tekeze and its tributary rivers) vegetation (Table 4).

The result also showed negative correlation relation (r=-0.18, p=0.024) between species richness per plot (1-161) and altitudinal gradient (from 539-1111 m.a.s.l.) with statsitically significant variation in species richness being explained by altitude (Fig.10).The highest number of species (11) was recorded at plot 47 that was found in the mid-altitude ranges of community type 1 (610-640 m a.s.l.) while the least number of species (1) reported at plot 128 that was found at highest altitude ranges of community type 3 (674-1111 m.a.s.l.). Additionally, number of species in community types 1 (610-640 ma.s.l.) and 2 (539-607 m.a.s.l) fell approximately to nearby the regression line. Community types 1 and 2 were found in the lower and middle altitude the park vegetation, which had higher species (137) occurring in 117 sampled quadrats (4.6 ha).

Table 4: Species richness, Shannon-Wiener diversity index, and evenness of Kafta-Sheraro National Park vegetation

Community type	Altitude (m.a.s.l)	Species richness(S)	Diversity index (H')	H_{max} (lnS)	Evenness $J= H'/H_{max}$
1 (90 plots)	610-640	87	2.81	4.46	0.630
2 (27 plots)	539-607	50	2.82	3.91	0.720
3 (44plots)	674-1111	66	2.75	4.19	0.656
Average		67	2.46	2.77	0.668

The regression analysis relationship of species diversity and eveness (equitability index) response to altitude were statistically non significant at p=0.28 (a) and p=0.48 (b) per plots respectively (Fig.11).

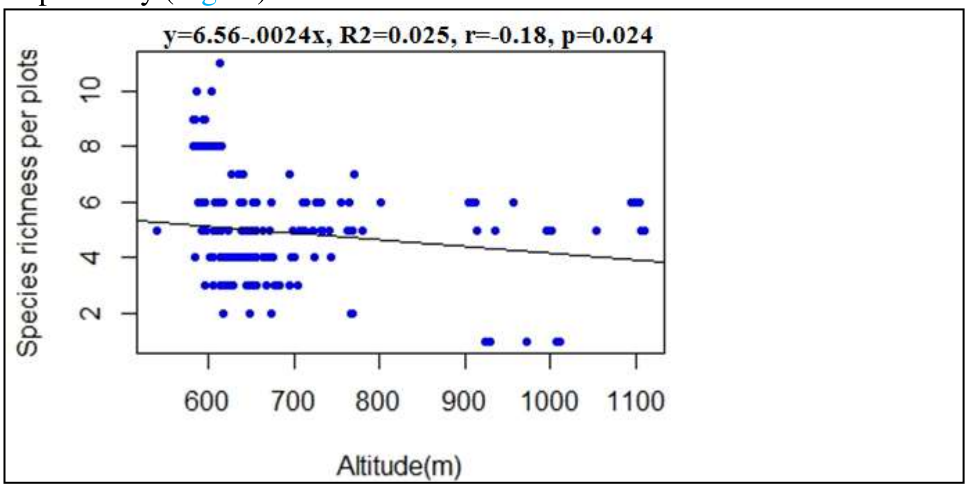

Fig. 10: Scatter plots with least squares regression line showing relationship between patterns of species richness per plot and altitude. Least square regression line equation: Species richness per plot(y) =6.56-0.0024Altitude(x); Correlation coefficient(r) = -0.18; coefficient of determination (R^2) =0.025; estimate for the slope=-0.32295183+/-0.02308234 at a 95% of confidence level, and standard error of the regression slope=0.001056

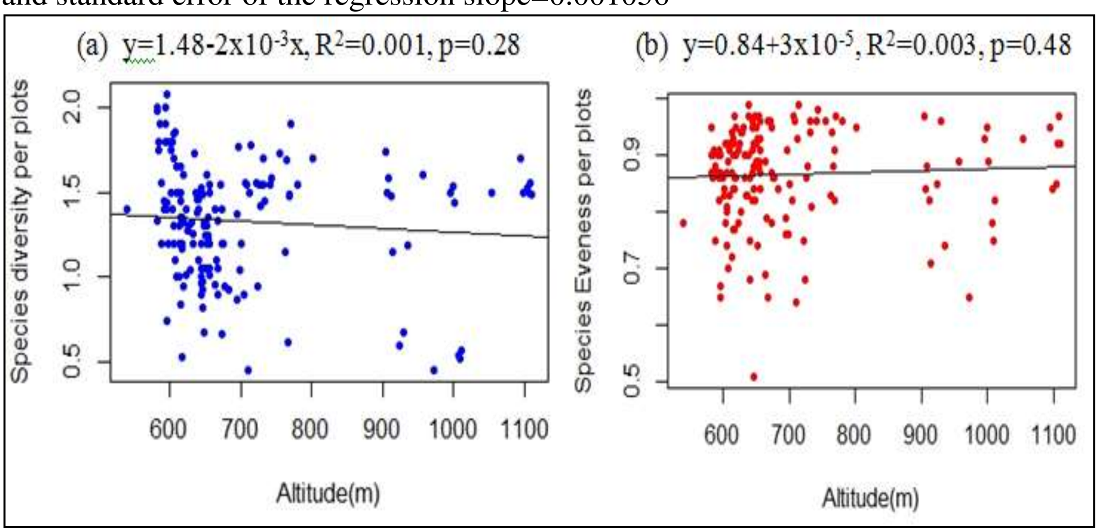

Fig.11: Scatter plots with least squares regression line showing relationship between patterns of species diversity and eveness per plot and altitude. Correlation cofficient: r=-0.08 (a), r= 0.05 (b)

3.2.4 Anthropogenic disturbance in the three communities

The estimated disturbance levels in the three plant communities varied from a maximum mean score total of 11.05 for *Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera* Community Type-3 and a minimum score of 8.9 for *Acacia mellifera-Balanites aegyptiaca* plant community Type-1 while 9.93 for *Hyphaene thebaica-Ziziphus spina-christi* Community Type-2 (Table 5). In the plant Community Type-3, almost all plots were subjected to signs of disturbance whereas; in the plant community-1(50% plots) and community-2(20% plots) did not show any signs of anthropogenic disturbance respectively.

Table 5: Degree of Anthropogenic disturbance (mean value) along the three plant communities

	Community type	GR	FWC	CC	CP	GM	IF	Total
1	*Acacia mellifera-Balanites aegyptiaca*	1.45	1.69	1.23	2.20	1.19	1.14	8.90
2	*Hyphaene thebaica-Ziziphus spina-christi*	1.79	1.43	2.50	2.07	1.93	1.21	9.93
3	*Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera*	1.91	0.80	3.30	1.93	1.93	1.18	11.05

Note: GR=grazing, FWC=Firewood collection, CC= Crop cultivation, CP= Charcoal production, GM= Gold mining, and IF= Illegal fire

The species richness of the three comminities along human disturbance intensity (no or low, moderate and heavey) was ploted and exhibited significantly. Community 1 species richness was influnced by human disturbance intensity at highly significant ($p<0.001$) level while community 2 and 3 were significant at ($p=0.04$ and 0.02) respectively. The mean range of heavy human disturbance was observed in *Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera* community type 3 where as the lowest was in *Acacia mellifera-Balanites aegyptiaca* community type 1(Fig.12).

In the present analysis also, human disturbances factors were compared with species richness, diversity and eveness using the Pearson correlation coefficient (r). The comparison correlation result of the three communities generally showed both negative and positive relationships (Table 6). In ***Acacia mellifera-Balanites aegyptiaca* community type** 1 firewood collection and crop cultivation had a significant weak positive relationship ($r=0.06$, $p=0.004$ and $r=0.46$, $p=0.05$) with a species richness respectively. Firewood was correlated negatively and crop cultivation positively with species diversity and eveness. Grazing, charcoal production, gold mining, and illegal fire showed a disturbance sign in the plots, however, statistically had no significant (weak) correlation relationship with species richness, diversity and eveness. Similarly, in ***Hyphaene thebaica-Ziziphus spina-christi community type* 2** a significant relationship was exhibited by crop cultivation ($r=0.73$, $p<0.001$) and charcoal production ($r=0.07$, $p=0.008$) with speciess richness. Species diversity and eveness were also weak positive correlation with both cultivation ($r=0.51$, $p<0.001$) and charcoal production ($r=0.08$, $p=0.008$). Grazing, firewood collection, illegal fire, and gold mining had no significant relationship with species richness; however, these variables showed a sign of disturbance in the entire sample plots of this community. In the plant community of ***Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera* type 3** a crop cultivation and illegal fire showed highly significant (strong) negative and positive correlation relationship (r=-0.611, p<0.001 and r=0.314, p<0.001) with species richness respectively. Diversity and eveness negatively correlated with cultivation and positively with fire. The rest human disturbance variables (grazing, firewood collection charcoal production and gold mining) in community 3 had no significant correlation (Table 6). Consequently, the cumulative human disturbance variables of the three communities were highly significant (p<0.001) over species richness, diversity and eveness.

