Interplay among African Bush Elephant (*Loxodonta africana* L.), Vegetations, and Humans in Kafta Sheraro National Park, Western Tigray: Implications for the Park Sustainability

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GRADUATE PROGRAMMES

This is to confirm that the dissertation prepared by Fitsum Temesgen Hailemariam entitled: **Interplay among African Bush Elephant (*Loxodonta africana* L.), Vegetations, and Humans in Kafta Sheraro National Park, Western Tigray: Implications for the Park Sustainability** and submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy (PhD) in Environmental Sciences (Natural Resources Conservation and Management) fulfills with the guideline of the University.

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DECLARATION

The study reported in this PhD dissertation, except where otherwise indicated, is my original work and has not been submitted for any degree or examination at any other university. This dissertation does not contain other personal data, pictures, or other information unless it is acknowledged that the data were sourced from other persons. Therefore, I confidently confirm my signs below.

This dissertation is submitted to fulfill the requirements for Degree of Doctor of Philosophy (PhD) in environmental sciences at Addis Ababa University and is deposited in the library of the University and open for readers as a source of information.

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Fitsum Temesgen, PhD dissertation defense, Addis Ababa University, July 2024

ABSTRACT

The study took place in Kafta Sheraro National Park (KSNP), a dry woodland and riparian forest habitat for elephants. Changes in the cover of this vegetation within and around the park are the basic driving forces of habitat change and human-elephant conflict (HEC). In the past ten years, HEC has been increasing due to the widespread conversion of woodland and riparian forests into cropland. The communities adjacent to the KSNP are profoundly dependent on natural resources, which affect the wildlife habitat; consequently, park management intervention is challenging. This study aims to investigate the interaction among elephants, vegetation, and humans, which in turn helps to determine the implications for park sustainability. Landsat sensors of the TM, ETM^+, and OLI images (1988 to 2018) and ground truth points were applied to assess the land use/land cover (LULC) change and normalized difference vegetation index (NDVI) features. The vegetation data were collected from 161 plots, each with a size of 400 m^2 for trees and shrubs, while subplot sizes of 100 m^2 for saplings and 25 m^2 for seedlings were established in the main plot. A diameter ≥2.5 cm and height **≥2** m were measured for trees and shrubs. The elephant food choice and its utilization effects on plant species were identified via direct field walk records on 112 plots. The drivers of LULC change, HEC, and the community's attitude of conservation were surveyed using randomly selected 395 households with questionnaire interviews focused on five basic questions/areas of interest, seven focus group discussions each averaging 12 to 38 respondents, and 32 key informant interviews. The LULC change results (1988 to 2018) showed that woodland and riparian vegetation decreased by 29.38% (367.85 km^2) and 47.11% (39.46 km^2), respectively, whereas shrub-bushland, grassland, bare land, and cultivated land increased by 35.28% (132.27 km^2), 43.47% (161.31 km^2), 27.52% (8.02 km^2), and 118.36 $km^{2,}$ respectively. According to the results of the NDVI, high to moderate vegetation decreased by 21.47% (464.6 km^2), while sparse and nonvegetation expanded by 19.8% (428.1 km^2) and 1.7% (36.5 km^2), respectively. However, there was a continuous decline in woodland cover. The park harbors 70 woody plant species, with 65.7% trees, 25.7% shrubs, and 8.6% trees/shrubs. The total basal area and density were 79.3 $\pm$ 4.6 m^2 ha^{-1} and 466 ±12.8 stems ha^{-1}. The dominant families were Fabaceae (16 species: 22.9%) and Combretaceae (8 species: 11.4%). *Acacia mellifera*, *Combretum hartmannianum*, *Terminalia brownii*, *Balanites aegyptiaca*, *Dicrostachy scinerea*, *Acacia senegal*, *Acacia oerfota*, *Boswellia papyrifera*, *Ziziphus spina-christi*, and *Anogeissus leiocarpus* were the most dominant and frequent species. The regeneration status of woody plant species in the park was categorized as "none" (73.45%), "poorly" (7.81%), and "fairly" (18.75%) regenerated". Expansion of settlement and cropland, human-induced fires, fuelwood collection, and gold mining were the major proximate drivers that significantly affected park resources. Forty-seven wild plant species and 12 cultivated crop species were utilized by elephants; among the wild plant species, 2.7% of seedlings and saplings and 97.3% of the mature stem plants were used. *Acacia mellifera* (23.9%), *Balanites aegyptiaca* (10.3%), *Acacia oerfota* (7.7%), *Dicrostachys scinerea* (7.2%), *Acacia senegal* (7.2%), and *Hyphaene thebaica* (5.7%) contributed the most to the elephant feed. The elephants selected strongly more than 41% of common wild woody species, while *Combretum hartmannianum* and *Boswellia papyrifera*, which are the most frequent in the park, were not utilized. Leaves/branches accounted for 85% of elephant consumption during the wet season, while 57.4% of the bark contributed to the diet in the late dry season. During the rainy season, the coverage of seasonal crops increased, leading to higher consumption in the period when Human-Elephant Conflict (HEC) reached its peak. Due to the expansion of cultivation by 118.36 km^2, elephant crop damage has continued to become a serious problem, and 72.2% of respondents confirmed that elephant damage to crops has increased in recent years. Crop damage was significantly ($p < 0.001$) affected by the distance between the settlement and the park and was relatively high as cropland was found inside and at the border of the park. The respondents, 81.99% and 44.95%, used gun sounds/banging noise materials and lighting fires/flashlights as the most common protection methods for elephant crop damage. The communities had both positive and negative attitudes toward the conservation of KSNP and elephants. The negative attitude was related to competition for park resources, conflicts between residents and park managers, and elephant crop damage. The awareness and attitude of the communities toward KSNP and elephant conservation significantly varied with age, education level, distance between settlement and park border, and crop damage trends ($p<0.001$). However, there is a good initiation for the conservation of the KSNP; the woodland habitat was affected by human-induced LULC change because the livelihood of local communities depends on crop and livestock production. The expansion of farming reduced the wildlife habitat, and crop fields were the key areas where HEC occurred, which is a challenge for the survival of elephants. Elephant crop damage negatively impacted community attitudes toward elephant conservation. Therefore, there is an urgent need to develop strategies for sustainable land resource management and wildlife conservation by encouraging community participation to protect the KSNP woodland habitat and adjacent natural resources. This approach will help to restore woodland habitat at the same time to minimize human-elephant conflict (HEC).

Keywords: *Land use/land cover change*; *Woody species regeneration*; *Human-elephant conflict; Communities attitude; wildlife conservation; Elephant diet*

DEDICATION

My thesis work is dedicated to my late honest father, Melake Tsige ***Temesgen Hailemariam (1937-June 2011 e.c.)****, who passed away while I was in an extensive field data collection; nevertheless, I did not forget him and your life rest in heaven. I also dedicate this work to my mother* ***Ametetsion Kebedew*** *and my sister* ***Tsige Temesgen,*** *who endured challenging time for two and a half years; and to my daughter* ***Fikir Fitsum,*** *who missed access to education for three years due to the civil war in the Tigray region.*

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LIST OF PUBLICATIONS

This PhD dissertation is categorized and arranged into **four** basic manuscripts that are previewed in reputable international journal order based on the following Arabic number (1-4) in the text as the first author and published/submitted for publication as follows.

1. **Temesgen,** F. & Warkineh, W. 2020. Woody species structure & regeneration status in Kafta Sheraro National Park Dry Forest, Tigray Region, Ethiopia. *International Journal of Forestry Research*, **Vol. 2020**, Article ID 4597456:1-22. DOI: https://doi.org/10.1155/2020/4597456

2. **Temesgen**, F. Warkineh, B. & Hailemicael, A. 2022. Seasonal land use/land cover change and the drivers in Kafta Sheraro National Park, Tigray, Ethiopia. *Heliyon*, **8**(12), e12298:1-21. DOI: https://doi.org/10.1016/j.heliyon.2022.e12298.

3. **Temesgen**, F. & Warkineh, B. 2023. Seasonal dietary preferences of the African Elephant (*Loxodonta africana* L.) in Kafta Sheraro National Park, Tigray Region, Ethiopia. Review accepted to *Hindawi International Journal of Ecology*; 2023; ID 6632467.

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Additional publications

Temesgen, F. and Warkineh, B. 2018. Biodiversity Status & Conservation Challenges of Protected Areas of Ethiopia**:** Awash and Nechsar National Park in Focus. A review. *Journal of Natural Sciences Research*, **8**(5):46-61.

Temesgen, F. Warkineh, B. & Asefa, A. 2021. Human Disturbance, Plant Species Composition, Diversity and Community Types of Kafta Sheraro National Park, Tigray Region, Ethiopia. Research Square preprint. DOI: https://doi.org/10.21203/rs.3.rs-230558/v1.

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Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES IN APPENDICES

LIST OF Acronyms

BA	Basal area
CBD	Convention on biological diversity
CEPF	Critical Ecosystem partnership fund
DBH	Diameter at breast height
ENMA	Ethiopian national meteorology agency
EWCA	Ethiopian wildlife conservation authority
ETH	Ethiopian herbarium
ETM^+	Enhanced thematic mapper plus
FAO	Food and agricultural organization
FGDs	Focus group discussions
GEF	Global environment facility
GIS	Geographical information system
GLM	Generalized linear models
GPS	Global positioning system
HEC	Human-elephant conflict
HWCs	Human-wildlife conflicts
IBM	International business machines corporation
IUCN	International union for conservation of nature
IVI	Importance value index
KIIs	Key informant interviews
KSNP	Kafta sheraro national park
LULC	Land use land cover
m.a.s.l	Meter above sea level
MLC	Maximum likelihood classifier
MEA	Millennium ecosystem assessment
MPA	Maputaland-pondoland-albany
NDVI	Normalized difference vegetation index
NIR	Near Infrared
NGS	National geographic Society
OLI/TIRS	Operational land imager/Thermal infrared sensor
PAs	Protected areas
PA	Producer accuracy
S.E	Standard error
SD	Standard deviation
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
TM	Thematic mapper
USGS	United states geological survey
UTM	Universal traverse mercator
WB	World bank
WCMC	World conservation monitoring center
WGS	World geodetic system
Mm	Micrometer
UA	User accuracy

CHAPTER ONE

1. INTRODUCTION

1.1 Background and Justification

Ethiopia is considered to be a biodiversity rich country and hosts two of the world's 36 biodiversity hotspots, the Eastern Afromontane and the Horn of Africa (CEPF, 2016; Hoffman et al., 2016). The country has a high level of endemism, a central origin and diversification for several animals, plants, and their wild relatives due to its dynamic geological history, and wide latitudinal and altitudinal ranges. The variability emerges in the presence of suitable habitats for the survival of various plant and animal species, which contribute to the overall existence of biodiversity (Gebregziabhere, 1989). Ethiopia is one of Africa's most diverse countries, with approximately 320 species of mammals, 36 of which are endemic (Wilson & Reeder, 2005) and one-fourth of which are large mammals, including elephants (Tefera, 2011). There are 926 species of birds, 24 of which are endemic (Tesfahunegny, 2016); 240 reptile species, 15 of which are endemic; 71 amphibian species, 30 of which are endemic (Largen & Spawls, 2010); ~351 species of fish, 37-66 of which are endemic (Golubtsov & Darkov, 2008); and more than 6000 species of vascular plants, more than 10% of which are endemic (Kelbessa & Demissew, 2014; Hedberg et al., 2009).

Most of the biological resources in the world are concentrated in protected areas (PAs) (Butsic et al., 2015; Coetzee et al., 2014; Geldmann et al., 2013; IUCN, 1994) because protected areas (PAs) play a vital role in biodiversity conservation (Chape et al., 2005). In the past few decades, the number of PAs in developing countries has expanded (Bruche et al., 2012). In Ethiopia, more than 55 protected areas (PAs) exist to protect and conserve natural ecosystems and wildlife heritage (Young, 2012). However, Ethiopian PA's resources are being degraded and fragmented at the highest rate because of livestock encroachment, expansion of settlement and cultivation, deforestation, mining, border conflicts between communities, and other drivers of land use/land cover change (Mulualem & Tesfahunegny, 2016).

Land use/land cover (LULC) change has increased globally during the biodiversity crises over the last four decades (Sharma et al., 2018; Butchart et al., 2010; Krauss et al., 2010). This global loss of biodiversity has great potential to interrupt relevant ecological processes and hinder essential ecosystem activities (Schmitz et al., 2014). Resources in and around PAs are more critical in developing nations where communities live adjacent to PAs; because their livelihoods are directly dependent on resources (Hartter and Southworth, 2009). In most parts of the world, the activities of communities around PAs are expected to negatively influence the PA's resources (Jones et al., 2018). Changes in LULC around PAs directly impact PA biodiversity and ecological processes (Jones et al., 2009; Hansen & Defries, 2007). In the last three decades, LULC change has occurred rapidly in PAs and is projected to continue (DeFries et al., 2005; Beresford et al., 2018).

Land use/land cover (LULC) change is the combined temporal interaction of social, economic, institutional, and environmental factors (Hassan et al., 2016; Li et al., 2009; Lambin et al., 2001). These factors influence the community's socio-economic and livelihoods in Sub-Saharan Africa, including Ethiopia (Maitima et al., 2010). In this region, high poverty and the expansion of agriculture were prioritized as drivers of LULC change (Mekuyie et al., 2018; Kawmi et al., 2015; Kindu et al., 2015). In semiarid areas of Ethiopia, including the study area, the expansion of croplands as a cost of woodlands was a major driver of change (Zewdie and Csaplovics, 2016), and our findings also showed similar patterns. The government-led resettlement program was another core driver of LULC change in Ethiopia because the program was implemented without due consideration of sustainable natural resources utilization (Yadeta et al., 2022; Mamude et al., 2021; Abera et al., 2020; Esa and Assen, 2017). Thus, the livelihood of resettled communities depends on the production of crops at the expense of woodland vegetation.

Cropland expansion has been reported to be the main driver of deforestation and leads to biodiversity loss (Haines, 2009; Lepers et al., 2005). The conversion of forest cover to human-made land uses, such as farmlands, has been reported by several PAs of the world (Duraisamy et al., 2018; Lu et al., 2018; Sancheza Reyes et al., 2017; Garrard et al., 2016) and Africa (Bailey et al., 2016). Extensive cropland expansion as a decline of woodland and dense forest has also been stated in Ethiopian PAs (Fetene et al., 2015; Nune et al., 2016; Workeneh & Kassaw, 2019). Human activities are the most significant factors adversely affecting the natural resources of Ethiopia (Marchant et al., 2018) and have detrimental impacts on the environment and community livelihoods (Gebreslassie, 2014; Tefera, 2011). Most of the LULC changes in the country have an expansion of farmland at the expense of forest/woodland cover (Lemenih et al., 2014; Kassa et al., 2014; Alemu et al., 2015; Zewdie & Csaplovics, 2016).

Globally, loss of habitat is one of the most important issues facing wildlife, causing to human-wildlife conflict (HWC) over resources (Wasser et al., 2009). Human-wildlife conflict (HWC) exists worldwide in one or another form as humans continue to encroach on wildlife habitats (Lamarque et al., 2009). It is increasing globally and is one of the main obstacles to wildlife conservation (Redpath et al., 2013). Conflicting between wildlife and people, specifically, those who share boundaries with PAs is a common phenomenon (Sitienei et al., 2014; Vijayan and Pati, 2009; Wittemyer et al., 2008) and a major problem in organizations that participate in nature conservation (Antoine et al., 2012). In East Africa, habitat fragmentation via political instability has led to a low priority for the conservation of wildlife (Blanc et al., 2007). Compared with the other regions, conflicts in East Africa, particularly human-elephant conflicts (HECs), are considered measurable issues (Amwata et al., 2006; Kioko et al., 2006).

The conflict between people and elephants is a particular case of HWC (Draheim et al., 2015). One of the major forms of human-elephant conflict (HEC) is crop damage (Long et al., 2020; Sitati et al., 2005; Sitati et al., 2003). Crop raiding enhances the negative perceptions of communities toward elephants, which can strongly undermine conservation efforts (Osborn and Hill, 2005). The abundance of African elephants is strongly associated with human livelihood activities, and human impacts on elephants are highly challenging for PAs and wildlife managers (Sitati et al., 2003; Mutinda et al., 2014; Said et al., 2016). Human-elephant conflict (HEC) is not a new phenomenon in Africa; however, due to the expansion of settlements and encroachments on elephant habitats, conflicts have increased from the past to recent times (Hoffmeier-Karimi and Schulte, 2015; Hoare, 2007). The conflict between humans and elephants is a challenge in many African countries and results to crop damage, which disturbs community livelihoods (van Aarde and Jackson, 2007) and negatively affects conservation efforts (Kamau, 2017; Osborn and Hill, 2005). Expansion of cropland, LULC change, low PA management, climate change and variability, and habitat degradation are sources of the conflict (Tiller et al., 2021; Mukeka et al., 2019; Lamarque et al., 2009; Wittemyer et al., 2008), and the causes are pronounced in developing countries (Mukeka et al., 2019). Human-elephant conflict (HEC) is more acute in villages close to PAs within settlements and farmland-dominated areas (Mmbaga et al., 2017c).

Elephants need a substantial amount of food both from inside and outside PAs (Douglas-Hamilton et al., 2005; Kshettry et al., 2020). The survival of elephants is dependent on places where human activities outside PAs are suitable for their existence (Okello et al., 2015). In many African countries, forage availability decline due to the degradation of habitat has created a challenge for elephant conservation (Blanc et al., 2007) because their movement in the landscape is predominantly determined by habitat quantity and food selection (Okello et al., 2015). Thus, information about elephant food choices is essential in planning for habitat management toward minimizing HECs. The elephant home range in Ethiopia's PAs has greatly decreased due to pressure increased by human-induced LULC change (Eshetu et al., 2019; Workeneh, 2016). Land use/land cover (LULC) change can be critical for the movement of elephants, whose existence depends on habitat conditions (Mmbaga et al., 2017a). Thus, safeguarding enough space and controlling HECs in Africa are the most important aspects of elephant management and conservation (Okello et al., 2015).

Negative interactions between people and wildlife not only have adverse effects on communities' livelihoods but also lead to negative attitudes toward wildlife conservation (Nelson et al., 2003). Managing competition between humans and wildlife for resources is a critical conservation issue (Woodroffe et al., 2005). The attitudes of local people toward wildlife are critical to managing conflicts (Naughton Treves and Treves, 2005). To ensure that wildlife management policies are effective under local conditions, it is important to understand the attitudes of local people to provide an overview of the cultural and social context of HWCs (Kideghesho et al., 2007). The assessment of local people's attitudes can predict the degree to which people are willing to coexist with wildlife and how people's attitudes influence conservation attitudes and vice versa (Tarrant et al., 2016; Browne-Nunez and Jonker, 2008). Therefore, to maintain the sustainable utilization of natural resources and the coexistence of humans and wildlife/elephants, it is paramount to provide periodic and updated ecological information for conservation managers and stakeholders who are participating in nature conservation.

Kafta Sheraro National Park (KSNP) was recognized in 2007 as a park in the western Tigray region of Ethiopia. The park is rich in natural vegetation (Friis et al., 2010), a diverse species of fauna (Girmay et al., 2020; Assefa and Srinivasulu, 2019; G/medhin et al., 2009) including great wildlife, particularly the home of African elephants (Mamo et al., 2012), and the hydrology of Tekeze river and its tributary rivers inside the park (field observation). However, human disturbances like cropland, fire, grazing, and mining threaten the biodiversity of the park (Girmay et al., 2020; Arafaine & Asefa, 2019; G/medhin et al., 2009). Moreover, the expansion of settlements adjacent to Kafta Sheraro National Park (KSNP) between 2000 and 2007; decreased woodland vegetation cover while agricultural land increased in and around the park (Moti et al., 2011). Moreover, cropland increased by 66.4%, while woodland decreased by 38.9% in 25 years (Alemu et al., 2015), and woodland area reduced by 50.6% from 1986 to 2014 (Zewdie and Csaplovics, 2016). On the other hand, between 2003 and 2015, inside KSNP, woodland vegetation cover declined by 51.2%, whereas cropland expanded by 2362% (Arafaine & Asefa, 2019). Similarly, the encroachment of human activities into wildlife habitats as a source of conflict (i.e., Human-wildlife/Human elephant conflict) has increased in recent years in and around KSNP (Kidane et al., 2024; Mesfin et al., 2021; Shimelse, 2021; Berihun et al., 2016; Mamo et al., 2012). However, the ongoing management practices of the KSNP are good relative to those of other PAs in Ethiopia; the home range of wild animals, specifically elephants, is limited to specific areas of park habitat. Most of the Tekeze riversides in the park area are cultivated from vegetable and fruit crops and are at risk of temporary human settlement shade (Personal field observation, 2018/19).

Regardless of whether a park has environmental and ecotourism-based economic significance for the area and the country, there is a knowledge gap concerning the interactions among elephants, vegetation, and humans, which are fundamental for the sustainable management and conservation of park resources. Therefore, there is an urgent need to develop a sound management plan for the effective management and conservation of KSNP and existing wildlife. This requires detailed investigations of trends in LULC change as a source of HEC, woody vegetation structure and regeneration status, food selections of elephants, and attitudes of residents toward the conservation of KSNP and elephants.

1.2 Statement of the problem

Ethiopia is characterized by ecologically rich biodiversity; however, the biological resources of wild animals (Tefera, 2011) and plants (Friis et al., 2011) are gradually shrinking. Forest disturbances and rapid rates of deforestation in the country mainly occur due to poor resource management and government land policy (i.e., the government needs to ensure rapid economic growth and poverty mitigation at the expense of natural resources) (Othow et al., 2017). To combat these problems, Ethiopia has established National Parks, Wildlife Sanctuaries, Wildlife reserves, Control Hunting Areas and Priority Forests, Biosphere Reserves, and Community Conservation Areas since 1966 (Vreugdenhil et al., 2012). However, most of Ethiopia's PAs are being increasingly degraded due to unsustainable natural resource management, habitat degradation, agricultural expansion, deforestation, border conflicts between communities, uncertain land tenure, and very low public awareness about the importance of biodiversity in minimizing the environmental degradation problems and life sustaining ecosystem services (Young, 2012). Poverty is another important driver of PAs degradation in Ethiopia with low income and productivity, limited capital accumulation and investment and high unemployment (Moges, 2013). Poverty is one of the biodiversity degradation since human beings are dependent on natural resources in Ethiopia (IBC, 2014).

The improper utilization of natural resources by the communities around PAs increases the degradation of wildlife habitats (Evangelista et al., 2007) and diversity (Bekele and Yalden, 2013). The destruction of wildlife habitats is a risk to their survival, distribution, and habitat continuity (Mamo et al., 2012; Vymyslicka et al., 2010). Animal husbandry, cropland expansion, and infrastructure development degrade habitats, leading to conflicts between humans and wild animals (Fernando et al., 2005). Human-wildlife conflict (HWC) is a serious issue in developing countries (Mwamidi et al., 2012) because in these countries crop and livestock production are the main sources of rural life existence (Teshome & Girmay, 2017; Fairet & Maguy, 2012). Human-wildlife conflict (HWC) arises mainly because of the LULC change pressure on wildlife habitats (Sanare et al., 2022). In Africa, HWC is more acute in the community settlements and their croplands close to PAs (Mmbaga et al., 2017c).

Ethiopia is relatively rich in biodiversity and is a central area of endemism worldwide despite the increasing severity of the degradation crisis. To minimize these problems, Ethiopia has attempted to conserve and manage biodiversity by establishing PAs for the past three decades. However, the expansion of PAs in Ethiopia is becoming increasingly common, and the suitable wildlife habitats of almost all parks including KSNP are collapsing gradually from time to time. Moreover, KSNP has faced serious problems related to encroachment following natural habitat changes by proximate local communities because their livelihood depends on parks' natural resources. This habitat cover change is a root cause of human-wildlife conflict (HWC) particularly human elephant conflict (HEC) by the special form of crop damage; consequently, management intervention of the park is challenging. Kafta Sheraro National Park (KSNP) is a natural habitat for famous wildlife, particularly African elephants; however, there is a knowledge gap regarding the habitat conditions of elephants in the park. Therefore, the purpose of this study was to determine the potential impact of various human activities on the conservation of elephant/wildlife environments and to design ways to answer the questions of KSNP sustainability about safeguarding critical elephant/wildlife habitats.

1.3 Objectives of the study

The general objective of this study was to investigate the interactions among African bush elephants (*Loxodonta africana* L.), the diverse vegetations, and humans and the influences of land use/land cover (LULC) changes on the sustainability of Kafta Sheraro National Park (KSNP) in general and on habitats elephants in particular. Specifically, the following four objectives were set:

1. Land use/land cover change and drivers of change (1988 to 2018) in the KSNP
2. Structure & regeneration status of woody species in the diverse vegetation types of the Park
3. Seasonal dietary preferences of African bush elephants (*Loxodonta africana* L.)
4. Human-elephant conflicts and attitudes of local communities toward the conservation of the
   African bush elephant (*Loxodonta africana* L.) and its habitats

1.4 Research questions

To meet the above objectives, this study aimed to answer the following questions.

- What is the extent of land use/land cover change in the park, and what are the drivers?
- How are the structure and regeneration status of woody species in the park affected by human disturbance and related factors?
- Which plant species do elephants prefer most, and does elephant diet selection differ seasonally? How are elephant diet preferences related to structure and regeneration?
- How is there a trend toward human-elephant conflict (elephant crop raiding) and community attitudes and perceptions toward KSNP and elephant conservation in the area?
- How are the land use/land cover changes related to the trend of human-elephant conflict?

1.5 Significance of the study

The study may address the gradual degradation of Kafta Sheraro National Park (KSNP), which is a natural habitat for wildlife, especially elephants, and has an important role to play in reducing park pressure that is becoming increasingly common. To ensure the sustainability of biodiversity and to help individuals adopt management plans to protect biodiversity, this approach is important. This study will help to provide important information to management authorities to propose future LULC planning and develop action plans to mitigate HEC. This dissertation provides fundamental information on the conservation challenges of wildlife habitats in KSNP and can be used to develop an effective management strategy for park sustainability. This study will support planners and policymakers in developing appropriate action plans for conserving KSNP and the generated data that might be used as sources of information for conservationist managers and inform the public about the status of wildlife habitats, the whole park, and the links between the economic and environmental value of wildlife and the vegetation cover. Based on the elephant food selection data, seasonal management should be improved for the long-term protection of this endangered species and its shrinking habitats. This dissertation will also continue to serve as a source of information to assist in steering the Park Management Program and will open doors to potential ecotourism destinations in the area or the country.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Protected areas (PAs) and land use/land cover change

Protected areas (PAs): believed to be one of the most effective means of protecting biodiversity (Chape et al., 2005). According to the IUCN, a protected area is defined as "an area of land and/or sea dedicated to the protection of natural biological diversity and associated cultural resources managed through legal means" (IUCN, 1994). In addition, due to their ecological, cultural, and economic value, PAs are protected. Globally, all PAs differ according to their category, level of protection, and national legislation regulating their protection (Dudley, 2008; IUCN, 1994). PAs are important for safeguarding biodiversity loss and supporting global conservation initiatives, which have focused on the expansion of PAs (IPBES, 2019). Currently, 14.9% (20 million km^2) of the Earth's land area and 7% (6 million km^2) of its marine areas are conserved within a global PA network (UNEP-WCMC, IUCN, & NDS, 2018). Despite the expansion of PAs, biodiversity in these areas is still declining because their establishment is not effectively managed (Leverington et al., 2010). Worldwide, human disturbances are the primary causes of biodiversity loss (IPBES, 2019) and are putting pressure on one-third of the world's PAs (Jones et al., 2018). A lack of traditional conservation, which prioritizes biological values over social values, has been identified in many conservation studies as the reason for the increased level of human-induced damage in PAs (Schulze et al., 2018; Oldekop et al., 2016; Andrade and Rhodes, 2012; Lele et al., 2010; West et al., 2006).

The fences and fines approach has been the focus of the traditional conservation paradigm in which human activities are considered incompatible with conservation (Oldekop et al., 2016; Andrade & Rhodes, 2012). People living adjacent to PAs are displaced from conservation areas and restricted in terms of resource access (Lele et al., 2010). Due to these restrictions and the lack of alternatives to the resources that are important for livelihood, local communities find different means to illegally enter inside PAs in search of natural resources (West et al., 2006). For example, local people in Mount Cameroon National Park intensified their poaching in response to the protectionist conservation policy (Nana & Tchamadeu, 2014). Likewise, in Myanmar, damages to PAs include the exploitation of nontimber products, fuel wood collection, fishing, hunting, grazing, and human settlements (Rao et al., 2002). The failure to consider the needs of local communities under “fences and fines systems” may lead to the degradation of PA biodiversity (Kideghesho, 2010). Even though stricter PAs may conserve more biodiversity, they still need investments and government supports (Gray et al., 2016). In developing countries with limited financial capacity and high natural resource dependency, the strict protection of PAs often costs surrounding communities and increases their antagonism, which results in a lack of community involvement and participation in conservation (Andrade & Rhodes, 2012). Moreover, people with limited livelihood options cannot follow the rules and regulations of PAs. Therefore, without local community support, threats to PAs are unlikely to be reduced unless partnership with the local community could be a long-term option for successful PA conservation (Htay et al., 2022).

Protected areas (PAs) are mainly focused on the maintenance of biological diversity and contribute to the economic development of a nation. In the past few decades, the number of PAs in developing countries has been increasing (Bruche et al., 2012). However, Ethiopian PAs were increasingly established 40 years ago, and the country had only two PAs (i.e., Awash and Simein Mountains National Parks) and, recently, has more than fifty-five PAs to protect and conserve the natural ecosystems and wildlife heritage of the country (Young, 2012). However, the coverage of PAs has increased in Ethiopia, and the value obtained is very low when compared to that in Kenya, Tanzania, and South Africa (Chanie and Tesfaye, 2015). Conversely, PAs are exposed to severe pressure, which damages their existence and sustainability due to anthropogenic effects (Reddy & Workeneh, 2014).

Land use/land cover (LULC) changes: The term land use/land cover (LULC) is conceptually different; even though in most cases it is used interchangeably. Land cover is defined as the attributes of the earth’s land surface captured in the distribution of vegetation cover, soil, and water bodies, including ice and groundwater. Additionally, land cover includes structures created specially by human activities such as settlements, croplands, and related structures (Lambin et al., 2003). Land use is defined as land management and biophysical manipulation or the techno-managerial aspect of a land use system (Turner et al., 1994; Turner II et al., 1990). Land use/land cover (LULC) change refers to the modification of existing land cover or the conversion of land cover to a new cover type (Ellis, 2006). The spatial and temporal pattern of change is due to functional and structural complexity between LULC change types (Quentin et al., 2006; Lambin et al., 2003).

Land use/cover (LULC) changes are among the major environmental problems in Ethiopia. Although the causes of LULC change vary from place to place, human-induced factors are the main driving forces (Lambin et al., 2003). High populations' expansions are common in Ethiopia, and their livelihoods directly depend on the exploitation of natural resources. Such rapid rates of vegetation conversion, unsustainable agricultural land use, and severe soil erosion and land degradation are the effects of LULC change in the highlands of Ethiopia. Because of population pressure, economic factors, and policy issues, settlements, farmland, and degraded lands have been expanding, while grasslands and forest areas have largely been diminishing (Assen, 2011; Gebrelibanos & Assen, 2013; Alemu et al., 2015). Moreover, LULC change is associated with deforestation, biodiversity loss, and land degradation (Maitima et al., 2009). Land use/ landcover (LULC) change is one of the challenges that strongly influence the process of agricultural development and the food security situation in Ethiopia. Ethiopia areas are experiencing extensive land use/land cover dynamics from natural vegetation to farming practices and human settlement (Mengistie et al., 2013).

Major drivers of land use/land cover change in PAs: Protected areas (PAs) are currently facing increasing challenges via human-induced activities. The root cause of the destruction of natural resources in parks is the existence of communities engaged in agriculture. Some of the dominant root causes of PA conservation challenges, including the study area (i.e., Kafta Sheraro National Park), are described in the following sections.

Habitat conversion: Natural vegetation is a significant basis for the livelihood of communities living around PAs and wildlife habitat corridors (Ollerer et al., 2019; Sasmita et al., 2013). Approximately 32.8% of world's PAs are under extreme human pressure via the change of the wildlife habitat into other forms of human land use (Jones et al., 2018). The global wildlife distributions have declined at an alarming rate, mainly due to their habitat alteration and destruction resulting from the expansion of agriculture and other related activities (MEA, 2005). The majority of people in least-developed countries depend on the exploitation of natural resources, mainly for agricultural expansion (WB, 2013). The extensive growth of agriculture in sub-Saharan Africa has increased the detrimental effect on biodiversity (Perrings & Halkos, 2015). The destruction of wildlife habitats is more pronounced in PAs of developing countries. In Ethiopia, increasing pressure from human and livestock populations and the expansion of settlements following agricultural practices are major threats to several PAs (Yadeta et al., 2022; Workeneh & Kassaw, 2019; Nune et al., 2016; Fetene et al., 2014; Solomon et al., 2014). For example, the landscape in Nechisar National Park experienced major changes between 1985 and 2013, with forest and grassland being the most threatened habitats; the mean patch size of forest decreased from 46.33 ha in 1985 to 13.88 ha in 2013, and the mean patch size of grassland decreased from 76.52 ha to 9.81 ha in the same period. The changes ranged from forest to cropland mean patches of 32.45 ha and from open grassland to land cover of undesirable nonnative species, as did extensive shrub encroachment mean patches of 66.71 ha in the grassland areas (Fetene et al., 2014). In Awash National Park, the area of scattered bushland drastically decreased by 29.4% between 1972 and 2006, that of grassland expanded rapidly by 14.2% between 1972 and 1986, and 10.5% between 1972 and 2006 reported. In addition to the ever increasing demand for farm and grazing land in and around the park, bare land expansion in some parts of the park, such as at Mount Fentale, 4.9% of the area became barren land between 1972 and 2006 (Solomon et al., 2014).

Livestock grazing: Globally, grazing by livestock has become an emerging risk factor for the management of PAs (Sasmita et al., 2013). Livestock overgrazing is an important cause of land degradation in arid (Perveen et al., 2008) and semiarid ecosystems of the world (Huang et al., 2007). Similarly, grazing by livestock has been an important issue for the management and conservation of PAs. As grazing occasions outside the PA have decreased, pastoralists are putting greater pressure on PAs, causing damage to fragile habitats, competition with wildlife, and potential for disease transmission (Alers et al., 2007). Livestock grazing also has strong negative impacts on wildlife, habitats, and the overall ecosystem function and structure (Mishra et al., 2003). Livestock usually compete with wild animals for habitat resources, including forage, water, and space. The resulting high livestock population densities put stress on the habitats of many wild animal species (Evangelista et al., 2007). Livestock often reveal the alteration of structure and species composition of natural vegetation. At sites where livestock grazing is more extensive, the vegetation types and composition change from more diverse to less diverse (Mamo et al., 2012).

Livestock grazing or browsing strongly affects the survival of seedlings and initiates the regeneration of understory species (Carolina and Javier, 2001). Unrestricted livestock movements in the forest might also compact soil, destroy seeds or deep into the soil where they are not able to regenerate easily (Wassie et al., 2009; Smit et al., 2006). The effect of human and livestock disturbances on wild animals' habitats is frequently measured in terms of changes and reductions in the quality and availability of habitat use (Tadesse and Kotler, 2013; Gilroy and Sutherland, 2007). For example, the gradual change of the Khata wildlife habitat by livestock grazing areas was due to the increasing level of grazing and browsing inside the forest of Bardiya, Nepal (Dahal et al., 2023). Similarly, in Ethiopia, pastoralists and semi-pastoralists graze their livestock and stay for half a year illegally inside PAs due to limited forage availability outside PAs (Estifanos et al., 2019). Livestock overgrazing is also a major problem in the habitats of Bale Mountain National Park (Fekadu et al., 2016).

Illegal fires: are major disturbances of ecosystems worldwide (Resco de Dios, 2020; Bowman et al., 2009) and occur predominantly across the African continent (Andela et al., 2017; Archibald & Hempson, 2016; Lehsten et al., 2010). Approximately 68% of the surface area of Africa burns annually (Lizundia-Loiola et al. 2020). Most of the illegal fires in Africa are caused by humans (Zubkova et al., 2019). Others have also reported that humans are regarded as the main source of wildfire, which accounts for 59-95% of ignitions globally (FAO, 2007). Repeated fires affect many ecological processes, such as nutrient cycling, soil organic matter content, vegetation structure and composition, and wildlife communities (Gandiwa et al., 2014). Some of the direct effects of fire on ecosystem fauna include absolute death and wounding, which can cause the displacement of animals and affect their distribution patterns at both local and regional scales (Hassan and Rija, 2011; Gandiwa, 2011; Gandiwa, et al., 2014). Illegal fires affect biological diversity and ecosystem function by damaging habitats, breeding sites and food, causing the loss of wildlife, territorial birds and mammals from their natural homes (Bowman and Murphy, 2010; CBD, 2010). In Ethiopia, fire occurrence is influenced by the expansion of croplands, deforestation, and the development of other land use changes over the past three decades (Teshome et al., 2019; Tibebu et al., 2018).

2.2 Vegetation regeneration and influencing factors

Tree species regeneration is a complex and fundamental process for maintaining and renewing forest stands over time (Ricard et al., 2003). The regeneration of woody plants refers to the recruitment, survival, and growth of seedlings and/or sprouts of a species in a given plantation (Lalfakawma, 2010). Regeneration occurs in nature from seeds and other vegetative means and subsequently germinates in situ, referred to as natural regeneration (Harmer, 2001). Natural regeneration is defined as the process of renewal and establishment of forests (Pardos et al., 2005) through the processes of seeding, germination, survival, and development (Matias et al., 2017). Forest reconstruction depends on natural resources across all plantations, and natural regeneration is very effective for forest development (Dong et al., 2018; Mc Conigley et al., 2015). Regeneration involves both physiological and developmental mechanisms inherent in plant biology, external ecological factors, and interactions with other biotic and abiotic, such as climate and disturbance (Price et al., 2001). Natural regeneration is a key component for ensuring the sustainability of forest and forest dynamics (Luo et al., 2017; Bose et al., 2016) because it has the potential for the development of future regeneration (Poorter et al., 2016). The absence or small number of seedlings and saplings of a tree species in a forest stand indicates weak regenerating, while a greater number of seedlings and saplings leads to good regeneration (Khumbongmayum et al., 2006). The maintenance of a forest stand with sufficient regenerating is the main target in conservation ecology because securing sufficient regeneration of vegetation is a great challenge in forest management (Bose et al., 2016).

Natural regeneration has also been used as a tool in large-scale restoration programs in degraded forest areas (Chazdon, 2017) especially, in tropical regions (De Carvalho et al., 2017). Regeneration development can restore degraded forest ecosystems, which can save time and costs and increase biodiversity (Ram et al., 2014). Seedlings are more stable in forest ecosystems following natural regeneration; however, in most plantations, regeneration is difficult due to artificial intervention coupled with overexploitation (Gao et al., 2020; Wang et al., 2010). Natural regeneration is more efficient than artificial planting at maintaining ecological sustainability because of the increase in young trees and the replacement of old and dead trees (Christian et al., 2018). Therefore, it is necessary to investigate naturally regenerated plants to balance production, recover ecosystems, and provide solutions for forest management (Zhao et al., 2021). The assessment of the species distributions and diversity of forests in tropical ecology should consider natural regeneration (Osem et al., 2009).

The regeneration potential of species in a plant community can be accessed from the total population changes of seedlings and saplings in the forest areas (Duchok et al., 2005; Tesfaye et al., 2002). The alteration of the overall pattern of the population of seedlings, saplings, and adults of a plant species can exhibit the regeneration status, which is used to determine the regeneration condition of the study areas. A population with a sufficient number of seedlings and saplings represents satisfactory regeneration performance, while an inadequate number of seedlings and saplings of the species in a forest indicates poor regeneration conditions (Tripathi & Khan, 2007). Therefore, understanding the pattern of vegetation regeneration enables the undertaking of forest management plans and helps to utilize forest ecosystems wisely and sustainably. Moreover, the computing of the ratio among mature trees, saplings, and seedlings can provide information regarding the distribution of mature trees, saplings, seedlings, and the general regeneration status of a specific forest area (Chauhan et al., 2008a).

The regeneration status of forest areas might be assessed by comparing the ratios of seedlings to saplings, seedlings to mature trees and saplings to mature trees. For example, in the Ethiopian NechSar National Park riverine forest, the seedling density was greater than saplings and mature trees (i.e., density of seedlings > density of saplings and seedlings > density of mature trees) within the study area (Kebebew & Demissie, 2017). Regeneration of a forest is classified as 'best regenerating', defined as the condition in which an adequate number of seedlings and saplings contributed to the mature population; 'reasonable regenerating', defined as the condition in which there is a fair number of seedlings, but the percentage of saplings is either lower than or close to that of the mature trees; and 'poorly regenerating', defined as the condition in which individuals are found at either the seedling or sapling stage only or in greater numbers than the mature trees. The fourth regeneration status is termed 'not regenerating,' in which a species is present only at the mature stage and does not experience regeneration at either the seedling or sapling stage (Khumbongmayum et al., 2006; Dhaulkhadi et al., 2008). The fifth regeneration status is termed 'newly regenerating', in which a species is present in seedlings and/or saplings and absent from mature individuals (Dhaulkhadi et al., 2008) (Appendix 1 Table 2).

Factors influencing vegetation regeneration: Regeneration success is highly variable among forest types and depends on disturbance conditions (Frelich, 2002). Generally, abiotic (environment) and biotic (plant structure) factors affect the regeneration potential of a given forest landscape and individual species (Bose et al., 2016). The interactions between plant populations and environmental factors (i.e., fire and climate) are potential causes affecting all the main phases of regeneration (seeding, germination, seedling survival and development) (Ribeiro et al., 2022). Moreover, the distance between seedlings and adult trees is one of the main drivers of forest succession, and a high regeneration ratio is recommended (Zhao et al., 2021); moreover, a distance of 1.5-4 m is recommended for good regeneration. In many ecosystems, that are experiencing either increasing or decreasing disturbance, the overall community structure changes (Shafroth et al., 2002). Disturbances, whether natural or manmade, strongly influence the community composition, tree population structure, and regeneration of forest ecosystems (Lalfakawma, 2010). The regeneration of a forest is affected not only by environmental factors but also by anthropogenic activities. Some of the anthropogenic activities strongly observed in Ethiopia include cutting trees for charcoal production, constructing woods and fences, mowing grasses for fodder and covering roofs of houses (Kebebew & Demissie, 2017; Kuma & Shibru, 2015). Human intervention, poor seed banks, deterioration of seeds, and disturbance by browsers and grazers are the factors contributing to poor regeneration (Lemenih and Teketay, 2006).

2.3 African bush elephant (*Loxodonta africana* L.) in Ethiopia

Ethiopian national parks hold one of the world's largest concentrations of large mammals, such as elephants (Groombridge, 1992). The African elephant (*Loxodonta africana*) is found in 37 African countries (Thouless et al., 2016). Ethiopia is a sub-Saharan African country characterized by several factors (Blanc et al., 2003). Formerly, within the last three centuries, they inhabited all of Sub-Saharan Africa in habitats ranging from tropical and montane to open grassland, semiarid bush and desert. In recent years, however, the poaching of elephants for ivory and human population growth and expansion have drastically reduced the species' range and numbers, and the majority of the remaining elephants exist in small pocks of protected land isolated by human settlements. Thus, globally, the number and distribution of these animals have greatly decreased (Demeke, 1997; Yalden et al., 1986).

In the 1970s the status of African bush elephants in Ethiopia became clearer and it emerged that most of Ethiopian elephants actually occurred in areas not previously described including the southwespart of the country from Mizan Teferi and Gura Ferda to the lowlands of Gambella. Numbers estimated in the 1970/80s from 6000 to 10,000 with trophy hunting yielding excellent tusks up to 160 pounds until the early 1990s. During the fall of Derg a countrywide wave of slaughtering of wildlife caused a huge decline of most of the wild animal populations including elephants (EWCA, 2015). The large herds of elephants in Gambella have also been decimated by the South Sudan Liberation Army for wildlife meat and ivory. This condition continued into the new millenniumand was only brought to an end by the peace in South Sudan in 2003-2004.At the time of writingthe instability in this area is again a serious threat to Gambella elephants. Overall, it is estimated that Ethiopia has lost about 90% of its elephants since the 1980s with elephants being extirpated from at least 6 of 16 sites reported in the early 1990s (EWCO,1991).

The total Ethiopian population is estimated at between ~1850-1900 animals' occurringin 6 main populations of Omo, Mago, Gambella, Kafta-Sheraro, Chebera Churchura National Parks and the Babille Elephant Sanctuary. In addition, elephant signs (footprints and dung) havebeen reported by conservation managers in the Alatish/Bejimez NPs and Mizan Teferi in southwest Ethiopia. Communities have reported observing elephants in the Geralle National Park area in southern Ethiopia and in the Dabus valley, at the confluence of the Abay and Dabus
rivers in the northwestern regional state of Benishangul-Gumuz. Formal estimates of the size ofthese 4 small populations are not available. Key information on elephant status and threats in the major populations was obtained by site level staff or from published orinternal reports after consultation with key partners (EWCA, 2015).

The African bush elephant (*Loxodonta africana* L.) is a number of wildlife species conserved in the Ethiopian PAs. Until the turn of the 19^{th} century, it was relatively abundant throughout the country, except in the northern highlands, the most densely populated part of Ethiopia that has been occupied by agriculture for thousands of years, and the denakil Desert in the northeast, where the scarcity of food and water has been common (Yalden et al., 1986; Bolton, 1973). Since that time, however, the elephant home range has been greatly reduced as a result of intensive hunting and increasing pressure from habitat destruction (Workeneh, 2016).

Currently, African bush elephants in Ethiopia exist in six known PAs, namely, Omo, Mago, Chebera-Churchura, Gambella, Kafta Sheraro National Parks, and the Babile elephant sanctuary. PAs are found in a variety of habitats, from the semiarid environment of eastern Ethiopia in the Babile elephant sanctuary to the most tropical forest in Chebera-Churchural National Park in the southwest. The conservation areas in the southwestern part of the country at Omo and Mago National Parks encompass the semidesert scrubland and Acacia commiphora woodland ecosystem types. Gambella National Park represents a lowland moist evergreen forest ecosystem type with a humid savanna. Kafta Sheraro National Park represents the dominant species of Acacia commiphora and Combretum Terminalia (EWCA, 2015; Workeneh et al., 2014).

2.4 Food selections of African bush elephant (*Loxodonta africana* L.)

The African elephant (*Loxodonta africana*, Blumenbach, 1797) is the largest terrestrial herbivore and pursues a generalized, mixed feeding strategy (graze and browse). Elephants are also considered major ecological drivers in the African savanna (Kerley et al., 2008). The metabolic rate and body size relationship suggest that African elephants are relatively nonselective or least selective among mammalian herbivores in their diet (Owen-Smith & Chafota, 2012). The digestive system of these elephants is simple, relatively rapid, and has a low digestive efficiency, only 40% of ingested food is assimilated (Morgan, 2007). Moreover, due to their low metabolic rate per unit of body mass, elephants can utilize plant materials even when their nutrient content and daily food intake range between 1 to 1.5% of their body mass (Woolley et al., 2010). Understanding the interactions between elephants and their habitats is valuable for assessing the welfare of elephant populations and their habitats (Mwambola, et al., 2014). As African elephants are generalist herbivores, they rely on widely distributed resources. Moreover, as bulk feeders, elephants prefer to spend most of their time in areas with high plant biomass (Olff et al., 2002). Elephants also can migrate long distances while searching for food and water and when escaping hunting activities (Mwambola, et al., 2014).

Elephants have mainly feed on green, nutritious grasses in the early wet season but a diet more browsing dominated in the dry season (Cerling et al., 2006). The diet became narrower and the intake of wood and bark tended to increase as the dry season progressed (De Boer et al., 2000). Over foliage, elephants select the best quality food to satisfy their metabolic requirements. This selection is dependent on plant availability, plant defenses, and chemical composition (Owen-Smith et al., 2006), and based on these factors, elephants either select or avoid forage items (Owen-Smith and Chafota, 2012). The availability of food determines the size of home ranges and the movement of elephants (Fernando et al., 2008). The foraging time of an elephant increases with increasing body size and can also be affected by decreasing browse density, resulting in further walking distances between feeding stations (Owen-Smith and Chafota, 2012). Elephants exhibit variation in the proportions of grass and browse in their diet, however, they exhibit a surprising degree of choice in their diet on both short-term and seasonal bases (De Boer et al., 2000), depending on the habitat type and structure (Owen-Smith et al., 2006). The amount of grass in an elephant’s diet varies both spatially and temporally, and grass is more important in the rainy season than in the dry season. The diet of elephants often includes a wide range of monocot and dicot species, with 50-120 species being used (De Boer et al., 2000).

Seasonal change and water availability: Elephant (*Loxodonta africana*) diets are indirectly determined by rainfall and seasonality (Loarie et al., 2009). In Africa, there have been changes in distribution, home range size, habitat selection of elephants, seasonal climatic changes and changes in food and water availability (Whitehouse and Schoeman, 2003). Due to fluctuations in these resources, elephants show preferences for some habitats and avoid others. As a consequence, in the dry season, the elephant range shrinks, and elephant activities are concentrated near water sources, where tree species are often evergreen (Owen-Smith and Chafota, 2012). Because of the various factors controlling food availability, this green-seeking behavior results in heterogeneous feeding preferences: in the wet season, elephant consumption increases while nutritional value is high, and grass biomass is widely available (Loarie et al., 2009); however, in the dry season, the consumption of woody species increases. However, African elephant movement is complex and seasonally variable; but in general, habitat use tends to increase with proximity to water sources (Harris et al., 2008). Although rainfall ultimately determines forage abundance at large scales, permanent water sources have also been demonstrated to influence elephant feeding habits at more local scales and frequently migrate to and congregate near permanent water sources, especially in the dry season (Ihwagi et al., 2009).

Elephants adjust their diet depending on the food availability and season (Cerling et al., 2004). Across the landscape food resources for elephants are distributed in mixed and vary in quantity and selections between seasons (Owen-Smith et al., 2006). Elephant food choice changes from green grass during wet seasons to browsing woody plants during dry seasons (Codron et al., 2011). As the dry season progresses, the intake of bark tends to increase as the food sources become lower and lower (De Boer et al., 2000). Elephants utilize a wide variety of vegetation communities and occupy large spaces for their food species' demands permit efficient and effective plant nutrient intake and vary in both the dry and wet seasons (Viljoen et al., 2013). Food selection for elephants is high and common in the presence of green grass and herbs during the wet season and lower during the dry season when browsing of woody plant species becomes increasingly important (O'Connor et al., 2007). During the wet months of the year, large amounts of grass are eaten, and these food types dry out in the dry season. Elephants consume progressively significant amounts of leaves and twigs from woody plant species, followed by the consumption of bark and roots as leaves dry over (Clegg and O'Connor, 2017).

2.5 Human-elephant conflicts (HECs)

Conflicts arise from a range of direct and indirect negative interactions between humans and wildlife (Nyhus et al., 2000) and occur widely across the world, constituting one of the greatest challenges to the conservation of wildlife. This can lead to negative attitudes of humans toward wildlife and potentially a severe detrimental effect on conservation (Nelson et al., 2003). Conflict between wildlife and people is also an important factor affecting the relationship between PAs and people who live near them (Nyhus et al., 2000). Conflicts are pronounced as the human population increases and the elephant population becomes more concentrated in isolated PAs and remnant forest habitats (Mir et al., 2015). Understanding the reasons for and potential solutions to these conflicts is necessary to improve the understanding of the relationships between elephant PAs and residents living adjacent to these areas (Ardiantiono et al., 2021). Complains from communities that are subject to regular crop depredation are frequently noted by PA managers, but detailed assessments of crop damage are rare, and testable hypotheses have been rarely developed to predict damage because of the complexity of the factors responsible (Naughton-Treves and Treves, 2005).

There are socioeconomic costs associated with human-wildlife conflict (HWC), which can outweigh the direct costs of agricultural damage and be a major component of the conflict as perceived by the local people (Ogutu et al., 2016). Human-wildlife conflicts (HWCs) present challenges to biodiversity conservation because humans damage and destroy their habitats for agricultural expansion (Mwangi et al., 2016). HWCs have caused a decrease in wildlife diversity and economic loss, such as crop raiding, livestock depredation and property damage, in many ecosystems worldwide (Holland et al., 2018; Ogutu et al., 2016). Hence, HWC has recently become a fundamental aspect of wildlife management and conservation. This represents the most complex challenge currently faced by conservationists worldwide. Conflict arises mainly because of the degradation and fragmentation of wildlife habitats by human activities such as logging, animal husbandry, agricultural expansion, and infrastructure development projects (Fernando et al. 2005). Thus, understanding the patterns of HWCs can help to better manage conflicts and reduce the negative impacts on both biodiversity and the community’s livelihood (Long et al., 2020).

