Zentrum für Entwicklungsforschung (ZEF)

Availability and Sustainable Harvesting of Wild Edible Plants in Turkana County, Kenya

Dissertation

zur Erlangung des Grades

Doktor der Agrarwissenschaften (Dr. agr.)

der Landwirtschaftlichen Fakultät

der Rheinischen Friedrich-Wilhelms-Universität Bonn

von

Wyclife Agumba Oluoch

aus

Nyando, Kenya

Bonn 2024

Referentin: Prof. Dr. Christine B. Schmitt

Korreferent: Prof. Dr. Christian Borgemeister

Tag der mündlichen Prüfung: 15.04.2024

Angefertigt mit Genehmigung der Landwirtschaftlichen Fakultät der Universität Bonn

KURZFASSUNG

Essbare Wildpflanzen (WEPs) sind weltweit wichtig für die Linderung von Armut und Unterernährung, insbesondere von Mikronährstoffmangel. Sie werden jedoch nur unzureichend genutzt, sind bedroht und ihre Verbreitungsmuster sind noch wenig bekannt, insbesondere in Anbetracht des Klimawandels. Verständnis dessen, wie Gemeinschaften die Verfügbarkeit von WEPs sowie Bedrohungen und Bewirtschaftungsoptionen wahrnehmen, könnte dazu beitragen, ihre Erhaltung zu verbessern und ihre nachhaltige Nutzung zu fördern. Mit Hilfe eines integrierten partizipatorischen Ansatzes, der lokales ökologisches Wissen indigener Gemeinschaften und wissenschaftliche Methoden einbezieht, untersucht diese Arbeit die Verfügbarkeit und nachhaltige Nutzung von WEPs im Bezirk Turkana, Kenia. Die Studie beleuchtet insbesondere, wie die Turkana-Gemeinschaften die Verfügbarkeit von WEPs wahrnehmen, bewertet Bedrohungen und Bewirtschaftungsoptionen für die WEPs und prognostiziert die potenziell geeigneten Lebensräume für ausgewählte WEPs in der Gegenwart und unter zukünftigen Klimabedingungen im Turkana County, Kenia. Diese Studie ist Teil einer größeren Studie mit dem Titel „Improving dietary quality and livelihoods using farm and wild biodiversity through an integrated community-based approach in Kenya“, die von der Bundesregierung finanziell unterstützt wurde.

Der Hintergrund der Studie, das Forschungsproblem, die Ziele und die Struktur der Arbeit werden in Kapitel Eins der Arbeit behandelt. In Kapitel Zwei wird der aktuelle Stand der Forschung in Bezug auf globale und regionale Fortschritte beim Verständnis von WEPs vorgestellt. Das Kapitel fokussiert auch auf die Belange, die für die in Kapitel Eins dargelegten spezifischen Ziele relevant sind, und bietet einen Überblick über das Konzept der Verfügbarkeit von WEPs, Bedrohungen für WEPs und deren Managementoptionen sowie über die Modellierung potenziell geeigneter Lebensräume für WEPs. Das Untersuchungsgebiet und das Studiendesign werden in Kapitel Drei vorgestellt. Die Ergebnisse von Fokusgruppendiskussionen mit Turkana-Gemeinschaften in Kenia, die in Kapitel Vier erläutert werden, zeigen, dass Entfernung, Saisonalität, Preis und Angemessenheit der geernteten WEPs für den Haushaltsverbrauch wichtige Parameter sind, die die Wahrnehmung von WEPs als verfügbar oder nicht verfügbar beeinflussen. Darüber hinaus wurden aus der thematischen Analyse von Texten aus den Gemeinschaften weitere

einflussreiche Determinanten für die Verfügbarkeit von WEP abgeleitet, darunter Kultur und Tradition, Verteilung von WEP, Saisonalität und Klimawandel.