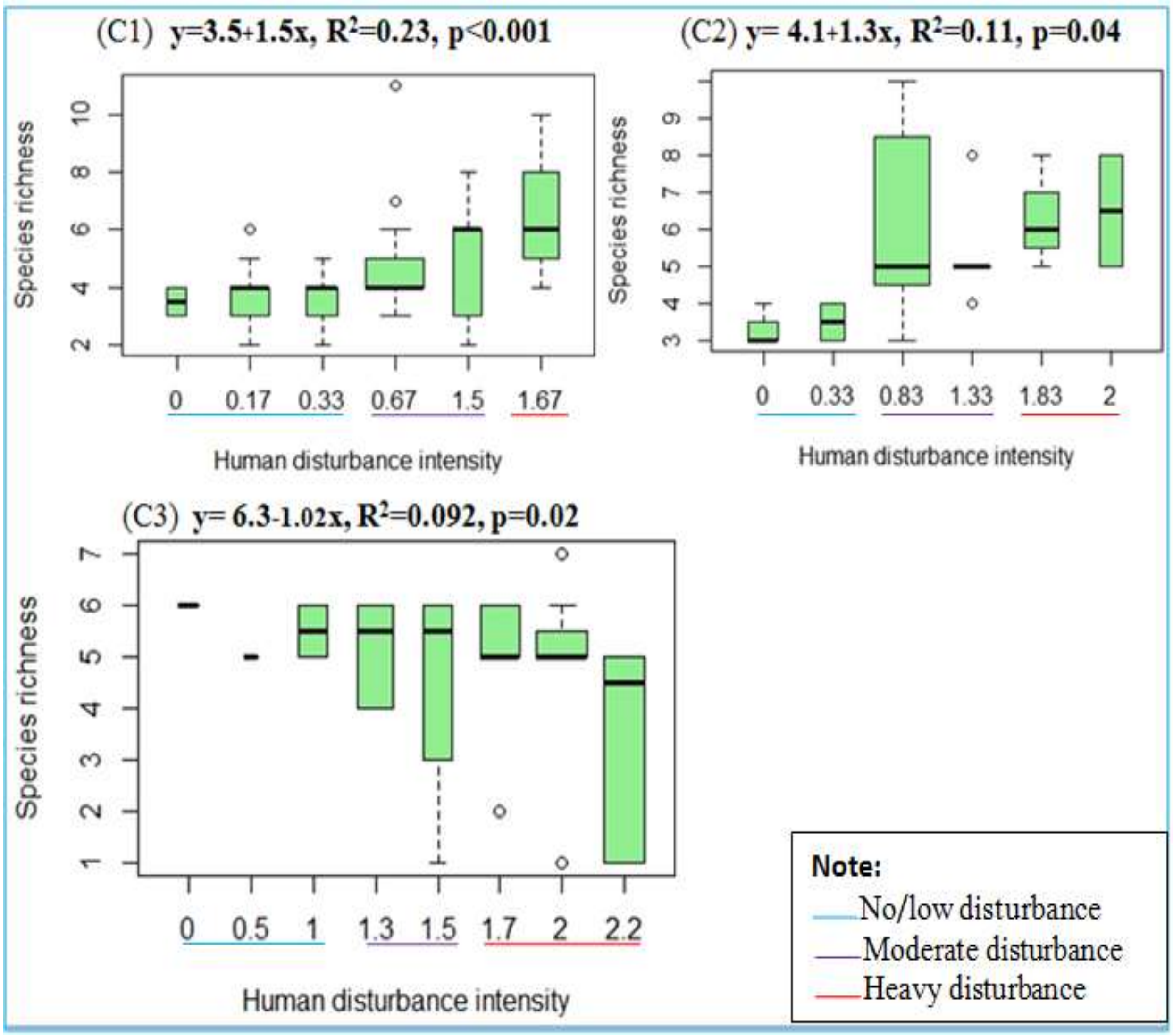

Fig.12: Box-plot showing the species richness (S) response of the three community along human disturbance intensity (no or low, moderate and heavy) for each community the degree of disturbance is presented. (C1=*Acacia mellifera-Balanites aegyptiaca*, C2=*Hyphaene thebaica-Ziziphus spina-christi* and C3=*Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera* community types).

Tabel 6: Pearson correlation coefficient (r) between species richness, diversity, eveness (p<0.001) and human disturbances variables of the three communities

1. ***Acacia mellifera-Balanites aegyptiaca*** **community type (C1)**									
Attributes	GR	FWC	CC	CP	GM	IF	SRI	DI	E
GR ($p=0.56$)^{ns}	1.00								
FWC ($p=0.004$)**	0.42	1.00							
CC ($p=0.05$)*	-0.16	-0.47	1.00						
CP ($p=0.9$)^{ns}	-0.23	-0.26	0.85	1.00					
GM ($p=0.9$)^{ns}	-0.04	-0.35	0.90	0.73	1.00				
IF ($p=0.8$)^{ns}	-0.03	-0.34	0.89	0.71	0.92	1.00			
#Species richness	-0.007	0.06	0.46	0.46	0.44	0.42	1.00		
#Species diversity	0.01	-0.05	0.45	0.39	0.43	0.46	0.58	1.00	
#Species eveness	-0.23	-0.32	0.02	-0.05	-0.02	-0.01	-0.08	0.31	1.00
2. ***Hyphaene thebaica-Ziziphus spina-christi community type*** **(C2)**									
Attributes	GR	FWC	CC	CP	GM	IF	SRI	DI	E
GR ($p=0.44$)^{ns}	1.00								
FWC ($p=0.38$)^{ns}	0.55	1.00							
CC ($p<0.001$)***	0.27	0.11	1.00						
CP ($p=0.008$)**	0.34	0.23	0.39	1.00					
GM ($p=0.86$)^{ns}	0.83	0.63	0.37	0.35	1.00				
IF ($p=0.11$)^{ns}	0.01	0.37	-0.36	0.43	0.00	1.00			
#Species richness	0.30	0.35	0.73	0.07	0.38	-0.20	1.00		
#Species diversity	0.24	0.11	0.51	0.08	0.23	-0.28	0.53	1.00	
# Species eveness	0.17	0.23	-0.12	0.16	0.21	0.22	-0.06	0.26	1.00
3.***Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera*** **Community type (C3)**									
Attributes	GR	FWC	CC	CP	GM	IF	SRI	DI	E
GR ($p=0.18$)^{ns}	1.00								
FWC ($p=0.90$)^{ns}	0.15	1.00							
CC ($p=0.0002$)***	0.01	0.08	1.00						
CP ($p=0.76$)^{ns}	0.07	0.05	0.80	1.00					
GM($p=0.4$)^{ns}	0.06	0.25	0.65	0.67	1.00				
IF ($p=0.0002$)***	0.34	0.18	0.13	0.08	-0.07	1.00			
#Species richness	0.009	0.02	-0.61	-0.49	-0.42	0.31	1.00		
#Species diversity	-0.002	0.09	-0.45	-0.29	-0.25	0.37	0.83	1.00	
# Species eveness	0.04	-0.03	-0.07	0.09	-0.02	0.18	0.28	0.65	1.00

$^{***}p<0.001$, $^{*}p<0.05$, $^{*}p<0.1$, ns= non significant, SRI= species richness, DI=diversity, E= eveness, GR=grazing, FWC=fire wood collection, CC= crop cultivation, CP= charcoal production, GM= gold mining, and IF= illegal fire

4. Discussion

4.1 Vegetation composition and diversity of the study area

The number of total species recorded in Kafta-sheraro national park (182 species) was higher than other areas of the country like Alemsaga:124 species (Getinet et al., **2015**); Chencha:174 species (Desalegn and Zerihun, **2005**; Denkoro forest :174 plant species, (Abate et al., **2006**), Dodola forest:113 species, (Kitessa et al., **2007**); Dello Menna :171 species (Motuma et al., 2010); Belete forest:157 species, (Kflay and Kitessa, 2014); Kimphe Lafa:130 plant species (Kedir et al., 2015); Peninsula-Zegie with 113 species (Alemnew et al., 2007); Grat-Kahsu dry Forest of Tigray region :102 species (Leul et al., 2010); Komto forest:180 plant species (Fekadu et al., 2015) and Tara Gedam with 143 species (Haileab et al., 2011); Bepo forest reserve Ghana:108 species, (Addo-Fordjour et al., 2009); Serengeti National Park, Tanzania:163 species (Mligo, 2015).

However, the species richness was lower than that of Sire Beggo:185 species (Abyot et al., 2014); Jibat forest:183 plant species (Tesfaye et al., 2013); Mana Angetu: 211 plant species (Ermias et al., 2008); Bale Mountains National Park: 230 species (Haile et al., 2008); Bonga forest:243 species (Ensermu Kelbessa and Teshome, 2008); Daketa valley:202 species (Demel and Tamrat,1995); Babile elephant sanctuary dry forest :237 species (Anteneh et al., 2011); Nechisar national park (208 species (Samson et al., 2010); Berbere forest: 201 species (Tesfaye et al., 2017a); Ilu Gelan district: 214 species (Zerihun et al., 2017); dry land vegetation of Wello: 216 species (Getachew et al., 2008), and Serengeti ecosystem Tanzania: 262 species (Mligo, 2015).

The dominant families occurring in the area were Fabaceae representing 37 species of (20.3 %), Poaceae 36 species(19.8 %) and Asteraceae 10 species (5.49%).The dominant families Fabaceae reported from similar vegetation studies of dry land deciduous forest: 26(15%) (Motuma et al., 2010); Odo forest: 8 species (Markos and Simon, 2015) Zegie peninsula:11 species (Alemnew et al., 2007);Tara Gedam forest (Haileab et al., 2005); Belete forest (Kitessa and Tsegaye, 2008); Nechisar national park (Samson et al., 2010); Grat-kahsu:12 species (Tesfay et al., 2019); Babile elephant sanctuary: 36 species (Anteneh et al., 2011); Sire Beggo: 23 species (Abyot et al., 2014); Berbere forest: 23 species (Tesfaye et al., 2017a); Ilu Gelan district: 23 species (Zerihun et al., 2017); Metema deciduous woodlands:16 (18.39 %) species (Haile et al., 2012b); Awash national park: 12 species (Yohannes et al., 2013);18(32.14%) species, (Kedir et al., 2015; Getachew et al., 2008; Teshome et al., 2004). Specially, the family Fabaceae contains drought tolerant, deciduous and spiny species that are well adapted to the prevailing drought conditions of the Kafta-sheraro national park and have potential to diverse ecologies of the countries. Those families also show dominant position in Flora of Ethiopia and Eritrea (Fabaceae: 678 species; Poaceae: 609 species and Asteraceae: 472 species (Ensermu and Sebsebe, 2014). Fabaceae and Asteraceae might have got the top dominant position probably due to having efficient pollination and successful seed dispersal mechanisms that might have adapted them to a wide range of ecological conditions in the past (Ensermu and Teshome, 2008).