Elephant crop damage: is a common management concern throughout the range of Asian and African elephants and is a serious issue for both conservation efforts and local economies (Chiyo et al., 2005). Elephant crop damage is currently one of the most prevalent forms of conflict between humans and elephants (Sitati et al., 2005; Sitati et al., 2003). The ongoing expansion of human settlements and related activities (Blanc et al., 2007) has resulted in increased levels of interaction (van Aarde & Jackson, 2007). The abundance and distribution of African elephants and the anthropogenic effects on these keystone species pose serious challenges for wildlife managers, the local community, and elephants (Sitati et al., 2003). Conflicting between humans and elephants is a problem throughout Africa and leads to damage to crops and livelihoods and negative attitudes toward wildlife (Mmbaga et al., 2017c). HEC is not a new phenomenon in East Africa despite promoting conservation motivation. However, due to the increase in settlement encroachment into elephant ranges, HEC incidence has greatly increased (Hoffmeier-Karimi & Schulte, 2015; Hoare, 2007).

Elephant crop damage has a direct impact on human livelihoods by destroying their field crops (van Aarde & Jackson, 2007); this leads to a negative perception of communities toward elephants (Osborn & Hill, 2005). Although crop raiding has several potential causes, including proximity, density, and seasonal availability (Sitati et al., 2003), seasonal differences in nutrient concentrations of wild and cultivated plants have also been suggested to contribute to crop raiding in several studies because food crops are highly digestible, high in energy and low in secondary compounds. Some or all of these factors may make them particularly attractive to elephants (Nyhus et al., 2000). Moreover, in Kibale National Park, which is near the elephant habitat for crops, the timing of crop ripening and the dense spatial distribution of crops relative to wild food were driven by elephant crop raiding (Rode et al., 2006).

Crop damage is more to occur along the boundaries of PAs and usually decreases with increasing distance from the boundary. Elephants have acute spatial awareness, and they are likely able to recognize the transition between ‘safe’ forest and ‘dangerous’ farmland. Few elephants will risk going deep into the farming area, so the majority of damage occurs on farms bordering PAs (Parker et al., 2007). Crop damage caused by raiding wildlife is a prevalent form of HWC that occurs along protected area boundaries. Commodity crops tend to be destroyed and consumed by elephants during crop raiding due to the availability of palatable plant species (Berliani et al., 2018). The individual economic losses resulting from crop-raiding can be relatively high in developing countries because farmers are poor and rarely compensate for their losses (Rao et al., 2002). Therefore, assessing the trends in HEC impacts is essential for identifying key drivers of conflicts and devising management strategies (Redpath et al., 2013). Thus, effective monitoring and evaluation systems are needed in conflict areas (Stem et al., 2005).

The conflict between humans and African bush elephants (i.e., crop raiding) in Africa took a long time ago (Long et al., 2020; Hoffmeier-Karimi and Schulte, 2015). In Ethiopia, elephants are reported as crop raiders and given more attention. However, researches related to African bush elephant interaction with cropland are limited in Ethiopia; human-elephant conflict (HEC) in the form of crop damage in the country PAs is a common phenomenon. A few assessments were conducted in some PAs. For example, 14 different types of cultivated crop damage were recorded in the Babile elephant Sanctuary because crops are attractive to elephants as alternative sources of food creating conflict with communities living adjacent to PAs (Biru and Bekele, 2012), in Chebera Churchura National Park, 61 crops damaged by elephants with a great loss in the residents economy and the crops damaged by elephants were vegetables, fruits, and cereals (Tsegaye et al., 2022). Similarly, HEC was reported in Kafta Sheraro National Park (Kidane et al., 2024; Mesfin et al., 2021; Berihun et al., 2016). Therefore, the present study clarifies the interaction between elephants and the proximate community livelihood (i.e., crop production) of Kafta Sheraro National Park.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location of the study site

Kafta Sheraro National Park (KSNP) was designated as a park in 1999, E.C./2007G.C (letter, No: 13/37/82/611), with an area of 2176.43 km^2. For many years, the park named "Shire Wildlife Reserve", which was recognized in 1965 E.C/1973 G.C by Lueul Mengesha Seyum as a forest reserve, ordered the reserve area to be free from grazing (Sources:Oral communication), and with an estimated area of 750 km^2 governed by the natural and wildlife resources department of western zone, Tigray National Regional State. Blanc et al. (2003) also reported a "Shire Wildlife Reserve", which is one of the nine elephant home areas in Ethiopia. Kafta Sheraro National Park (KSNP) is located in Kafta humera and Tahitay adiyabo weredas (districts) of the western and northwestern Zones of the Tigray region 1356 km from Addis Ababa and 490 km from Mekelle City. It is situated in northern Ethiopia between latitude $14^0 05'$-14^0 27′ N and longitude $36^0 42'$-$37^0 39'$ E. The park is bordered by Eritrea in the north and transverse by the Tekeze River (Figure 1). The elevation of the park area varies from 552 to 1222 meters above sea level (m.a.s.l.). The landforms of the areas are heterogeneous and consist of a flat plain undulating to rolling, some isolated hills and ridges, a chain of mountains, and valley (Field observation of 2018/19).

3.1.2 Farming practices

Agriculture is the main economic activity and a source of existence for residents adjacent to KSNP. The local communities in Kafta humera and Tahitay adiyabo weredas/districts, which surround the park, are dominated by mixed farming involving crop and livestock production (Dejene et al., 2013). Approximately 69% of the farmers practiced a rain-fed crop-livestock farming system, 28% annual crop cultivation, and 3% livestock rearing. The land use in the districts was characterized by a crop production dominated by rainfed crop cultivation, which included cereals (31.24%), pulses (5.94%), oilseeds (predominantly sesame (60.87%)), and vegetables and fruits (1.95%) (KHWDA, 2006). In the study area, crop production is the major source of income for the proximate farmers. Sesame (*Sesamum indicum* L.), cotton (*Gossypium hirsutum*), and sorghum (*Sorghum bicolor* L.) are the dominant cultivated crops (Source: field observation, 2018-2020). Most of the Tekeze riversides in the park area are cultivated from vegetable and fruit crops and are at risk of temporary human settlement shade (Figure 2).

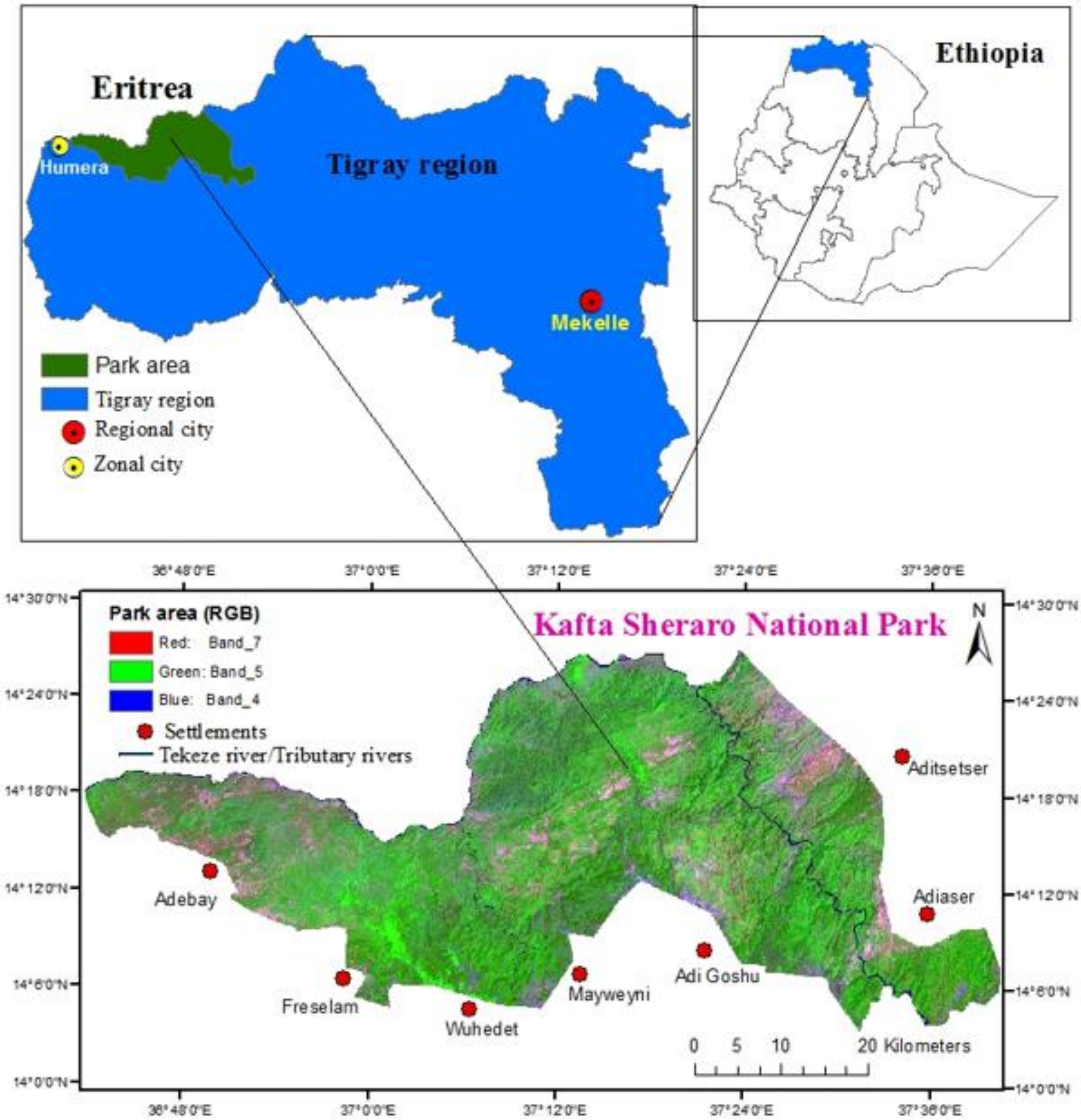


Figure 1. Location map of Kafta Sheraro National Park (KSNP) in the Tigray region (Extracted map by Fitsum Temesgen)

Figure 2. Tekeze riverside irrigated farmland and temporary settlements inside of the Kafta Sheraro National Park (Photo by Fitsum Temesgen, 2018/19)

3.1.3 Climate

The climate of the area is generally characterized by hot to warm semiarid lowlands with seasonal rainfall. The maximum monthly temperature occurs in April (43.7°C), while the minimum monthly temperature occurs in December (19.2°C) and January (19.1°C). The mean monthly temperature ranges from 28.35°C to 35.1°C. The coolest temperature occurs from July to September, while the warmest temperature occurs from March to May. The maximum mean monthly temperatures occur in March (33.15°C) and May (34.4°C), while the minimums occur in August (28.35°C) and January (28.65°C). The rainfall pattern greatly varied with the month of the season. Short rains occur from May to mid-June and September, whereas long rains occur during July (174 mm) and August (252 mm). The near stations of Humera and Shiraro towns with meteorological center record data (ENMA, 2018) were used for rainfall and temperature analysis of the park (Figure 3). Because of the scarcity of up-to-date meteorological data of the stations we took from 1966 to 2016 years range.

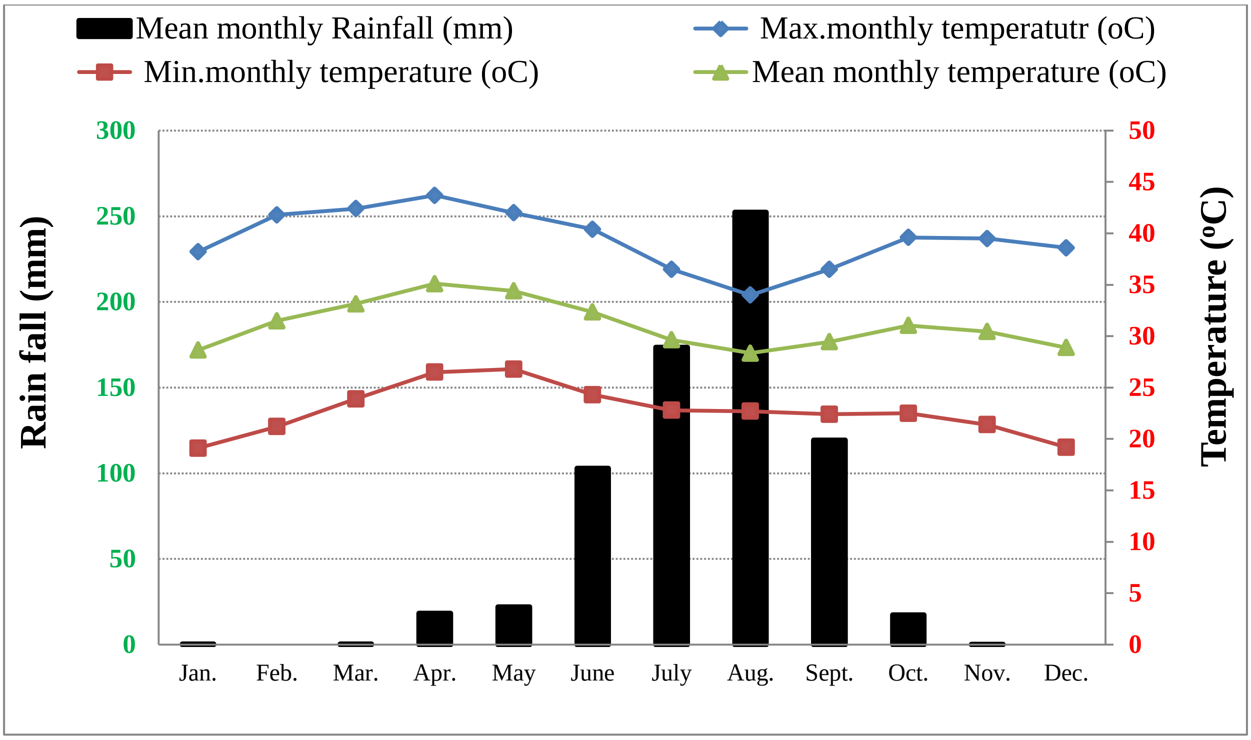


Figure 3. Monthly temperature (°C) & mean monthly rainfall (mm.month[1]) of Humera & Shiraro Districts Meteorological Center (1996-2016) (ENMA, 2018) (Extracted by Fitsum Temesgen)

3.1.4 Vegetation

Based on the vegetation classification of Ethiopia (Friis et al., 2010), Kafta Sheraro National Park (KSNP) forest communities are broadly categorized as *Acacia-Commiphora* 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 the dominant species(Friis et al., 2010;Temesgen et al., 2021). The selected parts of this study were dominated by *Boswellia papyrifera*, which is a frankincense-producing tree (Eshete et al., 2011). Thus, the severity and vegetation cover decline are greater in these lowland PAs because these areas are remote for basic livelihood access and have improper utilization of natural resources (Feoli et al., 2002). The KSNP harbors more than 70 woody species, 46 trees, 18 shrubs, and 6 tree/ shrubs (Temesgen and Warkineh, 2020). The most dominant and frequent tree species in the park are *Acacia mellifera*, *Combretum hartmannianum*, *Terminalia brownii*, *Balanites aegyptiaca*, *Dicrostachy scinerea*, *Acacia senegal*, *Acacia oerfota*, *Boswellia papyrifera*, *Ziziphus spina-christi*, and *Anogeissus leiocarpus* (Temesgen and Warkineh, 2020).

3.1.5 Fauna

According to a preliminary survey, the park is home to 42 mammals, 9 reptiles, 167 bird species, unidentified fish, and crocodile species (Shoshani and Demeke, 2008). After ten years of research, the total number of bird species identified in the KSNP decreased to 158 (Girmay et al., 2020). Moreover, the park is also extremely important and could be the only site in Ethiopia for wintering migratory birds of the Demoiselle crane (*Anthropoides virgo)* (G/medhin et al., 2009). The presence of large mammals, such as African elephant (*Loxodonta africana*), Caracal (*Felis caracal*), Leopard (*Panthera pardus*), Greater kudu (*Tragelaphus strepsiceros*), Oribi (*Ourebia ourebi*), Waterbuck (*Kobus ellipsiprymnus*), Spotted hyena (*Crocuta crocuta*), *Crocodile sp*., Warthog (*Phacochoerus africanus*), Aardvark (*Orycteropus afer*), Anubis baboon (*Papio anubis*), Grivet monkey (*Chlorocebus aethiops*), and Roan antelope (*Hippotragus equinus*) (Shoshani and Demeke, 2008), together with the hydrology of the Tekeze River, make Kafta Sheraro National Park (KSNP) a significant site for conservation priority.

3.1.6 Unique features of Kafta Sheraro National Park (KSNP)

Migratory bird species: a Wintering site of the Demoiselle crane (*Anthropoides virgo),* which is the only avifauna species found at Ethiopian bird sites. According to a preliminary survey, more than 20,000 Demoiselle cranes seasonally exist on Tekeze riversides; it does usually arrive in the park in the middle of December and leave the area in April (G/medhin et al., 2009). Generally, including cranes, there are 158 bird species in the park (Girmay et al., 2020).

Gum and resin sources: Some of the Kafta Sheraro National Park (KSNP) species were *Boswellia papyrifera*, *Acacia senegal*, *Acacia seyal*, *Acacia polyacantha*, *Commiphora boranensis*, and *Sterculia africana*. For example, the locally known ‘Meker’ (*Boswellia papyrifera*) is the dominant plant species inside and outside the southern part of the park, and this plant has commercial value because it is a source of aromatic resin or frankincense. Specifically, this plant is a potential source of job opportunities and income generation for the whole Tigray region (Oral communication and field observation, 2019-2020).

Permanent River: Half of the northern and northeastern parts of the park are enclosed and traverse the eastern part of the Tekeze River (Figure 1), and the presence of many tributary rivers is a basic environmental factor for the life of existing wildlife, particularly African bush elephant (*Loxodonta africana* L.) and the Demoiselle crane (*Anthropoides virgo*).

Nonrenewable natural resources: The area naturally has a high deposition of gold, sandstone (Marble), and other expensive stone minerals. This creates a source of income for the whole Tigray region of young age categories (Field observation on the extraction site and Table 23 interview).

Wild honey: This area is also a potential source of natural honey for nearby communities. Wild honey is collected from communities for household consumption and is rarely sold as traditional medicine in the local markets of Humera and Adebay towns (Table 23 interview and field observation).

3.2 Land use land cover data (Objective-1)

3.2.1 Satellite image collection and field observation data

Satellite images: thematic mapper (TM**)**, Enhanced thematic mapper plus (ETM^{+}**)**, and Operational Land Imager/Thermal Infrared Sensor (OLI/TIRS) satellite sensor data were used to identify LULC changes in 1988, 1998, 2008, and 2018 (Figure 4). The periods/years before and after the resettlement of the people and establishment of the park were selected for KSNP LULC changes evaluation. Because, the resettlement program in the area started in 1991, and the park was established in 2007. The 1988, 1998, 2008, and 2018 images were specifically selected because these years were consecutively available in the USGS-deposited data. The images were downloaded from http://earthexplorer.usgs.gov and covered by the path/row (170/50). Three images with less than 2% cloud and the rest of the images with no cloud cover were selected from among the images for each year to minimize errors during classification. A total of 25 images, 4 for LULC change identification, and 21 for normalized difference vegetation index (NDVI) analysis were downloaded. The NDVI data was collected both for the dry and wet seasons. The dry season of the area was defined from November to May, and the wet season was defined from June to October. We classify the wet season as the early wet season and the late wet season. However, the images for the NDVI were taken for the late wet season between the end of September and October and for the dry season between March and April. These months were chosen for all satellite image sensors because they were found to have no cloud cover and water vapor. The detailed description of each satellite sensor for LULC change classification is presented in Table 1, while NDVI analysis is obtained in Table 2.

Table 1. Data type and description of the satellite images used in the LULC change analysis

Satellite	Sensor type	Path/ Row	Acquisition date	Spatial Resolution(m)	Bands (B) used for spectral signature	Bands wave length (μm)
Landsat5	TM	170/50	23-10-1988	30	B1,B2,B3,B4,B5,B7	0.48-2.20
Landsat5	TM	170/50	19-10-1998	30	B1,B2,B3,B4,B5,B7	0.48-2.20
Landsat7	ETM^+	170/50	06-10-2008	30	B1,B2,B3,B4,B5,B7	0.48-2.22
Landsat8	OLI/TIRS	170/50	10-10-2018	30	B2,B3,B4,B5,B6,B7	0.45-2.29

Note: TM=thematic mapper, ETM^+=enhanced thematic mapper plus, OLI=operational land imager, TIRS=thermal infrared sensor and B=band, and calendar order (day-month-year).

Table 2. A detailed description of the satellite images used for the NDVI analysis

Satellite ID	Sensor type	Path/Row	Acquisition date	Spatial Resolution(m)	Sources
Landsat 5	TM	170/50	13-03-1988	30	USGS
Landsat 7	ETM^+	170/50	20-10-2007	30	USGS
		170/50	26-03-2007	30	
		170/50	06-10-2008	30	
		170/50	28-03-2008	30	
		170/50	09-10-2009	30	
		170/50	16-04-2009	30	
		170/50	12-10-2010	30	
		170/50	18-03-2010	30	
		170/50	15-10-2011	30	
		170/50	21-03-2011	30	
		170/50	01-10-2012	30	
		170/50	08-04-2012	30	
Landsat 8	OLI/TIRS	170/50	26-09-2013	30	USGS
		170/50	28-03-2013	30	
		170/50	29-09-2014	30	
		170/50	21-03-2014	30	
		170/50	16-09-2015	30	
		170/50	08-03-2015	30	
		170/50	20-10-2016	30	
		170/50	26-03-2016	30	

Note: TM=thematic mapper, ETM^+=enhanced thematic mapper plus, OLI=operational land imager, TIRS=thermal infrared sensor, USGS= United States Geological Survey, calendar (day-month-year)

Field observation: Field visits were carried out from mid-June 2018 to the beginning of November 2018 to identify major LULC types and to collect field training points in the KSNP. Fieldwork is mainly focused on observing and capturing various LULC types using a digital camera, and each sampling location was recorded via the global positioning system (GPS) of the handheld Garmin GPS-60. Specifically, the classification was more accurate;

more than 100 ground truths (latitude and longitude records) were collected from each LULC type in the 2018 image, and a total of more than 700 points were collected from seven classes. The accuracy assessment was good for the Landsat-8 (OLI) images from the 2018 satellite because the points directly show recent features of the LULC categories. The ground control points were divided into two groups: one group for selecting training sites for classification and the second group for the accuracy assessment.

3.2.2 Household interview

The drivers of LULC change in the study were collected from three basic sources: (1) household-based questionnaires, (2) focus group discussions, and (3) key informant interviews.

Sampling design: The park is located in two weredas (districts) of Kafta humera and Tahitay adiyabo, seven Kebeles (Kebeles: the smallest governmental administrative units of Ethiopia) were purposively selected from the total area based on proximity to the park and their livelihood, which was directly dependent on the resources of the KSNP and its surrounding area. A random sampling method was used to select representative sample respondents for household interviews from individual kebeles. The total sample size of households was calculated using equation (1): Sampling technique (Cochran, 1977).

$$no = \frac{t^2pq}{e^2};\ \ n = \frac{no}{1+\frac{(no-1)}{N}} \qquad (1)$$

where no=assumed simple random (initially calculated) sample size of households (384); p=estimated proportion of the population to be included in the sample (i.e., 50%=0.5); q=1-p=0.5; t=uncertainty (number of standard errors) in the number of people depending on park resources of $\pm$5% (at the 95% confidence interval level, Z value =1.96); e=the margin of error (0.05); n=sample size; and N=the total number of household heads (i.e., 5458). Using eq. 1, the resulting sample size was 359; however, to compensate for and cover the nonresponse of households, the sample size was increased by 10% (36). Therefore, the total sample size of the selected households in this study was 395 (Table 3). For questionnaire distribution and interviews, households were randomly selected from each kebele.

Table 3. Sample household heads selected from seven kebeles of two weredas (districts)

Wereda (district)	Selected Kebeles	Total heads of household	Sample size has taken from each kebele		
			Male	Female	Total
Kafta humera	Adebay	2976	88	36	124
	Freselam	291	25	9	34
	Wuhedet	262	21	7	28
	Mayweyni	265	22	8	30
	AdiGoshu	671	55	17	72
Tahitay Adiyabo	Adiaser	324	28	9	37
	Aditsetser	669	51	19	70
Total		5,458	293	102	395

Questionnaires: Before the main data collection, the drafted questionnaire was amended before use and improved in quality/clarity based on a presurvey sample of 90 randomly selected individuals from seven kebeles who were ultimately excluded from the main sampled respondents. The household survey questionnaires included both open and closed-ended questions to gather information about the perceptions of the local communities toward LULC changes and the drivers of change in the KSNP from November 2018 to June 2019. The questionnaires covered 395 households from seven Kebeles (Table 4), and individual household responses took 50-70 minutes. The populations targeted for semistructured interviews were park near communities (villagers) that had direct interactions with KSNP, irrigation farm holders, and livestock owners. The questionnaires were designed to gather general household characteristics, forest coverage trends, perceptions of local people about LULC change, and drivers of change (Appendix 2). Finally, the illegal activities associated with cover change were ranked based on their degree of impact on the sustainability of the park.

3.2.3 Focus group discussions (FGDs) and key informant interviews (KII)

The household-based semistructured questionnaire data were supplemented and strengthened by interviewing focus group discussions (FGDs) on seven selected kebeles, Park Management Staff, kebeles, wereda, and zone administrators, including professional experts. A purposive sampling technique (i.e., community and religious leaders, long term lived people, high awareness of about park, professional experts in the districts) was used to select focus group discussions and key informant interviews.

Focus group discussions (FGDs): A group of participants was selected together to discuss the relevant issue of this study. The focus group discussions (FGDs) were applied within seven Kebeles in the study districts and involved elderly people who were older than 60 years and had lived in the area for more than 28 years. The total number of FGD respondents in the kebeles averaged from 12 to 38, covering seven FGDs in seven kebeles: Adigoshu (26), Mayweyni (13), Wuhedet (12), Adiaser (15), Aditsetser (27), Adebay (38), and Freselam (14). The elders were consulted for the age and history of the land use type and the main drivers of LULC change in the KSNP using open-ended questions. This approach has helped us to be aware of the ongoing LULC change (i.e., past and present drivers of LULC change) in the study area.

Key informant interviews (KII): The main objective was to collect information from a wide range of people who selected specific groups and had first-hand information about the ongoing problems that happened in the KSNP by the communities. The qualitative data were collected from key informants via direct individual interviews and focus group discussions. Thus, the researcher conducted three key informant interviews: (1) community administrators and professionals (i.e., crop and livestock production, forest and wildlife conservation; (2) religious leaders in the districts; and (3) management, experts, and scouts of the KSNP. Data were collected from a total of 32 individuals comprising 2 western and northwestern zone administrators, 2 wereda and 7 Kebele administrators, and 21 professional experts in crop production and natural resource management (i.e., forestry and wildlife experts). Moreover, the interviews were conducted with 27 Park Management staff members, consisting of 20 scouts, 6 field experts, and Park Manager (1).

The questionnaire for focus groups and key informant interviews were arranged a qualitative data collection by preparing a list of open-ended questions from specific topics of the study objectives (i.e., forest cover trend, past and present LULC, causes of LULC change, and community attitude to LULC change). The questions prepared by the investigator for elderly people were short, clear, and prepared in their local language (i.e., Tigrigna); however, for expert and professional informants, the questionnaires were broad and more formally phrased. Moreover, the selected groups engaged in detailed discussions, elaborations, and conversations on the issues raised (questionnaires). Finally, the investigator recorded the interview responses by taking a note and audio records.

3.2.4 Preprocessing, classification, and post classification processing of images

Preprocessing of images: it is imperative to develop an inline association between biophysical phenomena on the ground and acquired image data (Coppin et al., 2004). Before any activities, Landsat images (TM 1988 and 1998, ETM^{+} 2008, and OLI 2018 images) were geometrically rectified (geocoded) to the World Geodetic System 1984 (WGS 84), and a projection was set to the Universal Traverse Mercator (UTM) zone 37 N specific to Ethiopia.

Geometric and radiometric calibration: During image acquisition, satellite images have different types of distortions/noise, which reduce the quality of the image. The calibration of Landsat imagery was performed based on the known solar geometry and on the gain and bias values provided by the Landsat metadata (Hilker et al., 2012). For better performance of the Landsat time series of LULC change analysis, consistent image sets of geometric and radiometric corrections are the two significant activities (Rani et al., 2017; Hansen and Loveland, 2012). For the present study, geometric and radiometric (reflectance) corrections were carried out to decrease the negative atmospheric effect or correct for changes that occurred in scene illumination, atmospheric solar conditions, and viewing geometry, as applied by Chander et al. (2009). However, almost all the images were cloud-free, images with minimum clouds and cloud shadows were removed using a cloud mask (*fmask function*) with the ArcMap10.5 tool. Subsequent calibration activities, such as gap filling, layer stacking, and subsetting of bands, were performed.

Color combination of bands: This approach refines image interpretability by increasing the differentiability of objects in the image for classification. For better visualization of different objects in the images, we created a color combination by taking band 7 for infrared (2.064-2.345 μm), band 4 for near-infrared (1.547-1.749 μm), and band 1 for blue (0.772-0.898 μm), which were chosen for TM 1988, 1998 and ETM^{+} 2008. For OLI 2018, band 7 for infrared (2.107-2.294 μm), band 5 for near-infrared (0.851-0.879 μm), and band 4 for red (0.636-0.673 μm) were chosen. Preprocessing was performed using ENVI 5.3 software.

Land use/cover classes of image classification: The images were classified using the supervised classification algorithms in ENVI 5.3 because we were familiar with the study landscape. This classification method may be preferable for LULC change detection if prior information about the landscape is gained through personal knowledge of the study area (Rogan and Chen, 2004). The individual LULC class signatures of the polygons (training areas) were marked based on field observations, household knowledge, and color combinations of bands (image visual interpretation). Then, the image dataset in the LULC class is placed via the maximum likelihood classifier (MLC). Even though there are different classifiers, the MLC algorithm performed better when all the spectral bands were fit to vegetation (Manandhar et al., 2009). This technique also has a greater probability of weighting minority classes that can be swamped by the large class during training samples taken from images. The minority classes in the image have the opportunity to be included in their respective spectral classes (reduce uncategorized pixels) from entering another class (Othow et al., 2017). We described the individual LULC class of the study site based on the field observation and the existing land cover of the area. Accordingly, seven major LULC classes were recognized in the KSNP, and their descriptions were based on the author's prior knowledge of the study site and detailed field observations (Table 4).

Table 4. Land use/cover categories and explanations based on field observations in the KSNP

LULC type	Description
Woodlands	Large and medium trees which have medium canopy cover arise from lower range of grasses and herbs.
Shrub bush lands	Dominantly covered by short height shrub/ bush structure of plants and arise from mixed lower coverage of grasses and herbs.
Riparian forests	Dense canopy cover vegetation of the park along Tekeze River and its tributary rivers valley having vertical stratification and dominated by tall trees or wood lands.
Grasslands	Plains, rough ground & relatively hilly areas cover by predominantly grass species mixed with herbs and natural pasture for animals.
Agricultural land	Both rain fed crops and irrigated vegetable and fruit crops like banana and mango plantation. Areas of store house and farmhouses are also under agricultural land.
Water bodies	Water courses of Tekeze river, permanent & seasonal tributary rivers
Bare land	Areas including no vegetation cover, gravel roads, degraded lands, gold excavation areas, mixed sand and small gravel which are found in Tekeze River sides and its tributary rivers.

Generation of the map: Sometimes the classified groups manifest poor or unclear visual appearance. Hence, to refine and enhance the classified map quality, postclassification smoothing techniques are needed to obtain a smooth LULC map. This process results in the elimination of isolated pixels in the LULC classes. The visual interpretation technique was applied to obtain the final classified images. To better purify the classified image and to obtain the final output map, majority filter analysis of a 3x3 kernel window size postclassification program was applied.

Accuracy assessment: This approach is useful for assessing the quality of the data collected in the field and the classified images. This technique determines the sources of error encountered during the classification of satellite images (Congalton and Green, 2009). An accuracy assessment determined how accurately the ground-truth data region of interest agreed with classified images of the remotely sensed data in which precision testing was conducted using the kappa index (Keshtkar et al., 2017). We compare the accuracy assessments for 1988, 1998, and 2008 using ground sample points taken from Google Earth maps, long-lived resident interviews, and previously published research reports. However, for the 2018 satellite image classification and accuracy assessment analysis, more than 100 points were collected from each of the 7 classes (total above 700 points) of ground truth data/reference points using GPS. Generally, the accuracy is assessed using four parameters, user accuracy, producer accuracy, overall accuracy, and the kappa coefficient, which are derived from the error (confusion) matrix following eqs. (2-5) (Lillesand et al., 2008; Congalton and Green, 2009; Liu et al., 2007; Lung and Schaab, 2009).

User`s accuracy (UA) = $\frac{\text{Number of correctly classified pixels in each catagory}}{\text{Total number of reference pixels in that catagory (row total)}}\, x100\%$ (2)

Producer`s accuracy (PA) = $\frac{\text{Number of correctly classified pixels in each catagory}}{\text{Total number of reference pixels in that catagory (column total)}}$x100% (3)

Overall accuracy (OA) = $\frac{\text{Total number of correctly classified pixels (Diagonal)}}{\text{Total number of reference pixels}}\, x100\%$ (4)

Kappa coefficient (Kc) = $\frac{\mathrm{N}\sum^{m} \mathrm{Dij} - \sum^{m} \mathrm{Ri.Cj}}{\mathrm{N}^2 - \sum_{i,j=1} \mathrm{Ri.Cj}}$ (5)

Where N = the total number of pixels, m = the number of classes, Σ Dij=the total diagonal elements of an error matrix (the sum of correctly classified pixels in all images), Ri = the total number of pixels in row i, and Cj=the total number of pixels in column j.

Land use/cover change trend analysis: The magnitude of change is the degree of expansion (+) or reduction (-) in the LULC size of the classes. A negative value represents a decrease in LULC size, while a positive value indicates an increase in the size of the LULC class. The magnitude and rate of LULC changes in Kafta Sheraro National Park between periods were computed using equations (6) and (7).

Change in each land cover class (km^2) = area of final year (km^2)-area of initial year (km^2) (6)

Change rate (%) = $\frac{\text{Area of final year} - \text{area of initial year}}{\text{Area of initial year}}\, x100$ (7)

The annual rate of change per year at four different intervals (i.e., 1988-1998, 1998-2008, 2008-2018, and 1988-2018) was calculated according to equations (7) and (8).

Annual rate of change (km^2/year) = $\frac{\text{Area of final year} - \text{area of initial year}}{\text{Time interval b/n initial \& final years}}$ (8)

Annual rate of change (%) = $\frac{\text{Area of final year} - \text{area of initial year}}{(\text{Time interval b/n initial \& final years}) \text{ X } (\text{Area of initial year})} x100$ (9)

Note: In this study, the time interval between the initial and final years for the three changes (1988-1998, 1998-2008, and 2008-2018) was 10 years, while for 1988-2018, it was a 30-year interval.

Change detection (transformation): The spatial trend in the LULC was analyzed by aggregating the study years into three time periods, namely, 1988 to 1998, 1998 to 2008, and 2008 to 2018. The transition matrix class was prepared for the time periods, and the transitions of various LULC categories were identified.

3.2.5 Normalized difference vegetation index (NDVI) analysis

Vegetation cover change: The normalized difference vegetation index (NDVI) is used to distinguish the forest cover status, degradation state, and extent of loss (Meneses-Tovar, 2011). Thus, NDVI information is relevant in the present study area because the influence of the local community on forest cover is relatively high. Landsat images from 1988 to 2018 were used to extract the following NDVI values for vegetation cover change classification: nonvegetation (-1.0-0.18), sparse vegetation (0.18-0.38), and high-moderate density (0.38-0.85) vegetation (Figure 8 & Table 10). The NDVI value ranges between -1 and +1. An increase toward +1 or an increase in positive NDVI indicates dense vegetation (vegetated plant canopy), and values close to zero or decreasing negative values (-1) indicate nonvegetation surfaces such as water and bare ground (Schnur et al., 2010). The NDVI has a high positive value for vegetated agricultural cover crops (Meneses-Tovar, 2011). NDVI value $\leq$ -1.0-0 (negative value) represents the water body while the value < 0.2 corresponds to the bare area of rock and sand (Shikhar and Akansha; Merwan et al., 2014). NDVI value 0.2-0.4 indicates shrub and grass (sparse vegetation) while moderate vegetation (0.4-0.6) and dense vegetation ($\geq$ 0.6) (Thorat et al., 2015; Haboudane, 2004). The NDVI is calculated based on the difference in the ratio of red (R) to near-infrared (NIR) reflectance using eqs. 10 and 11 (Naif et al., 2020; Bilgili et al., 2014).

Landstat-8, NDVI = $\frac{\text{Near\_ infrared(band 5)} - \text{Red(band 4)}}{\text{Near\_ infrared(band 5)} + \text{Red(band 4)}}$ (10)

Landsat-5, 7 NDVI = $\frac{\text{Near\_ infrared(band 4)} - \text{Red(band 3)}}{\text{Near\_ infrared(band 4)} + \text{Red(band 3)}}$ (11)

Note: In this analysis, the index was computed based on the difference in red band 4 (0.64-0.67 μm) reflectance and NIR band 5 (0.85-0.88 μm) reflectance of Landsat-8 (OLI sensor) from both dry (March-2018) and wet season (October-2018) satellite images. In addition, for the TM and ETM^+ sensors, there were 3 red bands (0.63-0.69 μm) and 4 NIR bands (0.77-0.9 μm).

NDVI–precipitation/temperature correlation analysis: The study site is located in a semiarid region where climate variables are limiting factors for vegetation cover determination. Among the climate variables, precipitation has a direct relationship with spatial and temporal changes in the NDVI. Due to the absence (discontinuous) of remotely sensed satellite images between 1996 and 2006, the NDVI relationship with climate variables analysis was conducted between 2007 and 2016. During these periods, continuous satellite image data directly matched the recorded precipitation and temperature data collected during the same years and seasons. Thus, the relationships between the NDVI response and precipitation and/or temperature were examined separately through a simple linear regression model, using equation (12), for one decade.

$$NDVI = a \pm b * \text{rainfall or temperature} + \varepsilon \quad (12)$$

Where NDVI=dependent factor, rainfall or temperature=independent factor, a=intercept, b=partial slope coefficient for variable rainfall or temperature, and ε=random error. The seasonal mean NDVI, annual seasonal rainfall, and seasonal mean temperature were analyzed for the period from 2007 to 2016. The significance of the mean NDVI change was evaluated at the 95% confidence level ($p<0.05$).

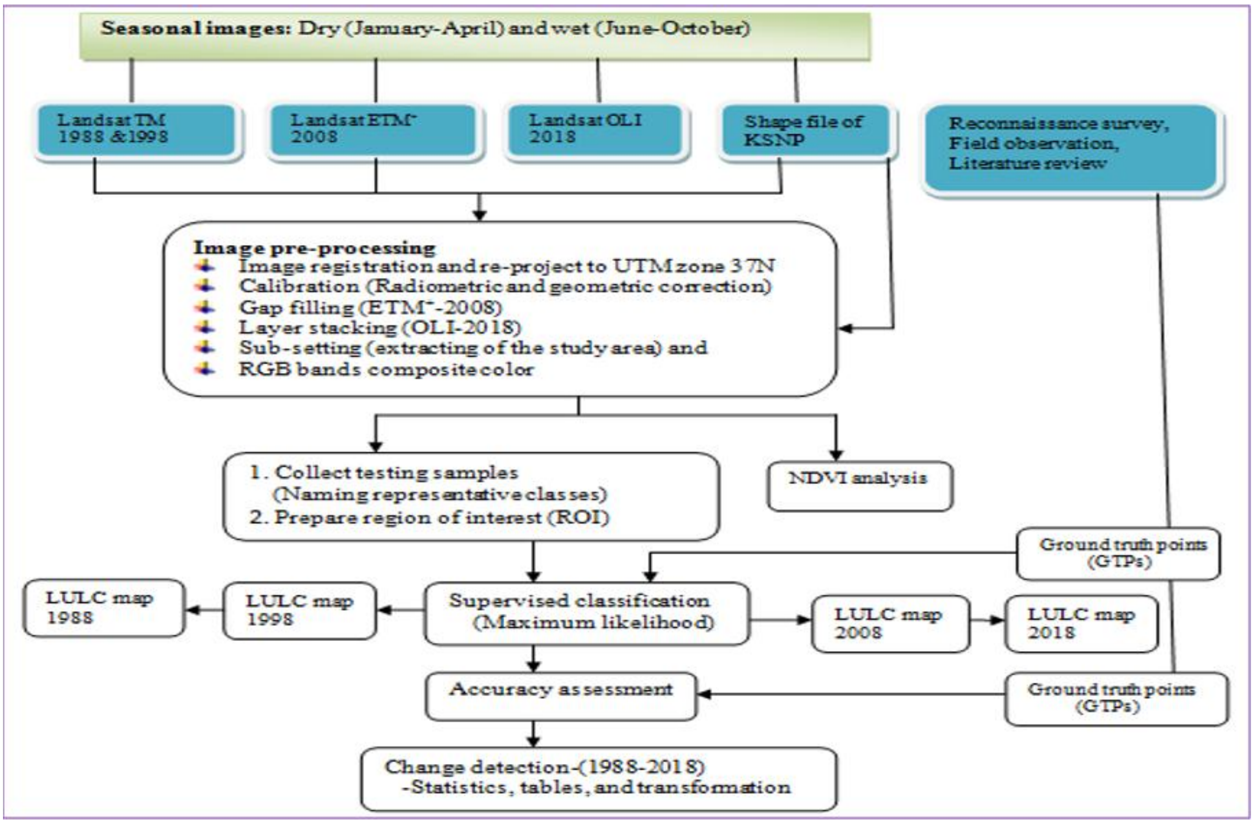


Figure 4. Flow diagram summary of steps and data utilized in image analysis

3.2.6 Socioeconomic and associated statistical analysis

The data collected from the sampled households were quantitatively analyzed, whereas the data from focus group discussions (FGDs) and key informant interviews were analyzed qualitatively. Descriptive statistics, such as the mean and percentage, were used to describe the socioeconomic variables of the households and summarize their responses using tables and figures. The interviewees' awareness of the drivers of LULC change responses to the selected socioeconomic variables was analyzed by Pearson's chi-square test (a nonparametric test). The main drivers of LULC change obtained from the household surveys were summarized by the ranking method. In this method, the index was calculated as a ranking ratio with the principle of weighted average adopted by Musa et al. (2006), as described in equation (13).

$$\text{Index} = \frac{R_n * C_1 + R_{n-1} * C_2 + \cdots + R_1 * C_n}{\Sigma R_n * C_1 + R_{n-1} * C_2 + \cdots + R_1 * C_n} \qquad (13)$$

Where, R_n = the value given for the least ranked level by respondents (in this study, the least rank is 4^{th}, then $R_n = 4$, $R_{n-1} = 3$, $R_1 = 1$); C_1 =the counts of the 1^{st} ranked, C_2= the counts of the 2^{nd} ranked... and C_n = the counts of the least ranked (in this study, C_n = the count of the 4^{th} rank)

The correlations between the trends of different LULC change types were computed at significant level of $p<0.05$. Chi-square (X^2), regression, and correlation were performed using the R-statistical package (R-Core Team, 2019) and IBM SPSS statistics (IBM Corp, 2019).

3.3 Vegetation and human disturbance sign data (objective-2)

3.3.1 Data collection

Sampling design: A reconnaissance survey was undertaken for three months in 2018, to identify the forest sites/forest patches of the park, and vegetation distribution. During the surveying time, supportive information was collected from the park administrative office and local households living near the park. Following the survey, the Park Forest was classified into three strata (sites) based on homogeneity in floristic composition and distributional patterns of vegetation classification of Ethiopia (Friis et al., 2010) and pretest/preliminary vegetation survey data: (1) the *Acacia-Commiphora* woodland and bushland vegetation type, (2) the *Combretum Terminalia* woodland vegetation type, and (3) the Riparian/riverine vegetation type of the KSNP Forest. The variation in forest cover and area (km^2) of each stratum was calculated using ground survey GPS coordinates and Google Earth maps. LULC change in 2018 was also employed for total forest cover comparison. Based on the country vegetation distribution classification and field observations, *Acacia Commiphora* woodland relatively covers a large portion of the park, *Combretum Terminalia* woodland and riparian cover moderate and small portions of the park, respectively.

A systematic sampling technique was subsequently applied to the three strata to collect woody vegetation data following Kent and Coker (1992). According to McIntosh's (1985) species-area curve (minimal area) concept, the plot size was determined based on the pretest field trials. For this study, a total of 32 transect lines were placed 0.3 km apart along the three vegetation types. Along a line transect, 161 plots (1-76=from Acacia commiphora, 77-114=from riparian, and 115-161=from Combretum Terminalia strata), each with a size of 20 m × 20 m (400 m^2), were systematically established for trees and shrubs at approximately 0.2 km intervals. Within the main sampling plot, subplots of 5 m ×5 m (25 m^2) and 10 m × 10 m (100 m^2) were established for the seedlings and saplings, respectively. All transects and plots were located using the compass and geographical positioning system (GPS) of navigation.

Woody vegetation: Detailed vegetation data were collected during the flowering and fruiting seasons from August 26-December 30, 2018.

Trees and shrubs: In each plot, the main sample plots were 400 m^2; plants (stems) of all the tree and shrub species with a diameter at breast height (DBH) $\geq$ 2.5 cm of stems were counted, and their circumference was recorded and coverted to diameter. The plant species outside the plots were also recorded to provide a more complete list of species. The heights of individual trees and shrubs $\geq$2 m were recorded for every woody individual plant with a diameter $\geq$2.5 cm. The DBH was measured using a tape meter, while height was measured using a clinometer and visual estimation. Trees with multiple stems arising from the ground level were measured individually, and common diameters were calculated for all the stems by summing their square roots and forks below 1.3 m in height; these values were treated as a single individual, and the diameter below the fork plus the average diameter of all the stems above the fork were added following Brundrett et al. (1996) guidelines.

Sapling and seedlings: To collect data on the abundance of saplings and seedlings of each woody plant species, subplots of 10×10 (100 m^2) and 5 m × 5 m (25 m^2), respectively, were set up within the main plot. Saplings are young woody plants with a diameter at breast height (DBH) < 2.5 and height >1 m<2 m, whereas seedlings are woody plants with a diameter at breast height (DBH) < 2.5 cm and height $\leq$ 1 m following (Chauhan et al., 2008a) techniques. The height of each sapling and seedling was measured using a tape meter. During the study period, altitude, latitude, and longitude were also measured from the center of each main plot by a geographical positioning system (GPS).

Herbs and grasses sp.: Within each 25m^2 sub-plots, five 1m x 1m (1m^2) sub-plots were laid out.

Disturbance: human disturbances such as grazing intensity, human-induced fire, and gold mining signs were recorded from 161 sampled plots. Based on the reconnaissance survey, grazing intensity, fire frequency, and gold mining were identified as the most pronounced negative impacts in the park. The degree of impact in each main plot (400m^2) was estimated based on the qualitative presence and absence method. Thus, if any disturbance sign (i.e., grazed area/presence of livestock dung, burned vegetation by fire, or excavated vertical and horizontal profile of the soil to search for gold) was present in the plots, it was scaled as presence (score=1); if there was no disturbance sign (plots were free from grazing impacts, no signs of burning, or no signs of excavating the soil profile) in the plots, it was scaled as absence (score=0). Livestock dung, footprints, and path of livestock grazing indicate grazed/browsed plots. Burned tree branches, stems, herbaceous layer and the whole tree represent eroded plots by fire. The seasonal fires and grazing were related to vegetation data collection time. Land preparation for cultivation was high during October to December while grazing was high during the whole wet season. Vegetation data were collected from October to December during plant flowering and fruiting season.

Plant species: Identification of species name started in the field by recording the local names of plant species by asking local elders and referring to the scientific name using Flora of Ethiopia and Eritrea Volume-1 to Volume-8 (Hedberg et al., 2009a; Tadesse, 2004; Hedberg and Hedberg, 2003; Edwards et al., 1997; Edwards et al., 1995; Hedberg and Edwards, 1989). The specimens of identified and unidentified species were collected, pressed, and dried properly, following standard Ethiopian Herbarium (ETH) procedures, and taken to the Addis Ababa University Herbarium for further confirmation and identification of unidentified specimens of these species.

3.3.2 Woody species structural data analysis

The diameter, height, basal area, tree density, frequency, and importance value index describe the woody vegetation structure of a given forest. The following formulas were utilized in the Microsoft Excel program and are presented in the descriptive statistics section.

Diameter at breast height (DBH): diameter of woody species arbitrarily arranged in diameter class intervals. The diameter of theshrubs of the plant species of Kafta Sheraro National Park (KSNP) was classified into nine classes of 10 cm intervals: 2.5-10, 10.1-20, 20.1-30, 30.1-40, 40.1-50, 50.1-60, 60.1-70, 70.1-80 and >80.1 cm.

Height: The heights of the individual/ shrub species were arbitrarily defined by height class intervals. The height of the plant species was classified into seven classes of 5 m intervals: (<=4, 4.1-9, 9.1-14, 14.1-19, 19.1-24, 24.1-29 and >29.1 m). The densities of individuals within the diameter at breast height (DBH) or height class were summed.

Frequency of species: the probability of finding a species in a given sample area (Kent and Coker, 1992).

$$\text{Frequency (F)} = \left(\frac{\text{Number of plots in which a species occurs}}{\text{total number of plots laid out in the study site}}\right) x100 \qquad (14)$$

$$\text{Relative frequency (RF)} = \left(\frac{\text{frequency of a single species}}{\text{total frequency of all species}}\right) x100 \qquad (15)$$

Finally, the frequency was summarized by class interval following Lamprecht (1989). The park was divided into seven classes of 15% intervals (<=5, 5.1-20, 20.1-35, 35.1-50, 50.1-65, 65.1-80 and >80.1%).

Density: The density of species is the number of individuals of each species within the quadrat (Kent and Coker, 1992). The sum of individuals per species was analyzed in terms of species density ha^{-1} (Mueller-Dombois and Ellenberg, 1974).

$$\text{Density (D)} = \frac{\text{number of abovground stems of a species}}{\text{Number of quadrats} * \text{quadrat area}} \quad (16)$$

$$\text{Relative density (RD)} = \frac{\text{Density of a single species}}{\text{Total density of all species}} \quad (17)$$

The density was arranged by class intervals following a dry forest study. The Park Forest was classified into five density class intervals: <=2, 2.1-10, 10.1-50, 50.1-100, and >100.1 stems ha^{-1}.

Basal area: the area outline of a plant near the ground surface (m^{2}ha^{-1}) (Kent and Coker, 1992).

$$\text{Basal area (BA)} = \frac{\pi d^2}{4} \text{ where } \pi = 3.14 \text{ and d = diameter at breast height (m)} \quad (18)$$

Dominance: the degree to which a species occupies a space at ground level (Mueller-Dombois, and Ellenberg, 1974).

Dominance = the mean basal area per species * abundance (n<u>o</u>) of the species (19)

$$\text{Relative dominance (RDO)} = \left(\frac{\textit{dominance of a single species}}{\textit{total dominance of all species}}\right)x100 \quad (20)$$

Importance Value Index (IVI): This index indicates the relative ecological importance of a given woody species at a particular site (Kent and Coker, 1992).

IVI= Relative density (RD) + Relative frequency (RF) + Relative dominance (RDO) (21)

Species richness **(**number of species ha^{-1}**):** is the number of species in a given sampled area. Species richness was calculated following equation (22):

$$\text{Richness} = \frac{\text{Number of species}}{\text{Sampled area (ha)}} \quad (22)$$

Species diversity**:** The woody species diversity was expressed and computed using the Shannon-Wiener Diversity Index and evenness Index (Barnes et al., 1998; Krebs, 1989). High Shannon-Wiener Diversity Index indicates low community disturbance whereas low index value shows high disturbance and computed using equation (23).

$$\sum_{i=1}^{S} (Pi)(\ln pi) \quad (23)$$

Where, H'=the Shannon-Wiener diversity index; ∑=sum of species 1 to species S; S=number of species encountered; Pi=*ni*/*N, is* the proportion of the total number of all species in a quadrat; ni=a number of individuals of species i; N=the total number of individuals of all species, and ln=natural logarithm in base e

Equitability index (Evenness): is measured of species dominance and species show evenly spread/ distributed pattern in a community. Evenness index is calculated by equation (24).

$$J=H'/H \ \frac{H'}{\ln s} = \sum_{i=1}^{S} \frac{(Pi)\ (\ln pi)}{\ln S} \qquad (24)$$

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.

3.3.3 Woody species regeneration data analysis

The regeneration status of Kafta Sheraro National Park (KSNP) woody species was computed by comparing seedlings and saplings with mature tree density (Tiwari et al., 2010; Chauhan et al., 2008a; Chauhan et al., 2008b; Dhaulkhandi et al., 2008) techniques. If the seedling > sapling > mature tree ("best" regenerating); mature tree > sapling > seedling ("reasonable" regenerating); if a species survives only in the sapling stage ("weak" regenerating) (even saplings <, >, or=to mature); if a species is absent both in the sapling and seedling stages but present as mature ("not" regenerating); or if a species has the absence of mature but only sapling and/or seedling stages ("new" regenerating).