Wichtige Bedrohungen und Bewirtschaftungsoptionen für WEPs, wie sie von den lokalen Gemeinschaften diskutiert und bei den Feldbegehungen beobachtet wurden, werden in Kapitel Fünf der Arbeit aufgezeigt. Die Rangfolge der Bedrohungen und Bewirtschaftungsoptionen war in den untersuchten Gemeinden mit unterschiedlichen ökologischen und sozioökonomischen Merkmalen verschieden. Klimawandel, Überbesatz, Überernte und invasive Arten waren die am höchsten eingestuften Bedrohungen für WEPs. Die Abschwächung des Klimawandels, die Erhaltung des lokalen Wissens, die Auswahl, Vermehrung, Verarbeitung und Vermarktung von WEPs standen unabhängig von den sozioökonomischen und ökologischen Merkmalen der untersuchten Gemeinden ganz oben auf der Liste der möglichen Managementoptionen. Kapitel Sechs bildet den Abschluss der Hauptkapitel der Studie, indem die Ergebnisse der Modellierung der potenziell geeigneten Lebensräume für WEPs im Bezirk Turkana vorgestellt werden. Etwa die Hälfte der 23 untersuchten WEPs hat derzeit potenziell geeignete Lebensräume, die mindestens die Hälfte der Landfläche des Bezirks Turkana (~68.253 km^2) umfassen. Unsere Prognosen für die Zukunft zeigen, dass etwa die Hälfte der WEPs potenziell geeignete Lebensräume verlieren wird, wobei sich ein ähnliches Muster für den Artenreichtum innerhalb des Bezirks ergibt.

Die Hauptergebnisse dieser Arbeit zeigen, wie wichtig es ist, das lokale ökologische Wissen der lokalen Gemeinschaften in die Untersuchung ihrer wertvollen Ressourcen, insbesondere der WEPs, einzubeziehen. Darüber hinaus werden in der Arbeit die größten Bedrohungen für WEPs sowie Managementoptionen aufgezeigt. Die Ergebnisse ebnen auch den Weg zum Verständnis der potenziell geeigneten Lebensräume für WEPs in den ariden und semiariden Regionen im Nordwesten Kenias. Diese Ergebnisse unterstreichen die Notwendigkeit, lokales ökologisches Wissen in die Schutzbemühungen für WEPs einzubeziehen. Sie liefern wertvolle Erkenntnisse für künftige Schutz- und nachhaltige Bewirtschaftungsstrategien zur Verbesserung der Nahrungsvielfalt unter Verwendung der lokal verfügbaren WEPs der lokalen Gemeinschaften in der Region. Der in dieser Arbeit verfolgte Ansatz unterstreicht die Bedeutung der Nutzung der Wahrnehmungen indigener Gemeinschaften und der Durchführung von Felduntersuchungen zur

Bewertung von Bedrohungen und Bewirtschaftungsoptionen für WEPs. Die Ergebnisse dieser Arbeit können insbesondere dazu beitragen, die nationale Lebensmittel- und Umweltschutzpolitik in Kenia zu verbessern, damit mehr WEPs eingesetzt werden und ihr potenzieller Nutzen zur Linderung von Hunger und Unterernährung bewertet werden kann, insbesondere bei der Verwirklichung ihrer nachhaltigen Nutzung in ariden und semiariden Gebieten im Nordwesten Kenias.

ABSTRACT

Wild Edible Plants (WEPs) are important globally in alleviating poverty and malnutrition especially micronutrient deficiency. However, they are underutilized, threatened, and their distribution patterns are not well understood especially considering the changing climate. Understanding how communities perceive availability of WEPs as well as threats and management options, could help in enhancing their conservation and foster their sustainable utilization. Using integrated participatory approach involving local ecological knowledge from indigenous communities and scientific methods, this thesis explores availability and sustainable harvesting of WEPs in Turkana County, Kenya. Specifically, the study assesses how Turkana communities perceive availability of WEPs, assesses threats and management options for the WEPs, and predicts the potentially suitable habitats for selected WEPs at present and under future climate conditions in Turkana County, Kenya. It forms part of a major study "Improving dietary quality and livelihoods using farm and wild biodiversity through an integrated community-based approach in Kenya" that received financial support from the German government.