The highest Shannon - Wiener diversity index and evenness in the study area were (H’= 2.82, J=0.72) which is comparable with other Ethiopian forests.Yemrehane Kirstos Church: H’=2.88, J=0.79 (Amanuel and Gemedo, 2018); Berbere: H’=2.95, J=0.76 (Tesfaye et al., 2017a); Tara Gedam*:* H’ = 2.98, J=0.65 (Haileab et al., 2011); Doshke: H’=3.04, J=0.85 (Ayalew et al., 2018). But diversity index is higher than Grat-Kahsu protected dry natural vegetation of Tigray region: H’=2.38 (Tesfay et al., 2019) and H’=2.4: (Mligo, 2015). Diversity indices provide more information about community composition than simply species richness by taking into account relative abundance of different species (Giliba *et al*., **2011**). Usually Shannon-Wiener diversity index (H') varies between 1.5 and 3.5 rarely exceeds 4.5 as supported by (Kent and Coker, **1992**). According to (Barbour *et al*., **1987**), Shannon's index of value greater than 2 is assigned as medium to high diversity.

4.2 Socio-economic important of plant species

Kafta-sheraro national park forest consists of locally available home commodity tools, medicinal value, natural gum and resin bearing species of acacia, Boswellia, Sterculia, Commiphora and palms. Similarly as reported by (Chikamai, **1996**; Vollesen, **1989**) over 60 gum and resin bearing species are found in Ethiopia. Some of the species of Kafta-Sheraro National Park were *Boswellia papyrifera*, *Acacia Senegal*, *Acacia seyal*, *Acacia polyacantha*, *Commiphora boranensis*, *Hyphanene thebaica* and *Sterculia Africana*. From the listed species in the park *Boswellia papyrifera* was dominant and also reported by (White, **1983**) geographically being dominant in Ethiopia, Eritrea and Somalia. Internationally the resin of *B. papyrifera* is an important commodity as it is a source of essential oils in among others the cosmetic and pharmaceutical industry (Mulugeta and Demel, **2003**). The leaves and seeds of *B.papyrifera* are highly valued as dry season fodder for goats, camels and other livestock's (Kindeya et al., **2003**). The leaves, barks, root, and the resin are also used as traditional medicines for curing various diseases (Abeje et al., **2005**; Tucker, **1986**). *Hyphanene thebaica* leaves are widely used for weaving mates, bags, baskets and coarse textiles while fruits are edible (Mohamed et al., **2008**).

4.3 Altitudinal difference and plant communities

Elevation across the kafta-sheraro national park (KSNP) was found to significantly affect the distribution of woody plant species among the identified three communities. The regression analysis of the study exhibited that the woody trees/shrubs species richness was significantly correlated with altitude. Elevation is known to influence species distribution through its direct effects on climate (Jafari *et al*., **2004**). Statistically, the impact of altitude on species divesity were not significant, however, there was a mean variation of plant diversity and eveness along altitude. Consquently, the elevation variation between sites (cummunities) was relatively limited in this study area. Because it was a key factor in separating our communities is likely due to its co-variation with the type of parental material (Zebire *et al*., **2019**), and its effects on the communities hydrological regimes which exerts strong influence on species composition (Clilverd *et al*., **2013**)..For example, in the riparian site of the KSNP (here after community 2) is strongly influenced by seasonal floods and overflows from the streams discharging into Tekeze River. Moreover, the dry season water availability is higher close to streams at this lower elevation. In contrast, community 1 and 3 is typically characterized by dry sites (water stress) for 8 months due to its location away from Tekeze river and tributary rivers, inaddition these areas (sites) are in higher elevations which are more exposed to illegal fire during the prolonged dry season. By considering other factors, according to Chang *et al*. (**2005**) plant species diversity response to altitudinal gradients was reported in five major alternatives as: (1) decline with higher altitude; (2) increase with higher altitude; (iii) bulge at mid-altitude; (iv) dip at mid-altitude; or (v) have no clear relationship with altitude.

4.4 Human disturbance across the plant community types

Human-environment interactions often have pronounced effects on forest ecosystems and their potential to provide ecosystem services (Keenan *et al*., **2015**; Ge *et al*., **2019**). Human disturbance significantly impacted species composition, species richness and diversity of the identified plant communities. The three plant communities in Kafta-sheraro national park varies in species richness, diversity and eveness. This variation might be created by pronounced human interference in the park vegetation. According to Utaile *et al*. (**2020**) human disturbance intensity significantly influenced community composition, and positively correlated with species richness and diversity. In this study **Community 1** had relatively highest species composition and intermediate diversity. This community with the lower diversity because its species are unevenly distributed and highest species was recorded. Community 1 has more priority of conservation as a usual site of African elephant, even though, most area of this vegetation was highly affected before 12 years being used as farming land, grazing area and charcoal production but now it is in good regeneration status of Acacia and Balanites tree species. Moreover, herb and grass species are dominant as result disturbance events that created gaps in canopy cover increasing open spaces in favor of herbaceous species. Species richness and diversity can also increase following human disturbances which favors shrubs and bush expansion (Sahu *et al*., **2008**; Asefa *et al*., **2015**). In the long term, increasing cover of such disturbance may recover and establishment of native species (Asefa *et al*., **2015**). Partially, in this site African elephant population and firewood collection (Fig.**13a**) have influenced the speciess richness and diversity of vegetation regeneration activities. For example, *Adansonia digitata* and *Sterculia Africana* species had absent of seedling and sapling in this community. Firewood collection significantly influnced species richness and diversity of *Acacia mellifera-Balanites aegyptiaca* community type (C1). Community 1 is relatively less affected when we compare with community 2 and 3 by disturbance variables like cattle grazing, illegal fire and extensive farming because the site is more or less protected from 2007 by the government as usual habitat of African elephants.

Community 2 has held the highest species diversity even though species composition was lowest. This community was with the higher diversity because its species are evenly (homogenous) distributed and relatively lowest species were recorded. Community 2 vegetation stands are concentrated along Tekeze river and its tributary streams. Still now along the Tekeze river side irrigation of dominant banana plantation (Fig.**13b**) and other fruits and vegetables crops cultivation, illegalfire, gold mining, animal rearing and charcoal production were dominantly influenced this vegetation community(Fig.**13c** & **d**). It was also noticed large hectares of the vegetation coverage was being converted to banana plantation farm. Many investors are working in Tekeze river side fruit production. From the statistical correlation analysis crop cultivation by irrigation and charoal production are highly significant and more influnced the speciess richness and diversity of the riverine forest of this community. About

29,760 km^2 is deforested in Africa and 80% of this is charcoal based deforestation (Neufeldt et al., 2015). As reported by Msuya et al. (2010) charcoal burning to be the main causes of forest degradation in Tanzania.

Fig.13 photographs showing human inducing disturbances in Kafta-sheraro national park: firewood collection in *Acacia mellifera-Balanites aegyptiaca* community (a), banana (*Musa sp.)* and maize (*Zea mays*) cultivation in Tekeze river sides (b), charcoal product loaded by horse cart(c) and traditional gold mining (d)

Community 3 had intermediate species richness and lowest diversity than community one and two. This community was the lowest diversity because its species are unevenly distributed and relatively lower than community one species were recorded. During field observation this community was highly influenced by seasonal farming through burning (fire) and cultivation of cereal crops (Fig.14d), mass grazing and browzing of animals (Fig.14 a & b) can be found in (Fitsum and Bikila, 2020), gum and raisin collection, gold mining, and charcoal production. Moreover, mass conversion of vegetation area into cultivation of *Sesamum indicum* was increasingly practiced by the surrounding of the local communities (Fig.14c). Illegal fire hinders *Boswellia papyrifera* seedling and sapling regeneration capacity. Community 3 was the most disturbed, i.e. having the highest mean human disturbance, likely due to proximity to adjacent agricultural activities. As Htun *et al*., (**2011**) reported that human disturbances generally can cause various impacts on forest communities of Popa Mountain Park, Myanmar and in Ngumburuni Forest Reserve Tanzania also reported that fire was observed to be the central part of several disturbances such as shifting cultivation, charcoaling, and logging (Kimaro and Lulandala, **2013**). Moreover, in Pugu Forest Reserve of Tanzania fire incident affects significant habitat destruction (Milgo, **2019**). In conclusion, community two and three of this study are directly interlinked with nearby human community livelihood.

a b

c d

Fig.14: photographs showing anthropogenic activities: Livestock browsing and grazing (**a** & **b**), *Sesamum indicum* cultivation (**c**) and *sorghum bicolor* cultivation (**d**) inside Kafta-Sheraro National Park dry forest

The results from the three communities were generally arranged in increasing disturbance scores as: *Acacia mellifera-Balanites aegyptiaca* community <*Hyphaene thebaica-Ziziphus spina-christi* <*Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera* community. All three communities are subjected to disturbance by firewood collection, charcoal production and illegal fire. The energy consumption and house building of the park surrounding villages are totally depending on trees. Community-3 was ranked as highly disturbed in all variable categories and had a greater disturbance score than community 1 and 2 because of its proximity to human settlements, suitability to agriculture and less attention was given by the responsible sector for protection. As result of the disturbance level in community 1 is low, the composition and species richness of this community are relatively high.