3.3.4 Human disturbance computation

The magnitude of the impacts of the disturbance was quantified based on the variable score absence and presence qualitatively recorded in each plot. The type and degree of human disturbance were analyzed for the three strata, and the scores of each type of disturbance obtained from the plots were summed, after which the average was taken. Finally, each vegetation site disturbance score is categorized as high disturbance and low disturbance rates. The three disturbance mean scores indicated that most of the plots with Combretum Terminalia and Riparian vegetation experienced disturbance and the 0.74 mean score indicated that most of the Acacia Commiphora sampling plots were low disturbance (Table 5).

Table 5. Human disturbance variables (mean values) along the vegetation sites

Vegetation strata	Average altitude (m)	Plots	Grazing	Fire	Gold Mining	Disturbance score
Acacia Commiphora	647.3	76	0.58	0.145	0.013	0.74
Combretum Terminalia	868.3	48	0.68	0.82	0.73	2.23
Riparian/riverine	597.9	37	0.76	0.90	0.84	2.50

3.3.5 Regression and correlation analysis

The analysis included the variation in the basal area (BA), seedling (S), sapling (SP), and mature tree (M) density of all the woody species in response to altitude along the sampling plots, which was estimated a simple linear regression fitting model to measure any significant. The simple linear regression model is mathematically represented in equation (25).

$$Y=\beta_0 \pm \beta_1 X_1+\varepsilon \qquad (25)$$

Where Y=dependent variable (BA, S, SP); β_0= intercept point of the regression line and y-axis; β_1= regression coefficient of the explanatory (independent) variable; X_1=independent variable (altitude); and ε=error.

The natural regeneration status (i.e., seedling, sapling, and mature tree) in response to altitude and human disturbance variables (i.e., grazing intensity, fire sign, and gold mining) was analyzed using a bivariate correlation (the association between two variables) statistical method. All analyses were facilitated using the R-statistical package (R-Core Team, 2019). For qualitative analysis, descriptive statistics were used, and these descriptive statistics were generated with Microsoft Office Excel software.

The Pearson correlation coefficient (γ) is mathematically calculated by equation (26).

$$\gamma = \frac{\sum xy - \frac{\sum x \sum y}{n}}{\sqrt{(\sum_x 2 - \frac{(\sum x)^2}{n})(\sum y^2 - \frac{(\sum y)^2}{n})}} \qquad (26)$$

Where x and y= are pairs of variables used for comparing associations; and n= is the number of observations (in this study, 161 plots).

3.4 Elephant seasonal diet preference data (Objective-3)

3.4.1 Observation of plant species utilized by elephant

Study design: Elephant diet studies can provide the initial step toward understanding the resource and habitat requirements of a species before any management efforts are initiated. A preliminary survey was carried out to differentiate elephant feeding routes and habitats foraged using vehicles for accessible areas and on foot for rugged areas. As confirmed by Steyn and Stalmans (2001), naturally, elephants exhibit a similar pattern of vegetation utilization and follow a connecting network of paths (i.e., localized distributions) from one food patch to the next food patch. We also used an excessive number of samples to estimate elephant diet preferences. Thus, the network of paths provided a basis for deciding on sampling procedures. Following the sampling plot concept developed by Steyn and Stalmans (2001), foraging paths were considered line transect walks and along their path length/foraging ways; 112 quantitative plots, each with a size of 40 m×40 m, were systematically developed at distances ranging from 200-250 m to check elephant utilization on vegetation (Figure 5). Plot dimensions were measured and delineated by walking 40 m to consecutive corners. All plots were located using the geographical positioning system (GPS).

*Direct method (transect-based feeding observation)***:** Plant species consumed by elephants were studied through direct examination of fresh feeding signs. The observation of elephant feeding signs on food trails determines the diet selection of elephants residing in different areas and traveling on different migration ways. Elephant feeding sites can be identified through their tracks and food scraps. Some of the indirect evidence of feeding site features includes elephant footprints; fresh dung piles near browsed foliage; and plant damage caused by elephant browsing, such as bark piles, branch breaking, and uprooting. As the study area (KSNP) is an open dry woodland with a high visibility field, it is relatively easy to study direct observations of elephant feeding habits. The plots were immediately examined after the herd left for another location. The data collected on the diets of the elephants were collected in both the dry and wet seasons; this might be attributed to the significant variation in plant preference during these seasons and in planning habitat management to reduce HEC. The recording of field data commenced anywhere between minutes and hours after the elephant herds had left the observed feeding areas. Field observers maintain a safe distance from the elephant herd to minimize disturbance. Supportive/cross check information was also collected from viewing distance using binocular, digital, and drone cameras.

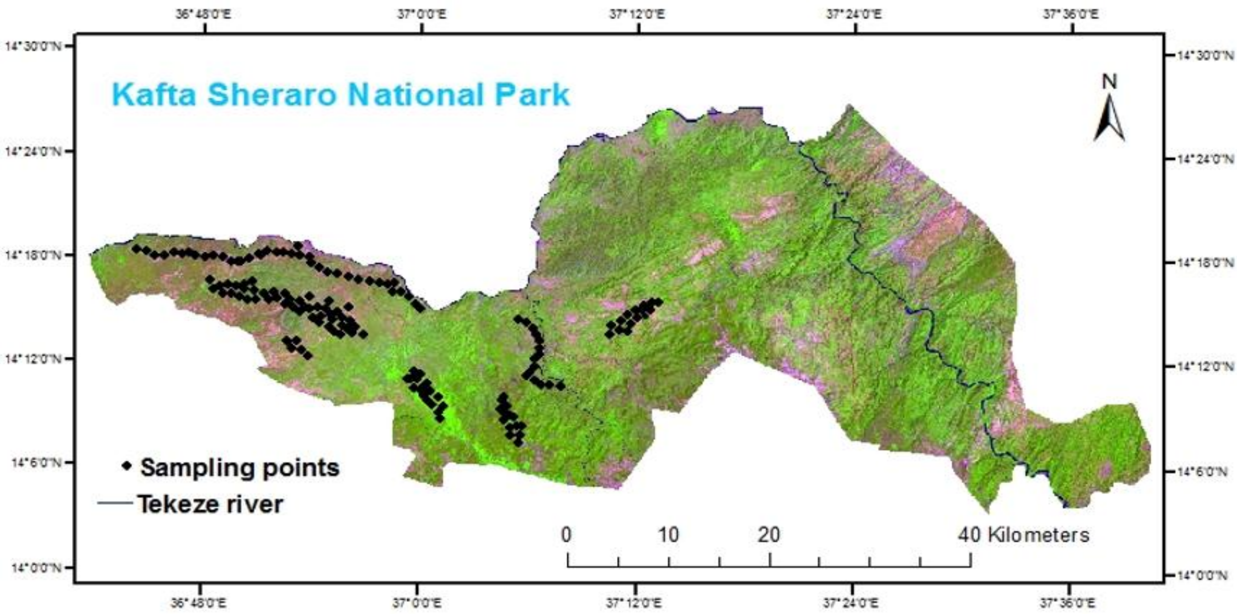


Figure 5. Map of the KSNP location of plots used for elephant feeding sign surveys

During the field survey, all plant species in each plot that did not show any signs of utilization or signs of being browsed/grazed by elephants were recorded and identified as trees, shrubs, herbs, grasses, or climbers; the plant parts consumed were classified as leaves, branches, bark, stems, fruits or shoots; the type of habitat; the season type (dry or wet); and the coordinates of the sample sites were determined using GPS. Furthermore, for each of the woody species utilized in a specific plot, the stem/canopy height size classes were assigned as (i) seedling/sapling (regeneration: < 2 m) and (ii) mature: 2.0-3.0 m, 3.0-4.0 m, and >4.0 m tall, while the type of utilization impact recognized as (i) stem branch breaking, (ii) mainstem breaking, (iii) bark stripping, and (iv) whole stem uprooting/felling/push were recorded. Finally, all plant species showing signs of being consumed by the elephants were recorded, photographed, collected, pressed, and dried; common names were identified if known by the locals (refer to objective 2).

To improve the data collection, direct elephant feeding observations were strengthened by interviews with wildlife scouts and residents. Data on elephant food selections were gathered during the dry season (early dry season: November to January; late dry: February to May 2018-2019) and from June to October 2018-2019 for the wet season.

3.4.2 Elephant feeding frequency/abundance analysis

The vegetation data analysis emphasized the comparison between availability and utilization. The relative availability of each species was compared with the actual utilization of this species. The diet composition was quantified by identifying the variety of plant species consumed by elephants to compute their relative frequency and relative density (abundance). The feeding frequency was quantified using the frequency of occurrence of each food item expressed as the percentage and percentage availability of a species in the field. The relative frequency of the percentage of feeding signs was computed. The dietary contribution was ranked based on the frequency of plant species with feeding signs such as barking, browsing, stem and branch removal, and grass and herb species utilized. The elephant feeding signs survey was conducted by scoring the different signs according to the frequency with which the species had feeding signs and the parts of the plants consumed. Furthermore, the number of different plant parts removed across all individuals from all species was summed, and the relative dietary contribution of each plant part type was calculated by dividing the number of a particular plant part type by the total number of plant parts that were removed. The data were generated using Microsoft Excel and IBM SPSS version 26 (IBM Corp, 2019).

3.4.3 Elephant food plant preference indices and statistical analysis

The number of times the elephant records ate different plant species was expressed as a percentage of the total feeding record during the wet and dry seasons. For each season, the percentage of plant parts eaten was recorded. We calculated the availability of each plant species along the foraging pathway indicated by the elephant tracks and utilization, while the acceptance index was calculated for each plant species at the park site per plot. The preference index (PI) was calculated for each woody species by using the following equation adopted from (Koirala et al., 2016; De Boer et al., 2000; Fritz et al., 1996; Petrides, 1975) equ. (27).

$$\text{Preference index (PI)} = \frac{\text{utilization percentage (in the elephants diet)}}{\text{Percentage of plant species availability}} \qquad (27)$$

Note: The PI was calculated for the 41 woody principal food plants (Table 23)

The utilization and availability percentages of were determined using eqs. (28) and (29)

$$\text{Percentage of availability} = \frac{\text{Total number of individuals stems of a single species}}{\text{Total number of individuals of all species stems in all plots}} * 100 \qquad (28)$$

$$\text{Percentage of utilization} = \frac{\text{A given species stem in the diet per plot}}{\text{all species stem consumed per plot}} * 100 \qquad (29)$$

A PI score >1 indicates that a food utilizes proportionately more than it does in the environment (i.e., more frequently preferred plant species), and a PI score <1 indicates that a plant food is used proportionately less than it is present in the environment (i.e., less preferred plant species).

All the raw data were organized, tables were constructed, and graphs were constructed using Excel and IBM SPSS statistical version 26.0 (IBM Corp, 2019). A chi-square test was used to test for significant differences in food selections between plant parts (branches/leaves, stems, shoots, bark, and fruits), seasons (wet and dry seasons), type of utilization impacts (side branches, main stem, bark, and uproot/fell), utilized height size, and tree development stages. Pearson correlation (r) was used to test/estimate the deviation of the significant association between forage availability and the preference index and the correlation between the availability (relative abundance) of individual woody species and the utilization (frequency of feeding) of plant species by elephants. Chi-square (χ^2) and correlation tests were performed using the R statistical package (R-Core Team, 2019).

3.5 Human and elephant interactions (Objective-4)

3.5.1 Field survey on human-elephant conflict areas (crop raiding)

This field assessment supplements the socioeconomic survey and data from different seasons and times to observe and identify human-elephant conflict (HEC) areas by the movement and directions of elephant location evidence (e.g., footprint signs, dung signs, feeding signs, and signs of damaged trees), elephant groups involved in crop raiding; the duration of raiding; and control measures used by the local people in the study area. In the field survey, scouts and local people were guided to determine the common routes of the elephants. Every single reference point of the human-elephant conflict (HEC) survey on crops was recorded by a global positioning system (GPS); these points were the main and specific conflict areas in both the wet and dry seasons to determine any differential effects of interactions linked to seasons and to determine the nature and extent of elephant impacts across the sites. The HEC sites/areas were visualized or located on the map of the 2018 LULC change (Figure 28) using Arc GIS v10.5 software. Information on elephant crop damage or raiding was also accessed to determine food preferences and the degree of crop loss. The data also include information on the agricultural field locations of the affected and damaged households. The field observations took place from 2018 to September 2020 in both the wet and dry seasons.

3.5.2 Questionnaire survey samples

A preliminary survey was conducted one week before the actual questionnaire data collection (For detail explanation refers to objective 1). The data presented in this analysis were collected as part of a typical survey conducted in the KSNP between 2018 and 2019. The survey was conducted with a total sample of 395 local household residents from two districts (Weredas), namely, Kafta-Humera and Tahitay Adiyabo. Seven kebeles were purposively selected (detail refer to objective 1). The kebeles were selected based on proximity to the Park boundary (i.e., relatively short distance and high contact with PAs), high resource utilization and encroachment by the communities, and widespread observation of elephant crop raiding (i.e., a problem related to crop damage). Two of these kebeles in this sample (Adiaser and Aditsetser) are located within the eastern boundary of the KSNP. These areas are more affected by crop cultivation and animal grazing. Adigoshu, Mayweyni, and Wuhedet kebeles are located within the southern boundary of the KSNP, while Adebay and Freselam are found in the western part of the park. In these kebeles, elephant crop raiding is a dominant and challenging issue for the community.

The total number of households in each kebele was recorded (refer to objective 1 Table 3), while household heads were selected randomly from seven kebeles ranging from 6.5-21 km from the boundary of the park. The selected kebeles were divided into two distance categories during analysis: those less than 9.0 km from the boundary of the park were considered "close", whereas those above 9.0 km were considered "far away" (distant). The distances were determined by recording GPS points on the park boundary and kebeles (samples of individual residents' locations) and calculating the distance between them through ArcMap 10.5 software. Although all seven kebeles surveyed were outside the park boundary, most of their farming practices were inside and at the border of the KSNP.

3.5.3 Household socioeconomic and attitudinal responses

The data were collected from November 2018 to June 2019 through face-to-face semistructured questionnaire-based interviews. The purpose of the interviews was to assess the interactions of local communities with elephants and KSNP and their perceptions. The interviews consisted of both open and closed-ended questions. Open-ended questions were preferable for discussing and elaborating on some issues about elephant conservation. The interviews were limited to including one family head, either male or female, of an individual household. In this study, respondents who lived before 1991 were considered "long term lived", while respondents who came from other areas of the region after 1991 were considered "short term lived" (i.e., relocated from other areas of the region) because almost all those kebeles were well established after 1991.

Our questionnaire consisted of the following basic thematic sections/areas of interest. The first (1st) section investigated residents' natural resource utilization from the park relative to distance. In the second (2nd) section, we asked the respondents to rank the problematic wild animal species, particularly elephant species, and rate the damage at four levels (a=high problem, b=moderate problem, c=low problem, d=no complaint/no problem), which helped us determine the effect of elephant damage and compare it with that of other wild animals. Moreover, participants who selected that wildlife/elephant posed a problem (i.e., selected a, b, and c) had to identify a type of conflict in the KSNP that the individual households experienced over the previous ten years. The third (3rd) section included information about the situation of human-elephant conflicts: the elephant crop raiding trend (a=increasing, b=same, c=decreasing, and d=unknown); the time of crops visited by elephants (a=morning, b=night, c= afternoon, d=unknown); the season (a=dry season, b=wet season, c=both seasons, d=no opinion); and the control mechanism or action taken (gun sound/banging noisy materials, lighting fire/flashlight, alternative crop cultivation, and traditional fences) by the participants to prevent elephant crop damage and name and locate the areas where the most conflicts occurred within the study area. The final (4th) section explored the knowledge, attitudes, and perceptions of the local communities toward the conservation of the KSNP and African elephants. To assess local community attitudes toward elephant and park conservation, we employed 14 statements/questions about interviewees' attitudes toward conservation and the benefits of the KSNP and African elephant (Appendix 1 Table 8). The interviewees' responses to each conservation attitude statement were categorized and recorded on a 5-point Likert scale (Likert, 1932): (strongly agree =1, agree =2, neutral =3, disagree =4, and strongly disagree =5).

The questionnaires that included questions on background description and socioeconomic information, as well as park community interactions at the household level were utilized as independent variables, while dependent variables (i.e., attitude toward elephants and KSNP) were used in the logistic and generalized linear regression analyses employed in this paper. Avoiding unnecessary complications and fitting the questions according to the respondents' background and level of understanding. The questionnaire was administered to sample households in two separate seasons a wet season (June-November) and a dry season (December-May) from 2018 to 2019. The questionnaires were prepared and written in both the Tigrigna and English languages (Appendix 2); however, the interviews were carried out in the Tigrigna language, which is spoken by all people in the Tigray region.

3.5.4 Focus group discussion and key informant interviews

The household-based questionnaire data were supplemented and strengthened through FGDs of the seven selected kebeles, Park Management Staff, and kebele-to-zone administrators, including professional experts. The total number of FGDs and the number of respondents in each sampled kebele were already included in Objective 1. The FGDs emphasized the awareness and attitudes of residents toward the conservation of KSNP and African elephants and HEC inside and outside the park. The discussions were distributed across the study site divisions and were guided using a checklist of questions related to human-wildlife interactions on changing land use/land cover in the area.

Qualitative data were also collected from the kebele to the Zone Administrator and professional experts (for the detailed sample size, refer to objective 1). The data collected from these key informants were assessed for elephant crop raiding impacts in the local community and for compensation feedback, natural resource utilization, and techniques for minimizing negative impacts on park sustainability. Moreover, the interviews were conducted with a Park management staff member (for sample size, refer to objective 1). These individuals are front-line participants in the management and protection of African elephants in the area. The park management staff interviewed to gather information about the list of wildlife and estimate the number of elephants, the challenges faced in conserving the park in general and the elephants in particular, their opinions on solving the encountered conservation problems, and their local attitudes about the conflict between humans and wild animals (elephants).

3.5.5 Households' attitudes and related statistical analysis

The attitudes toward elephant conservation in the KSNP were estimated in response to the attitude statement ranging from strongly positive (1) to strongly negative (5) and the sum of the scales, which provided a total attitude composite score for each respondent. We generated a total of 14 attitude questions (i.e., seven for elephant and seven for park conservation attitudes). The internal uniformity of the total scores was tested using Cronbach's alpha coefficients (α) between 0 and 1 among the 7 statements. Finally, we calculated two indices (for elephant and KSNP) following (Cahyat et al., 2007) guidelines with IBM SPSS statistics 26.0 (IBM Corp, 2019). The Cronbach's alpha (α) coefficient was evaluated using the criterion of tolerable range >0.7 (DeVellis, 2003), indicating good internal uniformity. Statements that were internally inconsistent were removed following the guidelines outlined by George and Mallery (2003). The corrected relationship among the 7 statements of >0.5 was selected for interpretation. Appendix 1 Table 8 indicates that the Cronbach's alpha coefficient for the residents' attitude indices of elephants and the park was >0.7.

The means and percentages were used to describe the socioeconomic features of the respondents. Chi-square and association analysis were also performed to test the variables using the R-package (R-Core Team, 2019). The dependent variables were aware versus not aware of conservation or agree, disagree and neutral attitudes. A logistic model was used to test the effect of age, sex, education level, distance, and settlement conditions on respondents' knowledge about the conservation objectives of the park. We used a general linear model to identify the best variables or evaluate the impact of individual household age, sex, education, distance, land occupation type, and level of elephant crop damage (high, moderate, and low/no complaint) on perceptions toward elephant conservation. Other variables used for respondent responses to KSNP conservation include age, sex, education level, distance, existing period, land holding size, land occupation type, and awareness. The detailed codes of the variables are shown in Appendix 1, Table 9.

3.6 Software

In this study, specific software was utilized for visualizing, rearranging, analyzing, and interpreting the collected data. Excel 2010 and IBM SPSS version 26.0 (IBM Corp, 2019) were used for the raw data organization, table, and graph construction. ENVI 5.3 and Arc GIS 10.5 were used for image processing, analysis of image data and extraction of maps. The R-statistical package (R-Core Team, 2019) was also used for trend analysis of LULC change; correlations between different LULC changes and drivers of LULC change; correlations between elephant forage availability and preference indices; chi-square (χ^2) tests; regressions of the variation in basal area (BA), seedling (S), sapling (SP), and mature tree (M) density of all woody species in response to altitude along sampling plots; and correlations of regeneration status in response to altitude and human disturbance variables. IBM SPSS version 26.0 (IBM Corp, 2019) was also utilized to calculate respondents' attitudes toward the conservation of elephants and KSNP; binary logistic regression and generalized linear regression models (GLMs) were used to identify the best predictor variables. Microsoft Word and Microsoft Power Point 2010 were utilized for the report preparation of the dissertation.

CHAPTER FOUR

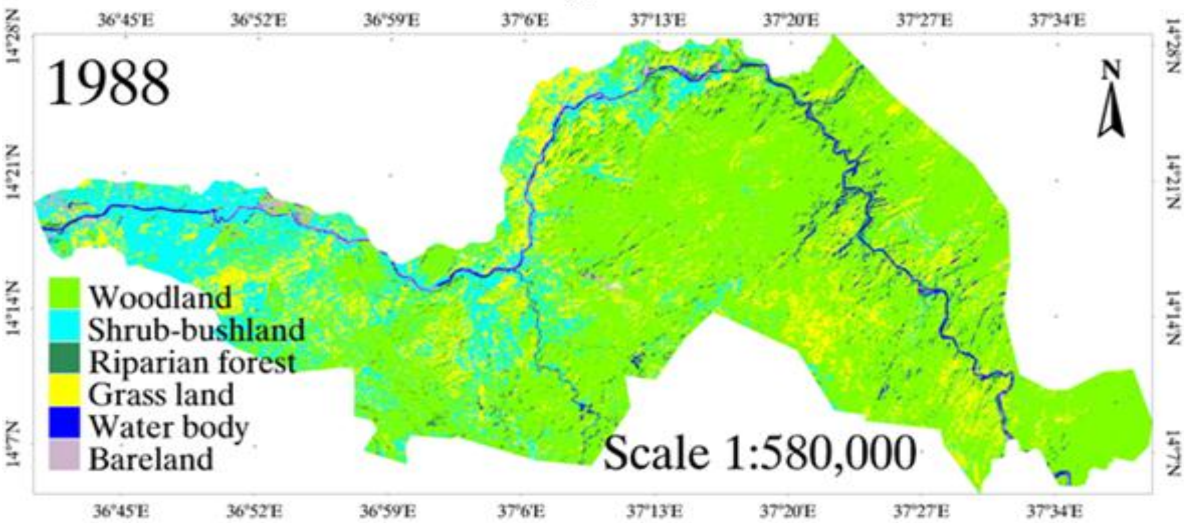
4. RESULTS

4.1 Land use/land cover changes from 1988 to 2018 (Objective-1)

4.1.1 Land cover classification map and accuracy assessment

A land use/land cover (LULC) map and categories of Kafta Sheraro National Park (KSNP) were identified for the years 1988 (a), 1998 (b), 2008 (c) and 2018 (d) (Figure 6). The major LULC included woodland, shrub bushland, riparian forest, grassland, agricultural land, water bodies, and bare land. The map accuracies from supervised classification approach were good. Table 6 clearly shows the accuracy assessment of the four periods based on the 2018 ground truth recorded data. Thus, the overall accuracies (OAA) during 1988, 1998, 2008, and 2018 were 88.6%, 88%, 82.26%, and 86.9%, respectively, and the kappa coefficients (Kc) were 0.85, 0.84, 0.79, and 0.845, respectively. Woodlands, riparian forests, agricultural lands, and water bodies were accurately classified, with user accuracy (UA) and producer accuracy (PA) greater than 88% for all the tested maps of 2018. However, for shrub bushland, grassland, and bare land cover, the UA ranged from 73.0% to 88.46%, and the PA ranged from 77.31% to 85.44% which is classified relatively low accuracy (Table 6). The classified pixel confusion matrix class LULC results for the 2018 OLI classified image using ground truth analysis are described in Appendix 1 Table 3.

(a)



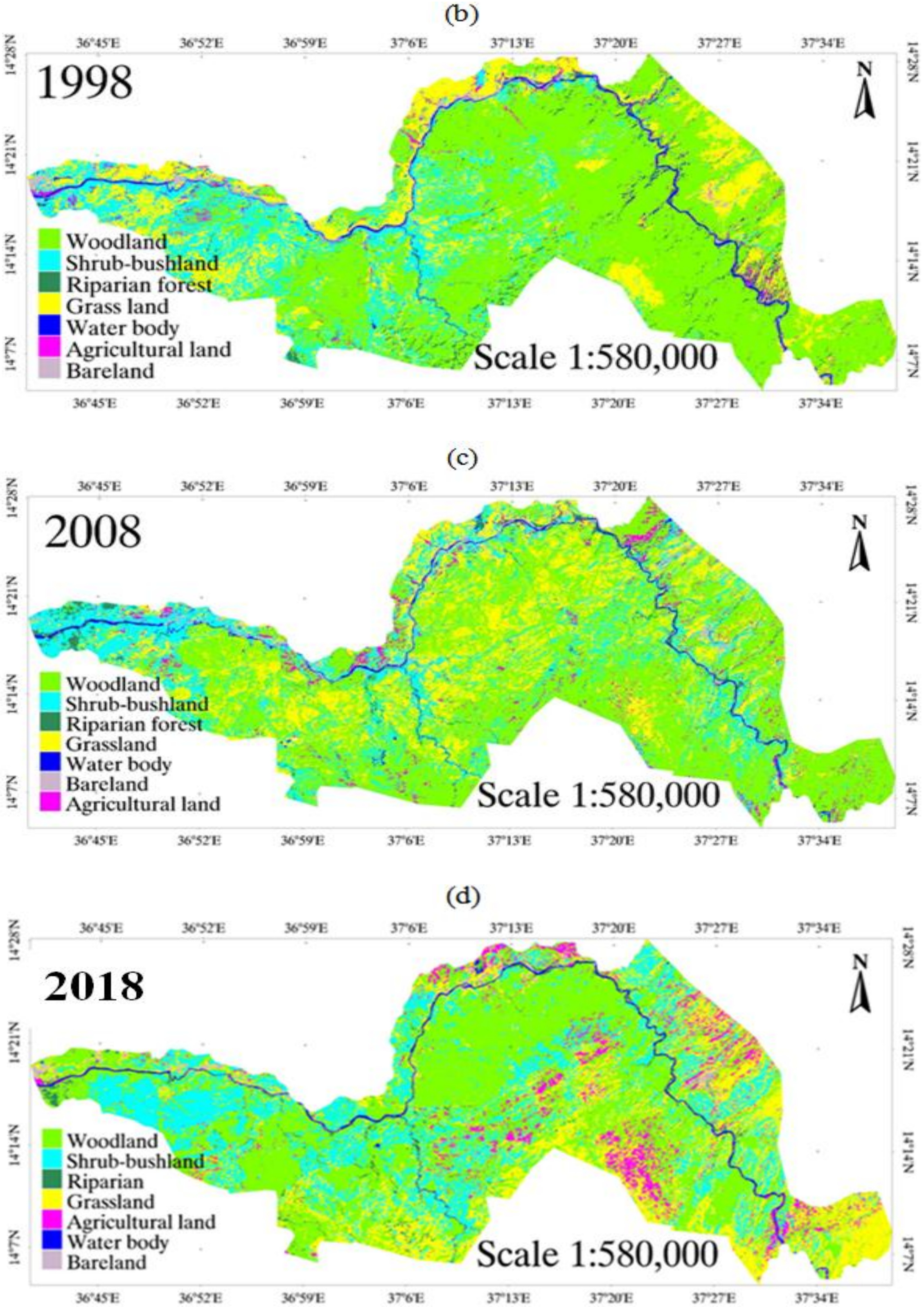


Figure 6. Land use/land cover change map for the years 1988 (a), 1998 (b), 2008 (c), & 2018 (d)

Table 6. Accuracy assessment for the 1988, 1998, 2008, and 2018 classified images

Land use land cover classes	1988		1998		2008		2018	
	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)	UA (%)	PA (%)
Woodland	90.46	87.15	93.79	94.15	88.69	66.54	88.97	88.36
Shrub bush land	77.65	82.20	84.20	92.39	75.54	86.64	88.46	77.31
Riparian forest	93.73	85.40	64.06	86.77	76.81	91.33	96.80	89.63
Grassland	77.57	96.35	96.92	88.59	75.47	94.65	73.00	82.49
Agricultural land	-	-	64.78	73.03	68.03	60.58	98.88	93.62
Water body	100.00	97.84	97.06	88.55	99.30	85.94	98.67	98.67
Bare land	97.71	95.09	87.09	95.87	95.31	96.64	79.28	85.44
Overall accuracy	88.6%		88%		82.26%		86.9%	
Kappa coefficient	0.85		0.84		0.79		0.845	

UA=user accuracy (%), PA=producer accuracy (%)

4.1.2 Magnitude and trends in land use land cover change (1988 to 2018)

The magnitudes of LULC types, rates of change, and annual rates of change per year from 1988 to 2018 are summarized in Tables 7. However, woodland area coverage was greatest in 1988; a continuous decline in woodland cover was observed in the three consecutive decades of the study period. The highest decrease of 124.8 km^2 (11.0%) was observed during 1998-2008; while the lowest decrease of 119.81 km^2 (9.57%) was observed between 1988 and 1998. Over thirty years (1988-2018), the area of woodland decreased by 367.85 km^2 (29.38%) at an average rate of 12.3 km^2 (0.98%) per year. The increase in shrub bushland area reached a maximum of 70.36 km^2 (16.1%) from 2008 to 2018. From 1988 to 2018, the shrub bushland cover increased by 132.27 km^2 (35.28%) at a rate of 4.41 km^2 (1.17%) per year. The area of riparian forest declined consecutively during 1988-1998 and 1998-2008 by 27.3 km^2 (22.85%) and 14.4 km^2 (8.78%), respectively. However, in the 3rd period (2008-2018), the forest area slightly declined by 7.83 km^2 (15%). In the three-decade study, this class decreased by 39.46 km^2 (47.11%) at an annual rate of 1.32 km^2 (1.57%) per year. The highest expansion of grassland was 79.82 km^2 (18.88%) between 1998 and 2008. However, the increase was very small from 2008 to 2018, which was 35.99 km^2 (7.25%) of the total area. During the 1988 to 2018 period, grassland expansion was 161.31 km^2 (43.47%) at an annual rate of 5.38 km^2 (1.45%) per year.

Agricultural land (irrigated and rain-fed crops) clearly showed greater expansion than did the other land cover classes. Crop cultivation inside the park was absent in 1988; however, it started after 1993 and continued as of 1998, 2008, and 2018, with extents of approximately

3%, 4.43%, and 5.48%, respectively. The highest expansion of cultivation was observed between 1993 and 1998, at 64.8 km^2, followed by 30.78 km^2 (47.5%) from 1998 to 2008. However, the expansion was relatively small, 22.78 km^2 (23.8%), between 2008 and 2018. From 1993 to 2018, cultivation increased by 118.36 km^2 at an annual rate of 3.94 km^2 per year. Water bodies: In three decades (1988-2018), water negatively changed by 13.29 km^2 (27.51%), with an annual rate of 0.44 km^2 (0.92%) per year. The highest expansion rate of bare land was 3.78 km^2 (11.8%) from 1998 to 2008, followed by 2.94 km^2 (10.08%) and 1.3 km^2 (3.61%) from 1988 to 1998 and from 2008 to 2018, respectively. Between 1988 and 2018, bare land expansion was 27.52% (8.02 km^2), with an annual rate of increase of 0.92% (0.27 km^2) per year.

Major LULC class transition: During 1988 to 2018, the transformation from major land cover classes to major land cover classes highlighted the large area of grassland gained from woodland (353.7 km^2) and subsequent shrub bushland (71.2 km^2). However, grassland gained a negligible area from the other land use/land cover classes. Similarly, agricultural land gained significant area from woodland (71.8 km^2), grassland (12.6 km^2), riparian vegetation (11.9 km^2), and shrub bushland (20.8 km^2). The highest loss was computed for woodland and shrub bushland class types throughout the studied period (Table 7).

Table 7. The magnitude and the rate of change in different LULC categories from 1988 to 2018*

and use land cover classes	1988		1998		2008		2018		1988-1998		1998-2008		2008-2018		Change between (188-2018)		Annual rate /year 1988-2019	
	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%	km^2	%
Woodland	1,252	58.0	1,132	52.4	1,007.3	46.6	884.0	40.9	-119.8	-9.6	-124.8	-11	-123.3	-12.2	-367.8	-29.4	-12.3	-1.0
Shrub bush land	374.9	17.3	402.4	18.6	436.8	20.2	507.2	23.5	27.4	7.3	34.4	8.56	70.4	16.1	132.3	35.3	4.4	1.2
Riparian forest	83.7	3.9	60.9	2.8	52.5	2.4	44.3	2.0	-22.8	-27.3	-8.8	-14.4	-7.8	-15.0	-39.4	-47.1	-1.3	-1.6
Grassland	371.0	17.2	417.5	19.3	496.3	23.0	532.3	24.6	46.5	12.5	78.8	18.9	36	7.25	161.3	43.5	5.4	1.4
Agricultural land[a]	0.00	0.0	64.8	3.0	95.6	4.4	118.3	5.5	64.8	-	30.8	47.5	22.8	23.8	118.4	-	3.9	-
Water body	48.30	2.2	49.2	2.3	34.6	1.6	35.0	1.6	0.9	1.9	-14.6	-29.7	0.42	1.23	-13.3	-27.5	-0.4	-0.9
Bare land	29.13	1.3	32.1	1.5	35.8	1.6	37.8	1.7	2.9	10.1	3.8	11.8	1.3	3.61	8.0	27.5	0.3	0.9
Total	2,159	100	2,159	100	2,159	100	2,159	100										

Major land cover classes of conversion from and to (1988 to 2018)

Change from class 1988	Change to class 2018	km^2	%
Woodland	Shrub bush land	174.3	15.0
Woodland	Grass land	353.7	30.5
Woodland	Agricultural land	71.8	6.2
Shrub bushland	Grass land	71.2	18.0
Shrub bushland	Woodland	134.8	30.3
Shrub bushland	Agricultural land	20.5	9.7
Riparian forest	Shrub bush land	11.5	12.9
Riparian forest	Woodland	40.1	45.0
Riparian forest	Agricultural land	11.9	6.9
Grassland	Agricultural land	12.6	2.8

4.1.3 Temporal and seasonal changes in the NDVI

Illegal fires, agriculture, fuel wood collection, and other related human-induced drivers of LULC change affected the vegetation of the KSNP. To assess vegetation cover changes of the park vegetation index (i.e., NDVI) analysis of the wet and dry seasons of thirty years (1988 to 2018) was used. The difference in the NDVI was shown between the dry (mid-March) and wet (mid-October) months of 1988 and 2018. The wet season had higher NDVI (0.85) in 1988 and 0.84 in 2018 from June to mid-October because the park areas were dominated by woodland, shrubland, and riparian (riversides) vegetation. In the dry season, from the end of December to the end of March, the maximum NDVI was 0.64 in 1988 and 0.49 in 2018 (Figure 7). In the dry season, vegetation areas were concentrated along the sides of the water points (i.e., Tekeze riversides and its tributary rivers) and the eastern riversides of the irrigated fruit plantations in the park. In the wet season, high NDVI was observed because, a section of the park area was used for rain-fed crop growing, expansion of grazing, illegal fires, and deforestation were observed during the field observation. The NDVI was in a similar range as those computed for the wet seasons of 1988 and 2018, whereas there was a significant change in the dry seasons in both years.

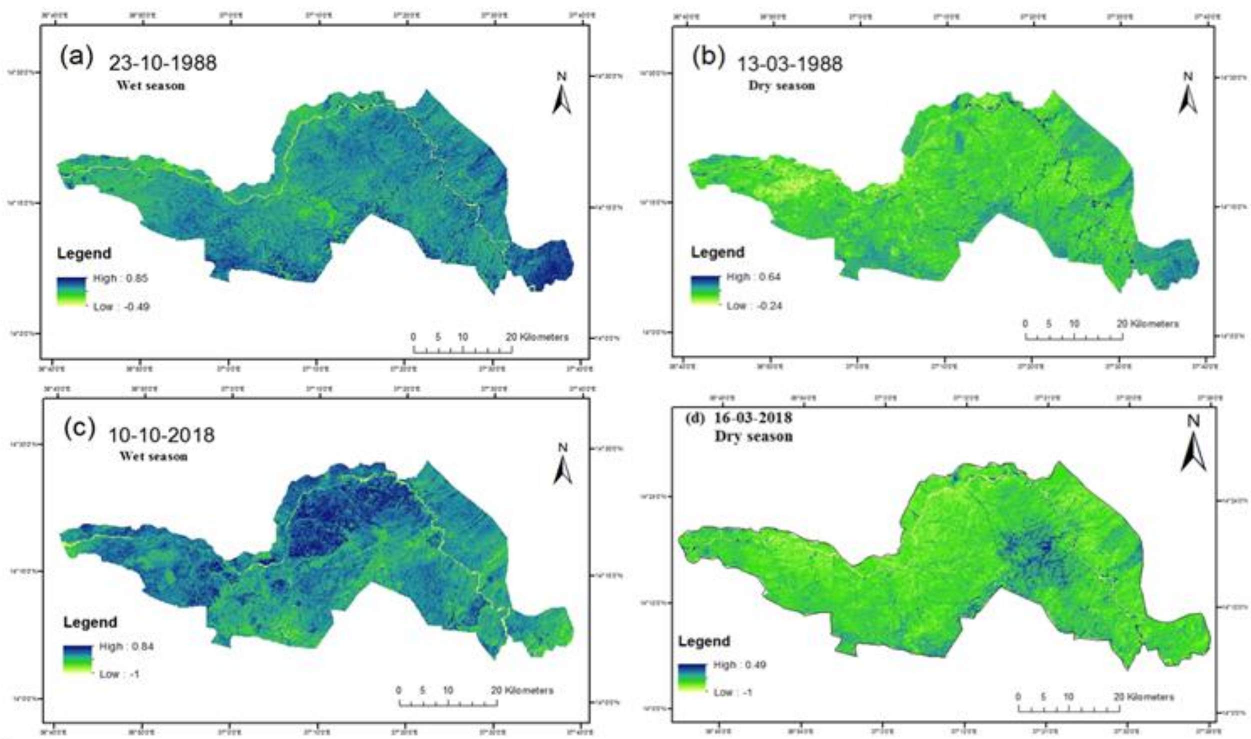


Figure 7. Seasonal variability of NDVI in KSNP for wet season (a and c) and dry season (b and d) during the years 1988 and 2018

The reclassification analysis of the NDVI also revealed a significant change in the vegetation cover (Figure 8 and Table 8). The high-to-moderate-density vegetation cover in 1988 was approximately 66.67%. However, the magnitude of its cover in 2018 declined to 45.2%. During the entire period from 1988 to 2018, the area of high-to-moderate-density vegetation decreased by 464.6 km^2. The sparse vegetation covered 29.8% of the total area of the park in 1988 but expanded to 49.6% in 2018. Sparse vegetation increased by 428.1 km^2, while the nonvegetation area expanded by 36.5 km^2 from the total area of the park between 1988 and 2018 (Table 8).

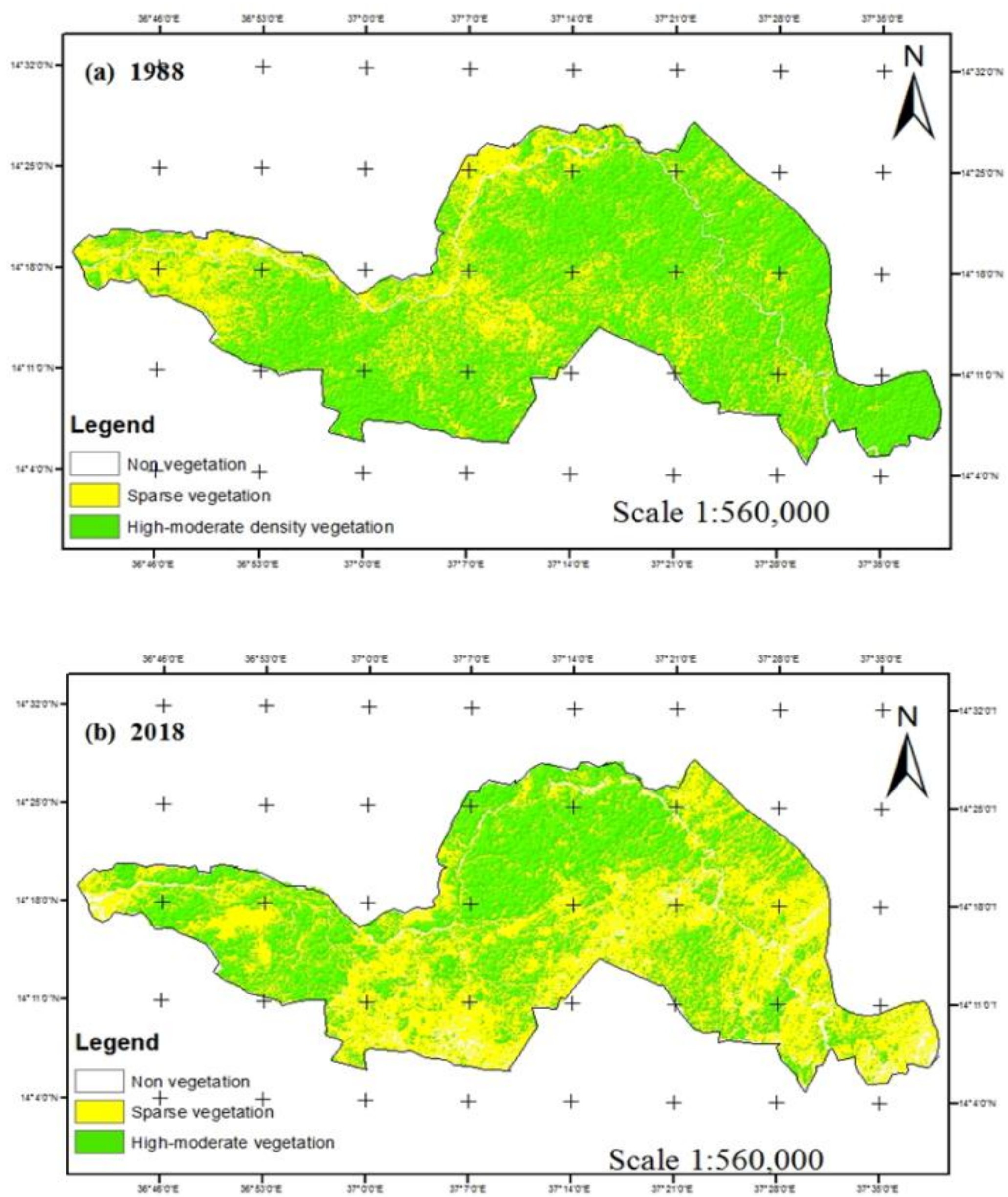


Figure 8. Vegetation cover change distribution maps of KSNP in 1988 (a) and 2018 (b)

Table 8. Normalized difference vegetation index cover changed between 1988 and 2018

Land cover class	1988		2018		1988-2018
	km^2	%	km^2	%	Change (km^2)
High-moderate density vegetation	1439.4	66.67	974.8	45.2	-464.6
Sparse vegetation	643.5	29.8	1071.6	49.6	+428.1
Nonvegetation	76.115	3.5	112.6	5.2	+36.5
Total	2,159	100	2,159	100	-

4.1.4 Relationships between the seasonal NDVI and precipitation/temperature

According to the wet and dry season Landsat data, the interannual variation in the NDVI during 10 years (2007-2016) was computed. The dry season mean NDVI indicated a significant decreasing trend ($p<0.05$), while the wet season variation was not significant over time. The dry season maximum mean NDVI value was a score for 2007 and 2008, while the minimum value occurred in 2016. In the wet season, the minimum and maximum mean NDVI values were 0.21 in 2012 and 0.33 in 2007, respectively (Figure 9a and b). In contrast, the rainfall did not significantly ($p>0.05$) vary during the specified period (Figure 9c and d).

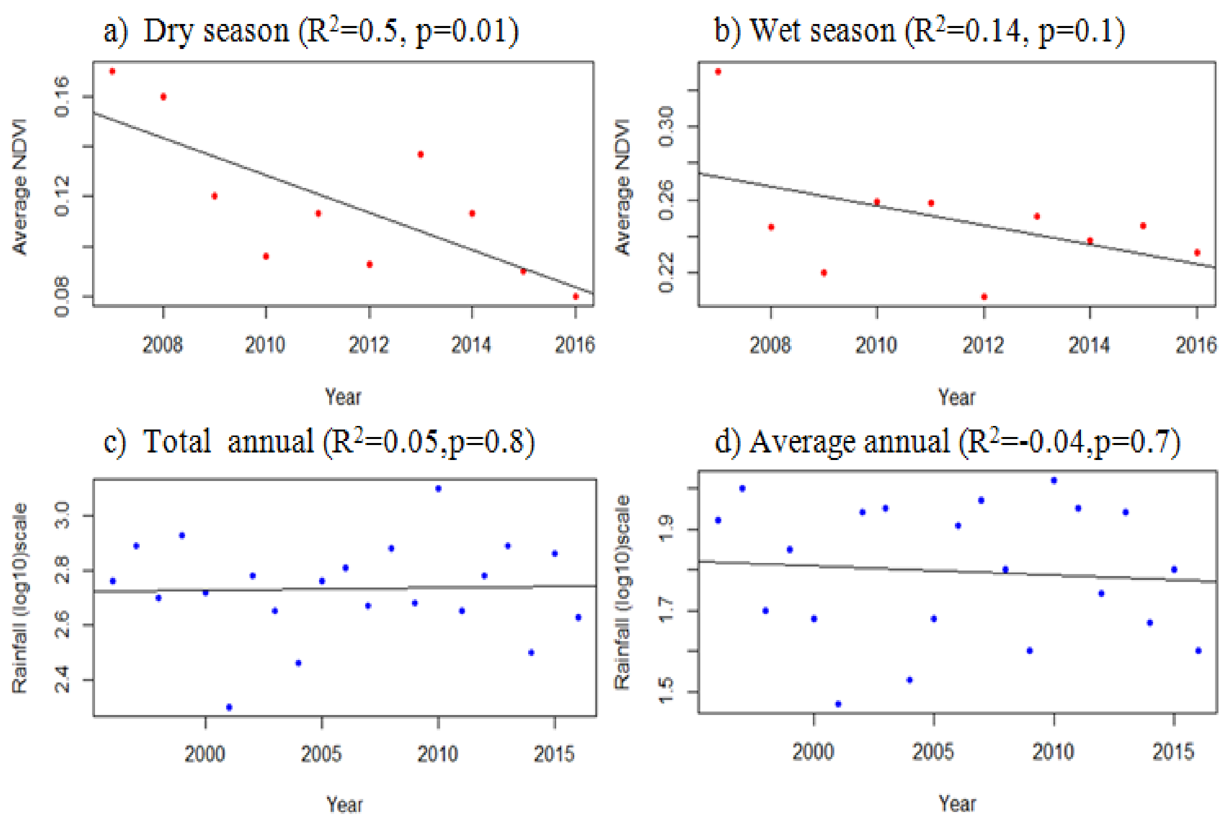


Figure 9. Seasonal mean NDVI between 2007 & 2016 in the dry & wet seasons (a & b)

The relationships between the NDVI rainfall and temperature were analyzed for ten years (from 2007 to 2016) because satellite image data and daily rainfall and temperature data were missing before 2007. Figure 10a-d summarizes the statistical analysis of the seasonal mean NDVI, mean annual rainfall (values scaled in Log10 to fit the NDVI values), and mean temperature between 2007 and 2016. Even if there was a change in seasonal rainfall and temperature, the correlation between the wet and dry season NDVIs and these two climate variables was not significant ($p>0.05$). The variation and slight decreasing trends in the NDVI might have occurred due to several activities of the local communities, such as extensive woodland conversion to cultivation and extinguishing of illegal fires and the dominant nature of the scattered woodland vegetation composition of the park.

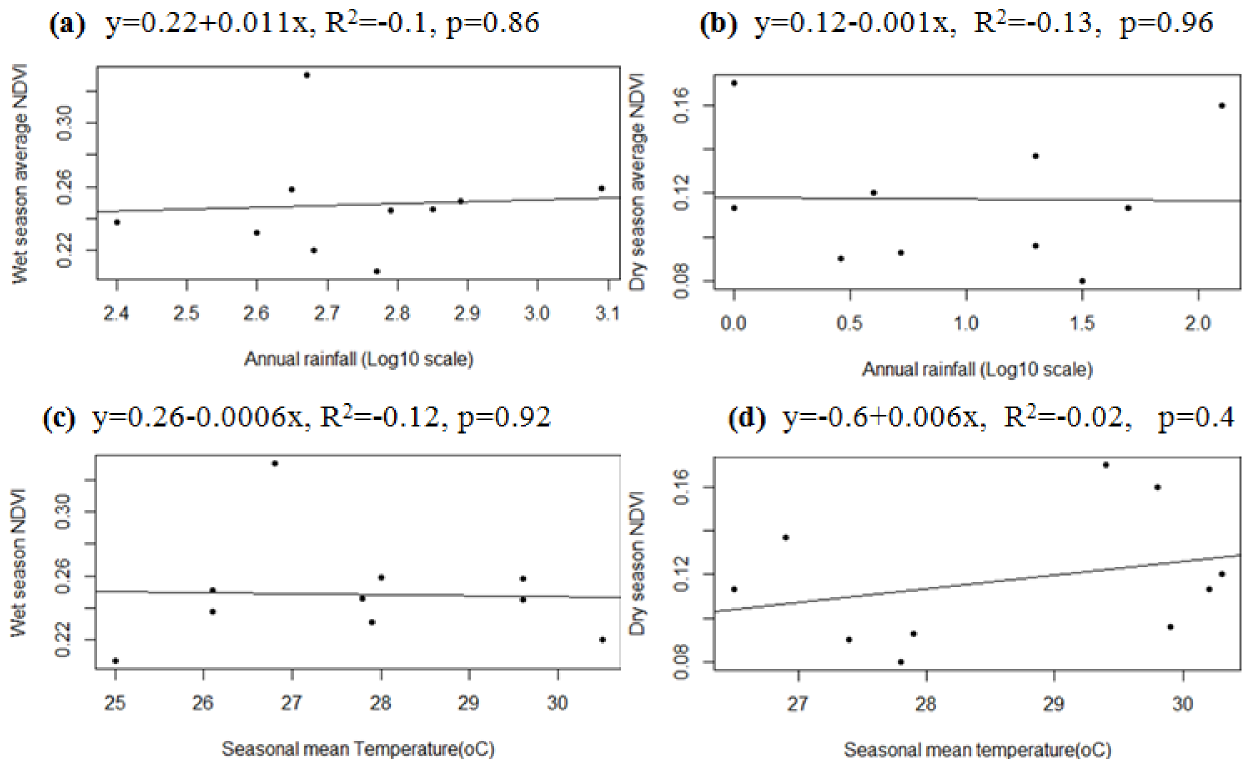


Figure 10. Relationship of average NDVI with rainfall (mm) (a & b) & temperature (^{0}C) (c &d)

4.1.5 General socioeconomic characteristics of the sampled households

The respondents varied in sex ratio, age categories, level of education, and related socioeconomic characteristics.There was a significant difference in the age categories of the respondents (χ^2 =15.4, df =2, p = 0.0004); more than 50.6% (n=200) were between 22 and 41 years old, while 16% (n=63) and 33.4% (n=132) of the interviewees were 42 to 51 years old and older, respectively. Many (59%) of the respondents settled far from the park (i.e., greater than 9 km), whereas 41% (n=162) of the respondents were close (i.e., less than 9 km) to the park border. The educational status of the respondents significantly differed (χ^2 = 49.6, df =2, p < 0.001): 25.8% (n=102) had informal education, 74.2% (293) had formal education (1-8th =65.1% and 9-12th =9.1% grades), and none of the respondents had more than secondary-level education. Most of the respondents (70.6%) had 4-6 household members. Moreover, 22.9% and 6.5% of the 2-3 and 7-8 household members, respectively, had a mean age of 4.5±1.2 years (SD). The farm size of the respondents varied from 1 to 10 hectares, with an average of 3.9 hectares (Table 9).