Background to the study, research problem, objectives, and structure of the thesis are covered in Chapter one of the thesis. Chapter two, presents the state of the art in terms of global to regional advances in understanding WEPs. The chapter also narrows down to concerns that are relevant to the specific objectives set out in Chapter one and offers reviews on the concept of availability of WEPs, threats to WEPs and their management options, as well as on modeling of potentially suitable habitats of WEPs. The research study area and study designs are presented in Chapter three. Results from focus group discussions with Turkana communities of Kenya presented in Chapter four show that distance, seasonality, price, and adequacy of harvested WEPs for household consumption were important parameters influencing the perception of WEPs as available or not. Additionally, the thesis derived other influential determinants of availability of WEPs including culture and tradition, distribution of WEPs, seasonality, and climate change from thematic analysis of texts from the communities.

Important threats and management options to WEPs as discussed by the local communities and observed in the field plot surveys are presented in Chapter five of the thesis. Rankings of threats and management options differed across the study communities with differing environmental and socio-economic characteristics. Climate change, overstocking, overharvesting, and invasive species were the highest-ranked threats to WEPs. Mitigation of climate change, local knowledge preservation, selection, propagation, processing, and marketing of WEPs ranked high among possible management options irrespective of the socio-economic and environmental characteristics of the study community units. Chapter six marks the end of major study chapters by presenting the results from modeling of the potentially suitable habitats of WEPs in Turkana County. About half of the studied 23 WEPs have current potentially suitable habitats spanning at least half of the Turkana County land area (~68,253 km^2). Our future predictions showed loss of potentially suitable habitat by about half the WEPs with similar pattern for richness within the county.

The major findings of the thesis indicate the importance of including the local ecological knowledge from local communities in studying their valuable resources, specifically WEPs. Further, major threats facing WEPs as well as management options are highlighted in the thesis. The findings also pave way for understanding of the potentially suitable habitats of WEPs for the arid and semi-arid regions of northwestern Kenya. These major findings call for emphasizing the need to include local ecological knowledge in conservation efforts of WEPs. These results provide valuable insights for future conservation and sustainable management strategies to improve dietary diversity using locally available WEPs of local communities in the region. The approach employed in the thesis emphasizes the relevance of leveraging indigenous communities' perceptions and conducting field plot surveys to assess threats and management options for WEPs. Particularly, the findings of the thesis can help in improving national food policies and environmental conservation policies in Kenya to embrace more of WEPs and further evaluate their potential use in alleviating hunger and malnutrition especially in realizing their sustainable use in arid and semi-arid lands of northwestern Kenya.

ACKNOWLEDGEMENTS

This thesis received financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ) commissioned and administered through the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Fund for International Agricultural Research (FIA), grant number: 81235248. I am very grateful for their support. Secondly, I acknowledge The Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT) that coordinated the project. Specifically, I appreciate the guidance of the principal investigator Dr. Céline Termote whose and support made field data collection possible. I appreciate, in equal measure, the support from my supervisors, Prof. Dr. Christine B. Schmitt and Prof. Dr. Christian Borgemeister. Their deeper thoughts into the project guided the study throughout the four-year period. I also fully appreciate my tutor, Dr. Cory Whitney, for the guidance and systematic guidance while writing the thesis. I further appreciate the support from Dr. Guenther Manske and Ms. Maike Retat-Amin during my early study period at the Center for Development Research (ZEF). Their support made settling and studying in Bonn smoother. I further appreciate invaluable support from Max Voit and Dr. Silke Tönsjost. Colleagues, with whom I took interdisciplinary and disciplinary courses at ZEF, feel much appreciated. Special gratitude goes to Hina Amber with whom I shared many life experiences and spent special moments. Elizabeth Ndunda for unimaginable psycho-sociological support. Dr. Arif Budy Pratama, who made my settling in Tannenbusch Mitte memorable, feel much appreciated.

I wish to appreciate my research team with whom I traversed the expanse of the study area. I sincerely appreciate Francis Odhiambo Oduor (The Alliance of Bioversity International and CIAT), Philip Abura (Research Assistant), and Robert Esekon (Research Assistant) for their endurance during the fieldwork periods. I cannot forget the support from my long-term friend, Ms. Antonine Aluoch Ooko (*Daktari*) whose emotional support and encouragement has made me reach this far academically. To this end, I channel special gratitude to my wife Christine Auma, son Aldrin Kelly, daughter Emelia Keline, my mum, and brother Harrison for their support and understanding during my absence from home to study in Bonn.