Therefore, the variation in species composition and diversity of a plant community is directly related to soil contents, altitude, aspect, moisture, illegal human activities and grazing intensity (Tamrat, **1993**). Furthermore, human impact created more variation than other environmental gradients on species composition of a community (Leul et al., **2010**); high anthropogenic influences (selective removal of economically important trees and grazing by livestock) could contribute for the low species richness and diversity in a given forest (Fekadu et al., **2013**); climate change and anthropogenic disturbances (Darbyshire et al., **2003**); high human dependence on natural resources by the local community within any ecosystem has caused depletion in resources (Brookfield et al., **2002**); intensive anthropogenic activities in unprotected habitats had caused heavily degraded and increased scarcity of resources outside the protected areas, and communities were forced illegally obtained resources from the adjacent protected areas (Mligo, **2015**). Moreover, in oak forests of Iran plant composition and plant diversity were decreased dramatically along the disturbance gradient (Eshaghi Rad et al., **2018**).

Even if the effect of grazing was not statistically significant on species richness and diversity of Kafta-sheraro national park of the three communities, species richness declines in heavy grazing natural vegetation (Tessema et al., **2011**). Grazing activity by livestock not only affects understory density but other structural attributes, for example, a high density of livestock in forest areas declines the value of abundance, size and stand basal area of woody plants (Echeverria et al., **2007**; Veblen et al., **1993**). Moreover, regeneration of trees is significantly affected by the presence of livestock (Zamorano-Elgueta et al., **2012**). Livestock also affects understory structure by grazing and trampling the herbaceous layer (Belsky and Blumenthal, **1997**). Rummell (**1951**) showed that grazing by livestock reduced understory vegetation by 45-61% in ponderosa pine forests. Understory density mainly of bamboo was significantly reduced in highly grazed stands in comparison to less disturbed stands in Argentina (Veblen et al., **1993**).The lowest mean values of litter depth reported in plots that were subjected to the presence of livestock (Caviedes and Ibarra, **2017**). Livestock grazing of plant biomass located above ground minimizes the quantity of biomass for litter conversion (Belsky and Blumenthal, **1997**). Similarly, in California reported that litter depth was significantly lower in grazed sites in comparison to un-grazed sites when investigating the impact of cattle grazing on a coastal prairie plant community (Hayes and Holl, **2003**).

Traditional gold mining was another human-induced factor by digging the vertical soil profile of the park approximately 25-30m downward (Figure 13(**d**)). In addition to damage the plant root, gold mining had also a direct contributor to a fire extinigushing in the forest area by the gold miner in order to prepare their daily food. Statistically, there was no significant correlation between gold mining and species richness, diversity and eveness; however, the traditional gold mining showed a clear mean disturbance sign in almost all plots (Fitsum and Bikila, 2020). There were no previous research studies related to traditional gold mining impact on plant richness and diversity, except the study done on the negative impact of gold mining on the population of wildlife in Kafta Sheraro National Park (Berihun et al., 2016). Hence, it was very difficult to compare and contrast gold mining with other research findings (Fitsum and Bikila, 2020).

5. Conclusion

Kafta-sheraro national park (KSNP) vegetation and the hydrology of Tekeze River are ecologically and economically very important for livelihood of the surrounding community. The park has documented 182 species, 142 genera and 53 families. The site has high floristic composition similarity with dry protected areas (e.g. Babile elephant sanctuary woody species and Hugumburda forests of Tigray region) but dissimilar with Afromontane forests; because, structurally and floristically the tropical dry forests are less complex than the wet forests. Fabaceae and Poaceae were found to be the most dominant family followed by Astraceae, Combretaceae, Solanaceae, and Malvaceae while herbs were the dominant growth forms.

The vegetation of Kafta-sheraro national park (KSNP) vegetation was grouped into three plant community types. These communities were arranged along different altitudinal ranges. Plant community one exhibited the highest species richness (87) while the highest diversity and even distribution of individuals was observed for community type two. Community type three was with intermediate species richness and lowest diversity. The variation in species composition and richness among communities might be associated to altitudinal difference and degree of disturbance. Altitude is significantly correlated with specis richness all community types while it is more strongly correlated with community type 1. Human disturbance significantly influenced plant community composition and positively correlated with species richness and diversity of specific community type. Despite these disturbances, KSNP still holds important proportions of both animal and plant species. The ongoing human activities have already caused size and quality degradation of useful plants and enhanced species diversification impacts to the forest ecosystem.The similarity of communities was higher when we compare with dry vegetation type study in the region and the country. **Therefore,** detail study on conservation challenges of the park vegetation; the government and responsible sectors jointly work with the community for sustainable utilization of the forest resources; community awareness creation on environmental role of trees and develop alternative livelihood for the communities who are living near the park.

Abbreviations

FAO: Food and Agricultural Organization; KSNP: Kafta-sheraronational park; KSNPCL: Kafta Sheraro national park census list; NCSS: National Conservation Strategy Secretariat; CAP: community analysis package; ETH: Ethiopian Herbarium; GPS: Geographical positioning system; EWCA: Ethiopian wildlife conservation authority; and DBH: daimeter at breast height.

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Authors' contributions

Fitsum Temesgen has leaded the overall activities of the research process such as the design, data collection, entry, analysis, and interpretation of results as well as writing up of the draft manuscript. Bikila Warkineh has involved in constructive guidance, comments and suggestions on the manuscript. Addisu Asefa has also supported on comments of the paper.

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Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon request via personal email.

Ethics approval and consent to participate

Prior to conduct the research activities a research site permission letter was obtained from EWCA. Hence, as the researcher, the authors take full responsibility for all the contents and any mistakes in the document.

Consent for publication

Authors have agreed to submit for Forest ecosystem and approved the manuscript for submission.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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Appendix-1: List of plant species collected from Kafta-Sheraro National Park (T=Tree, H=Herb, S=Shrub, T/ S=Tree/ Shrub, C=Climber, R=Reed, G=Grass, Ha=Habit, C.Id= Collection Id., FT=Fitsum Temesgen)

Scientific name	Family name	Ha.	Local name (Tigrigna)	C.Id
Abelmoschus esculentus (L.) Moench.	Asteraceae	H	Wayka	FT89
Abutilon figarianum Webb.	Malvaceae	H	**	FT113
Acacia albida Del.***	Fabaceace	T	Momona	FT14
Acacia etbaica Schweinf***	Fabaceae	T	Seraw	FT50
Acacia lahai Steud. & Hochst.ex Benth.***	Fabaceae	T	Lahai adi	FT30

Appendix-1 continued

Scientific name	Family name	Ha.	Local name (Tigrigna)	C.Id
Acacia mellifera (Vahl) Benth.***	Fabaceae	T	Ktrit	FT12
Acacia oerforta (Forssk.) Schweinf.***	Fabaceae	S	Tekelbe	FT05
Acacia polyacantha Willd.***	Fabaceae	T	Gomoro	FT49
Acacia senegal (L.) Willd.***	Fabaceae	T	Kenteb	FT01
Acacia seyal Del.***	Fabaceae	T	Chea	FT10
Acacia sp. Mart.***	Fabaceae	T	Chgeno	FT47
Acacia tortilis (Forssk.) Hayne.***	Fabaceae	T	**	FT51
Acalypha crenata Hochst. ex A.Rich.	Malvaceae	H	**	FT93
Acalypha indica (L.)	Euphorbiaceae	H	**	FT111
Achyranthes aspera var.aspera (L.)	Amaranthaceae	H	**	FT75
Adansonia digitata (L.) ***	*Bombacaceae*	T	Dima	FT13
Aeschynomene paniculata Vogel.	Fabaceae	H	**	FT87
Allium cepa L.	Liliaceae*	H	Shigurti keyh	FT126
Allium sativum L.	Liliaceae*	H	Shigurti tsaeda	FT124
Alternanthera pungens Kunth.	Amaranthaceae	H	**	FT121
Amaranthus spinosus (L.)	Lamiaceae	H	**	FT98
Amphicarpa africana (Hook.f.)Harms	Fabaceae	C	**	FT69
Anogeissus leiocarpus (DC.) Guill.&Perr.***	Combretaceae	T	Hanse	FT08
Aristida adoensis Hochst. ex A.Rich.	Poaceae	G	**	FT141
Artemisia abyssinica Sch.Bip. ex A.Rich.	Asteraceae	H	Chena barya	FT135
Asparagus flagellaris (Kunth) Baker	Amaranthaceae	H	**	FT99
Aspilia guineensis Hoffm & Muschl.	Asteraceae	H	**	FT78
Balanites aegyptiaca (L.) Del.***	Balanitaceae	T	Mekie	FT04
Ballota nigra (L.)	Lamiaceae	H	**	FT116
Barleria prionitis (L.)	Fabaceae	H	Eshokanchwa	FT95
Bidens pachyloma (Oliv. & Hiern) Cufod.	Fabaceae	H	**	FT104
Blainvillea gayana Cass.	Fabaceae	H	**	FT82
Boscia angustifolia A.Rich.***	Capparaceae	T/S	**	FT46
Boswellia papyrifera Hochst. ex A.***	Burseraceae	T	Meker	FT26
Brucea antidysentrica J.F.***	Simaroubaceae	T	Melita	FT60
Buddleja polystachya Fresen.***	Loganiaceae	S	Metere	FT64
Burkea africana Hook.***	Caesalpiniaceae	T	Amangul	FT32
Cadaba farinosa Forssk.***	Capparaceae	S	**	FT37
Calopogonium mucunoides Desv.	Fabaceae	C	**	FT72
Calotropis procera (Aiton) W.T.Aiton***	Asclepiadaceae	T	Gindae	FT25
Capparis decidua (Forssk.) Edgew.***	Capparaceae	T	Malokza	FT19
Capsicum annuum L.	Solanaceae*	H	**	FT125
Carica papaya (L.)***	Caricaceae*	T	Papaya	FT55
Carissa edulis (Forssk.) Vahl.***	Apocynaceae	S	Agam	FT176
Casuarina equisetifolia (L.)***	Casuarinaceae	T	Shwshwit	FT18
Cenchrus ciliaris (L.)	Poaceae	G	Almet	FT137
Chamaecrista absus (L.)	Lamiaceae	H	**	FT101
Chamaecrista nigricans (L.) Moench	Fabaceae	H	**	FT74
Chascanum marrubifolium Fenol ex. Walp.	Verbenaceae	H	**	FT131
Chloris virgata Sw.	Poaceae	G	**	FT156
Cissampelos mucronata A.Rich.	Menispermaceae	C	**	FT67
Cissus guadrangularis (L.)	Vitaceae	C	Alke	FT65
Citrus aurantifolia (Christm.) Swingle***	Rutaceae*	S	Lemin	FT58
Combretum glutinosum Perr. ex DC.***	Combretaceae	S	**	FT34
Combretum hartmannianum Schweinf.***	Combretaceae	T	Tenkelba	FT02
Combretum molle R.Br.ex G.Don***	Combretaceae	T	**	FT35
Combretum sp. Loefl.***	Combretaceae	T	**	FT177
Commelina communis (L.)	Commelinaceae	H	**	FT109
Commiphora boranensis K. Vollesen***	Burseraceae	T	**	FT43