Table 9. General socioeconomic characteristics of the sampled households (N=395)

Household characteristics	Categories	Calculated values
Gender	Male	74.2%
	Female	25.8%
Age (years)	-	min:22; mean: 44.9+13.75 SD; max:75
Ethnic category	Tigraway	86.0%
	Kunama	14.0%
Family size	2-5;6-8	min: 2; mean: 5; max:8
Education status	Formal (1-12th grade)	74.2%
	Informal	25.8%
Resettlement status (1991-2002)	-	71.7%
Distance from settlement to park	5-10; 11-15; >15km	min: 6. 5; mean: 12.6; max:21
Respondents alternative income	-	12.9%
Energy for cooking	Fuel wood	94.7%
Farmland holding size	1-3ha; 4-7ha; >7ha	min:1; mean: 4.2; max:10 ha
Crop use (consumption & sale)	-	72.4%
Source of livelihood & income	Crop production	1(rank)
Land tenure (land use permits)	Legal	86.0%
	Illegal	14.0%

Note: N=total number of the sampled households interviewed; min=minimum; max=maximum

Approximately three-fourths of the sampled households were engaged in crop production and mixed crop and livestock production. However, a small portion of the respondents were involved only in livestock rearing and other additional activities coupled with farming. Crop production was ranked as the most important source of livelihood/income, followed by mixed crop and livestock farming in the districts (Table 10). The most important types of crops produced in the study area were rain-fed plants: sesame (*Sesamum indicum*), sorghum (*Sorghum bicolor*), finger millet (*Eleusine coracana*), teff (*Eragrostis tef*), and maize (*Zea mays* L.). In addition, the irrigated crops included banana (*Muza species*), mango (*Mangifera indica*), papaya (*Carica papaya*), onion (*Allium cepa*), garlic (*Allium sativum*), potato (*Solanum tuberosum*), and chili pepper (*Capsicum annuum*).

Table 10. The main life existence and economic activities ranked by respondents (N=395[$])

Activities	Number of respondents (n)	%
Crop production (rain fed and irrigated)	197	50.0
Livestock rearing	25	6.3
Mixed crop and livestock	173	43.7
Private and government employee	22	5.5
Self-business	17	4.3
Fuel wood (charcoal and fire wood collection)	5	1.3
Gold mining and aromatic resin collection	7	1.8

[$] The total number of interviewees was 395; however, overcounts are predictable due to multiple responses of households to questions.

4.1.6 Perceptions of communities on the trends and drivers of LULC changes

The participants were well aware that woodlands and riparian forests (i.e., Tekeze riverside vegetation inside the park) significantly declined during the study period ($p<0.001$). More than 89% of the local communities provided evidence for the decline in woodlands and riparian vegetation in the KSNP and adjacent areas. In contrast, more than 57% of the respondents recognized that the distance from the water source to the settlement exhibited constant trends. However, cropland, grazing area, bare land, resettlement, and road access to the park increased during the studied periods ($p<0.001$) (Figure 11).

The respondents identified 13 pronounced factors as key drivers of the observed LULC change in the KSNP. With the increase in legal and illegal settlements, cultivated land, illegal fires following encroachment by cultivation, seasonal grazing, firewood collection, and traditional gold mining were the most significant ($p<0.001$) ranked drivers (Table 13). These drivers predominantly related to woodland and riparian LULC classes' destruction. Likewise, from key informant interviews and focus group discussions (FGDs), similar feedbacks were also exhibited, and they were strengthened; expansions of settlements and agriculture, firewood collection, charcoal production, and land tenure (administration) problems were identified as the main causes of LULC change in the KSNP.

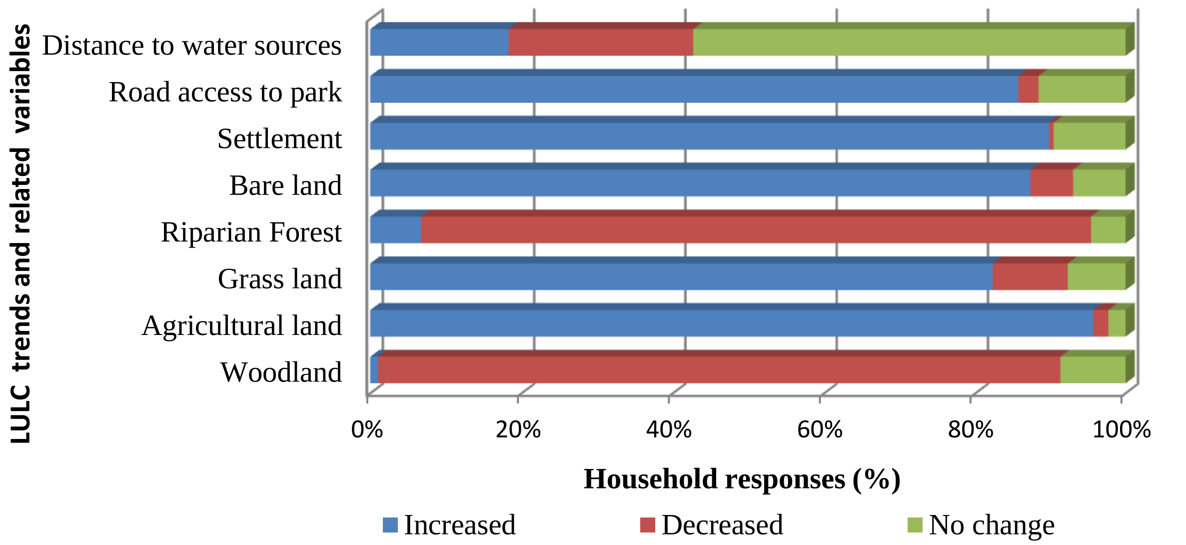


Figure 11. Respondents' awareness toward the trend of LULC and related variables (N=395)

Table 11. Drivers of LULC change recognized by the communities in the KSNP (N=395[$])

Land use/land cover change drivers	Number of households chosen thedrivers*				Total[1] score	Ranking[2] Ratio
	Rank (1)	Rank (2)	Rank (3)	Rank (4)		
Legal and illegal resettlement	156	94	45	15	1011	0.18
Expansion of cultivated land	104	84	61	16	806	0.14
Illegal fire	83	74	50	19	673	0.12
Expansion of grazing land	74	65	61	39	652	0.11
Firewood collection	59	46	63	46	546	0.09
Traditional gold mining	37	47	58	39	444	0.08
Charcoal production	35	56	43	41	435	0.07
Land administration problem	29	51	37	25	368	0.06
Natural resin collection	20	35	28	27	268	0.047
Ethio-Eritrean war (civil war)	14	19	18	16	165	0.030
Drought	11	21	11	16	145	0.025
Eritrean community intervention	7	22	9	13	125	0.022
Permanent and seasonal road	0	6	11	13	53	0.009
Σ weight total	-	-	-	-	**5691**	-

[1]Weight=$R_4C_1+R_3C_2+R_2C_3+R_1C_4$; [2]Index=$R_4C_1+R_3C_2+R_2C_3+R_1C_4/\ \Sigma\ R_4C_1+R_3C_2+R_2C_3+R_1C_4$ (5691)

*The negative importance of drivers decreases from Rank (1) to Rank (4)

[$] The total number of interviewees was 395; however, overcounts are predictable due to multiple responses of households to questions

4.2 Woody vegetation structure and regeneration status (Objective-2)

4.2.1 Species composition and diversity

Seventy woody species belonging to 34 families were identified in the Kafta Sheraro National Park (KSNP) forest (Appendix 1 Table 1). Of these species, 46 (65.7%) were trees, 18 (25.7%) were shrubs, and 6 (8.6%) were trees/shrubs (Table 14). Fabaceae was the most dominant family, occupying 16 species (22.9%), followed by Combretaceae-8 species (11.4%), Tiliaceae and Rhamnaceae, which were equally four species (11.42%), and Capparaceae and Anacardiaceae, which were three species each (8.58%). Burseraceae, Ebenaceae, Asclepiadaceae and Apocynaceae were two species each (11.44% of the total), and the remaining 24 families were represented by a single species each 34.32% of the total species (Table 12). Of the 70 species, 64 were used for the next analysis, and six species were outside the plots utilized for the composition list only (Table 14). The overall average Shannon–Wiener diversity (H') and mean evenness (J) index values of the Kafta Sheraro National Park (KSNP) entire forest of 64 woody species were H`=3.2 and J=0.77, respectively.

4.2.2 Density and frequency distribution of woody species

Density: The total density of Kafta Sheraro National Park (KSNP) woody species was 466 $\pm$ 12.8 stems ha^{-1}. *Acacia mellifera* was the most abundant species, with an abundance of 446 individuals and a density of 69.7 stems ha^{-1}. The densities of *Acacia mellifera*, *Combretum hartmannianum*, *Balanites aegyptiaca*, *Acacia oerfota*, *Boswellia papyrifera* and *Acacia senegal* were above 150 individuals, while *Dicrostachy scinerea* and *Combretum molle* had densities of 100 stems ha^{-1} and above (Table 13). The woody species density was classified into five class intervals: $\leq$ 2, 2.1-10, 10.1-50, 50.1-100, and >100.1 stems ha^{-1}. A total of 48.4% and 3.125% of the species occupied density classes $\leq$ 2 and 50.1-100, respectively (Figure 12).

Frequency: The most common woody species in the study area were *Acacia mellifera* (71.4%), *Combretum hartmannianum* (59%), *Terminalia brownii* (57.8%), *Balanites aegyptiaca* (46.0%), *Acacia senegal* (42.2%), *Acacia oerfota* (35.4%), *Boswellia papyrifera* (29.8%), and *Dicrostachy scinerea* (29.2%). Species such as *Acacia albida*, *Parkinsonia aculeate* and *Otostegia ellenbeckii*, each with a frequency of 0.62%, were rarely observed (Table 13). Kafta Sheraro National Park (KSNP) plant species was divided into six frequency classes' species occurrence among the sample plots. The woody plant species were predominantly concentrated in frequency class 6 (≤ 5%) (Figure 13).

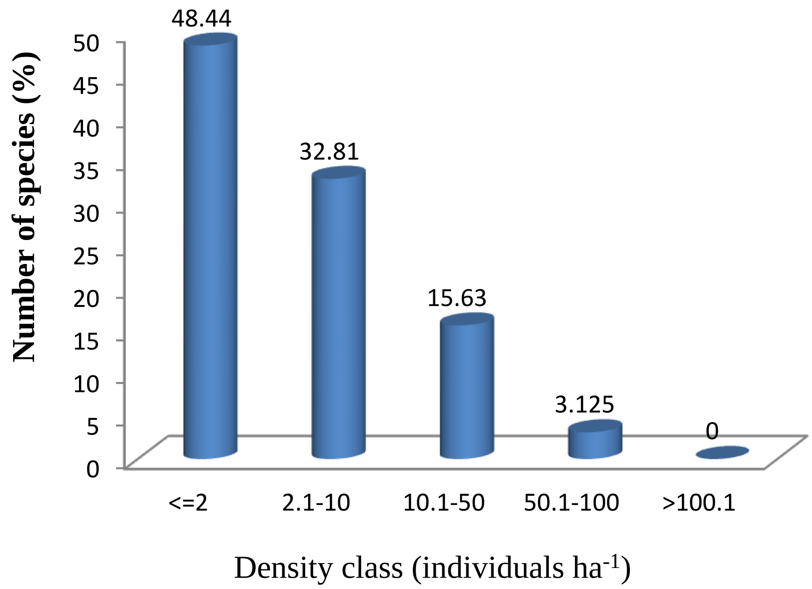


Figure 12. Woody plant species density by size class in KSNP

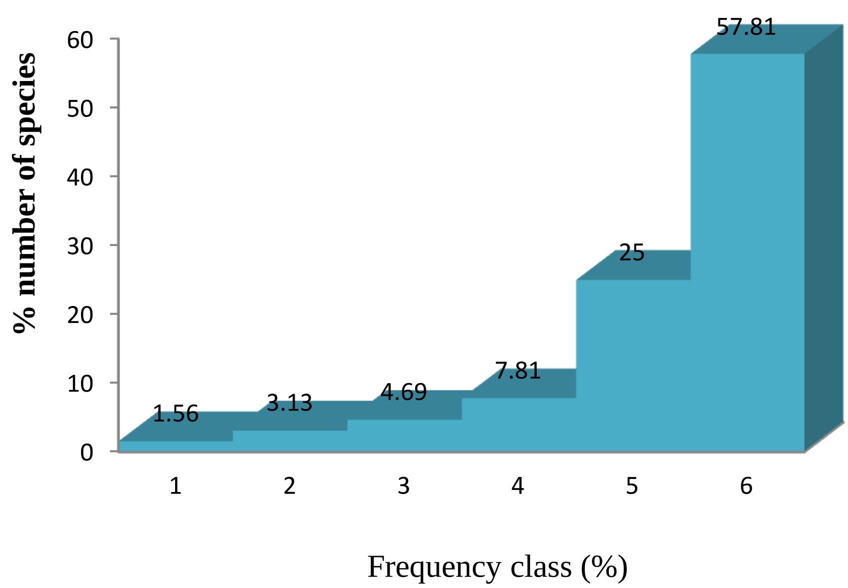


Figure 13. Woody plant species frequency class distribution of KSNP ([1]=65.1-80%, [2]=50.1-65%, [3]=35.1-50%, [4]=20.1-35%, [5]=5.1-20%, and [6]= ≤5%).

4.2.3 Basal area (BA)

The total basal area of woody species in Kafta Sheraro National Park with a diameter at breast height (DBH) ≥ 2.5 cm was 79.3 ± 4.6 m^2ha^{-1}. *Adansonia digitata* had the highest basal area (35.5 m^2ha^{-1}), followed by *Sterculia africana* (7.86 m^2ha^{-1}), *Tamarindus indica* (5.52 m^2ha^{-1}), *Anogeissus leiocarpus* (4.09 m^2ha^{-1}), *Ficus sycomorus* (3.63 m^2ha^{-1}), *Acacia lahai (*3.57 m^2ha^{-1}), *Balanites aegyptiaca* (2.90 m^2ha^{-1}), *Ziziphus spina-christi* (2.87 m^2ha^{-1}), *and Burkea afana* (2.67 m^2ha^{-1}) (Table 12). The BA distribution was highly consetrated between 500 m and 800 m altitude; however, between 800 m and 1200 m the distribution was rare. Genrally, the regression analysis of the relationships of all the mature trees basal areas with altitude revealed non significance between plots ($p=0.67$) (Figure 14).

Table 12. The most dominant families and basal area (BA) of species of KSNP

Family	Number of species	%	Scientific name	Average DBH(cm)	BA (m^2ha^{-1})	Relative BA (%)
Fabaceae	16	22.9	*Adansonia digitata*	134	35.5	44.8
Combretaceae	8	11.4	*Sterculia africana*	61.8	7.86	9.91
Tiliaceae	4	5.71	*Tamarindus indica*	52.0	5.52	6.96
Rhamnaceae	4	5.71	*Anogeissus leiocarpus*	44.9	4.09	5.16
Capparaceae	3	4.29	*Ficus sycomorus*	43.0	3.63	4.58
Anacardiaceae	3	4.29	*Acacia lahai*	42.2	3.57	4.50
Asclepiadaceae	2	2.86	*Balanites aegyptiaca*	37.9	2.90	3.66
Burseraceae	2	2.86	*Ziziphus spinachristi*	37.6	2.87	3.62
Ebenaceae	2	2.86	*Burkea africana*	36.7	2.67	3.37
Apocynaceae	2	2.86	*Terminalia brownii*	36.4	2.06	3.35
Others	24	34.32				

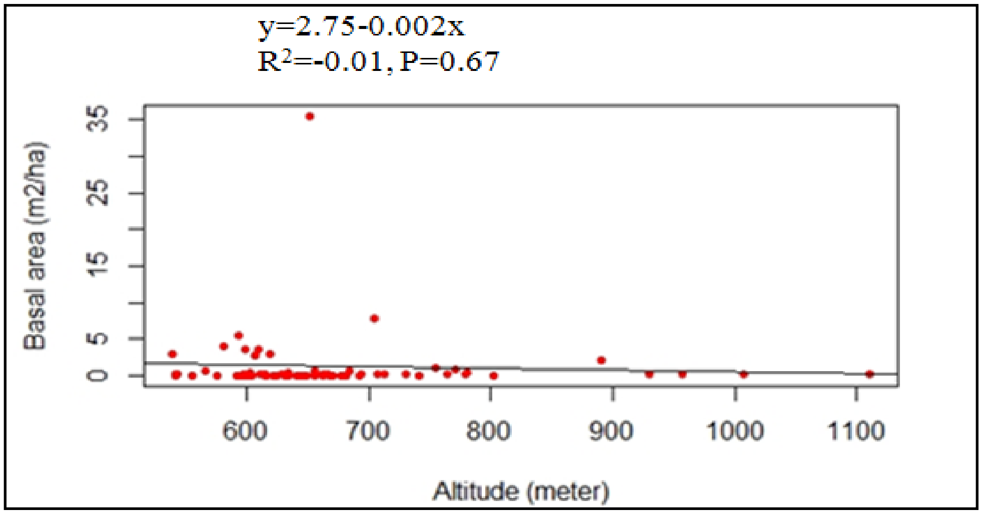


Figure 14. The pattern of basal area (m^2ha^{-1}) along the altitudinal difference (m) in the KSNP

4.2.4 Importance value index (IVI)

The importance value index (IVI) of woody species in Kafta Sheraro National Park (KSNP) ranged from 0.13% to 30.8%. Approximately 18.71% of the importance value indices were contributed by twelve species. The highest importance value index (IVI) was detected for *Adansonia digitata* (30.8%), followed by *Balanites aegyptiaca* (27.6%), *Acacia mellifera* (26.0%), *Terminalia brownii* (25.2%), *Combretum hartmannianum* (22.1%), *Anogeissus leiocarpus* (14.7%), *Tamarindus indica* (14.6%), *Ziziphus spina-christi* and *Sterculia africana* (27.4% each), *Acacia senegal* (11.8%), *Boswellia papyrifera* (11.7%), and *Acacia oerfota* (11.1%), which had importance value index (IVI) values above ten and were the most important species in the forest (Table 13). The tree species in the forest were grouped into five classes based on their importance value index (IVI): [1] = >15.1%, [2] =10.1-15%, [3] =5.1-10%, [4] =1.1-5% and [5] = ≤1%). A total of 46.9% of the species were in the importance value index (IVI) class (≤1%), while the lowest importance value index (IVI) was in the class >15.1% (Figure 15).

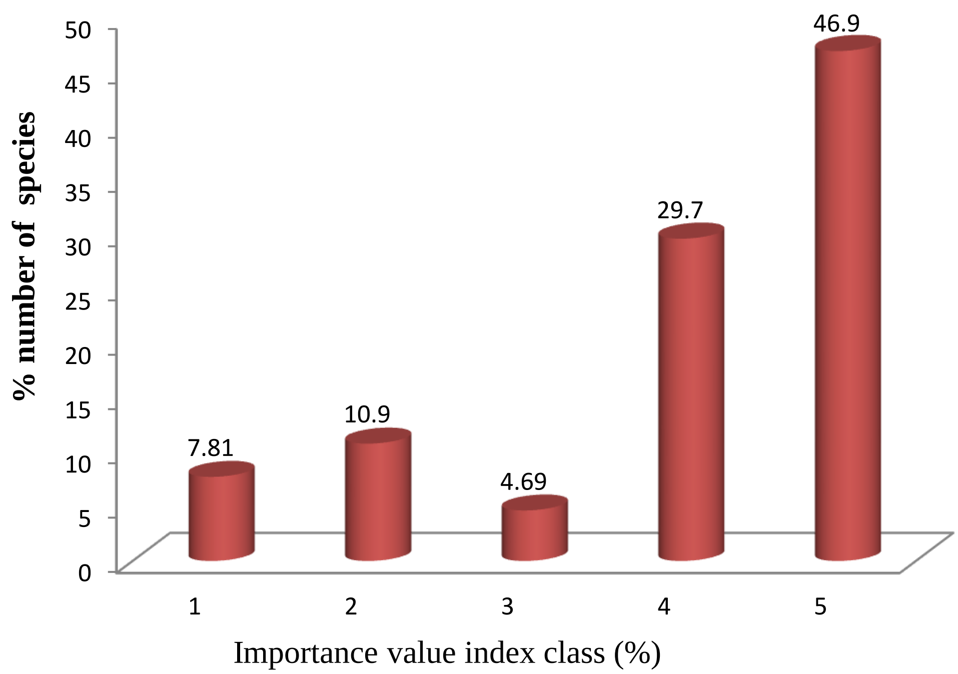


Figure 15. Importance value index class of trees and shrubs species in KSNP [1] = >15.1%, [2] =10.1-15.0%, [3] =5.1-10.0%, [4] =1.1-5.0% and [5] = ≤1.0%)

Table 13. Structural elements of woody plant species in Kafta Sheraro National Park

Species	AD	AB	D	RD	F	RF	BA	DO	RDO	IVI
Acacia senegal	4.6	159	24.8	5.33	42.2	6.26	0.05	0.301	0.222	11.8
Combretum hartmannianum	9.4	342	53.4	11.5	59.0	8.74	0.19	2.584	1.911	22.1
Dalbergia melanoxylon	8.4	46	7.19	1.54	17.4	2.58	0.14	0.262	0.194	4.31
Balanites aegyptiaca	38	188	29.4	6.3	46.0	6.81	2.90	19.59	14.49	27.6
Acacia oerfota	4.1	169	26.4	5.67	35.4	5.24	0.03	0.222	0.164	11.1
Dicrostachy scinerea	3.9	143	22.3	4.79	29.2	4.32	0.03	0.170	0.126	9.24
Grewia bicolor	2.5	31	4.84	1.04	9.94	1.47	0.01	0.016	0.012	2.52
Anogeissus leiocarpus	45	71	11.1	2.38	24.8	3.68	4.09	11.62	8.591	14.7
Sterculia africana	62	42	6.56	1.41	14.9	2.21	7.86	13.20	9.763	13.4
Acacia seyal	5.5	34	5.31	1.14	9.94	1.47	0.06	0.080	0.059	2.67
Maytenus senegallensis	5.6	6	0.94	0.2	2.48	0.37	0.06	0.015	0.011	0.58
Acacia mellifera	4.2	446	69.7	15	71.4	10.6	0.03	0.623	0.460	26.0
Adansonia digitata	134	27	4.22	0.91	10.6	1.56	35.5	38.31	28.33	30.8
Acacia albida	17	2	0.31	0.07	0.62	0.09	0.56	0.045	0.033	0.19
Jasminum abyssinicum	5.2	8	1.25	0.27	2.48	0.37	0.05	0.017	0.012	0.65
Ziziphus spina-christi	38	87	13.6	2.92	23.0	3.40	2.87	9.989	7.387	13.7
Tamarindus indica	52	59	9.22	1.98	19.9	2.94	5.52	13.03	9.634	14.6
Casuarina equisetifolia	5.2	69	10.8	2.31	15.5	2.30	0.05	0.149	0.110	4.72
Capparis decidua	4.6	4	0.63	0.13	1.24	0.18	0.04	0.007	0.005	0.32
Grewia villosa	3.6	11	1.72	0.37	4.97	0.74	0.02	0.011	0.008	1.11
Salvadora persica	2.8	5	0.78	0.17	1.86	0.28	0.01	0.003	0.002	0.45
Ziziphus mauritiana	9.8	4	0.63	0.13	1.24	0.18	0.19	0.03	0.022	0.34
Feretia apodanthera	7.5	3	0.47	0.10	2.48	0.37	0.11	0.013	0.01	0.48
Hyphaene thebaica	17	96	15	3.22	21.1	3.13	0.61	2.352	1.74	8.09
Calotropis procera	6.9	14	2.19	0.47	5.59	0.83	0.11	0.064	0.047	1.34
Boswellia papyrifera	11	178	27.8	5.97	29.8	4.42	0.25	1.794	1.327	11.7
Terminalia brownii	36.4	205	32	6.87	57.8	8.56	2.06	13.28	9.82	25.2
Grewia flavescens	5.5	13	2.03	0.44	6.21	0.92	0.06	0.033	0.025	1.38
Moringa stenopetala	5.8	4	0.63	0.13	1.24	0.18	0.11	0.018	0.013	0.33
Acacia lahai	42	6	0.94	0.20	2.48	0.37	3.57	0.857	0.634	1.2
Diospyros mespiliformis	13	30	4.69	1.01	9.32	1.38	0.35	0.42	0.311	2.7
Burkea africana	37	21	3.28	0.70	7.45	1.1	2.67	2.243	1.659	3.47
Ficus sycomorus	43	2	0.31	0.07	1.24	0.18	3.63	0.291	0.215	0.47
Combretum glutinosum	8	27	4.22	0.91	5.59	0.83	0.13	0.136	0.1	1.83
Combretum molle	6	117	18.3	3.92	11.2	1.66	0.07	0.335	0.247	5.83
Nerium oleander	2.5	3	0.47	0.10	1.24	0.18	0.01	0.002	0.001	0.29
Cadaba farinosa	5.4	6	0.94	0.20	1.24	0.18	0.06	0.014	0.01	0.4
Leptadenia lanceolata	4.6	3	0.47	0.1	1.86	0.28	0.03	0.004	0.003	0.38
Terminalia laxiflora	8.7	10	1.56	0.34	1.24	0.18	1.05	0.419	0.31	0.83
Solanum incanum	2.6	7	1.09	0.23	1.86	0.28	0.01	0.004	0.003	0.51
Grewia mollis	4.8	4	0.63	0.13	1.86	0.28	0.04	0.007	0.005	0.42
Lannea microcarpa	11	23	3.59	0.77	8.7	1.29	0.25	0.232	0.172	2.23
Commiphora boranensis	7.2	32	5	1.07	4.35	0.64	0.72	0.922	0.682	2.4
Stereospermum kunthianum	6.9	21	3.28	0.7	6.21	0.92	0.1	0.08	0.059	1.68
Pittosporum viridiflorum	9	17	2.66	0.57	3.73	0.55	0.42	0.047	0.034	1.16
Boscia angustifolia	6.4	7	1.09	0.23	1.86	0.28	0.08	0.022	0.016	0.53
Acacia sp.	11	11	1.72	0.37	2.48	0.37	0.25	0.109	0.08	0.82
Ziziphus mucronata	2.9	17	2.66	0.57	6.21	0.92	0.02	0.011	0.008	1.5
Acacia polyacantha	5.9	46	7.19	1.54	4.35	0.64	0.07	0.126	0.093	2.28
Acacia etbaica	11	5	0.78	0.17	1.24	0.18	0.22	0.045	0.033	0.38
Acacia tortilis	12	8	1.25	0.27	1.86	0.28	0.27	0.088	0.065	0.61
Parkinsonia aculeata	8.4	1	0.16	0.03	0.62	0.09	0.14	0.006	0.004	0.13
Ricinus communis	4.1	4	0.63	0.13	0.62	0.09	0.03	0.005	0.004	0.23

Table 13. Continued

Species	AD	AB	D	RD	F	RF	BA	DO	RDO	IVI
Melia azedarach	4.6	3	0.47	0.1	1.24	0.18	0.04	0.005	0.004	0.29
Carissa edulis	5.4	11	1.72	0.37	1.86	0.28	0.07	0.033	0.024	0.67
Combretum sp.	8.9	27	4.22	0.91	2.48	0.37	0.16	0.174	0.129	1.4
Sclerocarya birrea	19	15	2.34	0.5	3.11	0.46	0.7	0.419	0.31	1.27
Terminalia sp.	7.6	7	1.09	0.23	1.24	0.18	0.11	0.032	0.024	0.44
Diospyros abyssinica	8	14	2.19	0.47	2.48	0.37	0.30	0.226	0.167	1
Brucea antidysentrica	15	3	0.47	0.1	1.24	0.18	0.12	0.053	0.039	0.32
Plumbago zeylanica	2.5	5	0.78	0.17	1.86	0.28	0.01	0.002	0.002	0.45
Otostegia ellenbeckii	2.5	2	0.31	0.07	0.62	0.09	0.004	0.008	0.006	0.16
Senna sinqueana	2.5	1	0.16	0.03	0.62	0.09	0.002	0.007	0.005	0.13
Buddleja polystachya	2.6	2	0.31	0.07	1.24	0.18	0.003	0.011	0.008	0.26
Total	-	2984	466± 12.8	100	-	100	79.3± 4.6	-	100	300

Note: (AD=average diameter (cm), AB=abundance (individual stems), D=density (stems ha^{-1}), RD= relative density (%), F=frequency (%), RF=relative frequency (%), BA=basal area (m^2ha^{-1}), DO=dominance, RDO=relative dominance (%), IVI=importance value index (%))

4.2.5 Population structure of trees/shrubs species

Diameter and height class distributions of trees and shrubs species: The general diameter at breast height (DBH) and height class distribution of woody species density in the park exhibited an inverted J-shaped structure. The trees and shrubs were divided into nine diameter at breast height (DBH) classes: 2.5-10 cm, 10.1-20 cm, 20.1-30 cm, 30.1-40 cm, 40.1-50 cm, 50.1-60 cm, 60.1-70 cm, 70.1-80 cm and >80.1 cm. The majority of individuals were distributed in the first DBH class, at 2.5-10 cm (Figure 16). Twenty individuals of *Anogeissus leiocarpus*, *Sterculia africana*, and *Adansonia digitata* had a diameter at breast height (DBH) of 70 cm or greater. In the KSNP, the greatest diameter at breast height was recorded for fourteen individuals of *Adansonia digitata* (110-146 cm).

The tree height distribution was classified into seven classes: (≤ 4 m; 4.1-9 m; 9.1-14 m; 14.1-19 m; 19.1-24 m; 24.1-29 m; and >29.1 m). There was a greater number of tree and shrub individuals in the height class ≤ 4 m, which accounted for approximately 1711 stems (264 individuals ha^{-1}) (33.7%) of the total height classes. There were a greater number of trees/shrubs in the height class younger than 14 m, which accounted for 81% of the total population height classes. *Anogeissus leiocarpus*, *Adansonia digitata*, *Tamarindus indica*, *Sterculia africana*, *Diospyros mespiliformis*, and *Balanites aegyptiaca* had 39 individuals taller than 15 m in height. The highest height was recorded for the species *Anogeissus leiocarpus* (30 m) (Figure 16).

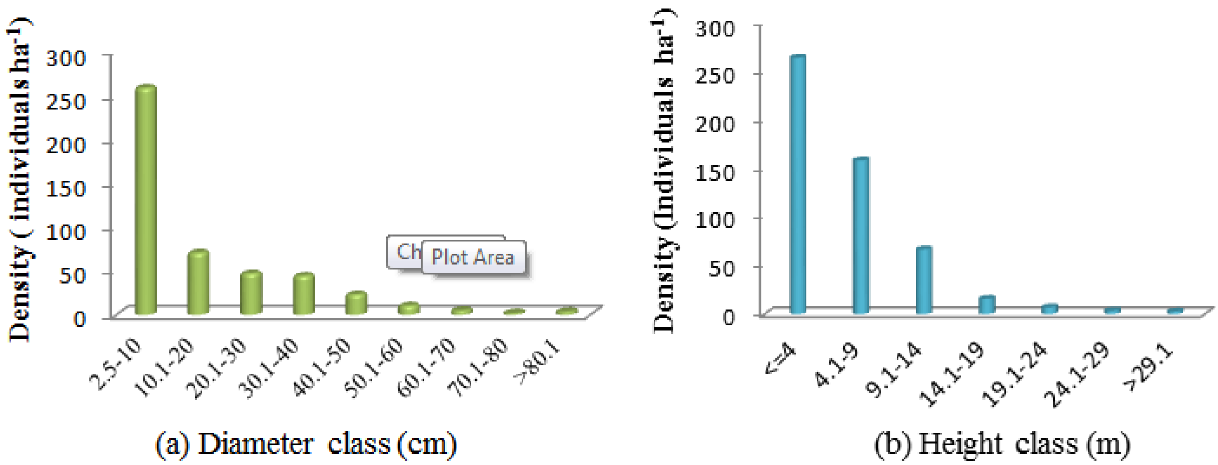


Figure 16. Diameter (a) and height (b) class distributions of woody species

Population structure of selected tree species: The population structure of KSNP individual tree species revealed eight predominant patterns of population based on nine diameters class.

(1) Individual species were concentrated only in the first diameter class (2.5-10 cm) but were absent in the remaining classes and represented by *Acacia mellifera* (Figure 17(a)). Additional species in this group included *Acacia senegal, Dalbergia melanoxylon*, *Acacia oerfota*, *Acacia seyal*, and *Dicrostachy scinerea*.

(2) The species concentrated within the first (2.5-10 cm) &second (10.1-20 cm) diameter classes. *Combretum hartmannianum* & *Boswellia papyrifera* were in this category (Figure17(b)).

(3) An inverted J-shape in which the highest number of individuals was present in the lower diameter classes, and the *only species was Anogeissus leiocarpus* (Figure17(c)).

(4) J-shaped, in which a higher proportion of individuals were present at a higher diameter classes and the trend decreased toward the lower diameter classes. Species of this pattern was *Ziziphus spina-christi* and *Tamarindus indica* (Figure 17(d)).

(5) Bell-shaped, in which a higher proportion of species were present in an intermediate diameter and the trend decreased in the lower and higher diameter classes. Species in this category were *Balanites aegyptiaca* and *Terminalia brownii* (Figure 17(e)).

(6) This pattern occurred only in the second diameter class (10.1-20 cm) and the only representative species was *Diospyros mespiliformis* (Figure 17(f)).

(7) Irregular distribution over diameter classes. Some diameter classes had a small number of individuals, while other diameter classes had a large number of individuals and even some were missed. The known species is *Sterculia africana* (Figure 17(g)).

(8) The diameter occurred only in the large class. *Adansonia digitata* was the representative species that occurred in the ninth (>80.1 cm) diameter class (Figure 17(h)).

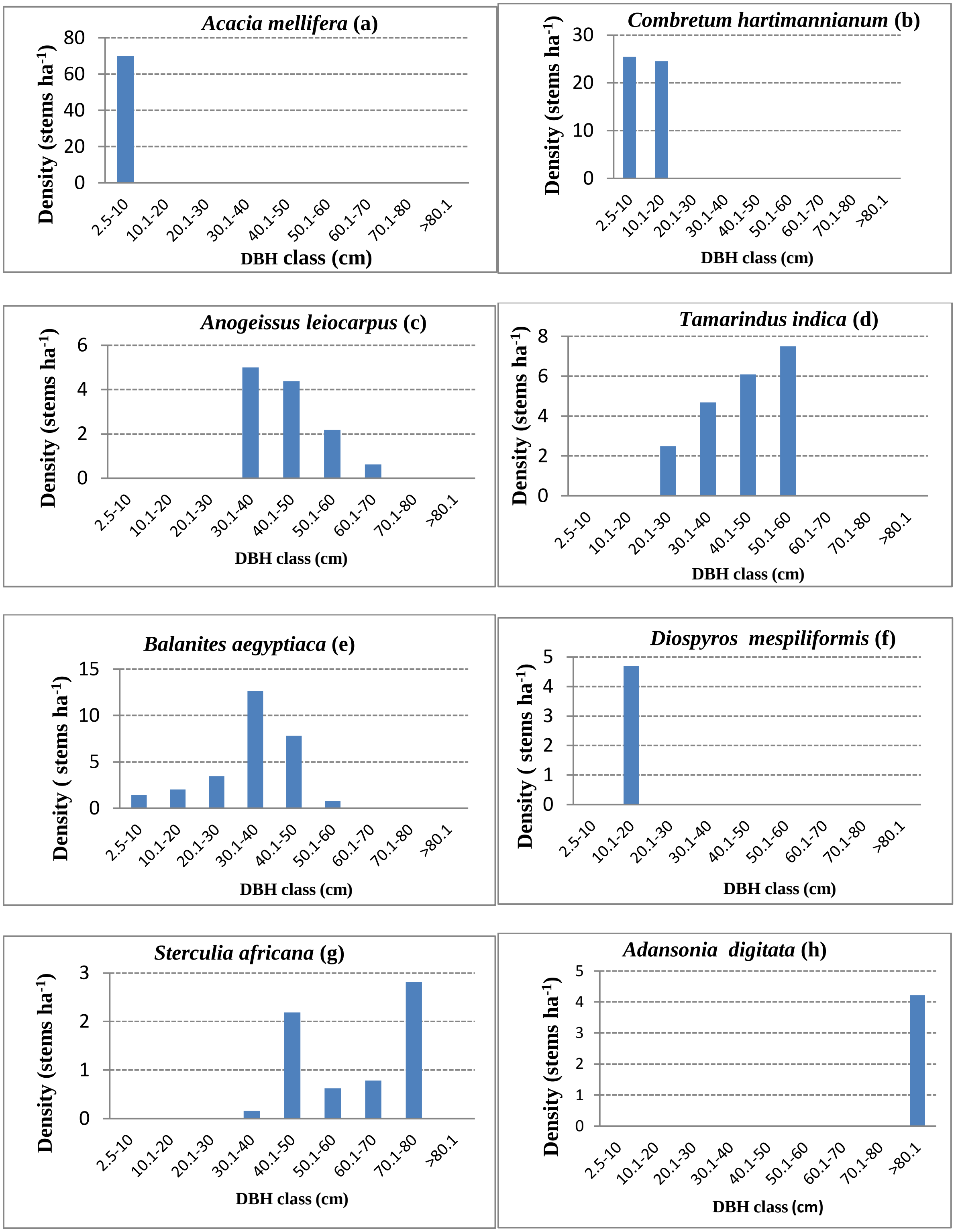


Figure 17. Representative population structural patterns of each tree species

4.2.6 Regeneration status of woody species

A total of 378 individuals, of which 68 stem (2.023%) seedlings and 310 stems (9.22%) saplings belonged to 64 woody species, were counted from all plots. Twelve woody species had both seedlings and saplings, five species had only saplings, and 47 species lacked both stages. The woody species with seedlings were *Acacia senegal*, *Combretum hartmannianum*, *Balanites aegyptiaca*, *Acacia oerfota*, *Dicrostachy scinerea*, *Acacia mellifera*, *Ziziphus spina-christi*, *Casuarina equisetifolia*, *Hyphaene thebaica*, *Boswellia papyrifera*, *Terminalia brownii* and *Acacia polyacantha*. The tree/shrub species with saplings were *Acacia senegal*, *Combretum hartmannianum*, *Dalbergia melanoxylon*, *Balanites aegyptiaca*, *Acacia oerfota*, *Dicrostachy scinerea*, *Acacia seyal*, *Acacia mellifera*, *Ziziphus spina-christi*, *Casuarina equisetifolia*, *Grewia villosa*, *Hyphaene thebaica*, *Boswellia papyrifera*, *Terminalia brownii*, *Combretum molle*, *Acacia polyacantha* and *Plumbago zeylanica*. A relatively high sapling density was exhibited by *Hyphaene thebaica* (16.1%), followed by *Balanites aegyptiaca* (15.8%), *Dicrostachy scinerea* (13.17%), *Casuarina equisetifolia* (8.64%), and *Acacia senegal* (7.82%) (Table 14).

The regeneration of the forest was examined by comparing the mature tree density with that of regenerating populations (seedlings and saplings) of the species. The total densities of the seedlings and saplings were 10.7 ± 0.4 and 48.6 ± 1.57 individuals ha^{-1}, respectively, which were lower than the density of the mature trees (466 ± 12.8) (Figure 18(a); Table 14). The KSNP trees/ shrubs exhibited different regeneration patterns, including ‘‘fair’’ regeneration (18.75%), ‘‘poor’’ regeneration (7.8%) and ‘‘none’’ regeneration (73.45%). However, the “good” and “new” regenerating statuses of the tree species were completely absent (Figure 18(b)). Twelve species, namely, *Acacia mellifera*, *Acacia oerfota*, *Acacia polyacantha*, *Balanites aegyptiaca*, *Acacia senegal*, *Boswellia papyrifera*, *Casuarina equisetifolia*, *Combretum hartmannianum*, *Dicrostachys cinerea*, *Hyphaene thebaica*, *Terminalia brownii*, and *Ziziphus spina-christi*, exhibited “fair” regeneration. *Dalbergia melanoxylon*, *Acacia seyal*, *Grewia villosa*, *Combretum molle*, and *Plumbago zeylanica* were found to be poor regenerating woody species (Table 14).

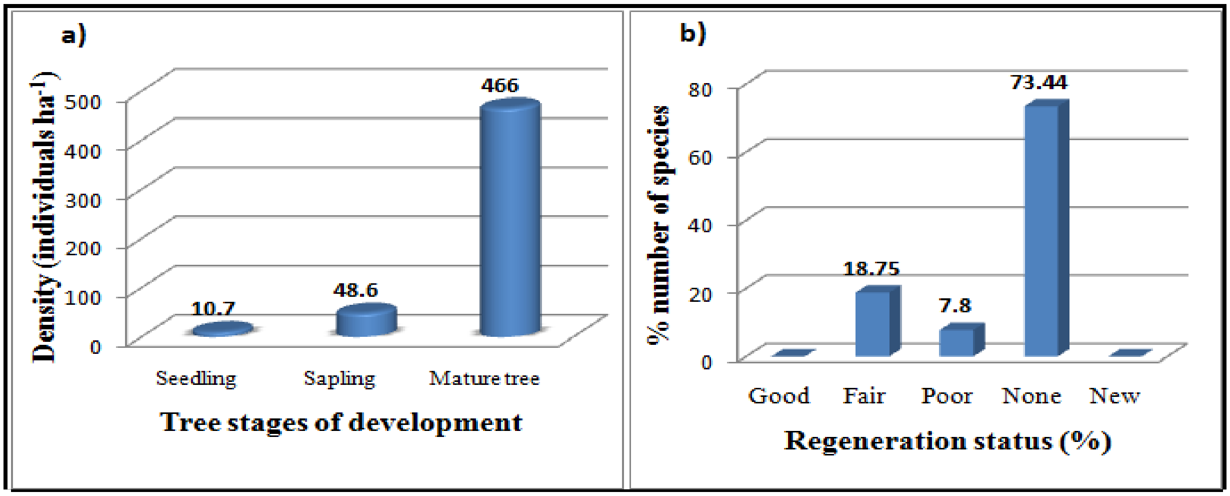


Figure 18. Density of seedling, sapling, and mature tree species (**a**) and regeneration status (**b**) of woody plants in the KSNP forest

The density of the seedlings and saplings correlation with the environmental factors was significant. Altitude was one of the basic environmental factors affecting plant regeneration in the KSNP (Table 18). As a result, the variations in sapling and seedling density across altitudes were statistically significant throughout the plots in the vegetation strata. Regression analysis revealed that the density of the seedling species significantly increased with increasing altitude (P=0.00026) (Figure 19(a)). Similarly, the density of saplings of all the species increased as the altitude increased (P<0.001) (Figure 19 (b)).

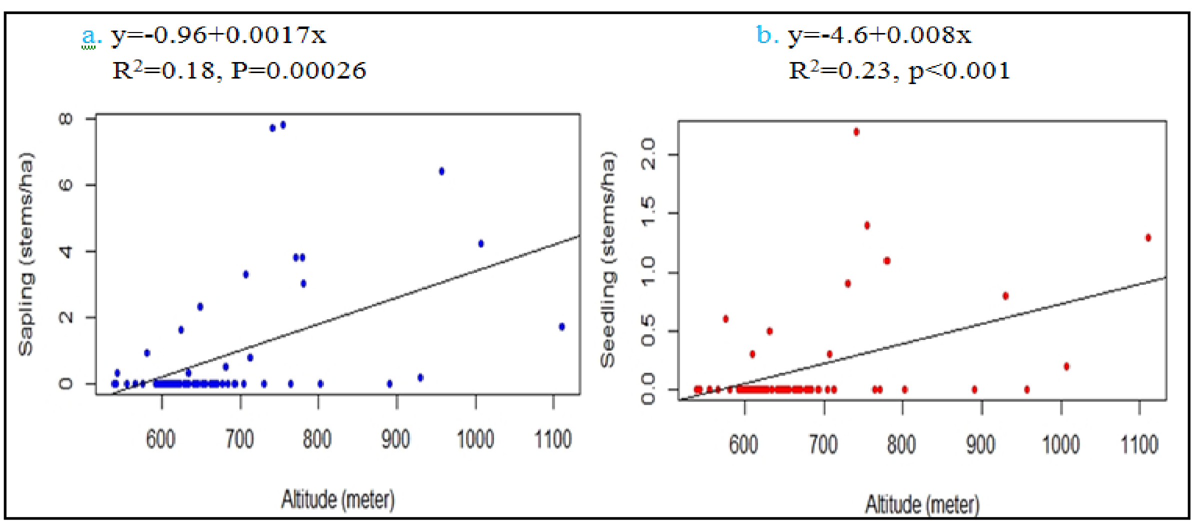


Figure 19. The relationship between sapling (a) & seedling (b) density (stems ha^{-1}) per plot versus altitude (m)

Table 14. Natural regeneration status of woody species in Kafta Sheraro National Park

S.No	Scientific name (Species)	Family	Hab.	SD	SPD	MD	RS
1	*Acacia albida* Del.	Fabaceae	T	0	0	0.31	None
2	*Acacia etbaica* Schweinf	Fabaceae	T	0	0	0.78	None
3	*Acacia lahai* Steud. & Hochst.ex Benth.	Fabaceae	T	0	0	0.94	None
4	*Acacia mellifera* (Vahl) Benth.	Fabaceae	T	2.2	3.8	69.7	Fair
5	*Acacia oerforta* (Forssk.) Schweinf.	Fabaceae	S	0.9	3	26.4	Fair
6	*Acacia polyacantha* Willd.	Fabaceae	T	0.8	1.6	7.19	Fair
7	*Acacia senegal* (L.) Willd.	Fabaceae	T	0.5	3.8	24.8	Fair
8	*Acacia seyal* Del.	Fabaceae	T	0	0.9	5.31	Poor
9	*Acacia sp.*Mart	Fabaceae	T	0	0	1.72	None
10	*Acacia tortilis* (Forssk.) Hayne.	Fabaceae	T	0	0	1.25	None
11	*Adansonia digitata* (L.)	Bombacaceae	T	0	0	4.22	None
12	*Anogeissus leiocarpus* (DC.) Guill. & Perr.	Combretaceae	T	0	0	11.1	None
13	*Balanites aegyptiaca* (L.) Del.	Balanitaceae	T	1.1	7.7	29.4	Fair
14	*Boscia angustifolia* var. *angustifolia* A. Rich.	Capparaceae	T/S	0	0	1.09	None
15	*Boswellia papyrifera* Hochst. ex A.	Burseraceae	T	0.6	1.7	27.8	Fair
16	*Brucea antidysentrica* J.F.	Simaroubacea	T	0	0	0.47	None
17	*Buddleja polystachya* Fresen.	Loganiaceae	S	0	0	0.31	None
18	*Burkea africana* Hook.	Caesalpiniaceae	T	0	0	3.28	None
19	*Cadaba farinosa* Forssk.	Capparaceae	S	0	0	0.94	None
20	*Calotropis procera* (Aiton) W.T.Aiton.	Asclepiadaceae	T	0	0	2.19	None
21	*Capparis decidua* (Forssk.) Edgew.	Capparaceae	T	0	0	0.63	None
22	*Carissa edulis* (Forssk.) Vahl.	Apocynaceae	S	0	0	1.72	None
23	*Casuarina equisetifolia* (L.)	Casuarinaceae	T	1.1	4.2	10.8	Fair
24	*Combretum glutinosum* Perr. ex DC.	Combretaceae	S	0	0	4.22	None
25	*Combretum hartmannianum* Schweinf.	Combretaceae	T	0.3	3.3	53.4	Fair
26	*Combretum molle* R. Br. ex G. Don.	Combretaceae	T	0	0.8	18.3	Poor
27	*Combretum* sp. Loefl.	Combretaceae	T	0	0	4.22	None
28	*Commiphora boranensis* K. Vollese	Burseraceae	T	0	0	5.00	None
29	*Dalbergia melanoxylon* Guill. & Perr.	Fabaceae	T	0	0.3	7.19	None
30	*Dicrostachys cinerea* (L.)Wight and Arn.	Fabaceae	T	0.3	6.4	22.3	Fair
31	*Diospyros abyssinica* (Hiern) F. White	Ebenaceae	T	0	0	2.19	None
32	*Diospyros mespiliformis* Hochst. ex A. DC.	Ebenaceae	T	0	0	4.69	None
33	*Feretia apodanthera* Delile.	Rubiaceae	S	0	0	0.47	None
34	*Ficus sycomorus* (L.)	Moraceae	T	0	0-	0.31	None
35	*Grewia bicolor* Juss.	Tiliaceae	T/S	0	0	4.84	None
36	*Grewia flavescens* Juss.	Tiliaceae	T/S	0	0	2.03	None
37	*Grewia mollis* Juss.	Tiliaceae	T	0	0	0.63	None
38	*Grewia villosa* Willd.	Tiliaceae	S	0	0.5	1.72	Poor
39	*Hyphaene thebaica* (L.) Mart.	Arecaceae	T	1.4	7.8	15.0	Fair
40	*Jasminum abyssinicum* Hochst. ex DC.	Oleaceae	S	0	0	1.25	None
41	*Lannea microcarpa* Engl. & K. Krause.	Anacardiaceae	T	0	0	3.59	None
42	*Leptadenia lanceolata* (Poir.) Goyder.	Asclepiadaceae	S	0	0	0.47	None
43	*Maytenus senegallensis* Forssk.	Celastraceae	T	0	0	0.94	None
44	*Melia azedarach* (L.)	Meliaceae	T	0	0	0.47	None
45	*Moringa stenopetala* (Baker f.) Cufod.	Moringaceae	T	0	0	0.63	None
46	*Nerium oleander* (L.)	Apocynaceae	S	0	0	0.47	None

Table 14. Continued

S.No	Scientific name (Species)	Family	Hab.	SD	SPD	MD	RS
47	*Otostegia ellenbeckii* Gurke.	Lamiaceae	S	0	0	0.31	None
48	*Parkinsonia aculeata* (L.)	Fabaceae	T	0	0	0.16	None
49	*Pittosporum viridiflorum* Sims.	Pittosporaceae	T	0	0	2.66	None
50	*Plumbago zeylanica* (L.)	Plumbaginace	S	0	0.2	0.78	Poor
51	*Ricinus communis* (L.)	Euphorbiaceae	S	0	0	0.63	None
52	*Salvadora persica* (L.)	Salvadoraceae	S	0	0	0.78	None
53	*Sclerocarya birrea* (A. Rich.) Hochst.	Anacardiaceae	T	0	0	2.34	None
54	*Senna sinqueana* (Delile) Lock.	Fabaceae	S	0	0	0.16	None
55	*Solanum incanum* (L.)	Solanaceae	S	0	0	1.09	None
56	*Sterculia africana* Del.	Sterculiaceae	T	0	0	6.56	None
57	*Stereospermum kunthianum* Cham.	Bignoniaceae	T/S	0	0	3.28	None
58	*Tamarindus indica* (L.)	Fabaceae	T	0	0	9.22	None
59	*Terminalia brownii* Fresen.	Combretaceae	T	0.2	0.3	32.0	Fair
60	*Terminalia laxiflora* Engl. & Diels.	Combretaceae	T	0	0	1.56	None
61	*Terminalia* sp.L.	Combretaceae	T	0	0	1.09	None
62	*Ziziphus mucronata* Willd.	Rhamnaceae	T/S	0	0	2.66	None
63	*Ziziphus spina-christi* (L.) Desf.	Rhamnaceae	T	1.3	2.3	13.6	Fair
64	*Ziziphus mauritiana* Willd.	Rhamnaceae	T/S	0	0	0.63	None
	(Mean±S.E)	-	-	10.7 ±0.4	48.6 ±1.7	466 ±12.8	-

Note: (MD =Mature density (stem ha^{-1}), SD=seedling density (stem ha^{-1}), and SPD= sapling density (stem ha^{-1}); regeneration status (RS) (G=good, F=fair, and P=poor and N=none/not regenerating); 0=absence of individuals in the seedling and/or sapling stages.
* Plant species recorded outside the plot area; Hab. =Habit, T=tree; S=shrub; T/S=tree/shrub

4.2.7 Altitude and human disturbance versus regeneration

In the present analysis, human disturbances (i.e., human-induced fires, gold mining, and grazing by livestock) at the plot level and altitudinal factors were compared with the densities of seedlings, saplings, and mature trees using the Pearson correlation coefficient (r). The correlation results generally showed both negative and positive relationships (Table 15). Altitude had a significantly weak negative relationship (r=-0.035 and -0.335, p=0.022) with the density of seedlings and mature trees and a positive relationship (r=0.016) with the density of saplings. Similarly, grazing had a significant negative correlation (r=-0.021 and -0.342, p= 0.0139) with the density of seedlings and mature trees but a positive relation with the density of saplings. Fire (p=0.014) also exhibited a negative relationship with the density of seedlings, saplings, and mature trees. However, gold mining showed a disturbance sign in the plots; it had no clear significant correlation (p=0.77) with the density of seedlings, saplings, and mature trees. Consequently, the cumulative human disturbance variables (grazing, fire, and gold mining) were highly significantly ($p<0.001$) related to regenerating population density (seedlings and saplings). Mature tree density was weakly negatively related ($r=-0.017$) to the density of the seedlings and weakly positively correlated ($r=0.008$) with the number of saplings (Table 15). This indicates that the competition of mature plants for resources influences the population density of seedlings and saplings.