DEDICATION

I dedicate this thesis to my late primary school teacher Mr. Joshua B. Adede (*Engineer*). Mr. Adede molded my brain into what could end up composing a thesis of this magnitude. Successful completion of this Ph.D. thesis is a candid testimony. Rest well '*Engineer*'.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS AND ABBREVIATIONS

AUC	-	Area Under the Curve
BIEN	-	Botanical Information and Ecology Network
BMZ	-	German Federal Ministry for Economic Cooperation and Development
CHELSA	-	Climatologies at High resolution for the Earth's Land Surface Areas
CIAT	-	The International Center for Tropical Agriculture
CU	-	Community Unit
FAO	-	Food and Agriculture Organization
FGD	-	Focus Group Discussion
FIA	-	Fund for International Agricultural Research
GBIF	-	Global Biodiversity Information Facility
GIZ	-	Deutsche Gesellschaft für Internationale Zusammenarbeit
IUCN	-	International Union for Conservation of Nature
RAINBIO	-	Response And Impacts of Natural and anthropogenic factors on BIOdiversity in tropical forests
SDG	-	Sustainable Development Goals
SDM	-	Species Distribution Model
SSP	-	Shared Socio-Economic Pathway
TAP	-	Turkwel Riverine Agro-Pastoral
TBP	-	Turkana Border Pastoral
TCP	-	Turkana Central Pastoral
TSS		True Skill Statistic
WEP	-	Wild Edible Plant
ZEF	-	Center for Development Research

Chapter 1: General Introduction: Wild Edible Plants

1.1 Background

Wild plants are defined by the Food and Agriculture Organization (FAO) as 'those that grow spontaneously in self-maintaining populations in natural or semi-natural ecosystems and can exist independently of direct human action' (Heywood, 1999, p. 2). Wild edible plants (WEPs) are such plants that 'are endowed with one or more parts that can be used for food if gathered at the appropriate stage of growth and properly prepared' (Kallas, 2010, p. 35). These plants have served important dietary and therapeutic roles in global human societies from early hunter-gatherer eons to the contemporary societies (Alarcón et al., 2015; Carvalho & Barata, 2016). WEPs are foraged from herbs, trees, shrubs, vines, sedges, rushes, and ferns, and other organisms like fungi, algae, and lichens (Alarcón et al., 2015). From these organisms, shoots, roots, fruits, flowers, tubers, stems, sprouts, seeds, nuts, barks, gums, and fronds are extracted for consumption (Ulian et al., 2020). The use values of these organisms are not restricted to nutrition but also ethno-pharmacology, ecosystem services (food for wild animals, contribution to water cycle, control of pests and diseases), construction materials, aesthetic values, and community specific cultural and religious significances (D'iaz et al., 2019).

There are about 7000 WEPs (Ulian et al., 2020) and 2000 species of mushroom (H. Li et al., 2021) used as food and beverages by communities globally. That is more than the narrow dietary width of cultivated crops that has been homogenized through time consisting of 92 species that account for 90% of food supply globally today (Khoury et al., 2014, 2019); posing a threat to global food security (Schunko et al., 2022). Only 30 crops contribute up to 95% of plant proteins and barely 10 species clusters account for 90% of international trade worldwide (Ngome et al., 2017). Scientists are starting to fully assay the nutritional benefits of these WEPs across communities and preliminary indications show comparable or better nutritional benefits from the WEPs versus crops (Flyman & Afolayan, 2006; Ngome et al., 2017; Peeters & Maxwell, 2011). The consumption of the diverse WEPs could thus be important in reducing hunger and malnutrition, especially micronutrient deficiency, across both poor communities and rich countries plagued by micronutrient deficiency (hidden hunger) (Ngome et al., 2017; E. Smith et al., 2019).