Appendix-1 continued

Scientific name	Family name	Ha.	Local name (Tigrigna)	C.Id
Conya canadensis (L.) Cronquist.Erigeron.c	Asteraceae	H	**	FT128
Cordia Africana Lam. ***	Boraginaceae*	T	Aki	FT181
Crotalaria ononoides Benth.	Fabaceae	H	**	FT102
*Cucumis prophetarum (*L.)	Cucurbitaceae	C	**	FT73
Cucurbita Maxima Duchesne.	Cucurbitaceae	C	**	FT68
Cymbopogon caesius (Hook.& Arn.) Stapf.	Poaceae	G	Tbrara	FT148
*Cynodon dactylon (*L.)Pers	Poaceae	G	**	FT161
Cynodon plectostachyus (K. Schum.) Pilg.	Poaceae	G	**	FT171
Cyperus rotundus (L.)	Cyperaceae	R	**	FT166
Cyperus scariosus R.Br.	Cyperaceae	R	Seti	FT159
Dactyloctenium aegypticum (L.) Willd.	Poaceae	G	**	FT147
Dalbergia melanoxylon Guill. & Perr.***	Fabaceae	T	Zibe	FT03
Datura stramonium (L.)	Asteraceae	H	Mezerbae	FT106
Delonix regia (Boj. ex Hook.) Raf.***	Fabaceae	T	**	FT172
Dichanthium annulatum var.*papillosum*(For.)***	Poaceae	G	**	FT182
Dicliptera verticillata (Forsk.) C. Chr.	Acanthaceae	H	**	FT115
Dicrostachys cinerea (L.)Wight and Arn.***	Fabaceae	T	Gonok	FT06
Digitaria abyssinica (Hochst. ex A.Rich.)	Poaceae	G	**	FT155
Digitaria velutina (Forssk.) P.Beauv.	Poaceae	G	**	FT173
Diheteropogon ampletcens (Hack.)	Poaceae	G	**	FT140
Dinebra retroflexa (Vahl) Panz.	Poaceae	G	Chwchwit	FT154
Diospyros abyssinica (Hiern) F. White***	Ebenaceae	T	**	FT59
Diospyros mespiliformis Hochst. ex A. DC.***	Ebenaceae	T	Aye	FT31
Dumasia villosa DC.	Fabaceae	C	**	FT70
Echinocloa pyramidals(Lam.)Hitchc.Chase	Poaceae	G	**	FT163
Eleusine coracana Gaertn.	Poaceae*	G	Dagusha	FT180
Eleusine indica (L.) Gaertn.	Poaceae	G	**	FT160
Epilobiumcilia Raf.	Solanaceae	H	**	FT108
Eragrostis cilianensis (All.)Vign.ex Janchen	Poaceae	G	**	FT145
Eragrostis tef (Zucc) Trotter.	Poaceae*	G	**	FT169
Feretia apodanthera Delile.***	Rubiaceae	S	Rowe	FT23
Ficus sycomorus (L.)***	Moraceae	T	Sagla	FT33
Galinsoga parviflora Cav.	Asteraceae	H	**	FT118
Grewia bicolor Juss.***	Tiliaceae	T/S	**	FT07
Grewia flavescens Juss.***	Tiliaceae	T/S	Betremushe	FT28
Grewia mollis Juss.***	Tiliaceae	T	**	FT41
Grewia villosa Willd.***	Tiliaceae	S	hable	FT20
Guizotia schimperi Sch.Bip. ex Walp.	Fabaceae	H	**	FT88
Hackelochloa granularis (L.) Kuntze	Poaceae	G	**	FT143
Halopyrum miicronatum L. ,Stapf.	Poaceae	G	**	FT149
Heteropogon contortus (L.) P.Beauv.	Poaceae	G	**	FT162
Hypanheuia hirta (L.) Stapf.	Poaceae	G	**	FT139
Hyphaene thebaica (L.) Mart.***	Arecaceae	T	Laka	FT24
Jasminum abyssinicum Hochst. ex DC.***	Oleaceae	S	**	FT15
Justicia flava (Forssk.) Vahl.	Acanthaceae	H	**	FT96
Kohautia cynanchica DC.	Malvaceae	H	**	FT90
Laggera alata (D. Don) Sch. Bip. ex Oliv.	Asteraceae	H	**	FT122
Lannea microcarpa Engl. & K. Krause.***	Anacardiaceae	T	**	FT42
Leptadenia lanceolata (Poir.) Goyder.***	Asclepiadaceae	S	**	FT38
Leucas martinicensis (Jacq.) W.T. Aiton	Lamiaceae	H	**	FT119
Mangifera indica (L.) ***	Anacardiaceae	T*	Mango	FT56
Maytenus senegallensis Forssk.***	Celastraceae	T	**	FT11
Melanocenchris abyssinica (R.Br. ex Fresen.	Poaceae	G	**	FT144
Melia azedarach (L.)***	Meliaceae	T	Nim	FT54

Appendix-1 continued

Scientific name	Family name	Ha.	Local name (Tigrigna)	C.Id
Meriandra dianthcra (Roth ex Roem.&Schult.	Acanthaceae	H	Sesegzbi	FT97
Moringa stenopetala (Baker f.) Cufod.***	Moringaceae	T	Shiferaw	FT29
Musa species (L.)	Musaceae*	H	Benana	FT136
Nerium oleander (L.)***	Apocynaceae	S	**	FT36
Nicandra physalodes (L.) Gaertn.	Solanaceae	H	Absho	FT112
Nicotiana tabaccum L.	Solanaceae	H	**	FT133
Ocimum gratissimum (L.)	Fabaceae	H	**	FT107
Olyra latifolia (L.)	Poaceae	G	Saeri harmaz	FT157
Otostegia ellenbeckii Gürke.***	Lamiaceae	S	Chendog	FT62
Oxytenanthera abyssinica (A.Rich.) Munro	Poaceae	G	Shambeko	FT164
*Panicum coloratum (*L.)	Poaceae	G	**	FT170
Parkinsonia aculeata (L.)***	Fabaceae	T	Tetem	FT52
Pennisetum glaucum (L.) R.Br.	Poaceae	G	**	FT167
Pennisetum typhoideum Stapf & Hubb.	Poaceae	G	**	FT165
Pentatropis nivalis J.F. Gmel.	Poaceae	G	Zeri seytan	FT150
Phragmites australis (Cav.) Trin. ex Steud.	Asclepiadaceae	C	**	FT174
*Phyllanthus maderaspatensis (*L.)	Euphorbiaceae	H	**	FT77
Physalis angulata (L.)	Solanaceae	H	**	FT110
Pittosporum viridiflorum Sims.	Pittosporaceae	T	**	FT45
Plectranthus fruticosus L'Her.	Asparagaceae	H	**	FT100
Plumbago zeylanica (L.)***	Plumbaginace	S	Aftuh	FT61
Poa annua L.	Poaceae	G	**	FT142
Polygala abyssinica ex. Fresen.	Asteraceae	H	**	FT83
Polypogon monspeliensis (L.)Desf.	Poaceae	G	**	FT153
Rhamnus prinoides L'Her. ***	Rhamnaceae*	S	**	FT179
Rhynchosia minima (L.) DC.	Fabaceae	C	**	FT175
Ricinus communis (L.)***	Euphorbiaceae	S	Guli	FT53
Rottboellia cochinchinensis (Lour.) Clayton	Poaceae	G	**	FT151
Salvadora persica (L.)***	Salvadoraceae	S	Shebelsha	FT21
Sauromatum venosum Dry land.ex.Aiton.	Araceae	H	**	FT134
Sclerocarya birrea (A. Rich.) Hochst.***	Anacardiaceae	T	**	FT57
Scorpiurus muricatus (L.)	Fabaceae	H	**	FT132
Senna obtusifolia (L.) H.S.Irwin & Barneby.	Euphorbiaceae	H	Abake harmaz	FT94
Senna occidentalis (L.)	Fabaceae	H	**	FT117
Senna sinqueana (Delile) Lock.***	Fabaceae	S	Hambhambo	FT63
Sesamum indicum (L.)	Pedaliaceae*	H	**	FT120
Sida acuta Burm.f.	Malvaceae	H	**	FT80
Solanum incanum (L.)***	Solanaceae	S	Engule	FT40
Solanum lycopersicum L.	Solanaceae*	H	**	FT123
Solanum tuberosum L.	Solanaceae*	H	**	FT127
Sorghum bicolor (L.) Moench	Poaceae*	G	**	FT168
Spermacoce pusilla Wall.	Fabaceae	H	**	FT85
Sterculia africana Del.***	Sterculiaceae	T	Darle	FT09
Stereospermum kunthianum Cham.***	Bignoniaceae	T/S	**	FT44
Stipa borysthenica Klokov ex Prokud.Wulf.	Poaceae	G	**	FT152
Stipa tenuissima Trin.	Poaceae	G	Choba	FT146
Streblochaete longiarista (A.Rich) Pilg.	Poaceae	G	**	FT138
Striga latericea Vatke.	Scrophulariaceae	H	Metselem	FT79
*Tamarindus indica (*L.)***	Fabaceae	T	Humer	FT17
Tephrosia pentaphylla (Roxb.)G.Don.	Fabaceae	H	**	FT76
Tephrosia purpurea (L.) Pers.	Fabaceae	H	**	FT81
Tephrosia virginiana (L.)Pers.	Fabaceae	H	**	FT105
Teramnus labialis var. *abyssinicus* (L.f.) Spr.	Fabaceae	C	**	FT71
Terminalia brownii Fresen.***	Combretaceae	T	Weyba	FT27