Table 15. Pearson correlation coefficient (γ) between the densities of seedlings, saplings, and mature trees (stem ha^{-1}) and human disturbances and altitude

Attributes	AL	GR	F	GM	SD	SPD	MD
Altitude (p=0.022)*	1.000						
Grazing (p=0.0139)*	0.182	1.000					
Fire (p=0.014)*	0.330	0.351	1.000				
Gold mining (p=0.77)^{ns}	0.498	0.422	0.724	1.000			
#Seedling density	-0.035	-0.021	-0.081	-0.115	1.000		
#Sapling density	0.016	0.003	-0.025	-0.045	-0.042	1.000	
#Mature tree density	-0.335	-0.342	-0.407	-0.382	-0.017	0.008	1.000

*p<0.05, ns= nonsignificant, SD= seedling density, SPD= sapling density, MD= mature density, AL= altitude GR=grazing F= fire and GM= gold mining

4.3 Elephants' dietary niche and feeding habits (Objective-3)

4.3.1 Plant species composition

Crop plant species: of the total cultivated plants from field observations and interviews in and around the KSNP, the African bush elephant feed on 12 species of both seasonal/rain-fed and irrigated crops. The five species were herbs (*Musa species*, *Abelmoschus esculentus*, *Solanum lycopersicum*, *Cucurbita pepo*, and *Solanum tuberosum*); five species of grass families (*Sorghum bicolor*, *Pennisetum typhoideum*, *Eragrostis tef*, *Zea mays*, and *Eleusine coracana*); and two species were trees (*Carica papaya* and *Mangifera indica*) that belong to a total of seven families. Commodity crops tend to be consumed by elephants during crop raiding (i.e., sources of conflict) due to the availability of palatable plant species. African elephants showed high preferences for different types of cultivated plant species and plant parts in the study areas. All parts (i.e., leaves, stems, bark, and fruits) of the cultivated plants consumed by the elephants, however, fruits

(100%) and leaves (83.3%) of the plant species were significantly the highest priority for selection in almost all of the foraged species (χ^2=81.4, p<0.001) (Table 16).

Table 16. Cultivated plant species and parts consumed by elephants in and around KSNP

Species scientific name	Local name (in Tigrigna)	Family	Parts foraged
Carica papaya	Papaya (ፓፓያ)	Caricaceae	Leaves, stems, fruits
Mangifera indica	Mango(ማንጎ)	Anacardiaceae	Leaves, bark, fruits
Musa species	Banana (በናና)	Musaceae	Psudostem, fruits
Sorghum bicolor	Mishela (ምሽላ)	Poaceae	Leaves, stem, fruits
Pennisetum typhoideum	Mishela mesali (ምሽላ መሳሊ)	Poaceae	Leaves, stem, fruits
Eragrostis tef	Taff (ጣፍ)	Poaceae	Leaves, stem, fruits
Abelmoschus esculentus	Wayka (ዋይካ)	Asteraceae	Leaves, fruits
Zea mays	Mishebahiri (ምሽባሕሪ)	Poaceae	Leaves, stem, fruits
Solanum lycopersicum	Komidere (ኮሚደረ)	Solanaceae	Leaves, fruits
Cucurbita pepo	Diba (ድባ)	Cucurbitaceae	Fresh fruits
Eleusine coracana	Dagusha (ዳጉሻ)	Poaceae	Leaves, fruits
Solanum tuberosum	Dinish (ድንሽ)	Solanaceae	Leaves, stem

Note: Local names are written in the Tigrigna language (using English and Ge'ez alphabets)

Wild plant species: out of the 2767 examined stems of the wild plant species, a total of 1649 individual stems exhibited signs of elephant feed(Appendix 1 Table 6). A total feeding signs from 974 stems were collected in the wet season and from 675 stems in the dry season for elephant consumption in the KSNP. A total of 47 wild food plant species used as feed by elephants were identified; these species belong to a total of 22 taxonomic families. Forty-five species were recorded directly from plots, while two species were recorded from distance sightings. Of the total 47 species of wild plants, 30 (63.83%) were woody trees; seven (14.89%) were shrubs, six (12.76%) were trees/shrubs, three (6.38%) consumed as family Poaceae were grass, and one herb (2.13%) were consumed by an African elephant in both the dry and wet seasons (Table 17).

Approximately 63% of the elephant diets were from five families, namely, Fabaceae, Combretaceae (5 species=10.64%), Tiliaceae (4 species=8.51%), Poaceae (3 species=6.38%), and Rhamnaceae (3 species=6.38%). The remaining 17 families (those with prevalence above 36%) were represented by only one species (Appendix 1 Table 6). Based on the overall relative percentage of diet contributed, *Acacia mellifera* was the most common plant species consumed

(24.3%), followed by *Balanites aegyptiaca* (10.4%), *Acacia oerfota* (7.8%), *Dicrostachy scinerea* (7.3%), *Acacia senegal* (7.3%), and *Hyphaene thebaica* (5.8%). In the KSNP, of the 47 wild species consumed by elephants, 43 species were browsed and covered 91.5% of the total feed, whereas approximately 8.5% of the grazed species contributed to the diet of the elephants (Table 17).

4.3.2 Seasonal variation of elephant feed species and plant parts used

Wet and dry seasons: The plant species that were utilized by elephants in the KSNP significantly varied with the season (χ^2=63.06, df=1, p<0.001). More plant species were selected and utilized during the wet season than during the dry season. Of the total utilized species (i.e., 47 species), 10 species were utilized by the elephant only during the wet season, 3 species were utilized only in the dry season, and 34 species were consumed during both the wet and dry seasons. The diversity index showed that most of the species foraged during the dry season and also foraged during the wet season. However, some of the plant species used during the wet season were not feed during the dry season. *Grewia villosa*, *Combretum molle*, *Ziziphus mucronata*, *Terminalia laxiflora, Olyra latifolia*, *Guizotia schimperi*, *Stereospermum kunthianum Pennisetum glaucum*, *Cynodon dactylon*, and *Anogeissus leiocarpus* were utilized by elephant only in the wet season but didnot feed during the dry season. *Adansonia digitata*, *Sclerocarya birrea*, and *Ziziphus mauritiana* were utilized elephant in the dry season but rejected utilization during the wet season (Table 17).

The present analysis also quantified and ranked the contributions of individual plant species to the diet of elephants in both the wet and dry seasons. Consequently, the food contribution of woody plant species during the wet season exceeded 50%, and these woody plant species were utilized from four species, namely, *Acacia mellifera* (21.9%), *Balanites aegyptiaca* (10.1%), *Acacia oerfota* (8.11%), and *Dicrostachy scinerea* (7.39%). In the dry season, three species, *Acacia mellifera* (27.9%), *Balanites aegyptiaca* (11%), and *Hyphaene thebaica* (10.5%), contributed more than 50% of the elephant-estimated diet. Based on the ranking of dietary contribution, nine woody species counted for >72% of the estimated elephant diet during the wet season (χ^2=27.06, p=0.00069), whereas seven species constituted >79% of the estimated elephant diet during the dry season (χ^2=34.67, p<0.001) (Table 17; Figure 20).

Table 17. The abundance of plant species in elephant's food during the dry and wet seasons

Plant species	Plant habit	Wet season*	Dry season*	Sum	%	Parts eaten
Acacia senegal	Tree	65 (6.67%)	56 (8.3%)	121	7.34	L, B
Dalbergia melanoxylon	Tree	23	11	34	2.06	L, B
Balanites aegyptiaca	Tree	98 (10.1%)	74 (11%)	172	10.4	L, St, B, F
Acacia oerfota	Shrub	79 (8.11%)	50 (7.41%)	129	7.82	L, St, B, F
Dicrostachy scinerea	Tree	72 (7.39%)	49 (7.26%)	121	7.34	L, B, F
Grewia bicolor	Tree/Shrub	16	6	22	1.33	L, St, F
Sterculia africana	Tree	45 (4.62%)	1	46	2.79	L, St, B
Acacia seyal	Tree	18	10	28	1.7	L, B
Acacia mellifera	Tree	213 (21.9%)	188 (27.9%)	401	24.3	L, St, Sh, B,F
Adansonia digitata	Tree	***	47 (6.96%)	47	2.85	B
Acacia albida	Tree	2	1	3	0.18	L, B, F
Ziziphus spina-christi	Tree	52 (5.34)	18	70	4.24	L, St, Sh, B,F
Tamarindus indica	Tree	14	7	21	1.27	L, B
Grewia villosa	Shrub	3	***	3	0.18	L
Hyphaene thebaica	Tree	25	71 (10.5%)	96	5.82	L, Sh
Terminalia brownii	Tree	53 (5.44%)	14	67	4.06	L, B, F
Grewia flavescens	Tree/Shrub	6	3	9	0.55	L, F
Acacia lahai	Tree	1	2	3	0.18	L, B
Diospyros mespiliformis	Tree	14	10	24	1.46	L, B, F
Burkea africana	Tree	20	6	26	1.58	L, B
Combretum molle	Tree	51 (5.24%)	***	51	3.09	L
Cadaba farinosa	Shrub	1	1	2	0.12	L, B
Acacia species	Tree	4	2	6	0.36	L, B
Ziziphus mucronata	Tree/Shrub	9	***	9	0.55	L
Acacia polyacantha	Tree	22	17	39	2.37	L, St, B, F
Acacia etbaica	Tree	4	3	7	0.42	L, B
Acacia tortilis	Tree	2	2	4	0.24	L, B
Sclerocarya birrea	Tree	***	8	8	0.49	B
Olyra latifolia	Grass	+	***	----	-----	Sh
Stereospermum kunthianum	Tree/Shrub	17	***	17	1.03	L
Ricinus communis	Shrub	1	1	2	0.12	L, St, F
Grewia mollis	Tree	1	2	3	0.18	L, F
Solanum incanum	Shrub	2	1	3	0.18	L, St,Sh
Guizotia schimperi	Herb	+	***	----	----	Sh
Ficus sycomorus	Tree	1	1	2	0.12	L, B
Maytenus senegallensis	Tree	3	1	4	0.24	L
Combretum glutinosum	Shrub	15	4	19	1.15	L, B
Cordia africana	Tree	1	1	2	0.12	L, B, F
Terminalia laxiflora	Tree	5	***	5	0.30	L
Pennisetum glaucum	Grass	+	***	----	-----	Sh
Pittosporum viridiflorum	Tree	8	3	11	0.67	L, B
Cynodon dactylon	Grass	+	***	----	-----	L
Carissa adulis	Shrub	4	2	6	0.36	L, F
Parkinsonia aculeata	Tree	2	1	3	0.18	L, B, F
Salvadora persica	Tree/Shrub	2	1	3	0.18	L
Anogeissus leiocarpus	Tree	+++	***	----	----	L
Ziziphus mauritiana	Tree/Shrub	***	+++	----	----	L
Total	-----------	974	675	1649	100	------------

Note: L= leaves, St=stems, Sh= shoots, B= bark, and F=fruits; + =present; *Abundance of plant species foraged by elephants during both the wet and dry seasons; ***Plant species were absent in the elephant's diet during the dry/wet season (Sources: Fitsum Temesgen, 2018-2019 field survey); +++ Plant species feeding signs observed by field scouts

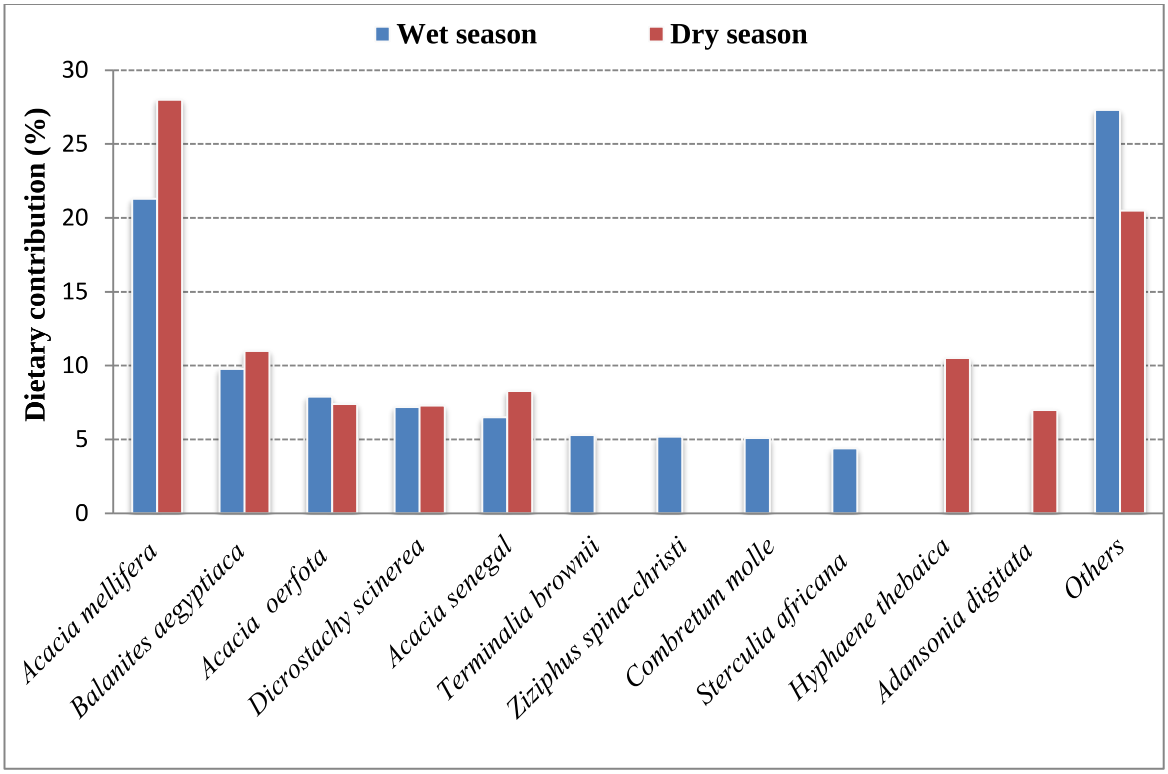


Figure 20. Relative food contributions of selected woody species on elephant diet during the wet season >72% and dry season >79%

Elephants exhibited high preferences for different plant parts for feed between seasons and among plant species. The parts of the plant consumed varied by season and plant habits. During the wet season, leaves/branches of woody plant species were the most commonly consumed (85.1% of species), followed by stems (19.15%) and fruits (17.02%), to the estimated intake of plant parts by the elephants almost entirely from trees and shrubs. Similarly, shoots (14.89%) in the wet season represented both herbaceous and woody species (6.38% and 8.51%, respectively), while bark (12.76%) made less of a contribution (Figure 21). In the dry season, approximately 57.44% of the estimated intake of plant parts from trees and shrubs was composed of bark, followed by leaves/branches (36.17%) and fruits (31.91%). To a lesser extent, stems (4.25%) and shoots (2.13%) were consumed (Figure 21). When feeding the elephant plant species, 10.64% of the species consumed four or more parts, 21.27% consumed three parts, 36.17% consumed two parts, and 31.91% consumed one part only during the wet and dry seasons (χ^2=22.22, p=0.001) (Appendix 1 Table 6). The branches and leaves of these plants were significantly more strongly selected by elephants than were the shoots, stems, barks, and fruits of the plant species during the wet season (χ^2=129.75, p<0.001), while the bark and fruits of the plant species were significantly more common in the dry season (χ^2=82.22, p<0.001). However, no signs of root consumption by elephants were observed throughout the study period.

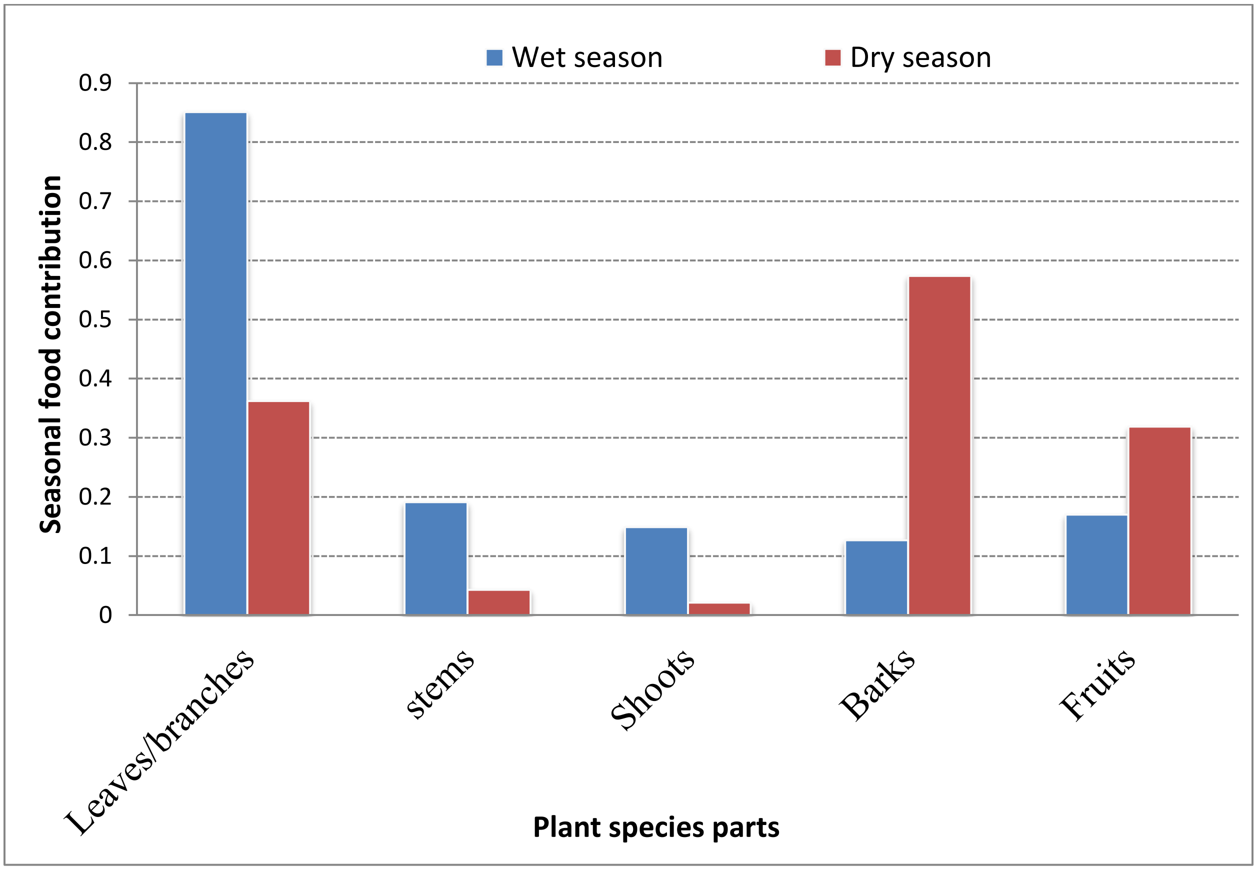


Figure 21. Estimated proportion of plant parts food contribution (%) for the elephant during the wet season (blue) and dry season (red)

4.3.3 Elephant feed plant species preferences ratio

Plant preference levels were predicted by ranking them according to the frequency of feeding signs found in the study area for each feed plant species. Based on the preference index (PI) analysis, the African elephant browsed plant species PI scores ranged from 1.643-0.629. More frequent species in the environment were less preferred by elephants included *Terminalia brownii*, *Tamarindus indica*, *Dalbergia melanoxylon*, *Combretum molle*, and *Acacia polyacantha*. Furthermore, the elephants showed greater preferences for common species such as *Acacia mellifera*, *Balanites aegyptiaca*, *Acacia oerfota*, *Ziziphus spina-christi*, *Dicrostachy scinerea*, and *Acacia Senegal* (Table 18). The less preferred species in our study analysis were indicated by a lower utilization frequency relative to their availability.

Table 18. Preference ratios for the most important woody plant species in the diet of elephant

Species scientific name	Plant availability (%)	Utilization (%)	PI
More preferred (PI >1)			
Adansonia digitata	1.735	2.789	1.643
Sterculia africana	1.807	2.729	1.544
Burkea africana	1.120	1.577	1.407
Acacia seyal	1.229	1.698	1.382
Stereospermum kunthianum	0.759	1.031	1.358
Diospyros mespiliformis	1.084	1.455	1.342
Hyphaene thebaica	4.662	5.822	1.249
Dicrostachy scinerea	5.891	7.338	1.246
Balanites aegyptiaca	8.674	10.43	1.203
Grewia bicolor	1.120	1.334	1.191
Acacia etbaica	0.361	0.424	1.175
Acacia oerfota	6.831	7.823	1.145
Acacia senegal	6.469	7.338	1.134
Ficus sycomorus	0.108	0.121	1.119
Acacia mellifera	23.35	24.44	1.042
Acacia albida	0.181	0.182	1.007
Ziziphus spina-christi	4.228	4.245	1.004
Less preferred (PI <1)			
Terminalia brownii	9.577	4.063	0.424
Grewia flavescens	0.687	0.546	0.795
Acacia lahai	0.289	0.182	0.629
Tamarindus indica	2.855	1.273	0.446
Grewia villosa	0.253	0.182	0.719
Dalbergia melanoxylon	2.385	2.062	0.864
Combretum molle	4.192	3.093	0.738
Cadaba farinosa	0.181	0.121	0.671
Acacia species	0.47	0.364	0.774
Ziziphus mucronata	0.831	0.546	0.657
Acacia polyacantha	3.108	2.365	0.761
Acacia tortilis	0.325	0.243	0.746
Sclerocarya birrea	0.542	0.485	0.895
Ricinus communis	0.181	0.121	0.671
Grewia mollis	0.253	0.182	0.719
Solanum incanum	0.289	0.182	0.629
Maytenus senegallensis	0.253	0.243	0.959
Combretum glutinosum	1.301	1.152	0.886
Cordia Africana	0.145	0.121	0.839
Terminalia laxiflora	0.434	0.303	0.699
Pittosporum viridiflorum	0.759	0.667	0.879
Carissa adulis	0.578	0.364	0.629
Parkinsonia aculeata	0.217	0.182	0.839
Salvadora persica	0.289	0.182	0.629

Note: PI=preference index

The elephant forage species shown in Table 19 revealed a highly significant positive correlation between the utilization of plant species by elephants and their preference indices ($r=0.301$, $p<0.001$) but a nonsignificant positive correlation between the availability of individual feed species in the park and the elephant preference indices ($r=0.153$, $p=0.23$). This indicates that food selection by elephants is not passively driven by relative abundance/availability but related to plant species specific preferences.

On the other hand, the strong positive correlation between the percentage of each species available in the environment and the percentage utilized in the diet (Pearson correlation: $r_p=0.97$) (Table 19) indicated that elephant food plants were utilized because of their abundance in the environment.

Table 19. Pearson correlation coefficient (γ) between the preference ratio and plant availability (%) and utilization (%)

Attributes	Availability (%)	Utilization (%)	PI
Availability (%) $p=0.23^{ns}$	1.000		
Utilization (%) $p<0.001$*	0.968	1.000	
Preference index (PI)	0.153	0.301	1.000

*$p<0.05$, ns=nonsignificant, PI=preference index

4.3.4 Effect of elephant utilization on plant species

Of the forty-one woody species (1649 stems) recorded for elephant utilization of natural forest in KSNP; nineteen species (78 stems) had fewer individual stems (abundance) and showed little sign of utilization by elephant; these species were excluded from the damaged impacts analysis. The remaining twenty-two species (1571 stems) exhibited some elephant utilization effects (Table 20). Most of the sampled stems were consequently utilized by elephants; more than fifty percent of the total sampled stems of woody plant species showed some degree of elephant feeding signs. On average, the majority of elephant utilization categories of a species comprised mostly breaking of branches followed by main stem breaking, bark striping, and uprooting/felling, which were observed in seven plant species ($\chi=58.84$, $p<0.001$, $df=4$) (Table 20). *Acacia mellifera*, *Balanites aegyptiaca*, *Acacia oerfota*, *Dicrostachy scinerea*, *Acacia senegal*, *Hyphaene thebaica*, and *Ziziphus spina-christi* were the most dominant species in the area and high utilization. In contrast, *Sterculia africana*, *Acacia seyal*, *Adansonia digitata*, and

Burkea africana were relatively less common in terms of dominance but were often selected by elephants. This indicated that these species were the most preferred food for elephants. However, *Combretum molle* and *Terminalia brownii* species were dominant in the park but had a low utilization (Table 20).

Table 20. Distribution of sampled stems by utilization category and individual species

Woody plant species name	Not utilized	Utilized categories				
		Branches broken	Main stem broken	Bark stripped	Uprooted /felled	Total stems
Acacia senegal	58 (32%)	75 (42%)	30 (17%)	16 (9%)	0	179
Dalbergia melanoxylon	32	20	10	4	0	66
Balanites aegyptiaca	68 (28%)	113 (47%)	30 (13%)	17 (7%)	12 (5%)	240
Acacia oerfota	60 (32%)	93 (49%)	36 (19%)	0	0	189
Dicrostachy scinerea	42 (26%)	84 (51.5%)	35 (21.5%)	2 (1%)	0	163
Grewia bicolor	9	18	4	0	0	31
Sterculia africana	4 (8%)	26 (52%)	6 (12%)	10 (14%)	4 (8%)	50
Acacia seyal	6 (17.5%)	16 (47%)	6 (17.5%)	4 (12%)	2 (6%)	34
Acacia mellifera	245 (38%)	256(39.5%)	110 (17%)	10 (1.5%)	25 (4%)	646
Adansonia digitata	1 (2%)	0	0	47 (98%)	0	48
Ziziphus spina-christi	47 (40%)	36 (31%)	21 (18%)	9 (7.7%)	4 (3.3%)	117
Tamarindus indica	58	5	0	16	0	79
Hyphaene thebaica	33 (25.5%)	20 (15.5%)	71 (55%)	0	5 (4%)	129
Terminalia brownii	198	52	9	6	0	265
Grewia flavescens	10	9	0	0	0	19
Diospyros mespiliformis	6 (20%)	14 (46.7%)	0	10 (33.3%)	0	30
Burkea africana	5 (16%)	6 (19%)	0	17 (51%)	3 (10%)	31
Combretum molle	65	43	8	0	0	116
Acacia polyacantha	47	25	10	4	0	86
Stereospermum kunthianum	4	17	0	0	0	21
Combretum glutinosum	17	15	0	4	0	36
Pittosporum viridiflorum	10	9	0	2	0	21
Total number of stems	1025	952	386	178	55	2596

The effect of elephant browsing on vegetation also varied with the tree developmental stage. A total of 76.7% of the regeneration stems and 36.7% of the mature stems were not utilized, while 24.3% of regeneration and 64.3% of the mature stems of a species were effectively utilized. The total utilized and not utilized stems significantly (χ=74.2, $p<0.001$, df=1) consisted small percentage of regeneration and large percentage of mature individuals. More than half of the regeneration and mature stems of a plant species were utilized, while >39% were not utilized. From the result, the most utilized categories by elephants were side branches main stems, bark, and uprooting/felling stems (Table 21).

Table 21. Effect of elephant utilization on vegetation (tree development stages) of KSNP

	Regeneration	Mature	Total
Not utilized	138 (76.7%)	887(36.7%)	1025 (39.5%)
Utilized			
Branches broken	10 (5.5)	942 (39%)	952 (36.7%)
Main stem broken	23(12.8)	363 (15%)	386 (14.9%)
Bark stripping/scratch	0	178 (7.3%)	178 (6.8%)
Tree uprooted/felled	9 (5%)	46 (2.0%)	55 (2.1%)
Number of sampled stems	180 (6.9%)	2416 (93.1)	2596

Elephant dietary use of plant species was selective and significantly varied with height class (χ=53.4, df=3, p<0.001). The results of utilization within the height class indicated that 2.7% regeneration (seedling and sapling) and mature stem height classes of 2.0-3.0 m (36.9%), 3.0-4.0 m (47.9%), and >4.0 m (12.5%) were utilized. Higher suitability for elephant utilization of plant stems was successively found in the 3.0-4.0 m and 2.0-3.0 m height classes. In contrast, regeneration (< 2.0 m) and mature (> 4.0 m) tall stems were relatively less utilized or damaged by elephants (Table 22). The highest percentage utilization was found for *Acacia mellifera* (25.5%), *Balanites aegyptiaca* (10%), *Acacia oerfota* (8%), *Dicrostachy scinerea* (7.7%), *Acacia senegal* (7.7%), *Hyphaene thebaica* (6%), and *Ziziphus spina-christi* (4.45%) (Table 22). These species could be considered the most preferred foods for elephants in the KSNP both in the wet and dry seasons.

Similarly, elephant utilization categories significantly varied with the individual species' height of both regeneration and mature stems. Stem branch utilization was higher in the 2.0-3.0m and 3.0-4.0m height classes, while very low utilization of stem branches occurred in the < 2.0 m and >4.0 m height classes. However, the bark was utilized more in the > 4.0 m height class, and elephants rejected plant bark utilization in the regeneration stage (< 2.0 m) and in the mature stems of the 2.0-3.0 m height class. The individual stems of plant species not utilized or ignored by elephants were greater in < 2.0 m and >4.0 m heights (Figure 22).

Table 22. Distribution of utilized sampled stems by height class and plant species

Species	Stems height size class (meter)				
	Regeneration	Mature			
	< 2.0 m	2.0-3.0 m	3.0-4.0 m	>4.0 m	Total
Acacia senegal	2(1.6%)	84(69.4%)	35(29%)	0	121 (7.7%)
Dalbergia melanoxylon	0	13	14	7	34
Balanites aegyptiaca	2(1.2%)	49(28.5%)	80(46.5%)	41(23.8%)	172 (10)
Acacia oerfota	4(3.1%)	109(84.5%)	16(12.4%)	0	129 (8%)
Dicrostachy scinerea	2(1.6%)	98(81%)	21(17.4%)	0	121 (7.7%)
Grewia bicolor	0	22	0	0	22
Sterculia africana	0	0	29	17	46
Acacia seyal	2 (7.0%)	14 (50%)	10 (36%)	2 (7.0%)	28 (2%)
Acacia mellifera	9 (2.24%)	69 (17.22%)	314 (78.3)	9 (2.24%)	401 (25.5%)
Adansonia digitata	0	0	0	47	47
Ziziphus spina-christi	3 (4.3%)	10 (14.3%)	45 (64.3%)	12(17.1)	70 (4.45%)
Tamarindus indica	0	2	3	16	21
Hyphaene thebaica	17(18.0%)	52 (54%)	27 (28%)	0	96 (6%)
Terminalia brownii	0	22	39	6	67
Grewia flavescens	0	2	7	0	9
Diospyros mespiliformis	0	4	10	10	24
Burkea africana	0	0	4	22	26
Combretum molle	0	15	36	0	51
Acacia polyacantha	2 (5%)	7 (18%)	30 (77%)	0	39 (2.5%)
Stereospermum kunthianum	0	2	15	0	17
Combretum glutinosum	0	5	10	4	19
Pittosporum viridiflorum	0	0	7	4	11
Total	43 (2.7%)	579 (36.9%)	752 (47.9%)	197 (12.5%)	1571

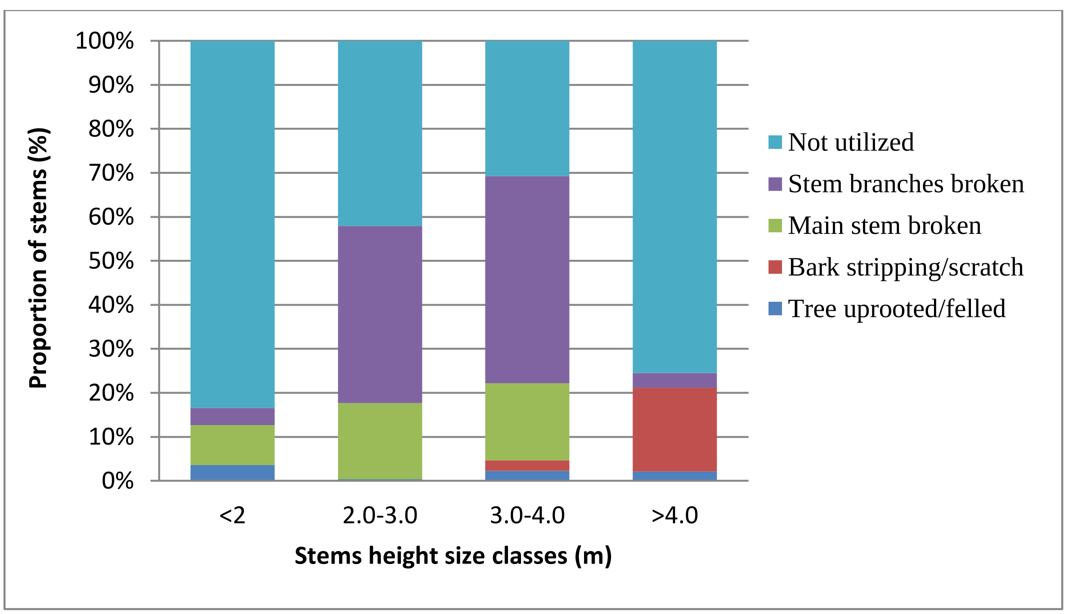


Figure 22. Proportion of stems species versus height from elephant's utilization (Note: < 2.0m= seedling and sapling stage), 2.0-3.0, 3.0-4.0m, and >4.0m= mature stems)

4.4 Human-elephant conflict and communities' attitude (Objective-4)

4.4.1 Human-elephant conflict (elephant crop raiding)

a. *Community utilization of Park natural resources versus proximity*: The local communities along the boundary of the KSNP utilized various natural resources from the park. A significant difference was observed among the respondents in terms of natural resource utilization in the park (χ^2 =74.33, df=6, $p < 0.001$). The majority (74.58%) of respondents used park as a means of grazing land (Table 23). Approximately 13.21% of the local community collected *Boswellia papyrifera* plants as sources of aromatic resin, which directly generates income. Moreover, woody plant species such as *Anogeissus leiocarpa* and *Dalbergia melanoxylon* and grass species are utilized as row material for house construction (30.38%) in the park.

Approximately 24.02% of the respondents consumed different types of food sources, such as fish, wild honey, and edible fruits of *Adansonia digitata*, *Tamarindus indica*, *Ziziphus spina-christi*, *Diospyros mespiliformis*, and *Ficus sycomorus*. Gold mining was another nonrenewable natural resource used by the respondents (18%). A total of 39.57% of the local people utilized the water source of the Tekeze River and its tributary rivers predominantly for drinking livestock and irrigation. The community also obtained other benefits, such as making traditional home equipment, such as mats, bags, and baskets, from the *Hyphaene thebaica* tree plant, traditional medicinal plants (e.g., *Plumbago zeylanica*), and sources of income (e.g., selling fuel wood, fodder, and wild honey). According to the distance from the selected kebeles to the park, significant variation was observed among the seven kebeles in terms of their natural resource consumption. For example, more than 93.0% of the respondents of Freselam and Wuhedet obtained grazing for their livestock following fuel wood sources (90.86%) from Wuhedet, whereas 53.78% and 32.31% of the respondents in Adiaser utilized grazing and fuel wood sources, respectively, from the KSNP.

Table 23. Types of natural resources used by the communities in relation to the distance from the settlement to the KSNP (m=months)

Kebele	Distance (km)	Natural resources types used (%)							
		Gold mining	Resin collection	Fuel wood	Grazing Livestock	Food source	Water source	House CM	Other (s)
Adebay	7.0-9.5	21.31	08.34	50.23	78.57 (4.5 m)	24.34	42.62	32.34	9.68
Adiaser	17.5-20	14.45	17.56	32.31	53.78 (4.6 m)	21.20	39.81	29.34	5.40
Adigoshu	13-15.5	19.81	20.41	37.34	68.59 (5.0 m)	24.32	43.00	31.23	11.11
Aditsetser	18.0-21	17.82	09.50	27.09	59.58 (4.2 m)	19.54	38.33	27.50	5.71
Freselam	7.0-9.0	18.23	11.30	90.86	93.45 (5.5 m)	26.12	38.51	33.52	8.82
Myweyni	8.0-10	16.16	11.73	41.05	72.00 (5.0 m)	25.21	37.06	28.60	10.0
Wuhedet	6.5-8.5	18.02	13.62	43.43	95.60 (5.4 m)	27.45	37.72	30.12	10.7
Average		18.00	13.21	46.04	74.51 -	24.02	39.57	30.38	8.77

Notes: The parentheses indicate the average grazing time per kebele; CM=construction materials, However, the total number of respondents was 395; overcounting is predictable due to multiple responses of households to questions.

4.4.2 Existing crop raiders and level of crop damage

A total of 395 households (~10% of the total population of the seven kebeles) were subjected to a semi-structured questinnaire based interview, which revealed that crop damage caused by wild animals has occurred consecutively over the past decade; however, no respondents reported other human-wildlife conflict (HWC) cases, such as injury to animals and humans or disease transmission to animals and humans. Qualitative and quantitative results indicated that crop raiding by elephants has continued to constitute a major problem and prevalent form of human-wildlife conflict (HWC) in the study area over the last 10 years (Figure 23). Most of the respondents (n=354, 89.62%) reported crop damage caused by elephants as "major", whereas Anubis baboon (1.2%, n=5) and porcupine (0.5%, n=2) reported "moderate damage", and none of the respondents reported major or moderate damage caused by grivet monkeys (*Chlorocebus aethiops*), common warthogs (*Phacochoerus africanus*), or greater kudu (*Tragelaphus strepsiceros*). The status of crop damage in these wild animals was categorized as minor or not because their negative impact on field crops in the local communities was practically negligible (Figure 23). Thus, the respondents recognized elephants as the most common crop pest problematic wild animal in Kafta Sheraro National Park (KSNP). Therefore, the results and discussion of HWC in our study focused on elephant crop damage and associated issues.

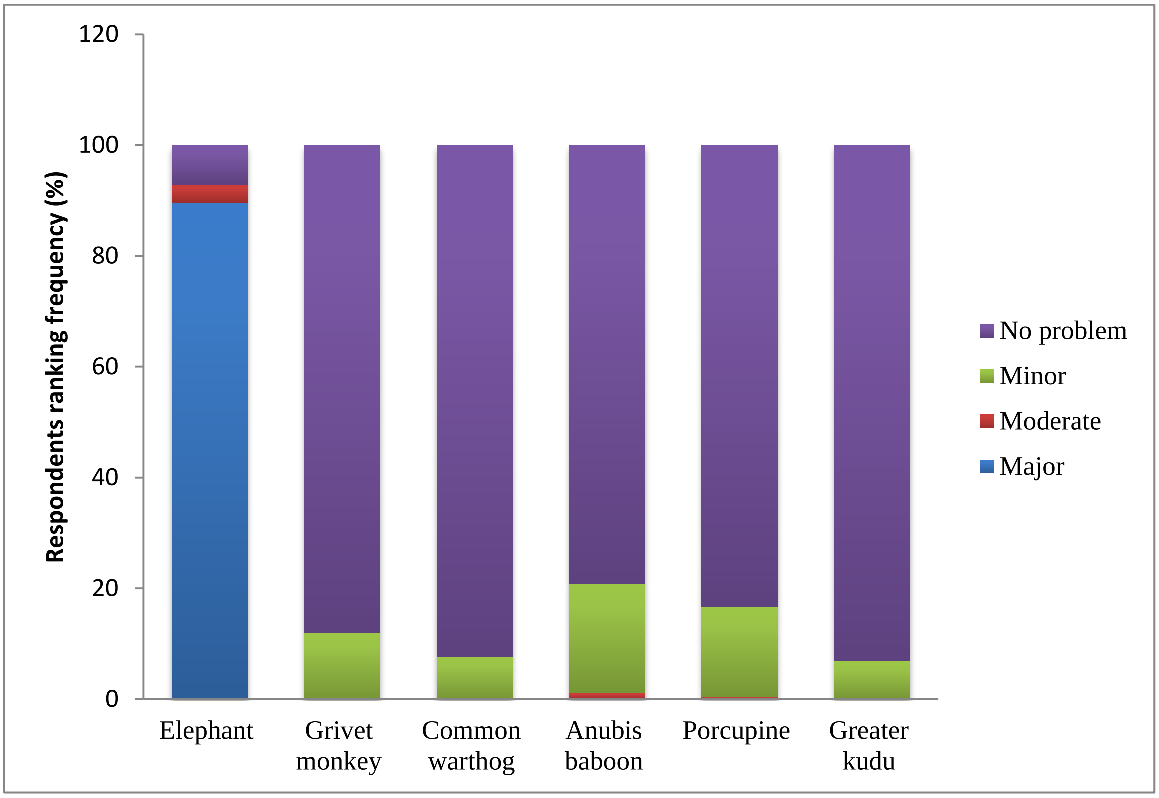


Figure 23. The existing crop raiders and the damage caused by each wild animal species (Level of damage scale as: 1 =major; 2=moderate, 3=minor, 4=no problem).

4.4.3 Factors affecting elephant crop raiding

Crop types and distribution: From the total cultivated crops found inside and outside the park, 12 different species of crops were visited and damaged by the incidence of elephant crop raiding. Among the most common raided cereal crops were maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L.), teff (*Eragrostis tef*), finger millet (*Eleusine coracana* L.), and pearl millet (*Pennisetum typhoideum*). Among the cereal crops, *Zea mays* and *Sorghum bicolor* were cross-checked by the respondents as the most preferable and most vulnerable crop types, respectively, by an African elephant. Moreover, vegetable types such as potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum*), okra (*Abelmoschus esculentus*), and duba (*Cucurbita pepo*) fruits, as well as fruits such as papaya (*Carica papaya*), mango (*Mangifera indica*), and banana (*Musa species*), were among the crops affected by elephants in the KSNP (Table 24).

Table 24. Proportion of households (%) indicated elephant crop visit to certain species in KSNP between 2018 and 2019 (N=107)

	Kebeles						
Crop name	Adebay	Adiaser	Adigoshu	Aditsetser	Freselam	Myweyni	Wuhdet
Zea mays	86.36	42.1	38.29	23.33	34.48	16.67	26.31
Sorghum bicolor	89.09	47.37	55.32	43.33	82.76	66.66	68.42
Eragrostis tef	0.00	21.05	8.51	33.33	10.34	8.69	0.00
Eleusine coracana	1.82	31.58	12.76	30.00	13.79	13.04	5.26
Pennisetum typhoideum	2.73	0.00	0.00	0.00	3.45	4.35	10.52
Solanum tuberosum	6.36	10.52	4.25	0.00	0.00	0.00	0.00
Solanum lycopersicum	4.54	0.00	6.38	6.67	0.00	0.00	0.00
Abelmoschus esculentus	9.09	5.26	0.00	0.00	3.45	4.35	5.26
Cucurbita pepo	11.82	0.00	2.13	3.33	0.00	4.35	5.26
Mangifera indica	0.00	15.79	10.64	0.00	6.89	0.00	0.00
Carica papaya	22.73	0.00	17.02	0.00	0.00	0.00	0.00
Musa species	0.00	10.52	14.89	10.0	0.00	0.00	0.00

Note: Percentages in the table include only repeated crop raiding households in the area

Elephant crop visit observation was done both the dry and wet seasons

Location of farmland and distance of residence to park: Regarding the change in damage over time, the majority of respondents (72.19%) revealed that the trend of elephant crop damage 'increased', while 9.78% of respondents selected stable damage. Only 7.01% of the respondents believed that the damage decreased because they relocated their field from the park during the past ten years. Some respondents (11.01%) were not aware of or complained about the change in crop damage because their farmland and settlement were free from elephant damage (i.e., far from the border of the park). The trend of crop damage differed significantly ($\chi^2 = 113.98$, df=3, $p < 0.001$) among the study kebeles (Table 25). Crop damage differed according to the location of the household farmland and the distance from the settlement to the park. The trend of crop damage was relatively greater for cropland found inside and at the periphery of the park than for farmland located relatively far from the park boundary. Similarly, communities living far from the park boundary are less influenced by elephant crop raiding than are those living close to the park boundary. The number of respondents who complained about crop damage significantly affected ($p<0.001$) the distance from the settlement to the park. Approximately 55% of the respondents of the kebeles complained more and settled less than 9.0 km (close) to the park. On the other hand, 45% of the respondents who settled longer than 9.0 km (i.e., relatively far) reported low crop damage in their field crops (Table 25).

Table 25. The proportion of the households' response toward the trend of crop damage by elephant during the past ten years inside & near KSNP

Kebele	Distance (km)	Sampled household (N)	Trend of crop damage by African elephant (%)			
			Increased	Stayed the same	Decreased	Unknown
Adebay	7.0-9.5	124	87.09	3.24	2.42	7.25
Adiaser	17.5-20	37	62.16	13.51	10.82	13.51
Adigoshu	13-15.5	72	66.67	12.50	9.72	11.11
Aditsetser	18.0-21	70	61.43	12.86	10.00	15.71
Freselam	7.0-9.0	34	82.35	5.89	2.94	8.82
Myweyni	8.0-10	30	70.00	13.33	6.67	10.00
Wuhedet	6.5-8.5	28	78.57	7.15	3.57	10.71
Average	---	---	72.19	9.78	7.01	11.01

Regarding the extent of elephant crop damage over ten years, the respondents' answers were categorized into four levels: high, moderate, low, and no problem/no complain. The degree of crop damage and yield loss complaints varied significantly among the local communities (χ^2 = 234.5, df = 3, $p < 0.05$). Most respondents reported that elephant infestations were associated with high crop damage, with an additional small respondents reporting that elephant infestations were not damaged or did not complain. Among the seven kebeles, the most common complaint was from Adebay, followed by Freselam, Wuhedet and Myweyni, while respondents from Adigoshu, Adiaser, and Aditsetser had low and no complaints about the impacts of crop damage caused by African elephants (Figure 24). The respondents announced that once elephants visit agricultural fields, they will severely damage crops within a short period. However, in Adebay, Freselam, Wuhedet, and Myweyni, which are the nearest kebeles to the border of the park, it is suggested that elephant poses the most damage, while more than 30% of the respondents answered "no damage" by an elephant in Adiaser and Aditsetser, which are the farthest kebeles (Figure 24).

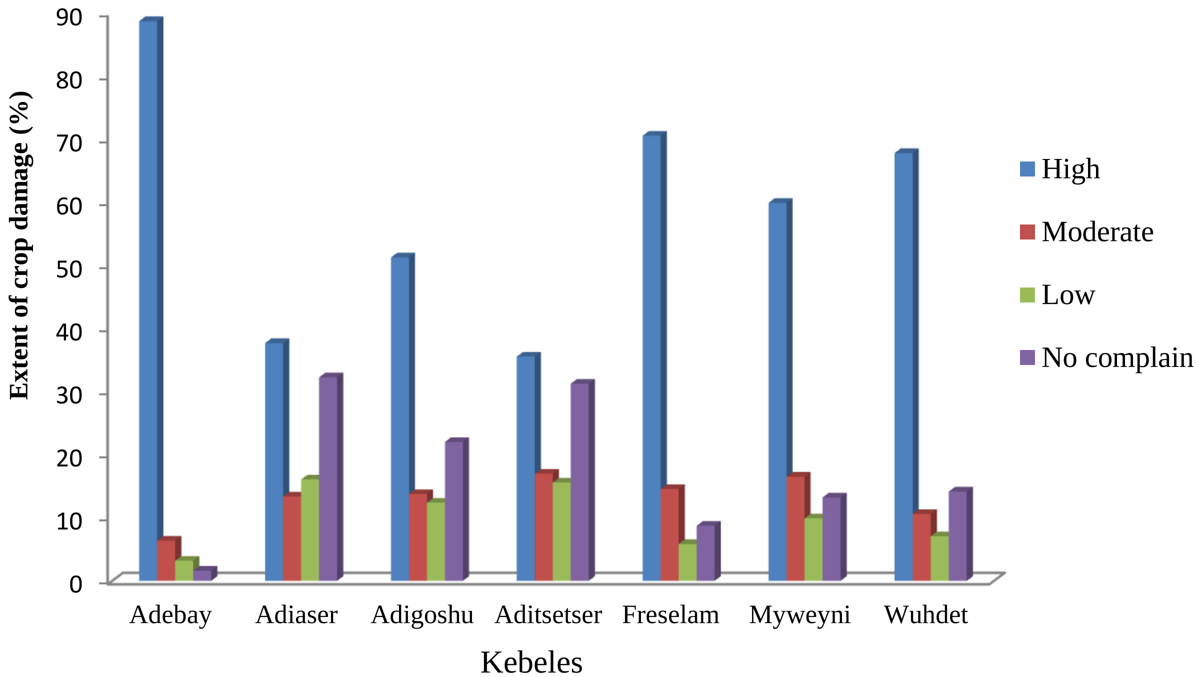


Figure 24. The extent of elephant crop damage (high=significant damage, moderate =medium damage, low=insignificant damage & no complain=absence of damage)

Season and duration of crop raiding: However, elephant crop raiding patterns occurred in both the dry and wet seasons; the majority of respondents believed that damage increased during the wet season. Of the total hectares of cropland damaged by African elephants during the surveyed period, most respondents (60.9%) answered that elephants more frequently visited their crops during the wet cropping season of rain feed, whereas 24.1% believed that they visited their crops during the dry season of irrigated crops. Some households (15.6%), particularly those living in Adiaser and Aditsetser kebeles (i.e., relatively farther kebeles from the park border), had no opinion regarding elephant season preferences, while none of the respondents chose both seasons for elephant crop raiding. The raids on rainfed cereal crops noticeably increased during the late wet season, whereas the raids on vegetables and fruits increased during the long dry season. There was a significant difference between seasons in terms of the size of damaged cropland ($\chi^2 = 234.5$, df=4, $p < 0.05$).

The number of field crops visited by African elephants varied with the duration of the daily pattern among kebeles (χ^2=76.86, df=3, $p < 0.0001$). The highest number of respondents (60.51%, n=239) confirmed that elephant crops visited their field crops more frequently during the nighttime (7:00 pm-6:00 am), and a few respondents (13.67%, n=54) detected damage during the daytime both in the morning (6:00 am-10:00 am) and afternoon (3:00 pm-6:00 pm). Some of the respondents (25.82%, n=102) were unable to identify the exact duration of crop raiding by elephants in their field crops (Figure 25).

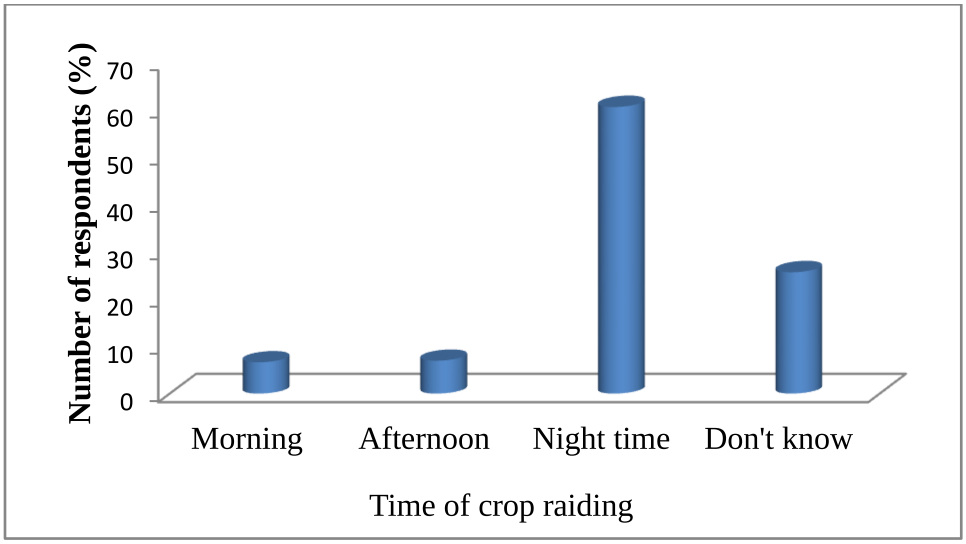


Figure 25. Elephants are visited crops inside & at the periphery of KSNP. Note: (Morning: 6:00 am-10:00 am; Afternoon: 3:00 pm-6:00 pm; & Night 7:00 pm-5:00 am)

4.4.4 Local traditional techniques for preventing crop raiding

The local community farmers adopted four major types of protection measures to minimize the amount of crop damage and yield loss caused by elephant crop raiding in the KSNP. On average, there was a significant difference among the elephant crop raiding protection approaches taken by the local community (χ^2 = 32.31, df = 3, p < 0.001). The major practices applied involved pursuing the noise of guns and other local material stimuli called “Wanchif” (i.e., Tigrigna name); physical barriers such as fencing of their cropland using locally available Achoria and Ziziphus plant species; making trenches of walls; local repellents such as lighting “Shig” (i.e., Tigrigna name); and flashlights around their farmland during the night; additionally, land use planning (i.e., alternative crop farming systems), such as replacing the repeated cultivation of elephant preferred crops (e.g., *Zea mays* and *Sorghum bicolor*), with nonpreferred crops (e.g., *Sesamum indicum*). Most of the respondents (81.99%) agreed that noise from a gun and other related noise-producing materials (e.g., drums, tin cans) was the most common and effective protection method used to pursue existing elephant crop raiding in all selected kebeles, followed by lighting fires and torch lights around cropland (44.95%), alternative crop cultivation

(37.21%), and physical barriers (30.80%). The respondents of 11.22% (did not express clear ideas (Table 26).