Against the backdrop of about 7000 established WEPs, some communities that are endowed with the WEPs, still underutilize them and record high levels of hunger and micronutrient deficiency (Termote et al., 2012). The link between consumption of WEPs and poverty, backwardness, and precarious livelihoods (Carvalho & Barata, 2016; Delang, 2006; Pawera et al., 2020) has been used to explain the counterintuitive phenomenon. However, in the context of this study (see section 3.1.13.1), the thesis assessed how local communities in arid and semi-arid lands of Turkana County, Kenya perceived availability of WEPs to help explain the underutilization. Availability, as a hypothesis in relation to WEPs, has been regarded as the ease of access and abundance of WEPs to the users/consumers (Albuquerque, 2006; Gaoue et al., 2017; Voeks, 2004). Additional considerations such as distance to harvest sites, ease of harvesting, ease of processing, portability, availability in the market, and price of the WEPs sold in the market have also been proposed (Albuquerque, 2006; Estomba et al., 2006; Gaoue et al., 2017) to explain how availability of WEPs is perceived. These were relevant for the arid and semi-arid Turkana context and were assessed in this thesis.

Global environmental changes, both natural and anthropogenic, are piling pressure on already struggling biodiversity including WEPs (Le Page, 2021). The pressure features a number of threats typical to the study area like uncontrolled fires, agricultural expansion, deforestation, overstocking, overharvesting, charcoal burning, invasive species, and erosion of local knowledge about WEPs (Asfaw, 2008; Badimo et al., 2015; Pawera et al., 2020). While some WEPs are adapted to arid and semi-arid lands like in northwestern Kenya, the compounding impact of both natural and anthropogenic pressures make their survival precarious. Efforts to sustain the survival of these valuable plants call for integrated participatory efforts in their management and conservation that includes all key stakeholders in the value chain of WEPs.

For informed conservation of WEPs, mapping and quantification of their present and potential future distribution is important. In developing world such as Kenya, WEPs are normally less addressed in food surveys and discussions (Ngome et al., 2017), and efforts to determine their distribution are very scanty. Only a few articles have addressed this important gap globally (Vincent et al., 2019) and in Southern Africa (Wessels et al., 2021) with a couple others assessing medicinal plants (Bariotakis et al., 2019; Mkala et al., 2022). It is imperative that to plan and execute better conservation strategies for WEPs, knowledge of their historic, current, and potential future distribution be considered. This is largely achieved through species distribution modeling (SDM) protocols that combine both occurrence records and environmental predictor variables in correlative modeling paradigm (Feng, Park, Walker, et al., 2019; Guisan et al., 2017; Zurell et al., 2020).

Although WEPs are important source of nutrition to societies across the globe, they tend to be underutilized, threatened by pressure piled from natural and anthropogenic environmental changes, and their distributions are not well documented to inform management and conservation for their sustainable use. This thesis used an integrated participatory approach to understand how indigenous Turkana communities in northwestern Kenya perceive availability of their WEPs, threats and management options for the WEPs and mapping their distribution. These communities are traditionally nomadic pastoralists and live in arid and semi-arid lands with established list of WEPs, yet they remain the most affected by hunger and malnutrition in the country. Specifically, the study focused on woody WEPs as they have longer lifespans thus the participants would interact, know, and use them better to warrant informative discussion in addressing objectives of our study. Woody WEPs also have relatively more observed records than herbs to enable building of models to predict their potentially suitable habitats. The study used both focus group discussions (FGDs) with key stakeholders and field surveys to gather data. Further, both online data archives of occurrence records of selected WEPs and environmental predictor variables were used in the study to help build SDMs for the WEPs in the region. Additional occurrence data were obtained from East African Herbarium in Nairobi and field observations.

1.2 Objectives

1.2.1 General objective

The general objective of the study is to assess availability of woody WEPs, their threats and management, and quantify their present and future potentially suitable habitats to help inform their sustainable use.

1.2.2 Specific objectives

Specifically, the research sought to:

i. Assess how Turkana communities perceive the availability of their woody WEPs in northwestern, Kenya. This is presented in Chapter 4.
ii. Assess the threats and management options to woody WEPs in Turkana County, Kenya. This is presented in Chapter 5.
iii. Predict changes in distribution of WEPs under climate change scenarios in Turkana County, Kenya. This is presented in Chapter 6.