Appendix-1 continued

Scientific name	Family name	Ha.	Local name (Tigrigna)	C.Id
Terminalia laxiflora Engl. & Diels.***	Combretaceae	T	**	FT39
Terminalia sp. L.***	Combretaceae	T	**	FT178
Tetrapogon villosus Desf.	Poaceae	G	**	FT158
Tribulus cistoides (L.)	Zygophyllaceae	H	**	FT114
Trigonella species L.	Polygalaceae	H	**	FT84
Triumfetta rhomboidea Jacq.	Rubiaceae	H	**	FT91
Vigna radiata subsp.sublobata (L.) R.Wilczek	Fabaceae	H	**	FT103
Wissadula amplissima (L.) R.E. Fries	Tiliaceae	H	**	FT92
Xanthium spinosum L.	Asteraceae	H	**	FT129
Xanthium strumarium (L.)	Asteraceae	H	**	FT130
Zehneria anomala C. Jeffrey	Cucurbitaceae	C	Hafaflo	FT66
Ziziphus mucronata Willd***	Rhamnaceae	T/S	Geba adgi	FT48
Ziziphus spina-christi (L.)Desf.***	Rhamnaceae	T	Geba	FT16
Zornia glochidiata Rchb. ex DC.	Rubiaceae	H	**	FT86
Ziziphus mauritiana Willd.***	Rhamnaceae	T/S	Andel	FT22

Note: (* =Plant species recorded outside quadrat area; ** common name is unknown) and *** (**Source:** Fitsum and Bikila, 2020)

Figures

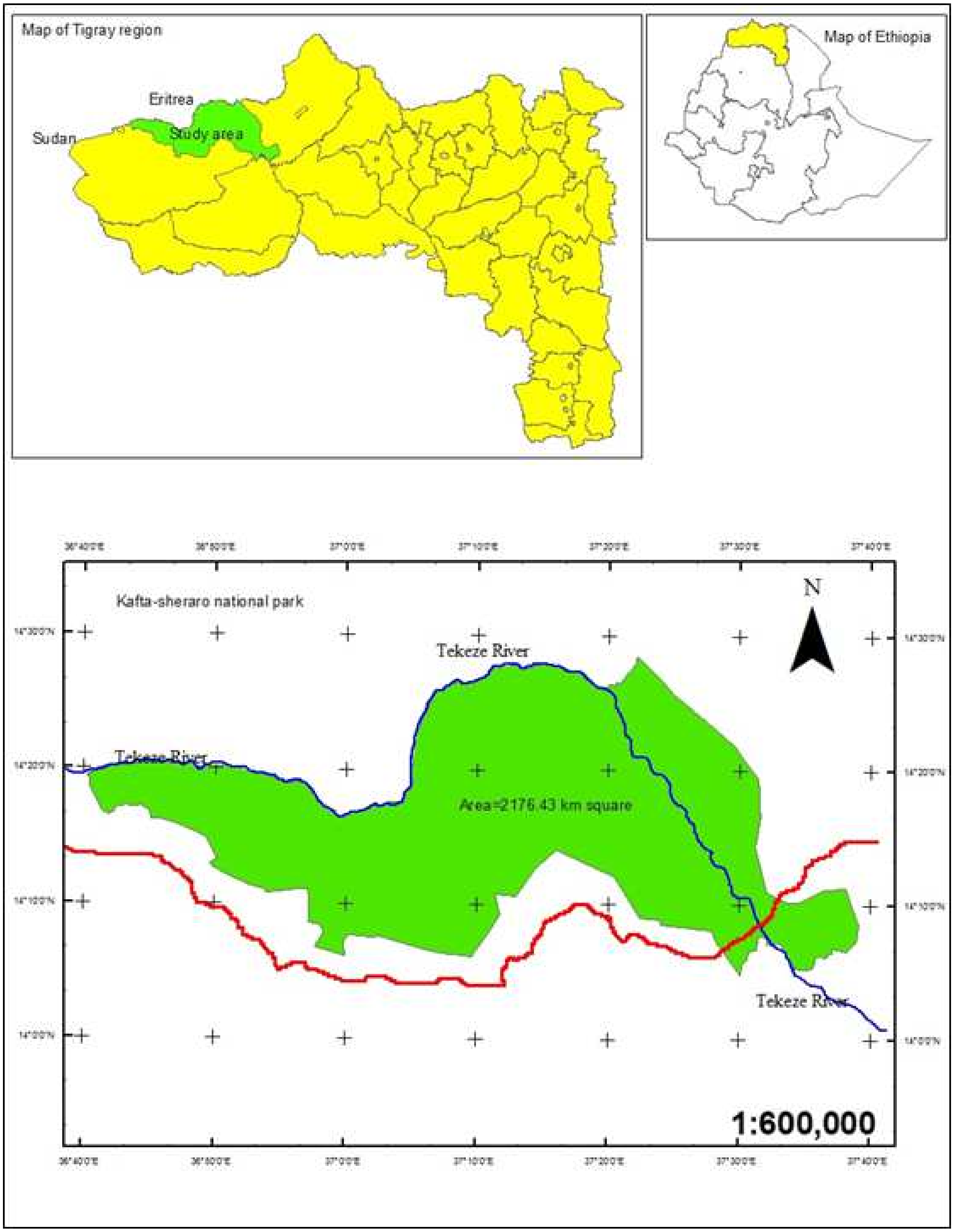

Figure 1

Location map of the study site (Source: Fitsum and Bikila, 2020) Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

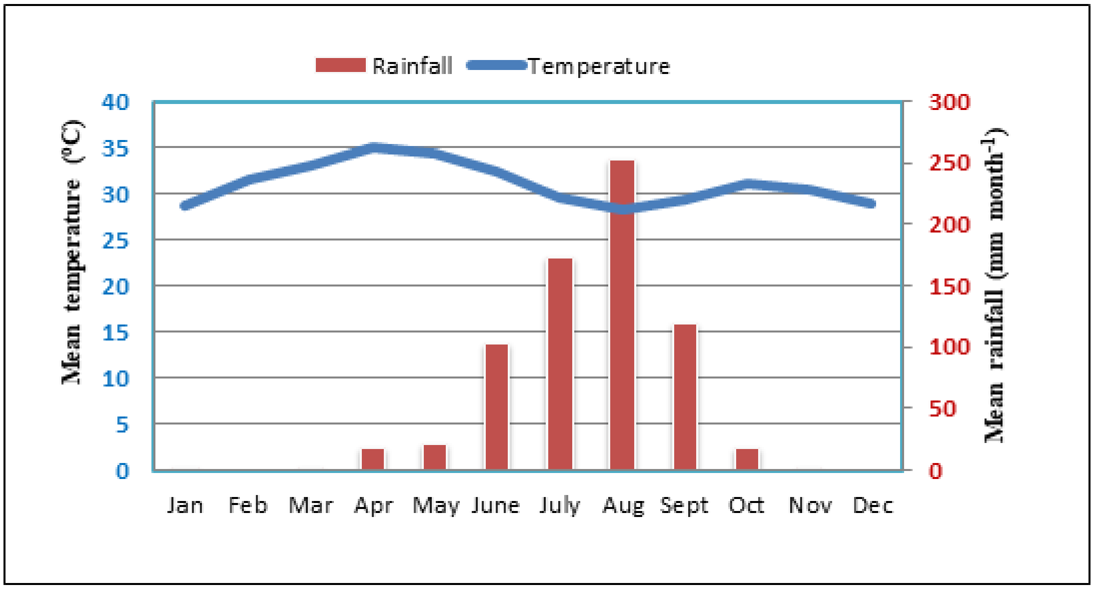

Figure 2

Average Rainfall and Temperature (Source: Fitsum and Bikila, 2020)

Figure 3

Tekeze riverside irrigated farm land and settlement in side Kafta-sheraro national park