Table 26. Respondents described the protection mechanism for the elephant cropsdamage in and around KSNP from 2018 to 2019 (N=395)

		Methods of protection (%)				
Kebele	N	Gun sound & banging noisy materials	Lighting fire & flashlight	Land use planning (alternative crop cultivation)	Local barriers (traditional fences)	No opinion about the methods
Adebay	124	92.74	56.45	44.35	37.09	0
Adiaser	37	78.37	40.54	32.43	24.32	21.62
Adigoshu	72	77.78	41.67	38.90	30.55	8.52
Aditsetser	70	74.28	38.57	28.57	22.86	24.28
Freselam	34	85.29	50.00	40.54	35.29	9.02
Myweyni	30	83.33	43.33	40.00	33.33	7.85
Wuhdet	28	82.14	44.12	35.71	32.14	7.26
Average	-	81.99	44.95	37.21	30.80	11.22

N=Sampled households

Note: However, the total number of respondents was 395; overestimates are predictable due to multiple responses of households to questions.

The respondents varied significantly (χ^2 =104.11, df=4, $p < 0.001$) in their view of appropriate sustainable and coexistence management strategies in response to conflicts with African elephants. Approximately 58% of the respondents suggested compensation from the government for damaged crops; 24.1% wanted the government to construct barriers between the park boundary and farmland. Others (10.0%) suggested the use of different traditional protection techniques to minimize the crop damage caused by African elephants, and 5.7% of respondents recommended resettlement/relocation of farmland owners to other wildlife-free areas. Only 2.2% of the respondents did not respond regarding the management technique, and none of the respondents proposed killing elephants as a solution to crop damage (Figure 26).

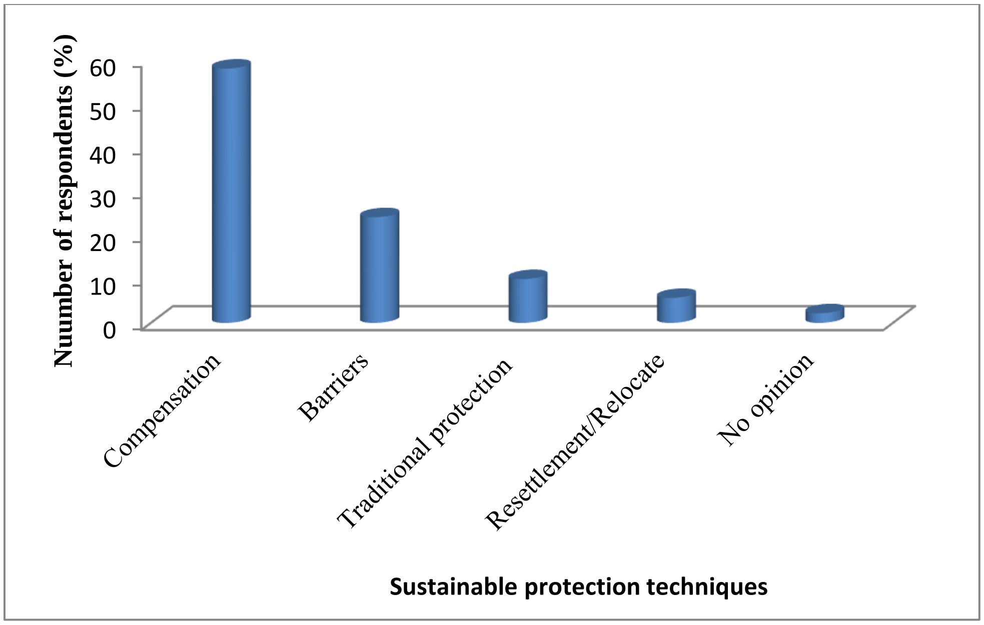


Figure 26. Sustainable management strategies recommended for elephant crop damage

4.4.5 Human-elephant conflict (elephant crop raiding) locations in the park

Human-elephant conflict (HEC) data were collected via repeated field surveys and interviews with respondents in the study area, i.e., Kafta Sheraro National Park (KSNP). The field survey was conducted from 2018 to September 2020 to show the locations of HEC distributions and respondents who observed elephant crop damage from the past ten years of experience to recent years (Figure 27). According to the questionnaire survey of 395 interviewed households adjacent to the KSNP, on average, 72.2% of the respondents confirmed that HEC (i.e., elephant crop raiding) increased in the area in the past ten years and that there was considerable crop damage (Table 27). More than 82% of the respondents mentioned that elephants damaged their seasonal and irrigated crops (Figure 25). Moreover, from the respondents' interviews, the participants were asked to name and locate the places where most conflicts occurred within the study areas. There was a significant cause-effect relationship between LULC change and HEC. Figure 27 shows the distribution of HEC areas where many conflicts related to crop damage caused by elephants occurred under the 2018 LULC change. From the LULC changes in the 1988 and 2018 images, large areas of woodland and riverside vegetation were converted to seasonal crops and fruit and vegetable gardens. However, crops in the 1988 LULC were absent, and in the 2018 record, there was a maximum. The conflict areas are located inside the KSNP and outside the park of adjacent agricultural fields. The respondents claimed that conflicts were common where the household’s agricultural fields (seasonal and riverside irrigated crops) were located inside and adjacent to the park boundary (Figure 27).

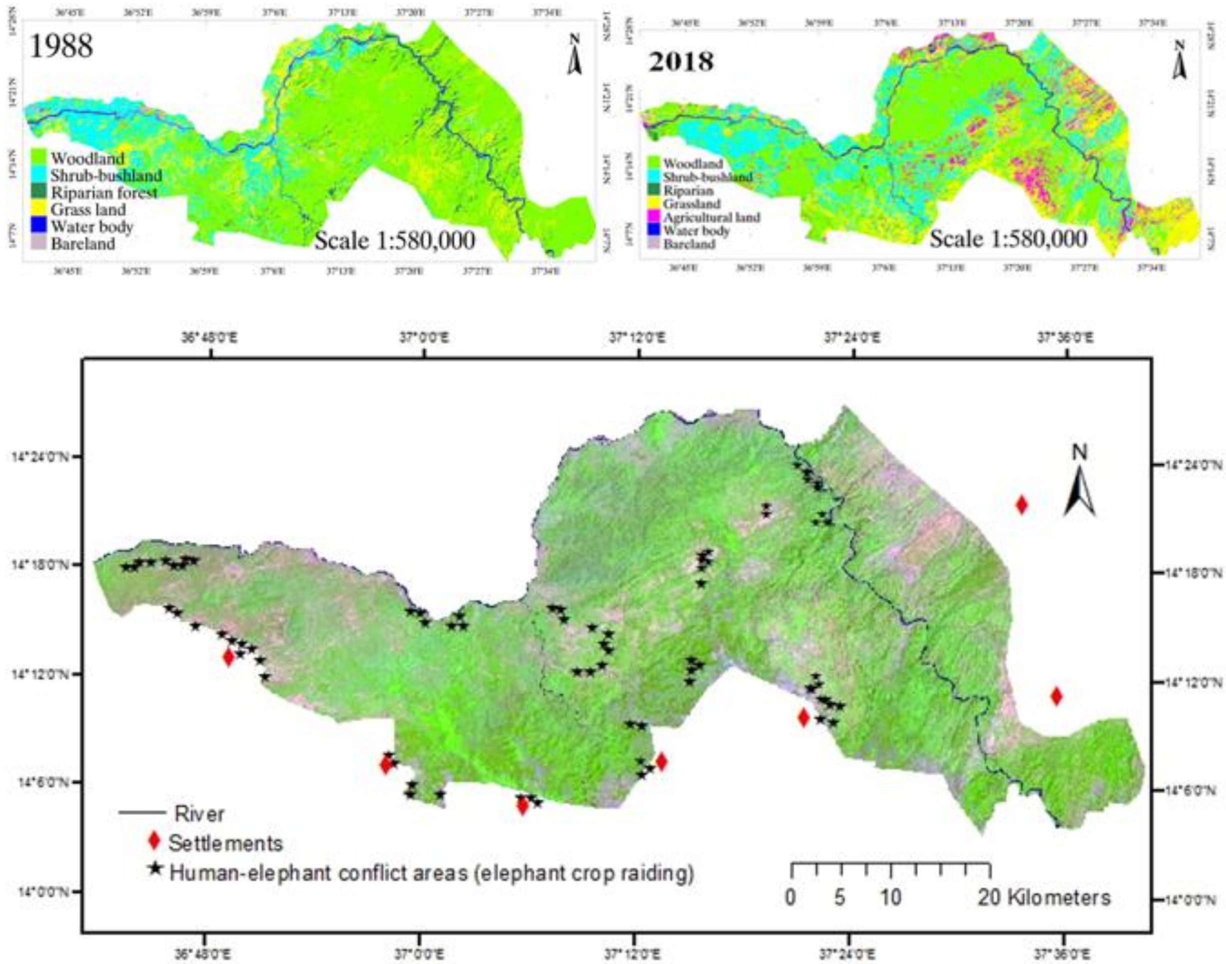


Figure 27. Human-elephant conflict/elephant crop raiding areas in LULC change 2018 image

4.4.6 Resident’s knowledge/awareness about KSNP

Most of the respondents (54.18%, n=214) were aware of the aim of establishing a PA (i.e., KSNP) and conserving natural resources in the park. However, the remaining respondents (45.82%, n=181) had little/no awareness of the conservation objectives of KSNP. The significance difference was tested based on the dependent variable of awareness/no awareness and the independent variables of age, sex, education level, settlement condition, and distance between the settlement and park. The most significant independent variables influencing the awareness of the local communities toward establishment and conservation of the park were sex (male, p<0.001), education (formal, $p<0.001$), age ($p<0.001$), settlement condition (long-term lived, $p=0.046$), and distance (6.5-9 km, $p=0.037$) (Table 27), whereas household size and settlement duration were excluded from the model equation ($p>0.05$) and did not influence the respondents' knowledge of KSNP conservation.

Table 27. Binary logistic regression model analysis of awareness/no awareness of the conservation of KSNP (N=395)

Independent variables	*B*	S.E	Wald	Df	*Sig.*	Exp (B) (95%C.I)
Gender						
Male	1.263	.323	15.26	1	.000	3.535 (1.87-6.66)
Female*	-	-	-	-	-	- -
Age (years)			79.15	2	.000	
22-39	4.595	.522	77.50	1	.000	98.97 (35.6-275.3)
40-57	3.112	.492	40.08	1	.000	22.46 (8.57-58.86)
> 58*	-	-	-	-	-	- -
Education level			42.54	2	.000	
Primary (1-8th)	2.118	.331	40.89	1	.000	8.31 (4.34-15.91)
Secondary (9-12th)	2.035	.572	12.68	1	.001	7.65 (2.50-23.47)
Informal*	-	-	-	-	-	- -
Settlement condition						
Long term lived	0.68	0.35	4.96	1	.046	1.98 (1.0-3.45)
Short term lived *	-	-	-	-	-	- -
Distance b/n settlement & park						
6.5-9.0 km	0.610	.293	4.332	1	.037	1.84 (1.04-3.27)
> 9.0 km*	-	-	-	-	-	- -
Constant	-5.624	.645	76.02	1	.000	0.004

Note: *Set as reference variables (variables that have little influence on the variation in awareness)

Entry and removal of variables were screened by the Wald forward stepwise method with probability of 0.05 and 0.1, and finally, three variables were eliminated from the equation

A positive coefficient (*B*) indicates a greater likelihood of conservation awareness significance test at ($p<0.05$, $p<0.01$, $p<0.001$)

4.4.7 Community attitude on the conservation of KSNP and elephants

Park: There was a significant difference in the attitudes of the community toward park conservation. The majority of the local communities supported the establishment and practice of KSNP conservation, respectively. This result indicated that the majority of the communities had positive attitudes toward the conservation of natural resources in the park. However, 60.5% of the interviewees agreed that the park had a positive impact on the conservation of natural resources, while around half of the interviewees did not perceive any benefits from the conservation of the park. Of the total respondents, 48.35% felt that KSNP conservation increased competition for resources among residents. More than half of the respondents complained that park conservation had led to conflict between the local people and the park managers (Table 28).

The internal consistency or relatedness of the seven questions was evaluated and measured using Cronbach's alpha (α). The validity of the model indicated that all seven attitude statements concerning elephant conservation were included in the final results of the reliability analysis because all the questions belonged to the recommended correlation scale and had corrected interitem correlation scores (i.e., how much each item correlated with the overall questionnaire score) greater than 0.5, while the final Cronbach's alpha coefficient of the elephant attitude index was 0.90 (Appendix 1 Table 7).

Elephant: Residents' attitudes of elephant conservation were evaluated in this study through seven attitude statements. Our results showed that most of the interviewees (59.80%) felt that elephants were responsible for raiding cultivated crops inside and outside the park. Although more of the local people (44.81%) supported the existence of elephants in their communities, most of the respondents (46.43%) opposed increasing the number of elephants in KSNP. On the other hand, more than half of the respondents supported the existence of elephants in communities, which initiated tourist attractions and were generally important to park ecosystems. A total of 48.72% of the sampled households believed that elephants have a natural right to live in the area. The majority of the respondents (53.31%) also supported the developmental conservation practices proposed in the Construction of Water Reservoirs project in the elephant conservation habitat of the KSNP, which addresses water security, especially during the dry season (Table 28).

The seven attitude statements toward KSNP conservation were addressed by individual households; however, our internal consistency evaluation model result showed that item statement three was excluded from the final result of the reliability of the attitude index because this question had corrected interitem total correlation scores less than 0.5. A decrease in this item increased the final Cronbach's alpha coefficient of the KSNP attitude index. The index had six statements with a high Cronbach's alpha coefficient of 0.89 (Appendix 1 Table 7).

Table 28. Households' response to the attitude statement toward the conservation of KSNP and African bush elephants

I. **Attitude statements toward Kafta Sheraro National Park**	Agree	Neutral	Disagree
1. From the beginning i supported the establishment of KSNP	49.87	12.15	37.97
2. I support the practices of KSNP conservation	52.91	14.18	32.91
3. KSNP has a positive impacts on natural resources conservation	60.50	10.63	28.87
4. KSNP conservation have brought positive change on the local community livelihood	27.35	23.04	49.61
5. Conservation of the whole district area brings happiness	60.00	16.71	23.29
6. KSNP conservation stabilizes communities utilization of NR	38.74	12.91	48.35
7. The relationship b/n community and park managers is good	34.17	11.65	54.18
II. **Attitude statement toward African bush elephant**	Agree	Neutral	Disagree
8. I support the existence of elephants in our community	44.81	16.46	38.74
9. I encourage to increase the no of elephants in the area	42.85	10.71	46.43
10. Conservation of elephants can open a door for tourist attraction	56.77	27.37	15.85
11. Elephants crop raiding doesn't a significant issue in the area	17.04	23.16	59.80
12. Elephants have the right to live in the area	48.72	14.10	37.18
13. Elephants are important to the whole KSNP ecosystem	51.91	19.59	28.50
14. Construction of water reservoirs assure elephant conservation	53.31	10.20	36.48

(NR=Natural resources)

4.4.8 Factors affecting attitudes toward KSNP and elephants conservation

Park: The variation in attitudes toward protected area (i.e., KSNP) conservation was significantly influenced ($p=0.008$) by respondents aged between 22 and 39 years (younger age) and 40 and 57 years (middle age), which positively impacted their attitudes ($p=0.029$). The education level of the local people significantly ($p<0.001$) explained the variation in this attitude, and those who attained formal education (i.e., primary and secondary education) had a positive attitude. The distance from the settlement to the park significantly ($p<0.001$) influenced the attitude of respondents toward park conservation, as the local communities that settled far (greater than 9 km) from the KSNP had more positive attitudes than those who settled close (6.5-9 km) to the park. Household experience knowledge was another significant determinant of residents' attitudes toward the conservation of PA natural resources ($p<0.001$) (Table 29). Settlement condition and land holding size did not significantly influence the regression model. However, an estimation of beta (β) indicated long-term lived respondents and 1-3.5 ha land holding size were more likely to have positive attitudes toward PA conservation than were those short-term lived and >3.5 ha land holding size respondents respectively (Table 29).

Elephant: The variation in attitudes toward elephant and elephant conservation was significantly influenced ($p=0.007$) by respondents aged between 22 and 39 years (younger age) and 40 and 47 years (middle age), which positively impacted their attitudes. The education level of the local people significantly ($p=0.003$) explained the variation in this attitude, and those who attended formal education had relatively positive attitudes (Table 29). The distance from the settlement to the park significantly ($p=0.002$) influenced the attitude of respondents toward elephant conservation, as the local community that settled far (greater than 9 km) from the KSNP had a more positive attitude than those who settled close (6.5 to 9 km) to the KSNP. Moreover, the two most important variables that significantly explained the variation in the interviewees' attitude scores were the crop damage trend and the degree of crop loss. The respondents who reported an increase in elephant crop raiding in the past ten years had a significantly ($p=0.004$) negative attitude toward elephant conservation, while those who reported a decrease and the same trend of crop raiding had a more positive attitude. The respondents who reported high and medium levels of crop damage had significantly negative perceptions ($p<0.001$ and $p=0.013$, respectively). Individual households that experienced low or no complaints about elephant crop raiding had more positive attitudes than those who experienced high or moderate crop damage (Table 29).

Table 29. Factors influencing local people’s attitudes toward KSNP and elephant conservation

	Kafta Sheraro National Park consrvation				African bush elephantconservation			
Independent variables	*B*	*S.E*	Wald χ^2	*P value*	*B*	*S.E*	Wald χ^2	*P value*
Age categories (years)								
22-39	+0.47	.18	7.1	.01	+0.026	.190	0.02	.007
40-57	+0.24	.16	2.3	.03	+0.12	.17	0.59	.74
> 58 *	-	-	-	-	-	-	-	-
Education level (grade)								
Primary (1-8th)	+0.76	.13	34.3	.00	+0.08	.132	0.41	.003
Secondary (9-12th)	+1.37	.21	40.7	.00	+0.4	.22	3.36	.021
Informal*	-	-	-	-	-	-	-	-
Distance b/n settlement & park (km)								
6.5-9.0	-0.43	.11	16.0	.00	-0.238	.12	3.99	.002
> 9.0*	-	-	-	-	-	-	-	-
Settlement condition								
Long term lived	+0.06	.12	0.3	.60				
Short term lived *	-	-	-	-				
Landholding size (ha)								
1-3.5 ha	+0.02	.11	0.02	.88				
> 3.5 ha*	-	-	-	-				
Awareness condition								
Aware	+0.7	.15	21.9	.00				
Not aware*	-	-	-	-				
Crop damage trends								
Increase					-0.75	.27	7.65	.004
Stayed same					+0.02	.23	0.01	.87
Decrease/no opinion*					-	-	-	-
Crop damage level					-	-	-	-
High					-1.1	.25	20.3	.00
Medium					-0.6	.25	5.55	.01
Low/no complain*					-	-	-	-
Intercept	3.07	.17	307	.00	1.7	.26	40.5	.00

Note: * references categories (>58 years old, female, informal education, resettled, >9km distance, land size >3.5 ha, landowner, no awareness, decrease/no opinion, and low/no complain on crop damage)

A positive (+) value for “*B*” indicates a positive impact of the variable on the attitude of the respondent, whereas a negative (-) value indicates a negative impact. χ^2=Chi-square

CHAPTER FIVE

5. DISCUSSION

5.1 Land use land cover change (Objective-1)

5.1.1 Accuracy assessment

The overall accuracy (OAA=86.9%) and kappa coefficient (Kc=0.845) of the KSNP in 2018 were greater than those studies in the Central Rift Valley of Ethiopia (Mesfin et al., 2020), protected and communal areas of Namibia (Kamwi et al., 2018), and Quirimbas National Park, Mozambique (Mucova et al., 2018). However, the overall accuracy and kappa coefficient are lower than those of Bale Mountain National Park, Ethiopia (Nune et al., 2016), the Biodiversity hotspot, South Africa (Bailey et al., 2016), and the Tarangire and Katavi Parks, Kenya (Mtui et al., 2017). The low user accuracy (UA)<80% or greater error accuracy for grassland and bareland and low producer accuracy (PA) for shrubland and grassland cover classes of KSNP in 2018 were not accurately assigned to the correct class and were mostly caused by a mix with the other land cover classes. Because PA shows the accuracy of the map from the maker's viewpoint and measures how often ground attributes under analysis are declared correct on the map. Whereas UA measures how often the classes defined on the map under analysis are present on the ground. For example, grass is often predominantly mixed with cultivated land, whereas woodland is mixed with shrub bushland due to its limited spatial resolution and image quality. The confusion between grass and cropland and between shrub and woodland classes in KSNP was due to the low image quality and resolution to identify the clear differentiation of similar LULC classes. As Duraisamy et al. (2018) stated, with low spatial resolution of images to view the natural vegetation makes it difficult to differentiate among closely related land covers. The classification was statistically significant and the Kc above 0.80 is mostly considered a strong agreement between the images based classified LULC classes and references data (i.e., the actual ground truth data). Generally, the agreement was compared with the following ranges; Kc<20%= poor; Kc=20%-40% (reasonable); Kc=40%-60% (good); Kc=60%-80% (very good); Kc ≥80% (excellent) rating (Jia and Richards, 2005).

5.1.2 Trends in land use/land cover change

The KSNP experienced extensive LULC change due to increased settlement united with the expansion of farming activities. The highest decline in woodlands occurred in the second period (1998 to 2008), whereas the rapid decline in riparian forests occurred in the first period (1988 to 1998). Because these periods took place, widespread expansion of dry-season irrigated land and wet-season rain-fed crops. An increase in the settlement around the park, cropland expansion inside and outside KSNP, and related human disturbance activities had great impacts on the destruction of woodland cover. The reduction of the Tekeze riverside riverine forest was due to extensive irrigated crop cultivation undertaken since 1993. In contrast, bare land, cropland, grassland, and shrub bushland expanded during the study period (1988 to 2018). This result is similar to the Babile Elephant Sanctuary from 1977 to 2017 study, in which woodland and riparian forests decreased, whereas cropland and bare land continuously increased (Workeneh & Kassaw, 2019). In contrast, these authors revealed that shrubland expanded throughout the study period as this class was dominant next to woodland in the area. Cropland expansion at the expense of woodland cover decline has also been reported in different areas of Ethiopia (Muhammed & Elias, 2021; Ewunetu et al., 2021; Takala et al., 2020). Similarly, shrubland, grazing land, settlement, cropland, and bare land increased as the forestland decreased (Asmame & Abegaz, 2017). In the central Rift Valley (1986 to 2016), cropland areas doubled, and grass/grazing land and bare land increased as the woodland destruction (Mesfin et al., 2020; Bekele et al., 2019; Garedew et al., 2009). A remarkable increase in cultivated land occurred at the expense/decline of forests (Liyew et al., 2019; Esa & Assen, 2017). The woodland and dense forest areas decreased by 34.6% and 59.9%, respectively, while cultivation expanded by a rate of 15 km^2/year (Abera et al., 2020). Including the present result, all the above-listed studies in Ethiopia showed that cropland has expanded intensively at the expense of/a decrease in dense forest and woodland cover. The conversion of woodland/forest vegetation to cropland has also been broadly reported in other African countries. For example, in Kenya (Erdogan et al., 2011; Maeda et al., 2010), the semiarid region of Uganda (Egeru et al., 2014), and the biodiversity hotspot of South Africa (Bailey et al., 2016) experienced an expansion of cropland and heightened encroachment of shrub bushland as the cost of woodland. In central Kenya, cropland and bare land increased by 160.45% and 73.2%, respectively, due to the destruction of forest area (Maina et al., 2020), while forestland in Quirimbas National Park decreased by 41.67% due to changes to other human-made LULC (Mucova et al., 2018).

5.1.3 Temporal and Seasonal Trends of the NDVI

The NDVI analysis of the study area (i.e., KSNP) was performed for the dry and wet seasons separately. The seasonal variation in the average NDVI between the wet and dry seasons was reported in semiarid areas (Amri et al., 2011; Ferreira et al., 2003). Likewise, in semiarid areas of Uganda, the NDVI in the wet season was greater than that in the dry season (Egeru et al., 2014). In our study, the NDVI results (1988 to 2018) also indicated a significant change in vegetation cover; the amount of high to moderate-density vegetation cover decreased while sparse vegetation and nonvegetation cover increased, from the total area of the KSNP. Consistent with our study, the dense vegetation cover decreased whereas the nonvegetation cover increased (Abera et al., 2020).

The variations in seasonal rainfall and temperature trends in the study period were not consistent with the mean NDVI trends in the wet and dry seasons. This directly reflects the influence of rainfall and temperature, which are not considered the main drivers of vegetation cover change in the KSNP. Due to the limited availability of local meteorological stations, a lack of advanced recording instruments and skilled manpower leads to low accuracy of climate variable data. Therefore, the statistical analysis revealed that precipitation and temperature were not considered the main drivers of vegetation cover change; rather, human-induced factors were the major factors influencing the decline in vegetation cover in the park. Moreover, dry season vegetation areas along the Tekeze riversides are independent of rainfall, as they directly access water from the river. However, the seasonal NDVI decreasing trends are more strongly linked with increasing human driving activities, such as the conversion of woody vegetation to seasonal cropland and bare land, loss of vegetation by fire, and fuelwood collection. In line with our findings, the Nechsar National Park vegetation cover decline was due to human-driven deforestation (Fetene et al., 2015). Similarly, the temporal NDVI decreases in Kafta humera district have changed woodland cover due to the expansion of cropland, wood harvesting, and settlements (Zewdie and Csaplovics, 2016). However, Ethiopian dry land vegetation productivity is dominantly controlled by the availability of moisture (Hailu et al., 2015); the low correlation between precipitation and the NDVI is due to the decline in vegetation cover (Li et al., 2004).

This is an indication of a slight response of degraded woodland areas to precipitation (Zewdie and Csaplovics, 2016).

In contrast to the present study, reports have shown that NDVI changes (either increasing or decreasing) are driven by precipitation or temperature in arid and semiarid areas of Africa (Ghebrezgabher et al., 2020; Martiny et al., 2006) and in Spain, Iraq, and China (Naif et al., 2020; Fensholt et al., 2012; Pei et al., 2019; Sanz et al., 2021). The spatiotemporal variation in the NDVI was determined by the variation in the temporal distribution of precipitation (Xia et al., 2014). On the other hand, the large differences in vegetation cover between the dry and wet seasons were due to climatological and human impacts (Al-Saady et al., 2015). Moreover, in a study in Ethiopia (Dagnachew et al., 2020), vegetation degradation was influenced mainly by both human-related factors and rainfall variability.

5.1.4 Drivers of land use/land cover change

Expansion of settlements and cropland, gold mining, civil war, illegal fires, and land administration problems mainly devastated the woodland and riparian habitats and unlikely increased shrubland, grassland, and bareland of the KSNP. Likewise, natural resign collection, fuel wood consumption, and grazing which were mostly destructed woodland habitat of the park were the main communities recognized drivers of LULC change inside and outside the KSNP .These drivers were generated by a scarcity of resources in the moderate and high altitude areas of the region coupled with resettlement from dense to less populated areas, low awareness of the environmental benefits of natural resources, lack of access to renewable energy sources (i.e., solar energy, electricity), and high poverty. Resettlement schemes by the government, as well as a few illegal ones, were highly expanded in the study area between 1991 and 2002. Due to this program, new settlement communities/villages, namely; Tekeze, Maytemen, Maykeyh, Freselam, Wuhedet, and Mayweyni, were established adjacent to the KSNP. Similarly, studies in Ethiopia have displayed that resettlement programs have caused a significant LULC change due to massive forest clearance and the depletion of natural vegetation cover in the Hawa Galan and Chewaka districts of Oromia (Yadeta et al., 2022; Abera et al., 2020), Gelda district, Amhara (Esa & Assen, 2017), and Esira district, southern region (Mamude et al., 2021). The proximate communities' to KSNP livelihood directly interlinked with crop production and animal production. Following resettlement, expansion of cropland mainly in the woodland and river sides of the park was observed. The main activities undertaken by the communities were land preparation for irrigated planting during the dry season and vegetable production, cereal crops production, and mass production of banana fruits along Tekeze river sides (Figure 28 b, c, & d).

The area has great potential for traditional gold mining and is a common activity that are an agent for other related drivers (i.e., fire, increase settlement) of the LULC change at the study site (Figure 28a). The activity of gold mining leads to a drift of people from other areas toward the mine sites and increased settlement in the surrounding area of the KSNP, and temporary structures are even constructed as places of residence inside the park. According to vegetation surveyed in the KSNP, the above-listed activities destroy natural vegetation by uprooting the plant root profile and are an approximate cause of extinguishing illegal fires (Temesgen and Warkineh, 2020). Gold mining in East Cameron (Kamga et al., 2020) and mining activities in Ghana (Garai and Narayana, 2018; Prosper et al., 2015) have had pronounced impacts on the destruction of vegetation.

Based on socioeconomic and field observation data, illegal fires are another significant driver of LULC change in the KSNP. The dry season fire was extinguished for different purposes by three agents: (1) farmers, (2) *Boswellia papyrifera* resin collectors, and (3) traditional gold miners. The local community farmers prepared the land for cultivation via the destruction of woodlands by burning, while resin collectors and traditional gold miners used fire for daily food preparation. All the agents destroyed the valuable natural resources of the park and promoted the migration of wildlife outside the park. The detailed human-induced fire hazard information related to LULC change reports is limited in Ethiopia; however, consistent studies in hot spot tropical countries of Brazil, the Serengeti ecological unit, and Cameroon for 18 months of daily fire observation records indicated a direct relationship between the occurrence of fire and LULC change (Eva and Lambin, 2000). On the other hand, a study of frequently burned areas in central Spain showed that pine woodland coverage decreased while shrubland increased (Viedma et al., 2006). Similarly, reports have indicated that human-induced fires greatly contribute to increasing the destruction of vegetation through the direct expansion of bare land areas (Prosper et al., 2015).

The land tenure system was another significant driver of LULC change, especially in rural communities. The land administration problem is a great issue that has been raised by the communities in the studied districts. According to the households and focus group discussions, the landowner certificate is in the hands of the district administrator, which leads to a gap and expansion of insecure land tenure in the district which is supported by Tsegaye et al. (2012). These kinds of activities also open the door to expanding illegal and unreasonable land invasion for cultivation. In the surrounding KSNP communities, approximately 14% of households lack legal land permits. Many reports have confirmed that insecure land administration is a determinant factor for LULC change (Ewunetu et al., 2021; Andarge et al., 2020).

Figure 28. Traditional gold mining activities (a) preparing land for irrigated planting (b) and cultivation of banana (c) and cereal crops (d) along the Tekeze riversides of KSNP (photo by Fitsum Temesgen, 2018 to 2019)

In addition to community pressure on natural resources, civil wars and border conflicts are other additional factors influencing the natural resources of Ethiopia. According to the household, group discussion, and interviews, the 1998/99 Ethio-Eritrea war predominantly destroyed the socioeconomic features of the Tigray region, including the uncounted vegetation and wildlife resources in and around the KSNP. During the war period, the military mechanization of the Eritrean troops crossed the park area and destroyed natural resources. This report is consistent with the Syrian conflict (2011 to 2018) and significantly influenced environmental resources

(Mohamed et al., 2020). Similarly, the civil war of Sri Lanka (1983 to 2009) affected forest reserves and generally PAs in the country (Rathnayake et al., 2020). The civil war of Sierra Leone (1991-2002) caused the shrinkage of the Kono district forest cover of the area (Wilson and Wilson, 2012).

5.1.5 Implications of LULC change for KSNP sustainability

Understanding and evaluating the spatial and temporal LULC changes in natural vegetation inside and outside the KSNP and the negative contributions of the local community to these changes is important. According to the classified images, changes were detected in different land cover classes in 1988, 1998, 2008, and 2018, which indicated that dominant woodland and riparian forest had transformed into cultivated land, grazing land, and bare land, respectively. As a consequence, the land surface was left with scattered vegetation and bare ground, which immediately showed how the natural vegetation (i.e., plant biodiversity) was lost over time and limited the habitat range for wildlife. Moreover, the change in the woodland area expanded into cropland, leading to encroachment of African elephant habitat and creating major challenges for free movement and foraging activities.

Similarly, the household, FGD, and key informant interview confirmed that the range of wildlife before 30 years of age was anywhere in the park area. Recently, suitable habitats for wildlife have contracted in specific areas of the park because cropland expansion coupled with the extinguishment of illegal fires has increased over time. Second, the encroachment of livestock, fuelwood collectors, and traditional gold miners led to disturbance and displaced wildlife from the long-existing habitat shifted to new habitat. The increasing demand of local communities for irrigated crop cultivation, livestock grazing, and other resource utilization were obstacles to wildlife movement and access to water, especially during the dry season. Such activities increased the conflict between wildlife/elephants and humans (HWC/HEC). Moreover, the conversion of the riparian forest to farmland (irrigated area) around water points is the immediate cause of wildlife free movement and blocks water access. Wildlife is also forced to migrate outside the park boundary. An inline study revealed that LULC changes reduced biodiversity (Ellis, 2006). Similarly, in Ethiopia, LULC change was reported to be an indication of plant species decline and wildlife habitat degradation (Asmame & Abegaz, 2017). A study in PAs of Mexico also indicated that a reduction in temperate and tropical vegetation cover damaged the overall biodiversity of the site (Sancheza Reyes et al., 2017). Farmland expansion as the cost of forest in Bale Mountain National Park led to increased habitat fragmentation and reduced size of available key areas for the endemic wildlife species (Muhammed & Elias, 2021). The expansion of cropland influences elephant habitats and increases the pressure for competition for resources between humans and elephants (Workeneh & Kassaw, 2019). The decline in woody savanna in Tarangire National Park was an indication of a risk to wildlife protection (Mtui et al., 2017).

5.2 Woody species structure and regeneration (Objective-2)

5.2.1 Diversity, density, and frequency distribution of plant species

Diversity: A high diversity index value shows low vegetation site disturbance while a low index value indicates high disturbance on the vegetation site structure of the specific areas (Atsbha et al., 2019). In KSNP, the Acacia commiphora (AC) vegetation site is relatively recorded with both higher species richness and diversity index than the Combretum terminalia (CT) and riparian (R) vegetation sites. This indicates repeated habitat disturbance in the CT and R vegetation sites due to frequent and intensive interference of humans and livestock grazing. The decline of species diversity in CT vegetation site could be a result of woodland destruction for crop production and loss of seedlings of some species unable to establish at an early stage of development and trampling by livestock. The R vegetation diversity decline might be due to forest destruction by fire for irrigated planting in KSNP. The comulative Shannon-Wiener diversity index (H'=3.2) and evenness (J=0.77) in KSNP are comparable to other Ethiopian forests. Yemrehane Kirstos Church: H'=2.88, J=0.79 (Ayanaw & Dalle, 2018); Tara Gedam*:* H' = 2.98, J=0.65 (Zegeye et al., 2011); Doshke: H'=3.04, J=0.85 (Sebsbe et al., 2018); Grat-Kahsu protected dry natural vegetation of Tigray region: H'=2.29, J=0.80 (Atsbha et al., 2019), and H'=2.4: (Mligo, 2015). The Shannon-Wiener diversity index is considered as high (H' $\geq$3.0), medium (H'=2.0-3.0), low (1.0-2.0), and very low (H' $\leq$ 1.0) (Cavalcanti and Larrazabal, 2004). Kent and Coker, (1992) also reported that most of the time the value of H' is in the interval of 1.5 to 3.5 rarely exceeds 4.5. Similarly, H' above 2 is considered as the vegetation site has a reasonable diversity (Barbour et al., 1987). A low equitability/evenness index indicates the dominance of one or few species in a vegetation site whereas high evenness shows that uniform distribution of species in vegetation sites as supported by Cavalcanti and Larrazabal, (2004).

Density: The total density of woody species in this study was 466 ± 12.8 ha^{-1} (64 species), which is lower than that of Kahtasa forest:505 stems ha^{-1} (Gebeyehu et al., 2019); Church forest:506.6 stems ha^{-1} (Ayanaw & Dalle, 2018); Babile Elephant Sanctuary: 1319 stems ha^{-1} (67 species) (Belayneh et al., 2011); Nechisar National Park: 887 stems ha^{-1} (118 species) (Shimelse et al., 2010); and Wof-Washa forest: 698.8 stems ha^{-1} (Fisaha et al., 2013) in Ethiopia and other dry tropical forest: 515 stems ha^{-1} (Chauhan et al., 2008a) and 537.3 ± 74.8 stems ha^{-1} (Maua et al., 2020). The density of tree species variation in forests has been reported to be due to variations in species composition, age structure (Ademoh et al., 2017), and the degree of disturbance (Sharma and Chaudhry, 2018). *Acacia mellifera, Combretum hartmannianum*, *Terminalia brownii*, *Combretum molle, Balanites aegyptiaca*, *Acacia oerfota*, *Boswellia papyrifera*, *Acacia senegal*, and *Dicrostachy scinerea* occupied more than 50% of the total stem density, and these species had relatively higher seedling and sapling densities in the study area. Moreover, these species are likely resistant to drought and disturbance (Berhanu et al., 2017). The absence of seedlings in some of the canopy trees of *Sterculia africana* and *Adansonia digitata was* attributed to disturbance and habitat unsuitability. In Ethiopia Church Forest, Wassie et al. (2009) revealed that disturbances play a significant role in reducing the population of the woody species.

Frequency: The frequency contributes to indicating the homogeneity and heterogeneity of vegetation for a given species (Zegeye et al., 2005). The study site has high species heterogeneity because of the greater percentage of species found in the lower-frequency class than in the higher-frequency class. According to Burju et al. (2013), low values at lower frequencies and high values at higher frequencies indicate similar species compositions. In contrast, a low percentage of species in the higher frequency classes reported a high degree of floristic heterogeneity (Ayanaw and Dalle, 2018; Dibaba et al., 2014; Shibru and Balcha, 2004). The variation in density and frequency between species may be attributed to habitat differences, habitat preferences among the species, species characteristics for adaptation, degree of exploitation, and conditions for regeneration (Zegeye et al., 2011).

5.2.2 Basal area of trees and shrubs

The basal area of all woody vegetation in the KSNP (79.3 m^2 ha^{-1}) is much greater than that in the dry land forest areas of Ethiopia and other regions. Nechisar National Park: 49.45 m^2 ha^{-1} (Shimelse et al., 2010), Babile elephant sanctuary:17.8 m^2 ha^{-1} (Belayneh et al., 2011), Grat

Kahsu, Tigray region: 8.25 m^2 ha^{-1} (Atsbha et al., 2019), Ecuador-Peru, deciduous forest: 3.7-37.71 m^2 ha^{-1} and Semideciduous forest: 3.45-56.72 m^2 ha^{-1} (Ortiz et al., 2019), South Nandi Forest: 26.8 ± 12.0 m^2 ha^{-1} (Maua et al., 2020), Wof Washa Forest: 55.9 m^2 ha^{-1} (Yirga et al., 2019); Church forest, Ethiopia: 72 m^2 ha^{-1} (Ayanaw & Dalle, 2018); virgin tropical forests in Africa: 23-37 m^2 ha^{-1} (Lamprecht, 1989), Jibat: 59.79m^2 ha^{-1} (Burju et al., 2013); woodlands of Metema: 42.54 m^2 ha^{-1} (Adamu et al., 2012).

The highest basal area of the individual tree species in the KSNP was contributed by *Adansonia digitata* (35.5 m^2 ha^{-1}), while the highest density was attributed to *Acacia mellifera* species (69.7 individuals ha^{-1}). This indicates that species with the highest basal area do not necessarily have the highest density, and the vi-versa is also true. This indicated that size differences between species are common in natural vegetation (Shibru & Balcha, 2004). Based on the regression analysis, the basal area exhibited a relatively greater value at lower altitudes. The probable reason was water access in the riverine forest and good conservation practices at the Acacia Commiphora site (lower altitude). Moreover, the selective cutting of trees is increasingly common in Combretum terminalia strata (i.e., relatively higher altitudes).

5.2.3 Importance Value Index (IVI)

Based on the vegetation ecology explanation, the importance value index (IVI) under a low or negligible vegetation disturbance is useful for determining the ecological significance of species (Lamprecht, 1989) and the degree of dominance and abundance of a given species about the other species in the area (Kent and Coker, 1992). Thirty percent of the woody species in the KSNP had an importance value index (IVI) of one or less, which was categorized under the rarest list species. *Maytenus senegallensis*, *Acacia albida*, *Jasminum abyssinicum*, *Salvadora persica*, *Ziziphus mauritiana,* and *Feretia apodanthera* were some of the least important species in the KSNP. The anthropogenic disturbances that are directly leading to the LULC change and its drivers are extensively increased inside and outside the park vegetation. Moreover, within thirty years, the conversion of woodland and riparian vegetation to cropland gradually increased in the park. Consequently, a significant number of plant species with a low value of IVI was recorded. This might be due to prolonged human interference on the vegetation of KSNP. Human disturbances could continue a challenge to determine and rank the real ecological significance nature of individual plant species and further discussion of the status of the park IVI.

Contradict to our result; the least important plant species (i.e., IVI) are usually common in open woodlands and savanna ecosystems (Hedberg and Hedberg, 2003). The IVI can be used to prioritize species for conservation, and species with a high IVI need less conservation effort, whereas those with a low IVI need greater conservation effort. The lowest IVI may indicate that woody species are threatened and need immediate conservation (Belayneh et al., 2011). Likewise, species with the lowest IVI and poor/none regeneration status in a given forest need to be prioritized for conservation (Zegeye et al., 2011).

5.2.4 Population structure and regeneration status of trees and shrubs

The diameter at breast height (DBH) and height are important indicators of forest reproduction and health status (Schulz et al., 2009). In general, the Park Forest species diameter exhibited an inverted J-shaped distribution, where species frequently had the highest frequency in the low-diameter class and a gradual decrease toward the higher class. The inverted J-shaped pattern reflects a normal population structure and indicates the existence of species under healthier conditions. However, the general pattern does not clearly show trends in population dynamics or recruitment processes for individual species (Gebeyehu et al., 2019; Dibaba et al., 2014). Seven discontinuous patterns (with the complete absence of individuals in some classes and fairly representative of individuals in other classes) were shown in the KSNP forest. Irregular (discontinuous) distribution patterns have been reported in Ethiopia (Terefe & Gure, 2019; Adamu et al., 2012; Tesfaye et al., 2002).

The regeneration status of KSNP was predominantly considered ‘not’ regenerating. The regeneration status of natural vegetation is considered to be not regenerative if a species is absent both in the sapling and seedling stages but is present as a mature tree/shrub (Tiwari et al., 2010; Dhaulkhandi et al., 2008). The regeneration and mature conditions of woody species are among the major factors that are useful for assessing their conservation status (Taye et al., 2002). The population structure, characterized by the presence of a sufficient population of seedlings, saplings, and adults, indicates the successful regeneration of forest species (Malik and Bhatt, 2016). In contrast, tree species that have no seedlings or saplings exhibit discontinuous population structures (Gebeyehu et al., 2019). The “poor” and “not” regenerating categories, which constitute 81.25% of the woody plants in the KSNP, include many useful tree species.

Sterculia africana, *Acacia seyal*, *Adansonia digitata*, *Burkea africana*, and *Grewia flavescens* are sources of food for African elephants (*Loxodonta africana* L.). The "poor" and "not" regenerating categories of woody species were reported in the Berbere forest (32.26%) (Bogale et al., 2017), Grat Kahsu dry land forest (26.56%) (Atsbha et al., 2019), and Wof-Washa forest (48%) (Fisaha et al., 2013). Even in a temperate mixed forest, 15% of the species did not regenerate (Paul et al., 2019). Most of the time "poor" and "not regenerating" plant species might be caused by overgrazing (Norden et al., 2011; Kuijper et al., 2010; Birhane et al., 2007), fuelwood collection, fire, mining, and poor biotic potential of tree species, which can affect either seed germination or successful conversion of seedlings to the sapling stage (Gebeyehu et al., 2019; Terefe & Gure, 2019; Zegeye et al., 2011; Ceccon et al., 2006). Young individuals of a plant species are more vulnerable to environmental stress or human disturbance activities (Maua et al., 2020).

5.2.5 Human disturbances impact on tree regeneration

The density of seedlings, saplings, and mature woody tree/shrub species was significantly correlated with altitude. However, the correlation between altitude and seedling/mature trees/ shrubs was weakly negative, while that between altitude and saplings was weakly positive. This is due to the multiple human factors influencing the natural regeneration of the KSNP forest. The main observed factors were livestock grazing, human-induced fire, and gold mining.

Livestock grazing is significantly associated with the density of seedlings, saplings, and mature trees. Grazing affects the regeneration status of vegetation by breaking adult plant shoots and leaves. Cattle foot crushing and sheep and goat browsing had damage to seedlings, saplings, and herbaceous plants (Figure 29a & b). Livestock grazing may also affect the regeneration of tree species in the open flat dry land forests of the KSNP. Grazing is an important predictor of plant regeneration in different dry forests of Ethiopia: deforestation and livestock pressure in Desa'a forests in the Tigray region have hindered the regeneration of shade-loving tree species (Aynekulu et al., 2009). Intensive browsing by free-grazing animals in open dry areas of the Tigray region damages young plants (Birhane et al., 2007) and the establishment of seedlings (Wassie et al., 2009). The duration of livestock (eight months per year) in the Desa'a Forest increased the destruction of vegetation structure and regeneration (Giday et al., 2018). Thus, livestock-free grazing throughout the year alters the density of seedlings (Guo Ruo et al., 2018).

Livestock browsing of vegetation can prevent the growth of new plants (Ortiz et al., 2019) and affect the densities of seedlings and saplings (Norden et al., 2011; Kuijper et al., 2010).

Human-induced fires for farm expansion damaged the structural regeneration of the stands of the species in the study area (Figure 29(c)). The densities of the seedlings and saplings were negatively correlated with fire. Continuous fires led to farm expansion because the cost of heavy forest removal reduced the number of seeds and the emergence of seasonal herbaceous species. Fire generally kills woody plant seedlings and saplings because the regenerating plants are small and lack strong physical protection, such as thick bark, against fire. In Ethiopia, reports related to the impacts of fire were limited; however, Gebreegziabher (1999) stated that fire was major damage to the Desa'a forest in southern Tigray, where 350 ha of forestland was destroyed in 1998. However, research on the influence of fire on woody vegetation regeneration in Ethiopia is still scarce, and several studies have shown that fire in world tropical forests increases young tree death and degrades the forest structure. For example, in an Amazonian forest, fires reduce the composition and change the structure of seedlings and saplings (Prestes et al., 2020). It also kills immature plant species (Xaud et al., 2013), reducing the abundance and richness of seedlings and saplings by killing them (Verma et al., 2017; Oliveira et al., 2014; Balch et al., 2011).

Moreover, gold mining via digging the vertical soil profile of the park was another human-induced factor in the KSNP (Figure 29(d)). In addition to uprooting plant roots, traditional gold mining also has a contribution to extinguishing fires in forest areas by gold miners to prepare their daily food. However, traditional gold mining was shown at the plot level & disturbed the woodland forest; statistically, there was no significant correlation between gold mining and the density of the seedlings and saplings. There have been few/no previous studies related to the impacts of traditional gold mining on plant regeneration, except for the negative impact of gold mining on the wildlife habitat in Kafta Sheraro National Park (Berihun et al., 2016).

The structural attributes of the stem density of trees are another internal influence on the regeneration of species. In the present study, the density of mature trees had a significant effect on the regeneration population (seedlings and saplings) experiencing high competition from adult trees, causing a strong negative effect on the survival of seedlings and saplings. These results are in agreement with those obtained for tropical forests (Mohammadi et al., 2017).

Resource competitive interactions among plant species determine the regeneration process of the species (Norden et al., 2011).

Figure 29. Photographs showing human disturbances inside KSNP Forest: Livestock browsing and grazing (a & b); human-induced fire influence in *Boswellia papyrifera*-dominant site (**c**); traditional gold mining (d)

5.3 Elephant dietary preferences (objective-3)

5.3.1 Plant species composition and selection/preferences

A study in Kafta Sheraro National Park (KSNP) confirmed that elephants foraged on a diverse range of plants with 59 recorded plant species (47 wild and 12 cultivated). However, in some studies, no comparable work has been done on the free-range of elephants. In Ethiopia, 59 plant species excluding crops (Biru & Bekele, 2012); 109 species including crops (Tsegaye et al., 2022); and in Campo-Ma'an National Park, Cameroon, 87 species (Djoko et al., 2022) were recorded. In Rubondo Island National Park, 20 species (Mwambola et al., 2014), Chobe National Park, 27 species (Owen-Smith and Chafota, 2012); Kruger National Park, 98 species (Viljoen et al., 2013); and Subtropical Thicket, 146 species (Kerley & Landman, 2006) of woody plants browsed by elephants (noted: all studies excluded grasses, herbs, and crops) in the diet of elephants. Therefore, the large difference in elephant diet composition among the study areas is probably due to the variation in plant species richness and diversity, which is consistent with the elephant food comprising 95 plant species in a more diverse woody savanna and mosaic vegetation of Mozambique (De Boer et al., 2000). The results are probably due to differences in sampling methods, sampling areas, variation in the vegetation conservation status of the areas (i.e., disturbed and undisturbed vegetation), composition, and duration of the study (Djoko et al., 2022; Mwambola et al., 2014).

Food selections have shown that elephants have a definite selection for certain woody plant species and reject others (Cardoso et al., 2020; Koirala et al., 2016; Viljoen et al., 2013; Owen-Smith & Chafota, 2012). In the KSNP, elephants demonstrated high to low preferences or total avoidance of different plant species. Elephants selected common and frequent plants such as *Acacia mellifera*, *Balanites aegyptiaca*, *Acacia oerfota*, *Dicrostachy scinerea*, *Acacia senegal*, and *Hyphaene thebaica*; however, *Sterculia africana*, *Acacia seyal*, *Adansonia digitata*, and *Burkea africana* are less common species (i.e., low occurrence/availability relative to other species) in the KSNP that are important in the diet of elephants. On the other hand, commonly abundant species of the park, such as *Combretum hartmannianum*, *Boswellia papyrifera*, and *Casuarina equisetifolia*, were among the woody species rejected by elephants in all seasons despite their high natural availability in the park. Even common species such as *Terminalia brownii*, *Combretum molle*, and *Anogeissus leiocarpus* were less preferred for elephant foraging activities. Consequently, the relative availability of plants and elephant feed preferences in the KSNP were not correlated ($p>0.05$). This finding indicated that food selection by elephants is not directly driven by the availability of plants in the environment/park but rather by elephant species specific choices (Koirala et al., 2016; Raubenheimer, 2011). Acacia species are commonly utilized by elephants during both the dry and wet seasons. This was due to the wide and dominant distribution of acacia species relative to other species in the park during the study period. Similarly, findings in Ethiopia PA (Biru & Bekele, 2012), and Zakouma National Park, Chad (Calenge et al., 2002), acacia species are commonly selected by elephants despite their relatively wide distribution in these parks. Moreover, the high water content of the stems/barks of the species during the dry season (Parker et al., 2003) may also explain the greater consumption of these plants.

The seasonal elephant crop raiding in the KSNP resulted in the consumption of twelve common crops. This is mainly due to the expansion of human resettlement adjacent to the park. For many years, natural habitats have been converted into croplands at an alarming rate to provide food for humans (Osborn & Hill, 2005; Woodroffe et al., 2005). In many parts of the world, wild animal crop raiding has an important impact on wildlife management or conservation and human livelihoods (Branco et al., 2019). Accordingly, the presence and expansion of croplands can significantly change the foraging behavior of herbivores (Fox & Abraham, 2017). In Africa, when elephant habitats are shrinking, food availability and selections control elephant movement, which leads to conflicts between humans and wildlife/elephants (Rode et al., 2006). In Ethiopia, HWC, particularly with elephants, is a serious problem that is caused predominantly by the overlapping space distribution of human socioeconomic activities and elephant distribution (Eshetu et al., 2019). Knowledge of elephant seasonal food availability and habits is important for minimizing and developing mitigation strategies for the negative impact of conflicts between humans and elephants (HEC) (Koirala et al., 2016).

5.3.2 Season and plant parts variation on elephant diets

African elephant diets include both grass and woody plant species (Kerley & Landman, 2006); however, food selection varies with the season (Marston et al., 2020; Ashiagbor & Danquah, 2017). In the present study, the results revealed that browsing woody vegetation was the dominant component of the elephant diet, in which little consumption of herbs and grasses occurred during the wet season while browsing woody plant species occurred during the dry season only; these findings are consistent with previous studies on African elephants (Shannon et al., 2013; Cerling et al., 2006) and Asian elephants (Koirala et al., 2016; Mohapatra et al., 2013). Elephants spend more time utilizing on browsing than on grazing species year round (Schwarz et al., 2020; Campos-Arceiz et al., 2008; Chen et al., 2006; Himmelsbach et al., 2006). In terms of the individual plant species, *Acacia mellifera* and *Balanites aegyptiaca* made the greatest dietary contributions to the elephant food throughout the year but were consumed more during the dry season, while *Acacia oerfota was* utilized more in the wet season. However, *Dicrostachys scinerea* contributed similarly in both the wet and dry seasons. Moreover, there was a high food contribution of *Hyphaene thebaica* in the dry season but very low consumption during the wet season, while *Adansonia digitata* was consumed more during the dry season but was only slightly utilized or absent in the wet season. In contrast, *Terminalia brownii*, *Ziziphus spina-christi*, and *Sterculia africana* contributed relatively more to the wet season; however, their use was very low during the dry season.