1.3 Structure of the Thesis

This thesis consists of eight chapters. Chapter 1 explores the background of WEPs globally, Eastern Africa, and Kenya. It also highlights research problem, objectives, and structure of the thesis. Chapter 2 details literature, revealing state-of-the-art in the study of WEPs. Description of the study area and methods used are in Chapter 3. Chapters 4 to 6 features published work on availability, threats and management, and potentially suitable habitat quantification of the WEPs, respectively. These are summarized in Table 1.1. Other published works during the project but not contributing directly to the thesis are highlighted in Table 1.2. Synthesis of the major findings from published works in chapters 4 to 6 is captured in Chapter 7. Chapter 8 gives the conclusions and recommendations of the thesis after which references and appendices mark the end of the thesis.

Table 1.1: Authorship and specific contributions

Author and title	Journal	Status of publication	Specific contribution of the thesis author
Oluoch, W. A., Whitney, C. W., Termote, C., Borgemeister, C. and Schmitt, C. B. *Integrated Participatory Approach Reveals Perceived Local Availability of Wild Edible Plants in Northwestern Kenya*	Human Ecology, 51(1), 59-74	Published, 2022	• Lead author • Development of ideas and research design • Data compilation and analysis • Writing and revision of the manuscript
Oluoch, W. A., Whitney, C. W., Termote, C., Borgemeister, C. and Schmitt, C. B. *Indigenous communities' perceptions reveal threats and management options of wild edible plants in semiarid lands of northwestern Kenya*	Ethnobiology and Ethnomedicine, 19(13), 1-15	Published, 2023	• Lead author • Development of ideas and research design • Data compilation and analysis • Writing and revision of the manuscript
Oluoch, W. A., Borgemeister C., Vidal Junior, J. D., Fremout, T., Gaisberger, H., Whitney, C. W., and Schmitt, C. B. *Predicted changes in distribution and richness of wild edible plants under climate scenarios in northwestern Kenya*	Regional Environmental Change Vol(issue), xx-yy	Submitted, 2023	• Lead author • Development of ideas and research design • Data compilation and analysis • Writing and revision of the manuscript

Table 1.2: Additional publications that have been developed during the course of this project, but are not essential working packages of the thesis

Author and title	Journal/Book/Report	Status of publication	Specific contribution of the thesis author
Mkala, E. M., Mwanzia, V., Nzei, J., **Oluoch, W. A.**, Ngarega, B. K., Wanga, V. O., Oulo, M. A., Munyao, F., Kilingo, F. M., & Rono, P. *Predicting the potential impacts of climate change on the endangered endemic annonaceae species in East Africa*	Heliyon, 9(6)	Published, 2023	• Data compilation and analysis • Writing and revision of the manuscript
Mkala E. M., Mutinda E. S., Wanga V. O., Oulo M. A., **Oluoch, W. A.**, Nzei J., Waswa E. N., Odago W., Nanjia, C., Mwachala G., Hu G., Wang, Q. *Modeling impacts of climate change on the potential distribution of three endemic Aloe species critically endangered in East Africa.*	Ecological Informatics, 71(101765)	Published, 2022	• Data compilation and analysis • Writing and revision of the manuscript
San S. M., Quartucci F. and **Oluoch W. A**. *Forest land degradation and restoration: lessons from historical processes and contemporary advances.*	In: G.S. Bhunia, U. Chatterjee, A. Kashyap, P.K. Shit (eds.): Land Reclamation and Restoration Strategies	Published, 2021	• Supervised the authorship of the chapter • Development of ideas and research design

Author and title	Journal/Book/Report	Status of publication	Specific contribution of the thesis author
	for Sustainable Development: Geospatial Based Technology Aprroach		• Writing and revision of the manuscript
Muoki, C. R., Maritim, T. K., **Oluoch, W. A.**, Kamunya, S. M., & Bore, J. K. *Combating Climate Change in the Kenyan Tea Industry*	Frontiers in Plant Science 11(339)	Published, 2020	• Development of ideas and research design • Data compilation and analysis • Writing and revision of the manuscript