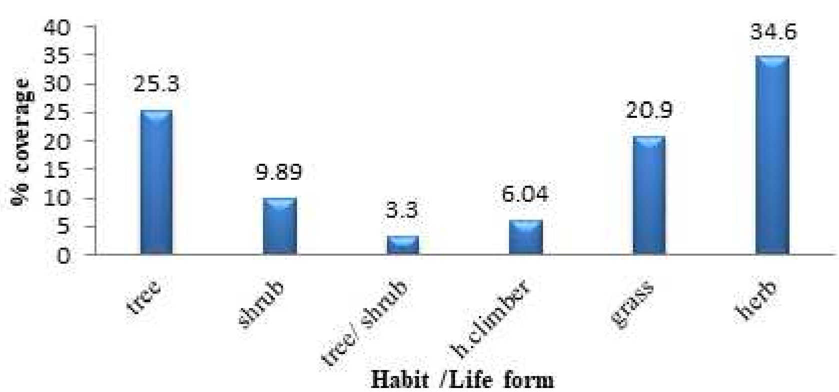

Figure 4

Life form (habit) distribution of Kafta-Sheraro National Park vegetation

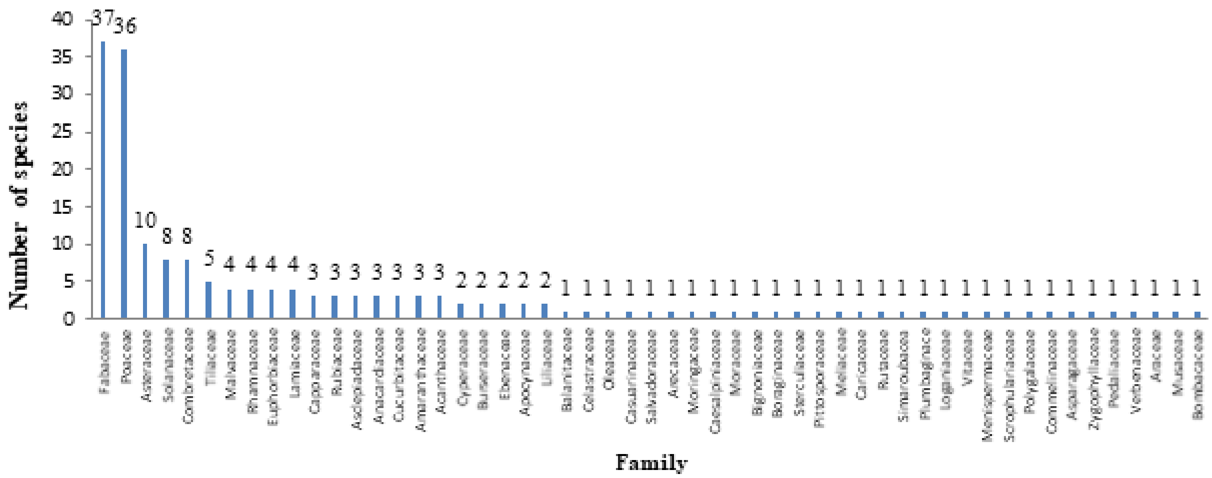

Figure 5

The number of plant species in each family in Kafta-sheraro national park (KSNP)

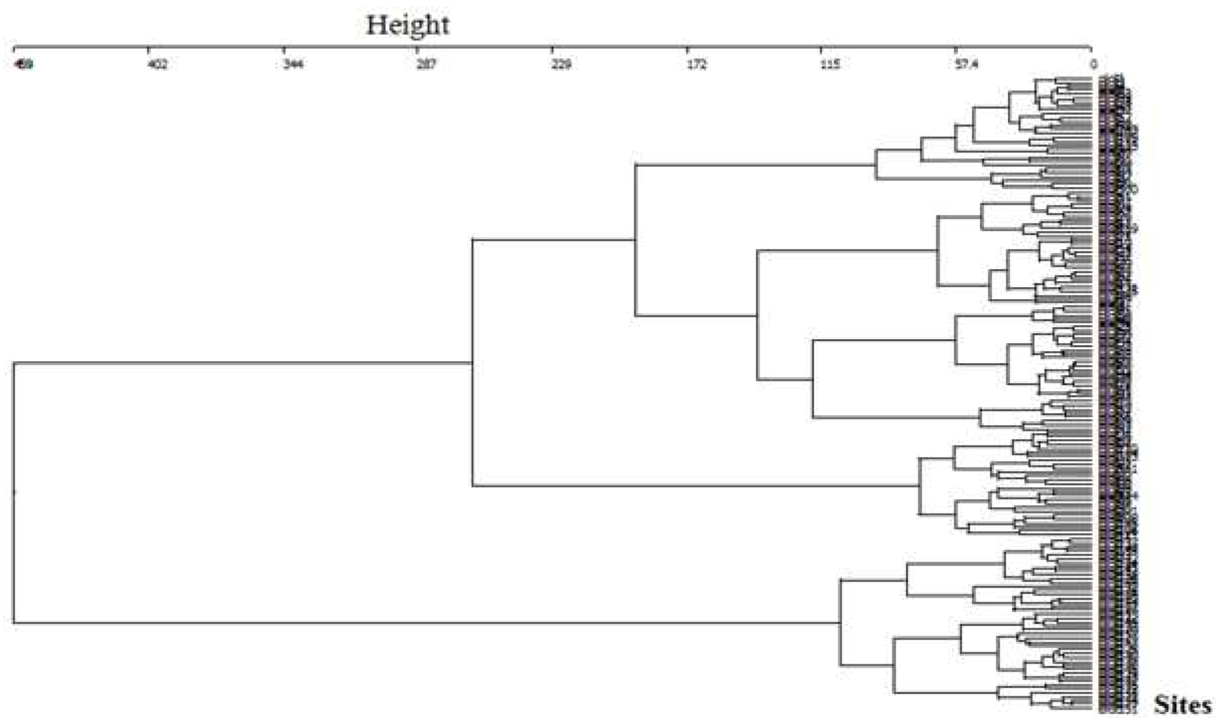

Figure 6

Dendrogram showing plant communities 'types of Kafta-Sheraro National Park using Agglomerative hierarchical Ward's method and Euclidean distance (C1plots:1-30,32,34,37-77, 79,84,88,91,93,96-100,103,107,109,112,119,131,133,135;C2plots:31,35,36,78,80-83,85,86,87,89,90,92,94,95,101, 102,104,105,106,108,110,111,113,114,161;C3plots:16,33,115-118,120-130,132,134,136,137-160).

Figure 7

Some floras of Acacia mellifera-Balanites aegyptiaca community type

Figure 8

Hyphaene thebaica- Ziziphus spina-christi community type

Figure 9

Combretum hartmannianum -Terminalia brownii dominated community type

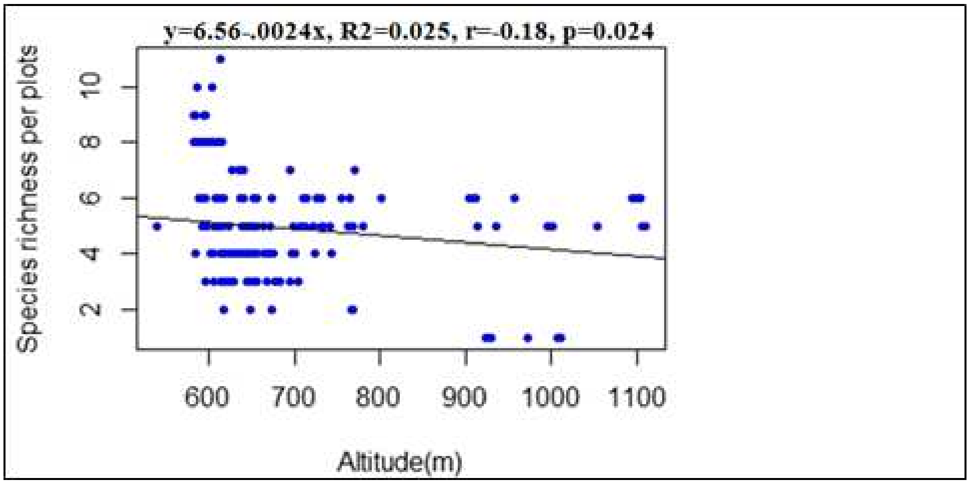

Figure 10

Scatter plots with least squares regression line showing relationship between patterns of species richness per plot and altitude. Least square regression line equation: Species richness per plot(y) =6.56-0.0024Altitude(x); Correlation coefficient(r) = -0.18; coefficient of determination (R2) =0.025; estimate for the slope=-0.32295183+/-0.02308234 at a 95% of confidence level, and standard error of the regression slope=0.001056