Seasonal movement and forage utilization by elephants is the major source of conflict with cropland. Elephants in the wet season migrate to favored natural habitats bounded by farmland. In the dry season, most of the woody plant species in the present study shade their leaves and dry seasonally, as this area is found in dry lowland environments. This might have created an elephant population concentrated along the Tekeze River, which is dominated by riverine forests and irrigated crops. Similarly, in the dry season, human-wildlife conflict (HWC) is pronounced around water points because African elephants depend on water; therefore, their foraging activities are close to those of rivers (Chamaille-Jammes et al., 2007; De beer et al., 2006; Gaylard et al., 2003; Redfern et al., 2003).

The proportions of different plant parts contributed to the entire wet and dry season (Figure 24). Elephant food selections differ for leaves, stems, fruits, bark, and other parts of woody and herbaceous species. Branches, including the leaves of grasses and herbs, were eaten more often than other parts of the plants in the wet season, while woody stems and bark dominated the dry season elephant diet. The food contribution of leaves in the wet season was 85.1%, and this was substituted by 93.6% of the bark and fruits during the dry season. The present result is consistent that the diet of forest elephants relies mostly on leaves and fruits during the wet season, whereas it relies mostly on bark during the dry season (Djoko et al., 2022). On the other hand, increased consumption of bark from many species in the dry season might be associated with moisture and resource limitations/the unavailability of alternative elephant food (Pradhan et al., 2008). In our study (i.e., KSNP), *Adansonia digitata* was the most important woody plant and had a high moisture content (soft and succulent stem) relative to other plant species on its bark, which consequently led to elephants strongly preferring bark during the dry season. In Chobe National

Park and Kasane Forest Reserve, the food intake of elephants shifted from 80% of leaves in the wet season to 94% of bark, and roots during the hot late dry season (Owen-Smith & Chafota, 2012). The time of year is another important factor in determining intense bark consumption by elephants, and studies have indicated that much bark utilization occurs toward the end of the dry season (Seloana et al., 2018; Mohapatra et al., 2013; O'Connor et al., 2007). This finding is consistent with the present study (i.e., in the KSNP), which included the late dry months of March, April, and May, during which high bark utilization was observed. However, after the rain started, the elephants expanded their foraging out of the park, which contributed to the observed low bark consumption in the early wet months from June to September.

5.3.3 Utilization effect of elephant on vegetation

Elephants in the KSNP utilized mature stems of a woody plant species relatively more selective than seedlings and saplings (regeneration stages), which indicates that there were specific stem size utilization selections. The variation in elephant utilization among tree developmental stages was probably due to the greater availability of mature stems, which are more abundant in the area and strongly selected than regeneration stems. According to the results of objective 2 (Figure 18 and Table 17), most of the woody species of KSNP exhibited ''poor'' regeneration (7.8%) and ''not'' regenerating (73.45%). The regeneration status of the park woody species was dominantly considered 'not' regenerating status: mature (88.76%) > saplings (9.22%) > seedlings (2.02%). Among the total examined elephant utilization species only *Acacia mellifera*, *Acacia oerfota*, *Acacia polyacantha*, *Balanites aegyptiaca*, *Acacia senegal*, *Dicrostachys cinerea*, *Hyphaene thebaica*, *Terminalia brownii*, and *Ziziphus spina-christi* exhibited "fair" regeneration, while *Dalbergia melanoxylon*, *Acacia seyal*, *Grewia villosa*, and *Combretum molle* exhibited "poor" regeneration and the majority of the species exhibited "not" regenerating. In a similar study in Africa, elephants were less favored or even completely rejected stems in the sapling stage (Owen-Smith and Chafota, 2012). Elephants do not browse all species equally and show a strong selection for some species, while rejecting others (Cardoso et al., 2020; Owen-Smith and Chafota, 2012). The African elephants in our study (i.e., KSNP) were selected to browse at the height of matured stems (2.0-4.0 m), which is similar to that of forest elephants who browse at a height of 3.0-4.0 m (Cardoso et al., 2020) and savanna elephants, which consume stems > 2 m (Morrison et al., 2015). However, this study showed that African elephants had no detectable effect on the species composition or diversity of the park, most likely because the population size of the elephant was small. Generally, damage to mature trees by elephants may be even less severe than expected consequently, the overall damage to plant stems in the KSNP was relatively not a serious issue. Similarly, in Lope National Park, elephants were found to be selective browsers, but their browsing was non-destructive and had little effect on stem size demography (Cardoso et al., 2020).

5.4 Human-elephant interaction & community attitudes toward conservation (Objective-4)

5.4.1 Human-elephant conflict (elephant crop raiding)

Most respondents in our study complained that the trend and level of human-elephant conflict (HEC) i.e., elephant crop damage increased during the last ten years. Traditional gold extraction, charcoal production, and grazing impacts on elephant conservation and sources of interactions between humans and elephants have been reported in the KSNP (Mesfin et al., 2021; Berihun et al., 2016). The community near the KSNP gained several natural resources from the park, such as fuelwood, grazing areas, income sources (gold and resin), and house construction materials. Similarly, natural resource utilization by communities adjacent PAs has been reported in Ethiopia (Kiros & Bekele, 2021; Eshetu et al., 2019; Megaze et al., 2017b; Reddy and Workeneh, 2014). The availability and scarcity of forest products in and outside PAs influence the attitudes of residents toward the protection of natural resources (Kideghesho et al., 2007). Due to population growth and increased demand for food, significant amounts of natural habitats are rapidly being converted to croplands leading to elephant crop damage (Branco et al., 2019). Human-elephant conflict (HEC) also creates a challenge for conservation practices, decreases residents' positive attitudes toward elephants (Abdullah et al., 2019; Talukdar and Choudhury et al., 2020), and increases the economic instability of the community (Webber et al., 2011).

Based on field observations and household interviews, maize (*Zea mays*) and sorghum (*Sorghum bicolor*) were reported to be the most selected and susceptible crops by African bush elephants. Based on the respondents' suggestions and attentive field observations, these crops have a wide distribution and high acceptance by elephants. The frequency of crop raiding was seasonal and appeared to be proportional to crop availability. The attractiveness and vulnerability of different crop types to elephants have been reported in different areas of Ethiopia and other African regions. Wheat and maize in Kenya (Mukeka et al., 2019); maize (82%) and finger millet in Tanzania (Mmbaga et al., 2017c); maize and sorghum in Tanzania and Zimbabwe (Mwakatobe et al., 2014); maize in Kamuka National Park, Nigeria (Ogunjobi et al., 2018); and cocoa and maize in Ghana (Harich et al., 2013) were the most elephant-targeted crops. Similarly, the crops frequently raided by Asian elephants include banana, cassava, sugarcane, and papaya (Webber et al., 2011) and rice, maize, and wheat (Neupane et al., 2017).

5.4.2 Determinant factors and prevention measures for elephant crop raiding

Location of agricultural field and distance between settlements and park: Human-wildlife conflict (HWC) is a pronounced issue in many African countries in which local communities live at boundaries/adjacent PAs (Angwenyi et al., 2021; Mukeka et al., 2019; Mmbaga et al., 2017c; Sitienei et al., 2014). The present study indicated that households living in proximity to KSNP and their farmland inside and/or at the boundary of the park were more influenced by wildlife/elephant crop damage and had great complaints about elephant-induced crop damage. In our study, kebeles (villages), such as Adebay, Freselam, Wuhedet, and Myweyni, which are characterized by high levels of elephant crop damage (i.e., above 60%), were observed because elephants were visited more frequently in these areas, and their farms are in proximity to the park boundary. Moreover, the local communities of these kebeles are located nearest to the KSNP, and most of their crops are found inside and across the border of the park area, which is 6.5-9.5 km away. Similar findings were reported in Ethiopia (Megaze et al., 2017a; Biset et al., 2019; Kebede et al., 2016), Tanzania (Kiffner et al., 2021; Holmern et al., 2007), Kenya (Long et al., 2020), Nigeria (Ogunjobi et al., 2018); Gabon (Terada et al., 2021), Ghana (Monney et al., 2010; Barnes et al., 2005), Serengeti National Park (Mwakatobe et al., 2014), and Blanc et al. (2007) who showed that the proximity of settlements or crop fields to PAs increases elephant and other wildlife crop damage incidents. In contrast, local communities living relatively far from the park boundary were less affected by elephant crop damage.

Seasonal and daily patterns of elephant crop raiding: Elephant crop raiding follows both seasonal and daily temporal patterns (Terada et al., 2021; Mmbaga et al., 2017c). In the present study, elephant crop raiding varied seasonally because the rainfall in the area is seasonal and controls the quantity of food and water availability. According to household responses and field observations, crop damage in the KSNP was greater during the late wet season between

September and November for seasonal crops (i.e., when rainfall terminated). These results are in line with those of a previous study in which crop raiding cases peaked after the wet season, as wild animals could attract mature crops, as reported in Kenya (Mukeka et al., 2019; Sitienei et al., 2014) and Tanzania (Mmbaga et al., 2017c). Similarly, in a study in Namibia, crop raiding occurred as crops ripened toward the end of the rainy season (Von Gerhardt et al., 2014). The probable reason for this difference in incidence in our study was that elephant crop raiding is related to the phenology of crop plants (crop maturity and harvesting time), particularly when they are most nutritious to them during the late wet season. In addition, as the wet season progresses and water becomes more readily available in all areas of the park, elephant populations are widely dispersed inside and outside the park. However, during the dry season, when water scarcity is very high, elephant concentrations are high near the water points of the KSNP (i.e., Tekeze River). During the dry season, the difference in availability between field crops and natural fodder greatly increased. Elephant crop raiding (60.51%) in this study took place during the night. As in our study, 95% of crop damage caused by elephants occurred during the night and early morning (Mmbaga et al., 2017c). A study in the Transmara district, Kenya, indicated that almost all elephant crop attack occurred during hours of darkness (Sitati et al., 2005). Crop visit by elephant occurs frequently at night (Terada et al., 2021; Kamau, 2017; Neupane et al., 2013; Graham et al., 2010); on the other hand, in Nigeria, elephant crop raiding was common during the early morning (Ogunjobi et al., 2018).

Local prevention and control measures for elephant crop raiding: The residents in the present study applied different traditional control methods to prevent elephant crop damage. Gun sounds and banging noise materials (beating drums and cans), lighting fires and flashlights, alternative crop cultivation, and physical barrier construction were some of the prevention methods. A consistent report by Mmbaga et al. (2017c) indicated that audio instruments such as shouting, banging on iron sheets, tins, drums whistles and night visual tools (e.g., lighting fires, torch lights) were used by residents around Rombo, Tanzania, as elephant repellents against attacking crop fields. Night burning fires, loud noises, and banging tin and drums combined with guarding efforts increased farmers' capacity to prevent elephant crop raiding (Sitati et al., 2005). Physical barriers in Myanmar (Sampson et al., 2019) and patrolling in China (Su et al., 2020) were the most preferable prevention measures for crop damage caused by elephants. Changes in land use practices (e.g., growing alternative crops) were suggested by Nepal residents to reduce HEC

(Neupane et al., 2017). However, for larger wildlife (such as elephants), manual guarding was the best controlling mechanism for preventing crop damage (Megaze et al., 2017a). Moreover, in other areas, the cultivation of less preferred crops by elephants, such as pepper (*Capsicum annuum*), is common for minimizing elephant crop raiding (Monney et al., 2010; Webber et al., 2011; Parker and Osborn, 2006). In our study (i.e., inside and outside the KSNP), elephants favored many crops above others and avoided certain crops almost entirely (e.g., sesame and cotton). The respondents in the study area had different views on the effectiveness of elephant crop damage control methods. They suggested that guarding together with noise, lighting fires and flashlight methods are effective at preventing elephant-induced damage. However, physical barriers such as the use of locally available materials to fence their croplands were less effective, as elephants were easily able to break through the fences. However, in the present study, this method was difficult to apply for producers who had large farm sizes.

5.4.3 Human-elephant conflict in changing LULC

The conversion of woodland to cropland inside and adjacent to KSNP disturbs the suitable habitat for elephants. Both the LULC change and HEC maps revealed that in three decades (1988 to 2018) cropland (seasonal and irrigated crops) increased by 118.36 km^2. The establishment of croplands was the product of human-induced LULC change and the existence of elephant crop damage in these occupied areas provided evidence that a strong relationship exists between HEC and LULC change. The communities around KSNP depend on park natural resources such as grass, fuelwood, gold mining, resin collection, and other associated benefits. The relationship between LULC change and HEC has been broadly reported in different areas. The expansion of settlements and farming activities in and around PAs increased wildlife crop damage in Ethiopia (Kiros & Bekele, 2021) and Kenya (Mukeka et al., 2019). Residents near forest areas rely on resources from PAs and the expansion of settlement and the conversion of forests to cropland adjacent PAs have increased negative interactions between humans and elephants leading to increased HEC (Billah et al., 2021); croplands and settlements were key areas for HEC (Nad et al., 2022); and increasing cropland use on the boundary of a PA in South Africa poses a source of conflict (Bailey et al., 2016). Human-elephant conflict (HEC) has been observed in many places by various human-induced LULC activities. In Africa and Asia, HEC increased in parallel with the expansion of croplands (Bal et al., 2011; Sitati et al., 2003). Changes in LULC due to the expansion of farmland were the main driver of HWC (Long et al., 2020). Land use/land cover (LULC) changes directly associated with wildlife habitat destruction, degradation, and the blockage of wildlife passages are sources of conflict (Gordon, 2009). Human encroachment into wildlife habitats increased, while the reduction in wildlife space and key areas has led to increased HWC (Okello et al., 2011). The existence and expansion of cropland, settlements, and infrastructure destroyed the elephant habitat and led to HEC (Mmbaga et al., 2017a, b & c). Land cover change predominantly impacts wildlife paths, natural habitats, and the accessibility of food resources for wildlife (Billah et al., 2021). Conflicts have mostly occurred inside, outside, and along major riverine key areas of PAs in India (Naha et al., 2019). The increase in human settlements around PAs potentially increases cropland and other human activities along the edges of PAs damaging their ecological integrity (Bailey et al., 2016).

5.4.4 Knowledge/awareness of the community about the park

The present results showed that more than fifty percent of the respondents were aware of the conservation objectives and role of KSNP. The awareness of local communities was affected by age, sex, education level, settlement condition, and distance between settlements and parks. Male respondents had greater park conservation awareness than females; this might be because females have less contact and less participation in nature conservation and related community issues. The respondents age 22 to 39 years and 40 to 57 years had greater awareness of park conservation. Most of these individuals achieved formal education compared with the other age groups. The low level of awareness indicated by the age group above 58 years might be due to a low education level, as more than thirty percent of the respondents had not achieved formal education. Similar findings by Lyamuya et al. (2016) and Carter et al. (2013) revealed that age differences affect respondents' awareness and attitudes toward PA conservation.

The education level of the respondents also influenced their awareness, and those who had a formal education were more aware than those with informal education. The respondents with formal education took natural resources courses and probably also experienced variation in awareness due to their capacity to read different types of nature-related conservation books and newsletters. The positive impacts of education on PAs were reported by Hariohay et al. (2018) and Mutanga et al. (2015). The settlements of households in proximity to the KSNP border were more aware than those far from the park because this might be posed through continuous contact with the park that agreed with (Angwenyi et al., 2021; Bitanyi et al., 2012). The respondents who lived long-term were more aware of PA conservation because households who had lived there and whose livelihood depended on natural resources for a long period had more experience than those who lived short-term (resettlers). A study by Hariohay et al. (2018) revealed that residents living close to PAs and who lived long-term in the area were more aware than people living far from PAs and who lived short-term.

5.4.5 Local community attitudes toward KSNP and elephant conservation

The communities adjacent to the KSNP had both positive and negative perceptions toward the park and elephant conservation. Some of the communities had positive attitudes toward park and wildlife conservation despite the restriction of access to resources from the park. The negative perceptions of the communities were mainly caused by respondents not receiving any financial support from the park; having crops damaged by elephants, and having conflicts with park management. Generally, the communities agreed with most of the conservation statements that measured their perceptions. Our results concur with those of studies conducted on Ethiopian PAs (Kiros and Bekele, 2021; Biset et al., 2019; Megaze et al., 2017a; Kebede et al., 2016) and other African PAs (Ardiantiono et al., 2021; Abukari and Mwalyosi, 2018; Mutanga et al., 2015; Gandiwa et al., 2014), and they suggested that the communities had positive and negative perceptions on PAs and their existing wildlife conservation. In South Africa and Kenya, local communities had more positive attitudes toward PAs and wildlife/elephant conservation, even though restrictions on resource use (Angwenyi et al., 2021; Ochieng et al., 2021). In addition, people residing adjacent to PAs in Nepal had positive attitudes toward elephants, as they received economic benefits from ecotourism (Neupane et al., 2017). Residents around Chyulu Hills National Park, Kenya, oversee the park resources, consider their right to livelihood and oppose elephant and PA conservation (Kamau, 2017). The conflict between humans and wildlife in Botswana PA increases the negative attitudes of communities (Mogomotsi et al., 2020). Crop damage & production loss by elephants in adjacent communities in Gabon PA decreases the positive perception of the residents of conserving elephants (Terada et al., 2021). The negative attitude of a community toward wildlife might increase due to the tension between residents and PAs authorities, poor communication, a lack of community participation in conservation, and a lack of financial compensation for wildlife attacks on human property (Dickman, 2010).

Factors influencing community attitudes toward KSNP and elephant conservation: age, education level, distance between the settlement and park, awareness conditions, and trend of elephant crop damage significantly influenced the community attitude response toward the conservation of KSNP and elephants. The respondents age 22 to 39 years and 40 to 57 years had more positive attitudes toward KSNP and elephants than were those in advanced age groups (over 57 years). The decrease in positive attitudes with increasing age might occur because aged people had their cropland inside the park, which included livestock, and most of them did not attain formal education. Education positively influenced the attitudes of communities toward the conservation of PAs and wildlife (Rahman et al., 2017; Parker et al., 2014), who suggested that formal/highly educated respondents supported the establishment and conservation of PAs and wildlife. Community members with higher education levels had more positive attitudes toward PA conservation than those with lower education levels (Mutanga et al., 2015).

The distance between residences and KSNP had a significant effect on the attitudes of the respondents. The communities that lived far from the park had more positive attitudes than those that lived close to the KSNP because they had less interaction with wildlife/elephants. In this study, most respondents living in Adiaser and Aditsetser kebeles relatively far from the park boundary exhibited positive attitudes toward conservation. While, the majority of residents who lived in Adebay, Freselam, and Wuhedet kebeles close to the park border had negative attitudes. This directly reflects that residents experienced frequent crop damage by elephants, a lack of alternative income, and restricted access to park resources, which led to a negative attitude toward conservation as supported by Ochieng et al. (2021) and Abukari and Mwalyosi (2018). The main drivers of community negative attitudes toward conservation were households living close to the PA boundary, losses due to wild animals, and restricted access to natural resources (Guerbois et al., 2013). In contrast, residents' proximity to the PA border affects their attitude positively toward the conservation, because residents gain job opportunities from developmental projects, which make them less dependent on the resources of the PA (Deng et al., 2015). Residents who lived away from PAs were less aware of the importance of conservation than were those who lived close to PAs (Rahman et al., 2017).

Regarding the residents' location in the elephant protecting area and elephant crop damage experience, respondents who damaged their crops by elephants expressed more negative attitudes toward elephants. Similarly, residents in areas where dominant elephant crop damage exhibit more negative attitudes toward elephant conservation (Ardiantiono et al., 2021; Neupane et al., 2017). Elephant crop attacks have increased the tension between Way Kambas National Park and communities, especially for communities that experienced crop damage by elephants (Andyono et al., 2018; Oelrichs et al., 2016). Crop damage by wildlife has influenced the perceptions of communities toward conservation (Hariohay et al., 2018; Mir et al., 2015). The majority of residents who lived with wildlife had negative attitudes about wildlife, as HWC has been a serious issue in the area (Long et al., 2020). The presence of crop damage and no benefits gained from elephants provided negative attitudes of the communities about the conservation of elephants (Taruvinga & Mushunje, 2014). On the other hand, receiving benefits from ecotourism and conservation activities of elephants improves local communities' positive attitudes (Sarker and Røskaft, 2014). Most of the local people (86%) who lived 0-5 km from the Maasai Mara National Reserve had a positive attitude toward the conservation of PAs, due to receiving some kind of benefit, and they expected to share profit from the reserve in the future, regardless of the existing cases of crop damage (Mojo et al., 2018).

CHAPTER SIX

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

Over the past thirty years, Kafta Sheraro National Park (KSNP) has experienced significant changes in land use/land cover (LULC). The degradation of woodland and riparian vegetation has led to an increase in shrubland, sparse vegetation cover, cropland, and grazing land. A major change was observed from woodland to rain-fed cropland and from riparian vegetation to irrigated land. The greatest change occurred between 1998 and 2008 compared with 1988 to 1998 and 2008 to 2018 due to the high resettlement program around the park. Analysis based on the NDVI showed that the density of woodland and riverside vegetation decreased from 1988 to 2018, while that of nonvegetation increased. This gradual change in vegetation cover was driven by increasing human-induced pressure on woodland resources. The expansion of settlements, human-induced fires following cultivation, grazing, fuelwood collection, and gold mining were the major factors affecting changes in wildlife habitat. The increasing trends of LULC change influence wildlife habitats, as the area is known home to African bush elephants and other wild animals which leads to human-elephant conflict (HEC).

Human-elephant conflict (HEC) caused by crop damage has increased in and around KSNP over the past decade, presenting a conservation challenge. The observed increase in elephant crop attacks was associated with LULC changes mainly caused by the expansion of settlements and the conversion of woodlands to croplands. Crop damage peaked during the late wet season when crops were ready for harvesting. The crop damage increased as the area of residential farmland closed the PA boundary. The residents of the KSNP had both negative and positive attitudes toward the park and elephant conservation. A negative attitude was associated with restrictive access to the natural resources of the park, crop damage by elephants, and an absence of benefits from conservation activities. Education level, distance between residences and park, and degree of elephant crop damage were major factors that significantly affected residents’ attitudes toward the conservation of KSNP and elephants. Elephant conservation attitudes significantly varied with the distance between residences and park, where local communities living very close to PAs and with frequent elephant crop damage occurrences had more negative attitudes toward elephant conservation. On the other hand, residents who lived relatively far from the PA border had more positive conservation attitudes than those living near the PA border.

However, the gradual decrease in woodland coverage was very high, despite the presence of 70 woody plant species. The population structure of the most common species of trees and shrubs revealed irregular patterns, revealing high variation among species population dynamics within the woodland forest and indicating low regeneration conditions. The irregular patterns of the species indicated the absence of plant populations in various diameter classes. The regeneration status of the tree species in the KSNP was predominantly “not” regenerating (73.45%). *Dalbergia melanoxylon*, *Acacia seyal*, *Grewia villosa*, and *Combretum molle*, are poor regenerating woody species, while *Sterculia africana*, *Adansonia digitata*, *Burkea africana*, and *Grewia flavescens* were not regenerating species that are sources of food for African elephants. The variation in the population structure and regeneration status of the park is due to the presence of strong and prolonged human disturbances in all the resources of the park. The park's most ecologically and economically important woody species had poor regeneration status due to human-induced disturbances such as livestock browsing, grazing, fires, and traditional gold mining. These factors decrease the density of seedlings and saplings of common tree species, which are economically and ecologically important in the Park Forest.

Elephants in the KSNP utilized mature stems of a woody plant species more selective than seedlings and saplings because the majority of the species are not regenerating. A wide range of plant species and plant parts are utilized in the seasonal food of elephants inside and outside the park. The wet season diet of elephants comprises a greater proportion of the species composition and plant parts than does the dry season diet. In the KSNP, the browsing of woody plant species is the dominant component of the elephant diet in both the dry and the wet seasons. Elephants utilize more leaves/branches than other plant parts during the wet season, and a larger proportion of bark is consumed during the dry season. The utilization and variation in seasonal food is a major source of conflict with agriculture. There was no association between the availability of plants and preferences for elephants, which indicates that elephant food selection does not depend on the availability of plants in the park despite specific choices. The impact of elephant utilization on stem branch breakage was high, while the impact on whole stem uprooting/felling was low for >2 m tall mature stems. Elephants also utilized crops in the study area, which were sources of conflict between communities and elephants. Thus, identifying aspects of elephant foods is relevant for minimizing human-elephant conflict.

6.2 RECOMMENDATIONS

The livelihood of the community around the Kafta Sheraro National Park depends entirely on agriculture. To maintain the sustainability of the park and its surrounding natural resources, future work should focus on understanding the linkage of communities' livelihood with Natural resources status of the area. It is important to involve the community in conservation efforts and address illegal activities in and around the park. The residents in the park who had no legal land permit, which caused the uncontrolled expansion of cropland unless a legal land certificate should be secured for all households to minimize the illegal expansion of farming. Educating the community about wildlife and nature conservation is crucial, and establishing buffer zones can help maintain a positive coexistence between the park and local communities. Additionally, promoting ecotourism and offering alternative job opportunities can benefit both conservation activities and community livelihoods.

The regeneration status of woody plant species in the park is predominantly categorized under not regenerating conditions. Research is needed on the soil seed bank and propagation methods used by each tree species to stimulate regeneration of target species of *Sterculia africana*, *Adansonia digitata*, *Tamarindus indica*, *Acacia seyal,* and *Burkea Africana*. Develop protection approaches for economically important tree species, such as *Boswellia papyrifera,* which is needed for effective productivity and protection of other related tree species in the park. The study provides general information regarding the ability of free-ranging elephants to forage different types of food plants in the KSNP. To develop plans for the improvement of seasonal elephant foods and long-term protection of wildlife habitats, related to the human-elephant coflict, which is currently a serious issue in the KSNP for the safeguarding of African elephants. The knowledge gained from elephant food selections and the availability of plant species will help environmentalists design a suitable plan for the restoration of disturbed habitats and for mitigating human-wildlife/elephant conflict in the study area.

LIMITATIONS

Due to the awkward situation at the border with Eritrea, we did not estimate how many elephants there were. Nevertheless, the Ethiopian Wildlife Conservation Authority (EWCA) prepared an aerial count of the population of elephants in the KSNP that was funded by the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF). I used information on the elephant population from the preliminary survey of the EWCA data and my fieldwork observation using a drone camera. Consequently, there was limited information on the comparison of elephant populations concerning their ability to use vegetation and changes in the composition of the landscape. The data were yet used to examine the physical damage category of utilization by elephants for each type of plant species.

Another limitation of this research was logistical constraints. Due to financial constraints, I estimated the dietary intake of elephants using field walk evidence of signs of feeding (i.e., at the plot level) and relative utilization percentage rather than domesticated (satellite tracking) elephants. However, these data were used to investigate the general information on the diet of the elephant population. In addition, except for elephant crop visit observations, direct field quantification of the extent of crop losses caused by elephants can not be carried out because of financial limitations. I used a questionnaire survey to examine HEC, except qualitative field observation on elephant crop damage. Detailed quantification of HEC enables us to connect spatial and temporal patterns of crop damage with natural elephant food. On the other hand, the regeneration status of the plant species of the park was quantified based on the presence and absence of seedlings and saplings in the sampled areas rather than the soil seed bank study. A detailed soil seed bank study would allow us to cross-check/prove the regeneration status of the park plant species specifically, with the results of ‘poor’ and ‘not’ regenerating plant species.

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APPENDICES

Appendix 1.

Table 1. List of plant species' scientific names, family names, life form, local name (Tigrigna), and collection IDs in Kafta Sheraro National Park (KSNP) Tigray region, Ethiopia (2018/2019).

Species names	Family	Habit	Tigrigna name	Coll.Id
Abelmoschus esculentus (L.) Moench.	Asteraceae	Herb	Wayka	FT89
Abutilon figarianum Webb.	Malvaceae	Herb	**	FT113
Acacia albida Del.	Fabaceae	Tree	Momona	FT14
Acacia etbaica Schweinf.	Fabaceae	Tree	Seraw	FT50
Acacia lahai Steud.	Fabaceae	Tree	Lahai adi	FT30
Acacia mellifera (Vahl) Benth.	Fabaceae	Tree	Ktrit	FT12
Acacia oerforta (Forssk.) Schweinf	Fabaceae	Shrub	Tekelbe	FT05
Acacia polyacantha Wild.	Fabaceae	Tree	Gomoro	FT49
Acacia senegal (L) Wild.	Fabaceae	Tree	Kenteb	FT01
Acacia seyal Del.	Fabaceae	Tree	Chea	FT10
Acacia sp. Mart	Fabaceae	Tree	Chgeno	FT47
Acacia tortilis Forssk.	Fabaceae	Tree	Lahai	FT51
Acalypha crenata Hochst.	Malvaceae	Herb	**	FT93
Acalypha indica L.	Euphorbiaceae	Herb	**	FT111
Achyranthes asepera var.aspera L.	Amaranthaceae	Herb	**	FT75
Adansonia digitata L.	Bombacaceae	Tree	Dima	FT13
Aeschynomene peniculata Vogel.	Fabaceae	Herb	**	FT87
Allium cepa L.	Liliaceae*	Herb	Shigurti keyh	FT126
Allium sativum L.	Liliaceae*	Herb	Shigurti tsaeda	FT124
Alternanthera pungens Kunth.	Amaranthaceae	Herb	**	FT121
Amaranthus spinosus L.	Lamiaceae	Herb	**	FT98
Amphicarpa africana Hook.f.	Fabaceae	Climber	**	FT69
Anogeissus leiocarpus Guill & Perr.	Combretaceae	Tree	Hanse	FT08
Aristida adoensis Hochst.	Poaceae	Grass	**	FT141
Artemisia abyssinica Sch. Bip.	Asteraceae	Herb	Chena barya	FT135
Asparagus flagellaris Kunth.	Amaranthaceae	Herb	**	FT99
Aspilia guineensis Hoffm & Muschl.	Asteraceae	Herb	**	FT78
Balanites aegyptiaca (L.) Del.	Balanitaceae	Tree	Mekie	FT04
Ballota nigra (L.)	Lamiaceae	Herb	**	FT116
Barleria prionitis (L.)	Fabaceae	Herb	Eshokanchwa	FT95
Bidens pachyloma (Oliv. & Hiern)	Fabaceae	Herb	**	FT104
Blainvillea gayana Cass.	Fabaceae	Herb	**	FT82
Boscia angustifolia A.Rich.	Capparaceae	Tree/Shrub	**	FT46
Boswellia papyrifera Hochst. ex A.	Burseraceae	Tree	Meker	FT26
Brucea antidysentrica J.F.	Simaroubaceae	Tree	Melita	FT60
Buddleja polystachya Fresen.	Loganiaceae	Shrub	Metere	FT64
Burkea africana Hook.	Caesalpiniaceae	Tree	Amangul	FT32
Cadaba farinosa Forssk.	Capparaceae	Shrub	**	FT37
Calopogonium mucunoides Desv.	Fabaceae	Climber	**	FT72
Calotropis procera Aiton.	Asclepiadaceae	Tree	Gindae	FT25
Capparis decidua Forssk.	Capparaceae	Tree	Malokza	FT19
Capsicum annuum L.	Solanaceae*	Herb	**	FT125
Carica papaya (L.)	Caricaceae*	Tree	Papaya	FT55
Carissa edulis Forssk.	Apocynaceae	Shrub	Agam	FT176
Casuarina equisetifolia (L.)	Casuarinaceae	Tree	Shwshwit	FT18
Cenchrus ciliaris (L.)	Poaceae	Grass	Almet	FT137
Chamaecrista absus (L.)	Lamiaceae	Herb	**	FT101

Table 1. Continued

Species names	Family	Habit	Tigrigna name	Coll.Id
Chamaecrista nigricans (L.) Moench	Fabaceae	Herb	**	FT74
Chascanum marrubifolium Fenol.	Verbenaceae	Herb	**	FT131
Chloris virgata Sw.	Poaceae	Grass	**	FT156
Cissampelos mucronata A.Rich.	Menispermaceae	Climber	**	FT67
Cissus guadrangularis (L.)	Vitaceae	Climber	Aalke	FT65
Citrus aurantifolia (Christm.) Swingle	Rutaceae*	Shrub	Lemin	FT58
Combretum glutinosum Perr.	Combretaceae	Shrub	**	FT34
Combretum hartmannianum Schweinf.	Combretaceae	Tree	Tenkelba	FT02
Combretum mollle R.Br.	Combretaceae	Tree	**	FT35
Combretum sp. Loefl.	Combretaceae	Tree	**	FT177
Commelina communis (L.)	Commelinaceae	Herb	**	FT109
Commiphora boranensis Vollesen	Burseraceae	Tree	**	FT43
Conya canadensis (L.) Erigeron.	Asteraceae	Herb	**	FT128
Cordia Africana Lam.	Boraginaceae*	Tree	Aki	FT181
Crotalaria ononoides Benth.	Fabaceae	Herb	**	FT102
Cucumis prophetarum L.	Cucurbitaceae	Climber	**	FT73
Cucurbita maxima Duchesne.	Cucurbitaceae	Climber	**	FT68
Cymbopogon caesius Hook. & Arn.	Poaceae	Grass	Tbrara	FT148
Cynodon dactylon (L.) Pers.	Poaceae	Grass	Tehag	FT161
Cynodon plectostachyus K. Schum.	Poaceae	Grass	Tsaeda tehag	FT171
Cyperus rotundus L.	Cyperaceae	Sedge	**	FT166
Cyperus scariosus R.Br.	Cyperaceae	Sedge	Seti	FT159
Dactyloctenium aegypticum (L.) Willd.	Poaceae	Grass	**	FT147
Dalbergia melanoxylon Guill. & Perr.	Fabaceae	Tree	Zibe	FT03
Datura stramonium L.	Asteraceae	Herb	Mezerbae	FT106
Delonix regia Boj.ex hook.	Fabaceae	Tree	Dridawa tkli	FT172
Dichanthium annulatum var.*papillosum*	Poaceae	Grass	**	FT182
Dicliptera verticillata Forsk.	Acanthaceae	Herb	**	FT115
Dicrostachys cinerea L.	Fabaceae	Tree	Gonok	FT06
Digitaria abyssinica Hochst.	Poaceae	Grass	**	FT155
Digitaria velutina Forssk.	Poaceae	Grass	**	FT173
Diheteropogon ampletcens (Hack.)	Poaceae	Grass	**	FT140
Dinebra retroflexa (Vahl) Panz.	Poaceae	Grass	Chwchwit	FT154
Diospyros abyssinica Hiern.White	Ebenaceae	Tree	**	FT59
Diospyros mespiliforms Hochst.	Ebenaceae	Tree	Aye	FT31
Dumasia villosa DC.	Fabaceae	Climber	**	FT70
Echinocloa pyramidals (Lam.)	Poaceae	Grass	**	FT163
Eleusine coracana Gaertn.	Poaceae*	Grass	Dagusha	FT180
Eleusine indica L.	Poaceae	Grass	**	FT160
Epilobiumcilia Raf.	Solanaceae	Herb	**	FT108
Eragrostis cilianensis All.	Poaceae	Grass	**	FT145
Eragrostis tef (Zucc) Trotter.	Poaceae*	Grass	Taf	FT169
Feretia apodanthera Delile.	Rubiaceae	Shrub	Rowe	FT23
Ficus sycomorus (L.)	Moraceae	Tree	Sagla	FT33
Galinsoga parviflora Cav.	Asteraceae	Herb	**	FT118
Grewia bicolor Juss.	Tiliaceae	Tree/Shrub	**	FT07
Grewia flavescens Juss.	Tiliaceae	Tree/Shrub	Betremushe	FT28
Grewia mollis Juss.	Tiliaceae	Tree	**	FT41
Grewia villosa Willd.	Tiliaceae	Shrub	hable	FT20
Guizotia schimperi Sch.Bip.	Fabaceae	Herb	**	FT88
Hackelochloa granularis L.	Poaceae	Grass	**	FT143
Halopyrum miicronatum L.	Poaceae	Grass	**	FT149
Heteropogon contortus L.	Poaceae	Grass	**	FT162
Hypanheuia hirta L. Stapf.	Poaceae	Grass	**	FT139

Table 1. Continued

Species names	Family	Habit	Tigrigna name	Coll.Id
Hyphaene thebaica (L.) Mart.	Arecaceae	Tree	Laka	FT24
Jasminum abyssinicum Hochst.	Oleaceae	Shrub	**	FT15
Justicia flava (Forssk.) Vahl.	Acanthaceae	Herb	**	FT96
Kohautia cynanchica DC.	Malvaceae	Herb	**	FT90
Laggera alata (D.Don) Sch.	Asteraceae	Herb	**	FT122
Lannea microcarpa Engl. & Krause.	Anacardiaceae	Tree	**	FT42
Leptadenia lanceolata (Poir.) Goyder.	Asclepiadaceae	Shrub	**	FT38
Leucas martinicensis (Jacq.) Aiton	Lamiaceae	Herb	**	FT119
Mangifera indica (L.)	Anacardiaceae	Tree*	Mango	FT56
Maytenus senegallensis Forssk.	Celastraceae	Tree	**	FT11
Melanocenchris abyssinica (ex Fresen.)	Poaceae	Grass	**	FT144
Melia azedarach (L.)	Meliaceae	Tree	Nim	FT54
Meriandra dianthcra (ex Roem.&Schult.	Acanthaceae	Herb	Sesegzbi	FT97
Moringa stenopetala (Baker f.) Cufod.	Moringaceae	Tree	Shiferaw	FT29
Musa species (L.)	Musaceae*	Herb	Benana	FT136
Nerium oleander L.	Apocynaceae	Shrub	**	FT36
Nicandra physalodes L.Gaertn	Solanaceae	Herb	Absho	FT112
Nicotiana tabaccum L.	Solanaceae	Herb	**	FT133
Ocimum gratissimum L.)	Fabaceae	Herb	**	FT107
Olyra latifolia (L.)	Poaceae	Grass	Saeri harmaz	FT157
Otostegia ellenbeckii Gürke.	Lamiaceae	Shrub	Chendog	FT62
Oxytenanthera abyssinica Rich. Munro	Poaceae	Grass	Shambeko	FT164
*Panicum coloratum (*L.)	Poaceae	Grass	**	FT170
Parkinsonia aculeata (L.)	Fabaceae	Tree	Tetem	FT52
Pennisetumglaucum L. R.Br.	Poaceae	Grass	**	FT167
Pennisetum typhoideum Stapf &Hubb.	Poaceae	Grass	**	FT165
Pentatropis nivalis J.F. Gmel.	Asclepiadaceae	Climber	**	FT150
Phragmites australis (Cav.)	Poaceae	Grass	Zeri seytan	FT174
Phyllanthus maderaspatensis L.	Euphorbiaceae	Herb	**	FT77
Physalis angulata L.	Solanaceae	Herb	**	FT110
Pittosporum viridiflorum Sims.	Pittosporaceae	Tree	**	FT45
Plectranthus fruticosus L'Her.	Asparagaceae	Herb	**	FT100
Plumbagon zeylanica L.	Plumbaginace	Shrub	Aftuh	FT61
Poa annua L.	Poaceae	Grass	**	FT142
Polygala abyssinica ex. Fresen.	Asteraceae	Herb	**	FT83
Polypogon monspeliensis (L.)Desf.	Poaceae	Grass	**	FT153
Rhamnus prinoides L'Her.	Rhamnaceae*	Shrub	**	FT179
Rhynchosia minima (L.) DC.	Fabaceae	Climber	**	FT175
Ricinus communis L.	Euphorbiaceae	Shrub	Gulii	FT53
Rottboellia cochinchinensis (Lour.)	Poaceae	Grass	**	FT151
Salvadora persica (L.)	Salvadoraceae	Shrub	Shebelsha	FT21
Sauromatum venosum Dry land.ex.Aiton.	Araceae	Herb	**	FT134
Sclerocarya birrea (Rich.) Hochst.	Anacardiaceae	Tree	**	FT57
Scorpiurus muricatus (L.)	Fabaceae	Herb	**	FT132
Senna obtusifolia L.Irwin & Barneby	Euphorbiaceae	Herb	Abake harmaz	FT94
Senna occidentalis L.	Fabaceae	Herb	**	FT117
Senna sinqueana Del.	Fabaceae	Shrub	Hambhambo	FT63
Sesamum indicum (L.)	Pedaliaceae*	Herb	Selit	FT120
Sida acuta Burm.f.	Malvaceae	Herb	**	FT80
Solanum incanum L.	Solanaceae	Shrub	Engule	FT40
Solanum lycopersicum L.	Solanaceae*	Herb	Komidere	FT123
Solanum tuberrosum L.	Solanaceae*	Herb	Dnsh	FT127
Sorghum bicolor L. Moench.	Poaceae*	Grass	Mshela	FT168
Spermacoce pusilla Wall.	Fabaceae	Herb	**	FT85

Table 1. Continued

Species names	Family	Habit	Tigrigna name	Coll.Id
Sterculia africana Del.	Sterculiaceae	Tree	Darle	FT09
Stereospermum kunthianum Cham.	Bignoniaceae	Tree/Shrub	**	FT44
Stipa borysthenica Klokov ex Prokud.	Poaceae	Grass	**	FT152
Stipa tenuissima Trin.	Poaceae	Grass	Choba	FT146
Streblochaete longiarista (A.Rich) Pilg.	Poaceae	Grass	**	FT138
Striga latericea Vatke.	Scrophulariaceae	Herb	Metselem	FT79
*Tamarindus indica (*L.)	Fabaceae	Tree	Humer	FT17
Tephrosia pentaphylla (Roxb.)G.Don.	Fabaceae	Herb	**	FT76
Tephrosia purpurea L.Pers	Fabaceae	Herb	**	FT81
Tephrosia virginiana L.Pers.	Fabaceae	Herb	**	FT105
Teramnus labialis var. abyssinicum (L.f.)	Fabaceae	Climber	**	FT71
Terminalia brownii Fresen.	Combretaceae	Tree	Weyba	FT27
Terminalia laxiflora Engl. & Diels.	Combretaceae	Tree	**	FT39
Terminalia sp. L	Combretaceae	Tree	**	FT178
Tetrapogon villosus Desf.	Poaceae	Grass	**	FT158
Tribulus cistoides (L.)	Zygophyllaceae	Herb	**	FT114
Trigonella species L.	Polygalaceae	Herb	**	FT84
Triumfetta rhomboidea Jacq.	Rubiaceae	Herb	**	FT91
Vigna radiata subsp.sublobata (L.)	Fabaceae	Herb	**	FT103
Wissadula amplissima (L.) Fries	Tiliaceae	Herb	**	FT92
Xanthium spinosum L.	Asteraceae	Herb	**	FT129
Xanthium strumarium L.	Asteraceae	Herb	**	FT130
Zehneria anomala Jeffrey.	Cucurbitaceae	Climber	Hafaflo	FT66
Ziziphus mucronata Wild	Rhamnaceae	Tree/Shrub	Geba adgi	FT48
Ziziphus spina christi L.Desf.	Rhamnaceae	Tree	Geba	FT16
Zornia glochidiana Rchb.	Rubiaceae	Herb	**	FT86
Ziziphus mauritiana Willd.	Rhamnaceae	Tree/Shrub	Andel	FT22

*=Plant species recorded outside the quadrat area, ** local name is unknown, Coll.Id=Collection Id., FT=Fitsum Temesgen

Table 2. The regeneration status of a forest can be determined by comparing a seedlings and saplings with mature individuals

S. No	Regeneration status	Seedling (SD)	Sapling (SP)	Compare to Mature tree stage
1	Good regeneration	ample	ample	Mature< SP<SD
2	Fair regeneration	ample	conditional	Mature>SP>SD
3	Poor regeneration	absent	present	Only SP survive, SP≤ Mature /SP ≥ mature
4	No regeneration	absent present	absent present	Only mature tree survive
5	New regeneration	absent present	present absent	Absent of mature individuals

Source: Tiwari et al., 2010; Chauhan et al., 2008a; Chauhan et al., 2008b; Dhaulkhandi et al., 2008)

Table 3. Confusion matrix for the 2018 OLI classified image

Classified data	Ground truth data Wood land	Shrub bushland	Riparian forest	Grass land	Agricultural land	Water body	Bare land	Total	UA (%)
Woodland	129	0	7	0	1	0	0	137	88.97
Shrub-bushland	6	92	0	6	0	0	0	104	88.46
Riparian forest	0	0	128	0	0	0	0	128	96.80
Grass land	0	22	0	146	1	0	14	183	73.00
Agricultural land	0	0	0	1	88	0	0	89	98.88
Water body	1	0	0	0	0	74	0	75	98.67
Bareland	0	5	0	18	0	0	88	111	79.28
Total	136	119	135	171	90	74	102	827	-
PA (%)	88.36	77.31	89.63	82.49	93.62	98.67	85.44	-	-
Over all accuracy					86.9%				
Kappa coefficient					0.845				

Note: classes are shown by the number of classified pixels, UA=user accuracy, PA=producer accuracy

Table 4. Summary of total and average annual rainfall data (1996-2016) from Kafta Sheraro National Park (mm=milli meter)

Year	Total annual rainfall mm	Total annual rainfall Value in (log10)	Average annual rainfall mm	Average annual rainfall Value in (log10)
1996	581.2	2.76	83.03	1.92
1997	791.1	2.89	98.89	2.00
1998	513.5	2.70	51.58	1.70
1999	845.3	2.93	70.44	1.85
2000	525.6	2.72	47.78	1.68
2001	198.3	2.30	29.61	1.47
2002	606.9	2.78	86.70	1.94
2003	453.2	2.65	50.36	1.95
2004	287.4	2.46	31.93	1.53
2005	582.1	2.76	83.16	1.68
2006	648.0	2.81	81.00	1.91
2007	470.1	2.67	94.02	1.97
2008	757.7	2.88	63.14	1.80
2009	480.7	2.68	40.06	1.60
2010	1266	3.10	105.5	2.02
2011	450.2	2.65	90.04	1.95
2012	601.5	2.78	54.68	1.74
2013	789.8	2.89	87.76	1.94
2014	319.3	2.50	45.61	1.67
2015	717.9	2.86	65.26	1.80
2016	430.3	2.63	39.12	1.60

Table 5. Normalized difference vegetation index (NDVI) between 2007 and 2016

Year	Average NDVI Dry season	Average NDVI Wet season	Year	Average NDVI Dry season	Average NDVI Wet season
2007	0.170	0.330	2012	0.093	0.207
2008	0.160	0.245	2013	0.137	0.251
2009	0.120	0.220	2014	0.113	0.238
2010	0.096	0.259	2015	0.090	0.246
2011	0.113	0.258	2016	0.080	0.231

Table 6. Species abundance (frequency) in the diet of elephant and their occurrence in the field, and preference index (PI) for the woody species (n=41) in the diets of elephant species

Species scientific name	No of sampled stems	No of feeding sign stems	Percentage availability	Percentage utilization	PI
Acacia senegal	179	121	6.469	7.338	1.134
Dalbergia melanoxylon	66	34	2.385	2.062	0.864
Balanites aegyptiaca	240	172	8.674	10.43	1.203
Acacia oerfota	189	129	6.831	7.823	1.145
Dicrostachy scinerea	163	121	5.891	7.338	1.246
Grewia bicolor	31	22	1.120	1.334	1.191
Sterculia africana	50	46	1.807	2.79	1.544
Acacia seyal	34	28	1.229	1.698	1.382
Acacia mellifera	646	401	23.35	24.32	1.042
Adansonia digitata	48	47	1.735	2.85	1.643
Acacia albida	5	3	0.181	0.182	1.007
Ziziphus spina-christi	117	70	4.228	4.245	1.004
Tamarindus indica	79	21	2.855	1.273	0.446
Grewia villosa	7	3	0.253	0.182	0.719
Hyphaene thebaica	129	96	4.662	5.822	1.249
Terminalia brownii	265	67	9.577	4.063	0.424
Grewia flavescens	19	9	0.687	0.546	0.795
Acacia lahai	8	3	0.289	0.182	0.629
Diospyros mespiliformis	30	24	1.084	1.455	1.342
Burkea africana	31	26	1.120	1.577	1.407
Combretum molle	116	51	4.192	3.093	0.738
Cadaba farinosa	5	2	0.181	0.121	0.671
Acacia species	13	6	0.470	0.364	0.774
Ziziphus mucronata	23	9	0.831	0.546	0.657
Acacia polyacantha	86	39	3.108	2.365	0.761
Acacia etbaica	10	7	0.361	0.424	1.175
Acacia tortilis	9	4	0.325	0.243	0.746
Sclerocarya birrea	15	8	0.542	0.485	0.895
Stereospermum kunthianum	21	17	0.759	1.031	1.358
Ricinus communis	5	2	0.181	0.121	0.671
Grewia mollis	7	3	0.253	0.182	0.719
Solanum incanum	8	3	0.289	0.182	0.629
Ficus sycomorus	3	2	0.108	0.121	1.119
Maytenus senegallensis	7	4	0.253	0.243	0.959
Combretum glutinosum	36	19	1.301	1.152	0.886
Cordia Africana	4	2	0.145	0.121	0.839
Terminalia laxiflora	12	5	0.434	0.303	0.699
Pittosporum viridiflorum	21	11	0.759	0.667	0.879
Carissa adulis	16	6	0.578	0.364	0.629
Parkinsonia aculeata	6	3	0.217	0.182	0.839
Salvadora persica	8	3	0.289	0.182	0.629
Total	2767	1649	--	--	--

Note: PI= preference index, n= number of woody plants; percentage of availability was calculated only for plant species consumed by elephants

Table 7. List of plant species recorded foraged by elephant in and outside Kafta Sheraro National Park is arranged by number of species per family, the plant habits, and plant parts consumed (leaf, stem, shoot, bark, and fruit)

s.no	Family	Species	Habit	Leaf	Stem	Shoot	Bark	Fruit
1	Fabaceae	*Acacia senegal*	T	√			√	
2	Fabaceae	*Dalbergia melanoxylon*	T	√			√	
3	Balanitaceae	*Balanites aegyptiaca*	T	√	√		√	√
4	Fabaceae	*Acacia oerfota*	S	√	√		√	√
5	Fabaceae	*Dicrostachy scinerea*	T	√			√	√
6	Tiliaceae	*Grewia bicolor*	T/S	√	√			√
7	Sterculiaceae	*Sterculia africana*	T	√	√		√	
8	Fabaceae	*Acacia seyal*	T	√			√	
9	Fabaceae	*Acacia mellifera*	T	√	√	√	√	√
10	Bombacaceae	*Adansonia digitata*	T				√	
11	Fabaceace	*Acacia albida*	T	√			√	√
12	Rhamnaceae	*Ziziphus spina-christi*	T	√	√	√	√	√
13	Fabaceae	*Tamarindus indica*	T	√			√	
14	Tiliaceae	*Grewia villosa*	S	√				
15	Arecaceae	*Hyphaene thebaica*	T	√		√		
16	Combretaceae	*Terminalia brownii*	T	√			√	√
17	Tiliaceae	*Grewia flavescens*	T/S	√				√
18	Fabaceae	*Acacia lahai*	T	√			√	
19	Ebenaceae	*Diospyros mespiliformis*	T	√			√	√
20	Caesalpiniaceae	*Burkea africana*	T	√			√	
21	Combretaceae	*Combretum molle*	T	√				
22	Capparaceae	*Cadaba farinosa*	S	√			√	
23	Fabaceae	*Acacia species*	T	√			√	
24	Rhamnaceae	*Ziziphus mucronata*	T/S	√				
25	Fabaceae	*Acacia polyacantha*	T	√	√		√	√
26	Fabaceae	*Acacia etbaica*	T	√			√	
27	Fabaceae	*Acacia tortilis*	T	√			√	
28	Anacardiaceae	*Sclerocarya birrea*	T				√	
29	Poaceae	*Olyra latifolia*	G			√		
30	Bignoniaceae	*Stereospermum kunthianum*	T/S	√				
31	Euphorbiaceae	*Ricinus communis*	S	√	√			√
32	Tiliaceae	*Grewia mollis*	T	√				√
33	Solanaceae	*Solanum incanum*	S	√	√	√		
34	Fabaceae	*Guizotia schimperi*	H			√		
35	Moraceae	*Ficus sycomorus*	T	√			√	
36	Celastraceae	*Maytenus senegallensis*	T	√				
37	Combretaceae	*Combretum glutinosum*	S	√			√	
38	Boraginaceae	*Cordia Africana*	T	√			√	√
39	Combretaceae	*Terminalia laxiflora*	T	√				
40	Poaceae	*Pennisetum glaucum*	G			√		
41	Pittosporaceae	*Pittosporum viridiflorum*	T	√			√	
42	Poaceae	*Cynodon dactylon*	G	√				
43	Apocynaceae	*Carissa adulis*	S	√			√	
44	Fabaceae	*Parkinsonia aculeata*	T	√			√	√
45	Salvadoraceae	*Salvadora persica*	T/S	√				
46	Rhamnaceae	*Ziziphus mauritiana*	T/S	√				
47	Combretaceae	*Anogeissus leiocarpus*	T	√				
48	Caricaceae	*Carica papaya*	T	√	√		√	

Table 7. Continued

s.no	Family	Species	Habit	Leaf	Stem	Shoot	Bark	Fruit
49	Anacardiaceae	*Mangifera indica*	T	√			√	√
50	Musaceae	*Musa species*	H	√				√
51	Poaceae	*Sorghum bicolor*	G	√	√			√
52	Poaceae	*Pennisetum typhoideum*	G	√	√			√
53	Poaceae	*Eragrostis tef*	G	√	√			√
54	Asteraceae	*Abelmoschus esculentus*	H	√				√
55	Poaceae	*Zea mays*	G	√	√			√
56	Solanaceae	*Solanum lycopersicum*	H	√				√
57	Cucurbitaceae	*Cucurbita pepo*	C.H					√
58	Poaceae	*Eleusine coracana*	G	√				√
59	Solanaceae	*Solanum tuberosum*	H	√	√			√

T=tree, S=shrub, T/S=tree/shrub, H=herb, G=grass, C.H=climber herb

Table 8. Reliability analysis (corrected interitem total correlation scores of individual statements and Cronbach's alpha coefficient (α)) of the elephant and KSNP attitude indices

Attitude toward Kafta Sheraro National Park	Mean	Standard deviation	Inter- item correlation	(α)
1. From the beginning i supported the establishment of KSNP	2.85	1.422	.773	
2. I support the practices of KSNP conservation	2.67	1.415	.779	
3. KSNP has a positive impacts on natural resources Conservation	2.56	1.351	.702	
4. KSNP conservation have brought positive change onthe local community livelihood	3.35	1.333	.715	0.90
5. Conservation of the whole district area brings happiness	2.50	1.263	.627	
6. KSNP conservation stabilizes communities utilization of natural resources	3.17	1.441	.748	
7. The relationship b/n community and park managers is good	3.22	1.551	.670	
Attitude toward elephants				
1. I support the existence of elephants in our Community	2.88	1.447	.814	
2. I encourage to increase the no of elephants in the area	2.97	1.505	.821	
3. Conservation of elephants can open a door for tourist attraction	2.38	1.071	.385	0.89
4. Elephants crop raiding doesn't a significant issue in the area	3.54	1.318	.517	
5. Elephants have the right to live in the area	2.86	1.380	.797	
6. Elephants are important to the whole KSNP ecosystem	2.59	1.425	.756	
7. Construction of water reservoirs assure elephant Conservation	2.77	1.466	.799	

Table 9. Dependent and independent variable codes for binary logistic regression and general linear model analysis in the conservation of African elephant and Kafta Sheraro National Park

Logistic regression analysis codes			
S.no	Variables	Codes of variable categories	%
1	Gender	Male=1	74.20
		Female=2	25.80
2	Age (years)	22-39 =1	50.60
		40-57=2	16.00
		>58=3	33.40
3	Education	Informal=0	25.80
		Primary (1-8th) =1	65.10
		Secondary (9-12th)=2	09.10
4	Settlement condition	Short term lived=0	71.65
		Long term lived=1	28.35
5	Distance b/n settlement & park	6.5-9.0 km=1	41.00
		>9.0 km=2	59.00
6	Awareness condition: Aware	Yes=1	54.18
	Not aware	No=0	45.82
Generalized linear models (GLMs) analysis codes			
1	Gender	Male=1	74.20
		Female=2	25.80
2	Age categories (Years)	22-39 =1	50.60
		40-57=2	16.00
		>58=3	33.40
3	Education level	Informal=0	25.80
		Primary (1-8th)=1	65.10
		Secondary (9-12th) =2	09.10
4	Distance b/n settlement & park	6.5-9.0 km=1	41.00
		>9.0 km=2	59.00
5	Settlement condition	Long term lived=1	28.35
		Short term lived=2	71.65
6	Land holding size	1-3.5 ha=1	34.30
		>3.5 ha=2	65.70
7	Land occupation type	Landless (rent)=1	17.60
		Owner=2	82.40
8	Awareness: Aware	Yes=1	54.18
	Not aware	No=2	45.82
9	Crop damage trend	Increase=1	79.10
		Stayed same=2	09.50
		Decrease/no opinion=3	11.40
10	Crop damage level	High=1	66.80
		Medium=2	11.60
		Low/no complain=3	21.60

Appendix 2. Community-based open and closed questions were asked of individual household heads in the Kafta Sheraro National Park (KSNP) Tigray region from November 2018 to June 2019 (in the English language).

Serial number of the interviewee: _________Date (date/month/year): ___________

GPS: X ___________Y____________Time taken:________

Introduction: The major aim of this research questionnaire was to understand how the local residents living surrounding Kafta Sheraro National Park (KSNP) interact with park wildlife and its whole natural resources, which are directly related to their livelihood. The specific purpose of this study was to collect relevant data regarding the background information of the respondents, the attitudes and perceptions of the local communities toward park and wildlife (elephant) conservation, human-elephant conflicts, land use/land cover history, and drivers of land use/land cover change in the KSNP. This questionnaire is part of a PhD thesis that is being conducted by Fitsum Temesgen (a PhD student from Addis Ababa University, Ethiopia). Therefore, you are kindly requested to provide correct information for questions that you want to answer. The symbol "X" is used if needed for each question response.

1. Background information of the interviewees

1.1 Gender (Put 'X')**:**

Male		Female	

1.2 Age**:**

< 20	21-35 years	36-50 years	51-65 years	above 66 years

1.3 Administrative description**:**

Kebele	Wereda	Zone	Region	Bihereseb (Ethnicity)

1.4 Marital status (Put (X')**:**

Single	Married	Divorce

1.5 Household members/family sizes**:** ______

1.6 Occupation**:** ______

1.7 Educational status (level)**:**

Informal	Formal					
	Grade 1-4	Grade 5-8	Grade 9-12	Diploma	Degree	Others……..

1.8 For how long have you been living in this area?

≤10 yrs [ ] 11-20 yrs [ ] 21-30 yrs [ ] 31-40 yrs [ ] above 41 yrs [ ]

1.9 Have you lived in other areas previously? Are you Resettler =0 [ ] or Native=1 [ ]

1.10 If your answer is “resettler=0” when was the resettlement period?

Before 1991	1991-2007	(2008-20018/19) Recently

1.11 What is your main source of livelihood and economic activities?

Sources of livelihood and income	Response
1. Irrigated crops production	
2. Rain fed crop cultivation	
3. Livestock rearing	
4. Free natural resources collection	
5. Others (specify)…………………	

1.12 Do you have any other alternative sources of income?
No=0 [ ] Yes=1 [ ]

1.13 If your answer is ‘yes=1’, list the types of work activities you occupied.

1.14 What are your main sources of energy for household consumption (specifically cooking purposes?)

Electricity	Fuel wood	Dung	Gas	Others……

1.15 How far do you live/your settlement from the border of the park area?

<5 km	5-10 km	10-15 km	15-20 km	>20 km

1.16 Where is your Farmland place?

1. Inside the park	2. Outside (near) the park (km)

1.17. Land type:

1. Owner	2. Land less (Rent from someone)

1.18 What is the type and size of your farmland occupied?

Type of farmland used	Response	Size (hectare)	Land use permit card
1. Irrigated land			
2. Rain fed crop cultivation L.			

1.19 What are the types of agricultural crops that grow on your farmland?

Give a specific common name of the plants:

Crops category	List of common and scientific names
1. Cereals crops	
2. Fruits	
3. Vegetables	
4. Oil and industrial crops	

1.20 For what purpose and use have you grown the crops?

Crop use	Names of the crop types
1. Food source (home consumption)	
2. Cash crop (sale)	
3. Both for food and cash	

1.21 Do you want to leave the area or stay here?

Stay ☐ Leave ☐

1.22. If you are happy to leave the area what are the challenges that you will expect? (Put 'X')

Challenges	Response (Rank)
1. Lacks alternative cultivated land	
2. Lacks choice of grazing land	
3. Lacks water for irrigation	
4. Disturbs livelihood style	
5. Destructs enormous fruit plantation	

1.23 Which natural resources do you require access to from the protected area? **(**Put 'X'**)**

Resources accessed	Response
1. Grazing	
2. Firewood and charcoal production	
5. Gold mining	
6. House construction materials and related	
7. Gum and resin collection	
8. Food collection (Wild honey, edible fruits, fish)	
9. Water sources	
10. Medicinal plants collection	
11. Others…..	

1.24 If your answer is grazing for how long your cattle graze in the park? **(**Put 'X'**)**

< 3 months	3-5 months	5-8 months	The whole year (12 months)

1.25 Is there any chance that the Eritrean community entered the park? **(**Put 'X'**)**

No=0 ☐ Yes=1 ☐

1.26 If your answer is 'yes=1' in which season does the Eritrean community cross the park border?

Season	Response
1.Dry season	
2.Wet season	
3.Both	

1.27 If your answer is ‘dry season=1’, what is the reason for crossing?

1.28 How would you evaluate the relationship between your community and the management of Kafta Sheraro National Park? **(**Put 'X')

Excellent	Good	Satisfactory	Poor	Bad	Don’t know

1.29 What are the problems faced with having cropland inside and near the KSNP? **(**Put 'X')

Problems	Response (Rank)
1. Damage crops by wildlife	
2. Loss of land utilization and livelihood	
3. Limited on access to resource use in the park	
4. Conflict with park staff	
5. Others (specify)	

2. Anthropogenic pressure exerted on Kafta Sheraro National Park natural resources

2.1. Historical information on the Kafta Sheraro National Park (KSNP) land cover type

I. What is/was the dominant land cover types clearly observed? Put in ranking order

Cover type	Rank
1. Grass with scattered trees	
2. Closed forest	
3. Wood land vegetation	
4. Bush land	
5. Open grass land	
6. Bare land	
7. Cultivation	
8. Water	
9. Others (specify)	

II. The dominant and economic significance of the woody plant species in the area you know are listed.

Common and scientific name of plant species	Use	Conservation status	Rank
1.			
2.			
3.			
………			
………			

III. What do you think about the past to present trends of LULC classes of the park (woodland, agricultural land, grass land (grazing areas), riparian forest, bare land, and settlement? **(**Put 'X')

Land use land cover catagories	Trends			
	Increased/ increase	Decreased/ decrease	Stayed/ stay the same	Don't know
1.Woodland: a. 1975-1991				
b.1991-2007				
c. 2008-2018/19				
2. Agricultural land				
3. Grass land				
4. Riparian forest				
5. Bareland				

IV. What about the change in the following infrastructures? **(**Put 'X')

Variables	Increased/ increase	Decreased/ decrease	Stayed/ stay the same	Don't know
1. Road access to park				
2. Water access (stream/pond)				

2.2. What are the immediate threats to Kafta-Sheraro National Park (KSNP) natural resources? Write your response category as follows: 1=Very high, 2= High, 3= Medium, 4=low (Put 'X')

Threats	1	2	3	4
1. Legal and illegal resettlement				
2. Expansion of cultivated land				
3. Expansion of grazing land				
4. Firewood collection				
5. Charcoal production				
6. Illegal fire				
7. Natural resin collection				
8. Traditional gold mining				
9. Ethio-Eritrean war				
10. Eritrean community crossing the park				
11. Permanent and seasonal road				
12. Drought				
13. Land tenure (Administration)				
Others specify……………				

3. Awareness and attitudes of local communities toward park habitat and wildlife conservation, particularly emphasis on African elephants

3.1. Do you have any knowledge or awareness about protected areas in National Park?

No=0		Yes=1	

3.2 Would you support the establishment of Kafta Sheraro National Park (KSNP)?

No=0		Yes=1	

3.3 If you support what are the benefits of Kafta Sheraro National Park (KSNP)?

3.4. If you didn't support what is your reason for Kafta Sheraro National Park (KSNP)?

3.5 Do you think the establishment of Kafta Sheraro National Park (KSNP) has a positive impact on the conservation of natural resources?

No=0		Yes=1	

3.6 Have you ever seen elephants inside and outside Kafta Sheraro National Park (KSNP)?

No=0		Yes=1	

3.7 Do you think the presence of elephants in this area has any benefit for the people?

No=0		Yes=1	

3.8 If your answer is "yes=1", what are the benefits of elephants? List them.

3.9 How many elephants would you estimate living in Kafta Sheraro National Park (KSNP)?

Less than 50	50-100	100-150	150-300

3.10 Have there been noticeable changes in elephant and other wild animal numbers over the past ten years?

Increased/increase (+)	Decreased/decrease (-)	Stayed/stay the same	Do n't know

3.11 If there has been an increase in numbers, what do you think are the causes?

Causes	Response (Rank)
1. Decreases disturbance	
2. Seasonal change	
3. Diet availability	
4. Water availability	
5. Increases conservation activity	

3.12 Are elephants seasonally moving to other places or border countries?

No=0 ☐ Yes=1 ☐

3.13 If elephants are transboundary, in which season do elephants move?

Season	Response	Season	Response
1. Early dry season		3. Early wet season	
2. Late dry season		4. Late wet season	

3.14 If your answer is 'late dry season', what is the main root cause for the movement of elephants to border countries during this period?

Causes	Rank
1.Dry season fire hazard	
2.Scarcity of food	
3.Riverside vegetation disturbance by cultivation	
4.Drought	
5.Others (specify)	

3.15 For how many months more elephants stayed in the park?

1-5 months ☐ 6-10 months ☐ 10-12 months

3.16 Do you think elephants and other wild animals should be protected in this area?

No=0 ☐ Yes= 1 ☐ explain why?

4. Summary of attitudes and perceptions of the sampled households concerning conservation of African elephant & Kafta Sheraro National Park (KSNP)

According to the following conservation initiatives, how is your attitude and feeling of choice based on the degree to which you agree/disagreement? We chose and put your feedback according to five Likert-type scale response options (1=strongly agree, 2=agree, 3=no opinion (neutral), 4=disagree, and 5=strongly disagree).

Attitude statement toward KSNP conservation		Likert scale				
		1	2	3	3	5
4.1	From the beginning i supported the establishment of KSNP					
4.2	I support the practices of KSNP conservation					
4.3	KSNP has a positive impacts on natural resources conservation					
4.4	KSNP conservation have brought positive change on the local community livelihood					
4.5	Conservation of the whole district area brings happiness					
4.6	KSNP conservation stabilizes communities utilization of NR					
4.7	The relationship b/n community and park managers is good					
Attitude statement toward elephant conservation		1	2	3	4	5
4.8	I support the existence of elephants in our community					
4.9	I encourage to increase the no of elephants in the area					
4.10	Conservation of elephants can open a door for tourist attraction					
4.11	Elephants crop raiding doesn't a significant issue in the area					
4.12	Elephants have the right to live in the area					
4.13	Elephants are important to the whole KSNP ecosystem					
4.14	Construction of water reservoirs assure elephant conservation					

Note: KSNP=Kafta Sheraro National Park

5. Human-elephant interaction and communities' perceptions of elephants

5.1 Can you list the wildlife species observed at your locality?

5.2 Does wildlife cause problems in your locality?

No=0 ☐ Yes=1 ☐

5.3 If yes=1 for how long? [ ]

5.4 What are the problems of wildlife species in your areas?

Conflict types	Response
1.Crop damage (feeding and crash)	
2.Domestic animal injury (depredation)	
3.Disease transmission for animal	
4. Human injury	
5. Others (specify)…	

5.5 If your answer is crop damage (crop raiding), list the wildlife species that have caused problems in the past ten years and rank them based on the level given below.

Name of wild animals	Rank (1=major; 2=moderate, 3=minor, 4=no problem)
1.	
2.	
3.	
4.	
5.	

5.6 Did you have any problems with elephant crop raiding in 2018-2020?
No=0 [ ] Yes=1 [ ]

5.7 Can you predict the trend of crop damage in the past 10 year?

Increased/increase	Decreased/decrease	Stay/stayed the same	Don't know

5.8 What crop types are damaged by elephants?

Crop type/plant name	Season	Habitat	Time	Size (ha)	Rank
1.					
2.					
3.					
4.					
5.					

5.9 Have you been forced to change your crops or abandon your farm because of elephant destruction?
No=0 [ ] Yes =1 [ ]

5.10 Can you weight the level of crop damage impacts or how much crop has been damaged by elephant?

High	Medium	Low	Don't know (No complain)

5.11 If your crop was severely damaged, was there any support or compensation given by the Government/stakeholders?
No=0 [ ] Yes=1 [ ]

5.12 In which season do you expect crop destruction to be more pronounced?

Dry season	Wet season

5.13 Why are the elephants concentrated in agricultural areas?

1.The farm is near to the park	
2.The farm is inside the park	
3.The farm is near to water point (riverside)	
4. Others (specify)…………………………	

5.14 What measures did you take to prevent elephant damage to crops?

Method of protection	Response
1. Gun sound and related noisy materials	
2. Local materials fences(physical barriers)	
3. Fire and flashlight	
4. Land use planning (alternative crop cultivation)	
5. No opinion about prevention	
5. Others (specify)……………………….	

5.15 What are the sustainable management strategies for elephant crop raiding you recommend?

Sustainable strategies	Response
1. Barriers	
2. Compensation	
3. Resettlement/ Relocate	
4. Traditional protection techniques	
5. Killing	
6. Others (specify)…………………….	

5.16 Do you expect Killing of Elephants to be a solution for crop damage?

No=0 ☐ Yes=1 ☐

5.17 How is your method of protection successful? Give your opinion.

Effective	Moderate	Not effective	Don't know

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ንሕድሕድ ተሓታታይ ስድራ ቤት ዝተዳለወ መሕተቲ ቅጥዒ (ብቋንቋ ትግርኛ)

አብ ክልል ትግራይ ነበርቲ ዙርያ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ መሰረት ዝገበረ ነፃን ግልፅን ሕቶታት ንሕድሕድ ተሓታታይ መራሒ/ተወካሊ ስድራ ቤት (ካብ ሕዳር 2010 ክሳብ ሰነ 2010 ኢ.ግ)

መእተዊ: ዕላማ ናይዚ መፅናዕታዊ ሓተታ 'ዚ ብዋናነት ዘትኩሮ ኣብ ምእካብ ኣገደስቲ ዝኮኑ መሰረታዊ (ማሕበራውን ኢኮነሚያውን) መረዳእታታት/ሓበሬታታት ናይቲ ቃለመሕተት ዝግበረሉ ሰብ (ተሓታታይ)፣ናይቲ ከባቢ ማሕበረሰብ ኣብ ምዕቃብ እቲ ሕዛእቲን ሓርማዝን ዘለዎ ግንዛበ/ኣፍልጦን ዘለው ማሕለካታትን፣ኣብ መንጎ ወዲ ሰብን ሓርማዝን ዘሎ ኣሉታዊ ዝምድናን ርክብን ፣ናይቲ ከባቢ ሕብረተሰብ ንሓርማዝ ዘለዎ ምልከታ፣ ኣራኣእያን ኣፍልጦን፣ ናይ ነዊሕ እዋን ታሪካዊ መረዳእታታትን ናይቲ ሕዛእቲ ዝሸፈኖ ተፈጥራዊ መሬት/ሰብ ስራሕ ትሕዝቶ (land use land cover) ፣ቀንዲ ምኽንያታት ምጉሕጋሕ/ምብራስ ንመሬት ዝሸፈኖ ተፈጥራዊ ትሕዝቶ፣እፅዋትን ካልኦት ሃፍቲ ተፈጥሮን፣ ናይ ወዲሰብ ኢድ ኣእታውነት ኣብ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ን ዝመሳሰሉ እዮም:: እዚ መሕተቲ ቅጥዒ ሓደ ክፋል ናይ ሳልሳይ ዲግሪ (ፒ.ኤች.ዲ) መመረቒ ፅሑፍ ኮይኑ ብተምሃራይ ፍፁም ተመስገን ሃይለማሪያም (ሳልሳይ ዲግሪ ኣዲስ ኣባባ ዩኒቨርሲቲ) ዝተዳለወ እዩ:: ስለዚ ንሕድሕድ ሕቶ ብድልየትኩም ንእትህብዎ መልሲ ትክክለኛ ዝኮነ መረዳእታ/ሓበሬታ ንክትህቡኒ ብትህትና ይሐተኩም::

1. መሰረታዊ መረዳእታታት (ማሕበራውን ኢኮነሚያውን ምንቅስቃስ) ናይቲ ተሓታታይ (ኣብ ሕድሕድ መልሶም/ሰን 'X' ምልክት የቐምጡ/ጣ)

1.1 ፆታ

ተባዕታይ		ኣንስታይ	

1.2 ዕድመ:

ትሕቲ 20	21-35	36-50	51-65	ልዕሊ 66

1.3 ምሕደራ ከባቢ፣ ትውልዲ፣ ሓረግ

ቀበሌ	ወረዳ	ዞባ	ክልል	ዓሌት/ሓረግ

1.4 ኩነታት መነባብሮ (ኩነታት ሓዳር)

ሓዳር ዘይብሉ	ባዓል ሓዳር	ተፋተሐ/ት

1.5 በዝሒ ኣባላት ስድራ ቤት: [ ]

1.6 ስራሕ፡ [ ]

1.7 ደረጃ ትምህርቲ:

ዘይስሩዕ ትምህርቲ	ስሩዕ ትምህርቲ					
	ካብ 1ይ-4ይ ክፍሊ	ካብ 5ይ-8ይ	ካብ 9ይ-10ይ	ዲፕሎማ	ዲግሪ	ካልኦትን

1.8 ኣብዚ ቦታ ንክንደይ ዓመታት ዝኣክል ነቢርካ/ኪ?

ትሕቲ 10 ዓመታት ☐ 11-20 ዓመታት ☐ 21-30 ዓመታት ☐ 31-40 ዓመታት ☐ ልዕሊ 41 ዓመታት ☐

1.9 ኣብ ካሊእ ቦታ ተቀሚጥኪ/ካ ትፈልጥ/ጢ ዶ? እወ ☐ ኣይፈልጥን ☐

1.10 መልስካ/ኪ "እወ" እንተኮይኑ ምዓዝ ኢካ/ኪ ብሰፈራ መፂኪ/ካ?

ቅድሚ 1983 ዓ.ም	ካብ 1983-1999 ዓ.ም	ካብ 2000-2011 ዓ.ም

1.11 መነባብሮካ/ኪ ኣበየናይ ዓይነት ስራሕ ዝተደረከ እዩ?

ሀ. መስኖ	
ለ. ምርባሕ እንስሳት	
ሐ. ክረምቲ ተጸቢካ ሕርሻ ምክያድ/ምሀርቲ ምሕፋስ	
መ. ካብቲ ሕዘእቲ ተፈጥራዊ ነገራት ብምስብሳብ	
ረ. ካልኦትን (ዘርዝር/ሪ)	

1.12 ኣማራፂ ናይ ገቢ ፍልፍል ኣለካ/ኪ ዶ?

እወ ☐ የብለይን ☐

1.13 መልስኪ/ካ 'እወ' እንተኮይኑ እቶም ትሰርሖም/ዮም ዓይነታት ተወሰክቲ ስራሕቲ ዘርዝር/ሪ

1.14 ኣብ ገዛካ/ኪ ትጥቀመሎም/መሎም ቀንዲ ፍልፍል ሓይሊ ብፍላይ ድማ መብሰሊ ምግቢን ተዛመድትን

ኤሌትሪክ	ዕንጨይቲ	ኩቦ	ጋዝ	ካልኦትን

1.15 መንበሪካ/ኪ ካብቲ ሕዛእቲ ብክንደይ ኪሎ ሜትር ርሒቁ ይርከብ?

<5ኪሎ ሜትር	5-10 ኪሎ ሜትር	10-15ኪሎ ሜትር	15-20ኪሎ ሜትር	>20 ኪሎ ሜትር

1.16 ናይ ሕርሻ ቦታካ/ኪ ኣበይ ይርከብ?

ኣብ ውሽጢ ሕዛእቲ	ካብ ሕዛእቲ ወፃኢ (ጥቃ)

1.17 ትሕዝቶ መሬት ፡ ናይ ባዕለይ ☐ ክራይ ☐

1.18 ዓይነትን ስፍሐትን ናይቲ ሕርሻካ/ኪ:-

ትጥቀሞ ዓይነት ሕርሻ		ስፍሐት (ሄክታር)	ናይ መሬት ትሕዝቶ መረጋገፂ ፍቃድ ኣለኪ/ካ
ሀ. መስኖ			
ለ. ክረምቲ ተፀቢካ ሕርሻ			

1.19 ኣብ ሕርሻካ/ኪ እንታይ ዓይነት ዝራእቲ/ቀወምቲ ተክሊ ኢካ ተዕቢ? ሕድሕዶም ብከባቢያዊ ሽም ግለፅ።

ዓይነታት ዝራእቲ/ቀወምቲ	ብከባቢያዊ ሽም ዘርዝሮም/ዮም
ሀ. ዝራእትን ጥረምረን	
ለ. ፍረምረ	
ሐ. ኣሕምልቲ	
መ. ቅብኣትን ካልኦትን	

1.20 ኣብ ሕርሻኪ/ካ ተፍርዮም/ይም ዓይነታት ዝራእቲ ነየናይ ጥቅሚ ተውዕልዮም/ሎም?

ናይቲ እክሊ ጥቅሚ	ሽም ናይቶም ዓይነታት እክሊ
ሀ. ንምግብነት ኣገልግሎት	
ለ. ንመሸጣ	
ሐ. ንምግብን ንመሸጣን	

1.21 ኣብዚ ቦታ ክትፀንሕ ዶ ትደሊ/ይ ወይስ ክትለቅቅ/ቂ?

ክፀንሕ ☐ ክለቅቅ ☐

1.22 ካብዚ ቦታ እንተለቂቅካ እንታይ ዓይነት ሽግራት/ፈተናታት ከጋጥሙኒ ኢልካ ትሓስብ/ቢ?

ፈተናታት/ፀገማት		
ሀ. ሕጽረት ኣማራፂ ተሓራሲ መሬት		
ለ. ሕጽረት መማረፂ መግሀፂ እንስሳት		
ሐ. ንመስኖ ዝከውን ሕፅረት ማይ		
መ. መነባቡረይ ብኣጠቓላይ ቅልውላው ይኣትዎ		
ረ. ናይ መስኖ ቦታይ ተክልታት ካብ ጥቅሚ ወፃኢ ይከውን		

1.23. ካብቲ ዝተከለለ ቦታ (ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ) ንመነባብሮካ/ኪ ትጥቀመሎም/ምሎም ነገራት ኣየኖት እዮም? (መልሶም/ሰን 'X ' የቐምጡ/ጣ)።

ምጥቃም ሀፍቲ ተፈጥሮ		
1. ንጋሀፂ እንስሳት		
2. ዕንጨይትን ፈሓምን		
3. ክረምቲ መሰረት ዝገበረ ዝራእቲ		
4. መስኖ		
5. ወርቂ ምውጻእ		
6. ንገዛ መስርሒ ሳዕርን ኦእዋምን		
7. ምስብሳብ ዕጣን		
8. ካብ ሕዛእቲ ምግቢ ምስብሳብ (ማዓር፣ዓሳ፣)		
9. ሕማማት ፈወስቲ ተክልታት		
10. ንገዛን ንእንስሳትን ማይ ምጥቃም		
11. ካልኦትን		

1.24 እንድሕር መልስካ "ጋሀፂ" ኮይኑ ንክንደይ ኣዋርሕ ዝኣክል ኢካ/ኪ እንስሳታትካ/ኪ ኣብቲ ሕዛእቲ ተግህፆም/ፅዮም? (መልስኩም 'X ' ኣቀምጥ/ጢ)

< 3 ወርሒ	3-5 ወርሒ	5-8 ወርሒ	ሙሉእ ዓመት(12 ወርሒ)

1.25 ናይ ኤርትራ ሕብረትሰብ ናብቲ ሕዛእቲ ናይ ምእታው ዕድል ኣለዎም ዶ?

እወ ☐ ኣይኣትውን ☐

1.26 መልስካ//ኪ "እወ" እንተኮይኑ ኣበየናይ ወቅቲ ወሰን እቲ ሕዛእቲ ኣቋሪጾም ይኣትው? (መልስኩም 'X ' ኣቀምጥ/ጢ)

ወቅቲ	
ሀ. ሓጋይ	
ለ. ክረምቲ	
ሐ. ሓጋይን ክረምትን	

1.27 እንድሕር መልስካ/ኪ "ሓጋይ" ኮይኑ ንምንታይ ኣብዚ ወቅቲ ዙይ ናብቲ ሕዛእቲ የቋርፁ? ዘርዝር/ሪ።

1.28 ከመይ ትዕቅኖ/ንዮ ኣብ መንን ናይቲ ከባቢ ነባራይ ማህበረሰበን ኣማሓደርቲ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ዘሎ ርክብ? (መልስኩም '**X** ' ኣቀምጥ/ጢ)

ብጣዕሚ ጽቡቅ	ጽቡቅ	ኣዕጋቢ	ድኩም	ሕማቅ	ሃሳብ የብለይን

1.29 ናይ ሕርሻ ቦታካ/ኪ ኣብ ውሽጢ ወይካዓ ጥቃ ሕዛእቲ ብምኳኑ እንታይ ዓይነት ሽግራት የጋጥሙካ/ኪ? (መልስኩም '**X** ' ኣቀምጥ/ጢ)

ሽግራት	
ሀ. ብእንሰሳ ዘገዳም ዝራእቲ ይጉዳእ	
ለ. ዝሕረስ መሬት ምሳንን መነባብሮካ ምዝባዕን	
ሐ. ምቅናስ ምጥቃም ሕዛእቲ ሀፍቲ ተፈጥሮ	
መ. ባእሲ ምስ ናይ ሕዛእቲ መማሓደርቲ ኣባላት	
ረ. ካልኦትን (ዘርዝር/ሪ)	

2. ቀንዲ ሰብ ስራሕ ማሕለካታት/ፀገማት ኣብ ምዕቃብ ሃፍቲ ተፈጥሮ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ

2.1. ታሪካዊ መረዳእታታት ንመሬት ዝሸፈነ ተፈጥራዊ ትሕዝቶ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ (መልስኩም ካብ ዝለዓለ ናብ ዝተሓተ ብደረጃ ኣቅምጥዎም) ።

I. በኣየናይ ተፈጥራዊ/ሰብ ስራሕ ትሕዝቶ እዩ እቲ ዝበለጸ/ዝዓበየ ናይቲ ሕዛእቲ መሬት ዝተሸፈነ?

ዝሸፈኖ ዓይነት	ደረጃ ምሃብ
1. ጥቅጥቅ ዝበለ ደኒ	
2. ጠንካራ ጉንዲ ዓበይቲ ኦማት	
3. በዝሒ ሳዕሪን ብሕልፍ ሕልፍ ዝበሉ ዓበይቲ ኦማትን ዝተሸፈነ	
4. ቆጥቋጥን ጉጫትን ዝዓብለሎ	
5. ሳዕሪ	
6. ነፃ ሓመድ(ተክሊ ዘይብሉ ቦታ)	
7. ሕርሻ ቦታ	
8. ማይ	
9. ካልኦትን (ዘርዝር/ሪ)	

II. ኣብቲ ከባቢ ብበዝሒ ዝለዓለ ቁፅሪን ኢኮኖሚያዊ ረብሓን ዘለዎም ጠንካራ ጉንዲ ዝተሸከሙ ኦማት ዘርዝርና ብደረጃ ኣቅምጦም።

ከባቢያዊ መፀውዒ እቶም ኦማት	ጥቅሙ	ኩነታት ኣታዓቃቅብኡ	ደረጃ
1.			
2.			
3.			
4.			
5.			
6.			

III. እንታይ ኣስተያየት ኣለካ/ኪ ብዛዕባ ዝሓለፉ እዋናት ንመሬት ዝሸፈኑ ተፈጥራዊ ትሕዝቶ ክፍልታት (ጠንካራ ጉንዲ ዝተሸከሙ ኦማት፣ ሕርሻ፣ ሳዕሪ (ናይ ጋህፒ ቦታ) ጥቃ ማይ ዘሎ ደኒ፣ነፃ መሬት፣መንበሪ) ዘሎ ለውጢ? (መልስኩም '**X** ' ኣቀምጥ/ጢ)።

ዓይነት ዝሸፈኖ ተፈጥራዊ ትሕዝቶ	ካብ ግዜ ናብ ግዜ ዘሎ ለውጢ			
	እናወሰከ	እናቀነሰ	ለውጢ የለን	ሓሳብ የብለይን
ጠንካራ ጉንዲ አማት:1975-1983 ዓ.ም				
1983-1999 ዓ.ም				
2000-2011 ዓ.ም				
ሀ. ቖጥቋጥን ጉጫትን				
ለ. ሕርሻ ቦታ				
ሐ. ሳዕሪ				
መ. ኣብ ጥቃ ማይ ዘሎ ደኒ				
ረ. ነፃ መሬት (ሓመድ)				

IV. ካብቶም ኣብ ታሕቲ ዝተጠቀሱ መሰረተ ልምዓታት ካብ ዝሰፈርካሉ ጊዜ ክሳብ ሎሚ ዘሎ ለውጢ እንታይ ይመስል? (መልስኩም '**X** ' ኣቀምጥ/ጢ)።

መሰረተ ልምዓት	እናወሰከ	እናቀነሰ	ለውጢ የለን	ሓሳብ የብለይን
ሀ. ናብቲ ሐዛእቲ መከየዲ መንገዲ ምቹውነት				
ለ. ማይ ኣቅርቦት (ምንጪ/ጉድጋድ ማይ)				

2.2. ንልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ቀጥታዊ ዝኮነ ሽግር/ፀገም ከስዕቡ ዝክእሉ ነገራት ፡ ካብ ደረጃ: 1-4 ኣቀምጥ/ጢ።

ሽግራት	ብጣዕሚ ዝለዓለ (1)	ዝለዓለ (2)	ማእከላይ (3)	ትሑት (4)
1. ሕጋዊን ዘይሕጋዊን ሰፈራ				
2. ምስፍሕፋሕ ሕርሻ				
3. ምስፍሕፋሕ ጋህዒ				
4. ንምግቢ መብሰሊ ዕንጨይቲ ምቁራፅ				
5. ፈሓም ምምራት				
6. ዘይሕጋዊ ሰደድ ሓዊ				
7. ተፈጥራዊ ዕጣን ምእካብ				
8. ባህላዊ ወርቂ ምውጻእ				
9. ናይ ኢትዮጵያን ኤርትራን ጦርነት				
10. ኤርትራ ብሄረሰብ ናብቲ ሕዛእቲ ምእታው				
11. ቀዋምን ግዝያዊን መንገዲ				
12. ድርቂ				
13. ሕጋዊ ዘይኮነ ምሕደራ መሬት				
ካልኦትን (ዘርዝር/ሪ)				

3. ናይቲ ከባቢ ማሕበረሰብ አብ ምዕቃብ እቲ ሕዛእቲ ብፍላይ ካዓ ንሓርማዝ ዘለዎ ም አፍልጦን ምልከታን/አስተያየትን

3.1 ብዛዕባ ዝተከለለ ቦታ/ ብሄራዊ ሕዛእቲ ሓፈሻዊ ፍልጠት አለካ/ኪ ዶ?

የብለይነን=0		እወ አለኒ,=1	

3.2 ምምስራት/ምቁቃም ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ትድግፎ/ፊ ዶ?

ኣይድግፍን=0		እወ ይድግፍ=1	

3.3 እንድሕር ትድግፎ/ፊ ኮይንካ/ኪ ጥቅምታት ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ እንታይ እንታይ እዮም?

3.4 እንድሕር ዘይትድግፎ/ፊ ምክንያትኪ/ካ

3.5 ምምስራት/ምቁቃም ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ኣብ ምዕቃብ ሃፍቲ ተፈጥሮ ኣስተዋጽኦ ኣለዎ ኢልካዶ/ኪዶ ትሓስብ/ቢ?

ኣይሓስብን=0		እወ ይሓስብ=1	

3.6 ኣብ ዉሸጢ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ወይ ካብ ሕዛእቲ ወጻኢ ሓራምዝ ርኢካዶ/ኪዶ ትፈልጥ/ጢ?

ኣይረአኩን=0		እወ =1	

3.7 ሓራምዝ ኣብቲ ከባቢ ምህላዎም ነቲ ከባቢ ሕብረተሰብ ጥቅሚ ኣለዎም ኢልካዶ/ኪዶ ትሓስብ/ቢ?

ኣይሓስብን=0		እወ=1	

3.8 መልስካ እወ=1 እንተኮይኑ, ጥቅምታት ሓርማዝ ዘርዝር.

3.9 ኣብ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ክንደይ ዝአክሉ ሓራምዝ ክህልዉ ኢልካ/ኪ ትግምት/ቲ?

ትሕቲ 50	ካብ 50 ክሳብ 100	ካብ 100 ክሳብ 150	ካብ 150 ክሳብ 300

3.10 ኣብ ዝሓለፉ ዓሰርተ ዓምታት ኣብዚ ከባቢ ቁፅሪ ሓራምዝን ካልኦት እንስሳ ዘገዳምን ለዉጢ ርኢካ/ኪ ዶ?

ወሲኮም (+)	ቀኒሶም (-)	ለዉጢ የለን	ምንም ኣይፈለጥኩዎን

3.11 ቁፅሮም ወሲኮም እንተይልካ/ኪ ምክንያቱ እንታይ እዩ?

ምክንያት	ምላሽ (ብምስራዕ)
1. ሁዉከት ምቅናስ	
2. ወቕቲ ምቕር	
3. እኩል ምግቢ ምህላዉ	
4. እኩል ማይ ምህላዉ	
5. ናይ ምዕቃብ ስራሕቲ ምዉሳኮም	

3.12 ሓራምዝ ወቕቲ ሓልዮም ናብ ካሊእ ቦታ ይስደዱ ዶ?

ኣይስደዱን=0 ☐ እወ=1 ☐

3.13 እዞም ሓራምዝ ይስደዱ እንተኮይኖም ኣብ ኣየናይ ወቕቲ ይከዱ?

ወቕቲ	ምላሽ	ወቕቲ	ምላሽ
1. ሓጋይ		3. ክረምቲ	
2. ፅዲያ		4. ቐዉዒ	

3.14 መልስካ/ኪ ፅዲያ እንተኮይኑ ምክንያቱ እንታይ እዩ?

ምክንያት	ምስራዕ
1.ናይ ሓጋይ ባርዕ ሓዊ	
2. ሕፅረት ምግቢ	
3. ኣብ ጥቃ ሩባ ዘሎ ደኒ ብሕርሻ ምጭንናቅ	
4. ድርቂ	
5.ካልኦትን (ዘርዝር/ሪ)	

3.15 በዝሒ ዘለዎም ሓራምዝ ኣብቲ ሕዛእቲ ንክንደይ ወርሒ ዝአክል ይፀንሑ?

1-5 ወርሒ ☐ 6-10 ወርሒ ☐ 10-12 ወርሒ ☐

3.16 ሓራምዝን ካልኦት እንስሳ ዘገዳምን አብዚ ቦታ ክዕቐቡ ኢልካ ዶ/ኪዶ ትሓስብ/ቢ?

ኣይሓስብን =0 [ ] ኣወ =1 [ ] ምኽንያቱ ግለፅ?

4. ነቲ መፅናዕቲ ካብ ዝተመረፁ ሕድሕድ ስድራ ቤት ኣብ ምዕቃብ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮን ሓራምዝን ዘለዎም ኣፍልጦ/ግንዛበ፣ ምልከታን ኣራኣእያን

በቶም ኣብ ታሕቲ ተገሊፆም ዘለዉ ናይ ምዕቃብ ሓራምዝ ሙሉእ ሓሳብ ምልዕዓላት, ሓሳብካ/ኪን ስምዒትካ/ኪን ንሕድሕድ ሙሉእ ሓሳብ በቲ ሊከርት (Likert) ዘቀመጦም ሓሙሽተ ዋና ናይ ምስምዕማዕ ደረጃታት ምርጫካ/ኪ ኣቐምጥ/ጢ. (1=ብዕቱብ ተስማዕሚዒ, 2=ተስማዕሚዒ, 3=ሓሳብ የብለይን, 4=ኣይተስማዕማዕኩን, & 5=ፈፂመ ኣይተስማዕማዕኩን).

ምልከታ ሙሉእ ሓሳብ ኣብ ምዕቃብ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራር		ሊከርት ስኬል				
		1	2	3	3	5
4.1	ካብ ምጀመርትኡ ምምስራት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ይድግፎ እየ					
4.2	ኣብ ምዕቃብ ልምዓት ብሄራዊ ሕዝእቲ ቃፍታ ሽራሮ ዝግበሩ ምንቅስቃሳት ይድግፎ					
4.3	ብልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ኣብ ምዕቃብ ሃፍቲ ተፈጥሮ ኣወንታዊ ኣስተዋፅኦ ኣለዎ					
4.4	ምዕቃብ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ኣብ መነባብሮ ናይቲ ከባቢ ሕብረተሰብ ኣወንታዊ ለዉጢ የምፅ እዩ					
4.5	ሙሉእ እቲ ከባቢ ምዕቃብ ደስታ ይፈጥር					
4.6	ምዕቃብ ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ዝተመጣጠነ ኣተቃቕማ ተፈጥሮ ሃፍቲ ናይቲ ከባቢ ክህሉ ይገብር					
4.7	ኣበ መንጎ ናይቲ ከባቢ ሕብረተሰብን ሕዛእቲ ኣማሓደርትን ዘሎ ርክብ ፅቡቕ እዩ					
ምልከታ ሙሉእ ሓሳብ ኣብ ምዕቃብ ሓራምዝ		1	2	3	4	5
4.8	ኣብ ከባቢና ሓራምዝ ምህላዎም ይድግፍ					
4.9	ኣብቲ ከባቢ ቁፅሪ ሓራምዝ ንክዉስክ የተባብዕ					
4.10	ምዕቃብ ሓራምዝ ንምስሓብ ሃወፅቲ በሪ ይከፍት					
4.11	ሓራምዝ ኣብ ዝራእቲ እቲ ከባቢ ዘብፅሕዎ ጉድኣት ዳርጋ የለን					
4.12	ሓራምዝ ኣብቲ ከባቢ ናይ ምንባር መሰል ኣለዎም					
4.13	ሓራምዝ ኣጠቃላይ ንስነ-ምህዳር ልምዓት ብሄራዊ ሕዛእቲ ቃፍታ ሽራሮ ጠቀሜታ ኣለዎ					
4.14	ናይ ማይ መጠራቀሚ ገንእታት ምስራሕ ኣብ ምርግጋፅ ምዕቃብ ሓርማዝ ኣስተዋፅኦ ኣለዎ					

5. ኣብ መንጎ ወዲ ሰብን ሓርማዝን ዘሎ ዝምድና/ርክብና ናይቲ ከባቢ ሕብረተሰብ ንሓርማዝ ዘለዎ ምልከታ፣ ኣራኣእያን ኣፍልጦን

5.1 ኣብ ከባቢካ/ኪ እትሪኦም/ዮም እንስሳ ዘገዳም ክትዝርዝር/ሪ ትክእል/ሊ ዶ?

5.2 ኣብ ከባቢካ/ኪ እንስሳ ዘገዳም ሽግር የብፅሑ ዶ?

ኣይፈጥሩን=0 [ ] እወ=1 [ ]

5.3 እንድሕር እወ=1 ንክንደይ ግዜ ዝኣክል?

5.4 ኣብ ከባቢካ/ኪ እንስሳ ዘገዳም ዘብፅሕዎም ሽግራት እንታይ እንታይ እዮም?

ናይ ግጭት ዓይነታት	ምላሽ
1.ኣብ ዝራእቲ ዕንወት ምብፃሕ (ምምጋብና ምብልሻዉ)	
2.እንስሳ ዘቤት ምጉዳእ (ምስዳድ)	
3.ሕማማት ምምሕልላፍ	
4. ኣብ ወዲ ሰብ ጉድኣት ምብፃሕ	
5. ካልኦትን (ዘርዝር)…	

5.5 እንድሕር መልስካ ኣብ ዝራእቲ ዕንወት ምብፃሕ (crop raiding) ኮይኑ, ኣብ ዝሓለፉ ዓሰርተ ዓመታት ሽግር ዘብፅሑ ዓይነታት እንስሳ ዘገዳም ዘርዝርና እቲ ኣብ ታሕቲ ተቀሚጡ ዘሎ ናይ ጉድኣት ስርዒት ደረጃ ሃብዮም/ሃቦም

ሽም እንስሳ ዘገዳም	ደረጃ (1=ከባድ፣ 2=ማእከላይ፣ 3=ቀላል ፣4=ሽግር የለን)
1.	
2.	
3.	
4.	
5.	

5.6 ካብ 2010-2012 ኢ.ግ ኣብ ዝራእቲ ብሓራምዝ ዝበፅሑ ዕንወታት ኣለዉ ዶ?

የለን=0 ☐ እወ=1 ☐

5.7 ኣብ ዝሓለፉ ዓሰርተ ዓመታት ኣብ ዝራእቲ ዝበፅሐ ክይዲ ዕንወት ክትግምት ትክእል/ሊ ዶ?

ወሲኩ	ቀኒሱ	ለዉጢ የለን	ኣይፈልጥን

5.8 ብሓርማዝ ዝተጠቅዑ ዓይነታት ዝራእቲ እንመን እዮም?

ዓይነት/ሽም ዝራእቲ	ወቅቲ	ሕዛእቲ	ግዜ	ስፍሓት (ሄክታር)	ደረጃ
1.					
2.					
3.					
4.					
5.					

5.9 ብምኽንያት ሓርማዝ ዘብፅሖ ጉድኣት ኣብ ምቅያር ዓይነት ዝራእቲ ወይካዓ ኣብ ምግዳፍ ሕርሻካ ተገዲድካ ዶ?

ኣይተገደድኩን=0 ☐ እወ =1 ☐

5.10 ደረጃ ነቲ ኣብ ዝራእቲ ብሓራምዝ ዝበፅሐ ዕንወት ክንደይ ዝኣክል ምካኑ ምምዛን/ምዕቃን ትክእል ዶ?

ዝለዓለ	ማእከላይ	ትሑት	ዝፈልጦ የለን (ኣስተያየት የብለይን)

5.11 እንድሕር ዝራእትካ ብሕሱም ዓንዩ ብመንግስቲ/ባዓል ድርሻ ኣካላት ሓገዝ/ካሕሳ ዝተገበረልካ/ኪ ኣሎ ዶ?

የለን=0 ☐ እወ=1 ☐

5.12 ዕንወት ዝራእቲ ኀሊሁ ዝረአ ኣበየናይ ወቅቲ እዩ?

ሓጋይ	ክረምቲ

5.13 ሓራምዝ ንምንታይ ኣብ ሕርሻ ቦታካ/ኪ የዘዉትሩ?

ምክንያት	ምላሽ
1. እተ ሕርሻ ኣብ ጥቃ ሕዛእቲ ስለ ዝኮነ	
2. እቲ ሕርሻ ኣብ ዉሽጢ ሕዛእቲ ስለ ዝኮነ	
3. እቲ ሕርሻ ኣብ ጥቃ ሩባ ስለ ዝኮነ	
4. ካልኦት (ዘርዝር/ሪ)	

5.14 ኣብ ዝራእቲ ብሓርማዝ ዝፅበሕ ዕንወት ንምክልካል እንታይ ዓይነት ስጉምቲ/መከላከሊ ሜላ ትወስድ/ዲ ኔርካ/ኪ?

መከላከሊ ሜላ	ምላሽ
1. ናይ ጥይት ድምፅን ካልኦት ድምፂ ዘሰምዑ ነገራትን	
2. ባህላዊ ሓፁር	
3. ሓዊና መብራህቲ ከህቡ ዝክእሉ ነገራት ምጥቃም	
4. ሓርማዝ ክጠልቦ ዘይክእል ዓይነት ዝራእቲ ምጥቃም	
5. ምንም ሓሳብ የብለይን	
5. ካልኦትን (ዝርዝር/ሪ)…………………………	

5.15 ብሓርማዝ ናይ ዝጥቅዑ ዝራእቲ ቀፃልን ዉሑስን ዝኮነ ምከላከሊ ሜላ ኣየናይ ትመርፅ/ፂ?

ቀፃልን ዉሑስን ዝኮኑ ናይ ምክልካል ሜላታት	ምላሽ
1. ሓፁር	
2.ካሕሳ	
3. ናይ ሕርሻ ቦታ ምቅያር	
4. ባህላዊ ምከላከሊ ሜላ	
5. ምቅታል	
6.ካልኦትን (ዘርዝር/ሪ)…………………	

5.16 ኣብ ዝራእትካ/ኪ ብሓርማዝ ዝበፅሕ ዕንወት ምቅታል መፍትሒ ክከዉን ይክእል እዩ ኢልካ ዶ ትሓስብ/ቢ?

ኣይሓስብን =0 ☐ እወ=1 ☐

5.17 መከላከሊ ሜላካ/ኪ ዕዉትነቱ ብከመይ ትዕቅኖ? ሓሳብካ/ኪ ሃብ/ቢ.

ኣዝዩ ዕዉት	ማእከላይ	ዕዉት ኣይኮነን	ሓሳብ የብለይን

Some of the photographs took by the author (here after Fitsum Temesgen) during his field work

Plate 1. Field observation and vegetation survey on Acacia commiphora wooded grass and bushland vegetation type with a dominant species of *Acacia mellifera and Balanites aegyptiaca* (a & b), Riparian vegetation type (along Tekeze river and its tributary rivers) with a dominant species of *Hyphaene thebaica* and *Ziziphus spina-christi* (c & d), and Combretum terminalia woodland vegetation type with a frequent species of *Combretum hartmannianum* and *Terminalia brownii* (e & f) with their wildlife habitats of Kafta Sheraro National Park (Photos by Fitsum Temesgen, 2018-2020).

A B

C D

Plate 2. Human induced disturbance activities inside Kafta Sheraro National Park vegetation types: Firewood collection for home consumption (A); Charcoal products loaded by horse cart for sell (B); Sesame (*Sesamum indicum*) cultivation for market sell (C) and Sorghum (*Sorghum bicolor*) cultivation for food consumption (D**)** in northeast part of the park (Photos by Fitsum Temesgen, 2018-2020).

A

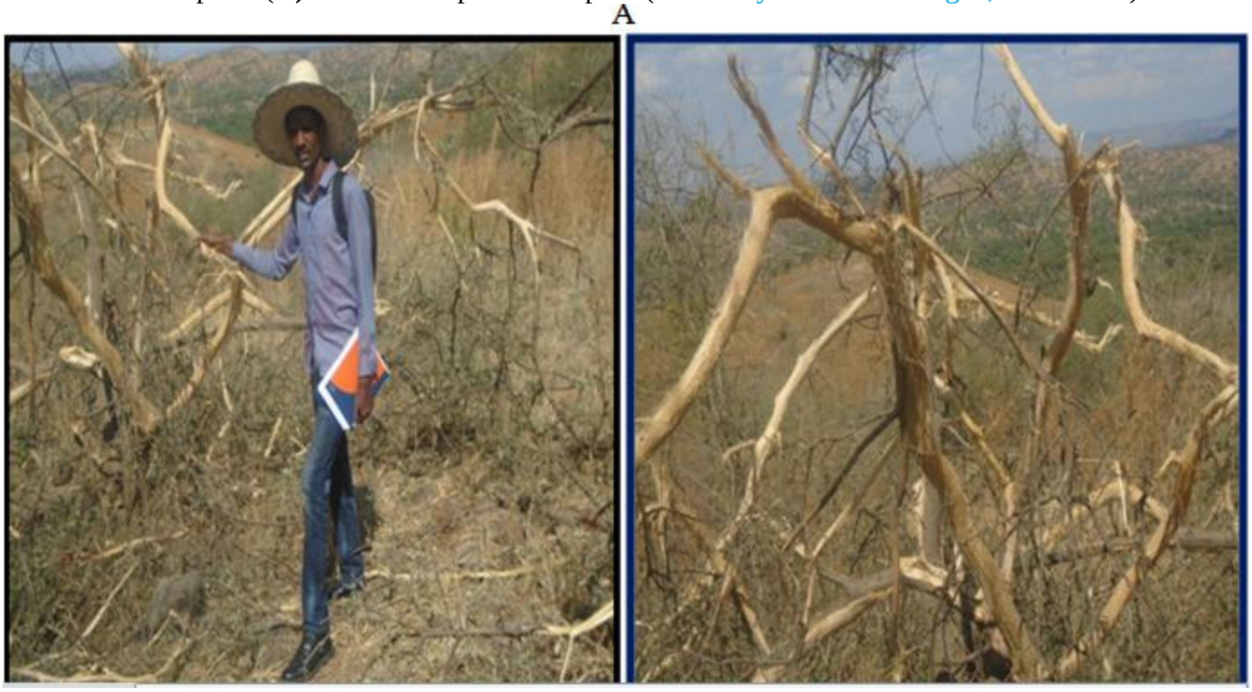

Plate 3. Some of the photographs took on common elephant feeding habits/signs in Kafta Sheraro National Park during wet and dry seasons (A) Broken branches & scratching stems of *Acacia mellifera*, (B) Uprooting and chopping of *Sterculia africana*, (C) Broken stems of *Balanites aegyptiaca*, (D) Bark stripping on *Burkea africana* species, (E) Elephants visit open Acacia habitat. **Remark:** The photo (Plate 1A) refers the corresponding author and Photo (Plate B) refers scouts of KSNP while conducting field work (Photos by Fitsum Temesgen, 2018-2020).