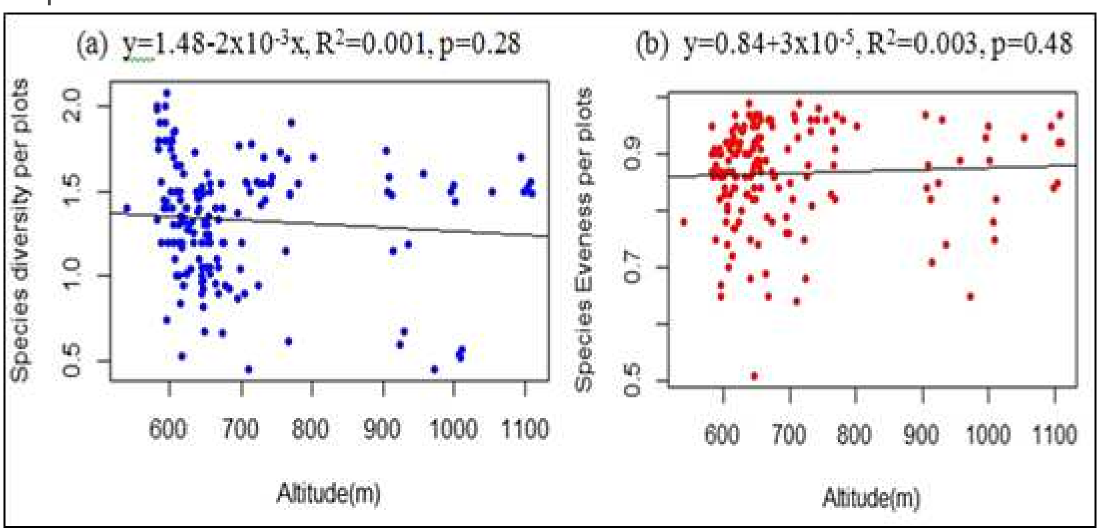

Figure 11

Scatter plots with least squares regression line showing relationship between patterns of species diversity and eveness per plot and altitude. Correlation cofficient: r=-0.08 (a), r= 0.05 (b)

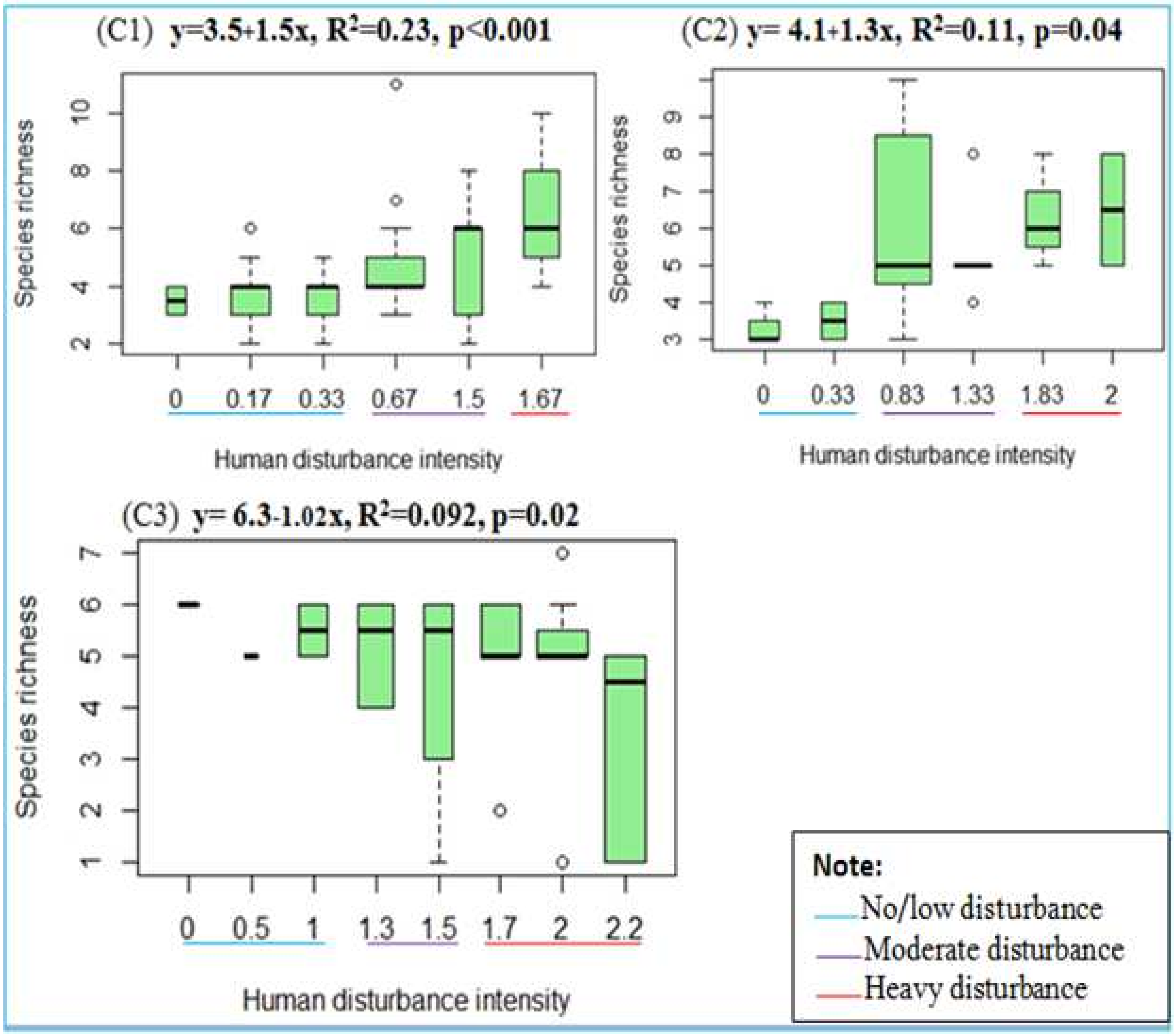

Figure 12

Box-plot showing the species richness (S) response of the three community along human disturbance intensity (no or low, moderate and heavy) for each community the degree of disturbance is presented. (C1=Acacia mellifera-Balanites aegyptiaca, C2=Hyphaene thebaica-Ziziphus spina-christi and C3=Combretum hartmannianum-Terminalia brownii-Boswellia papyrifera community types).

Figure 13

photographs showing human inducing disturbances in Kafta-sheraro national park: firewood collection in Acacia mellifera-Balanites aegyptiaca community (a), banana (Musa sp.) and maize (Zea mays) cultivation in Tekeze river sides (b), charcoal product loaded by horse cart(c) and traditional gold mining (d)

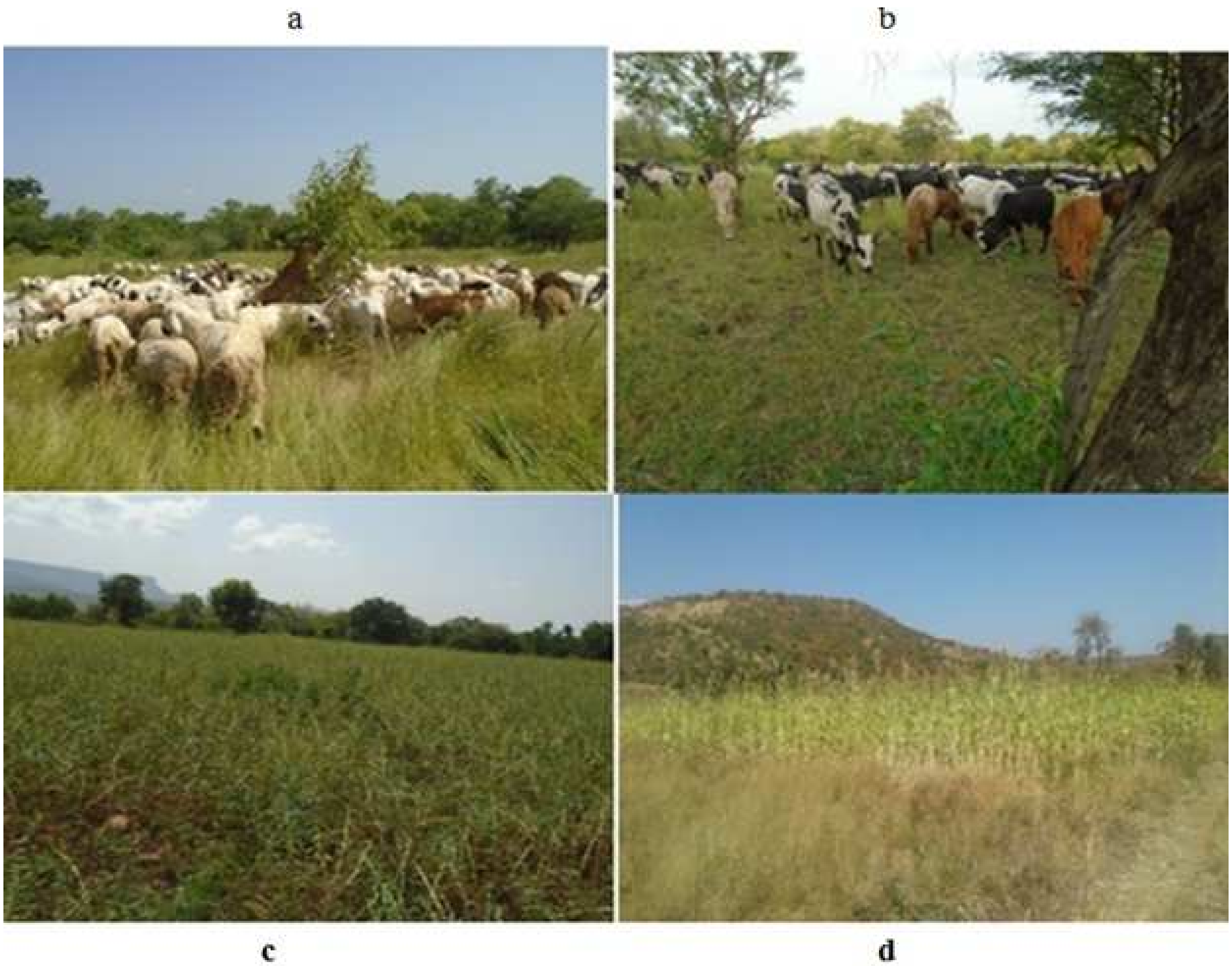

Figure 14

photographs showing anthropogenic activities: Livestock browsing and grazing (a & b), Sesamum indicum cultivation (c) and sorghum bicolor cultivation (d) inside Kafta-Sheraro National Park dry forest