Chapter 2: State of the art

2.1 Wild Edible Plants globally

WEPs, as defined by Kallas (2010, p. 2), have been part of human diets throughout history (Erskine et al., 2020; Harumi et al., 2019; Ajeet Singh et al., 2018) and their usage predates domestication of contemporary cultivated crops (King, 1994; Logan, 2015). Inclusion of WEPs in local diets has the potential to improve health, fight poverty, and alleviate hunger (Bhatia et al., 2018); the second item in the United Nations (UN) Sustainable Development Goals (SDG) (United Nations, 2017). These plants are also important relatives to cultivated crops hence contribute important germplasm for improving cultivated crops to maneuver evolving changes in the climate (Guarino & Lobell, 2011). However, their consumption is on the decline globally probably due to association of their usage with poverty, backwardness, and changes in lifestyles (Pawera et al., 2020) and their availability to local communities.

Bringing back WEPs to human diet (Ajeet Singh et al., 2018) calls for, among other aspects, investigating their availability, threats, and distribution across space and time. That could aid designing options for their sustainable exploitation. The effort has been exemplified in Europe where people with interest in WEPs are reinvigorating their culinary use from their nutritional values and preserve their traditional knowledge (Luczaj et al., 2012). That surpasses the traditional ethnobotanical investigations of listing plants known and used by a given community to a level of assessing their availability, understanding threats facing them, and mapping their distribution. Efforts to bring back WEPs to the diets of local communities globally have been reported in several places such as incorporation in education systems in Chile (Barreau et al., 2016), enhancement of in-situ conservation in Indonesia (Suwardi, Navia, Harmawan, Syamsuardi, et al., 2022), and cultivation at homes in Ethiopia (Birhanu, 2023) among others.

Consumption of WEPs aid in the fight against hunger and malnutrition especially among indigenous communities in arid and semi-arid lands with poor yields from cultivated crops (De Merode et al., 2004; Sundriyal et al., 2004). Even though large-scale crop production can contribute to reduction of hunger (Fonjong & Gyapong, 2021), narrow dietary width (consuming few crops) hinders nutritional diversity that is needed for good health (Aryal et al., 2018; Katoch & Katoch, 2020; Yazew, 2020). There is also relatively low resilience to pests, diseases, extreme weather events and climate change by cultivated crops compared to WEPs (Guarino & Lobell, 2011). People consuming diverse range of WEPs gain better nutritional security as the diverse WEPs make it possible to obtain important micro and macronutrients (Ray et al., 2020; Yazew, 2020).

Worldwide, a range of WEPs have been included in human diets with triple benefits of reducing hunger, malnutrition alleviation, and resilience to climate change and related hazards (Šarić-Kundalić et al., 2011; Yeşil et al., 2019). As the global human population ascends to 10 billion by 2050 and climate change and variability continue to derail performance of cultivated crops, resorting to WEPs could be a “safety net” for malnutrition alleviation (Bahar et al., 2020; Gerten et al., 2020; Searchinger et al., 2019). The plants are known to provide both income to indigenous communities and ensuring global food security (Addis et al., 2005; Ju et al., 2013; F. Li et al., 2015; Rasingam, 2012). Further, most WEPs are multipurpose plants serving a range of roles such as ethno-pharmacology, construction, fodder, fuel, and habitat for many animals such as birds (Dejene et al., 2020; Joshi et al., 2018) among other ecosystem services.

2.2 Wild Edible Plants in East Africa and Kenya

In Africa, consumption of WEPs characterizes all communities and some of the WEPs are special delicacies portraying cultural identities (Mokganya & Tshisikhawe, 2019; Ojelel et al., 2019). For example, in Ghana four WEPs of dietary interest showed huge potential in contributing to human nutrient provision due to their high micronutrient richness (Achaglinkame et al., 2019). Such is the case in Cameroon where *Irvingia gabonensis* (Aubry-Lecomte ex O’Rorke) Baill is considered an important food (Ngome et al., 2017). In Namibia and Zimbabwe to the south, WEPs are the most highly valued foods (Maroyi & Cheikhyoussef, 2017) apart from livestock products. Throughout East Africa, consumption of WEPs is invaluable pride of every community. The Karamajong people of Uganda consume a range of WEPs such as *Tamarindus indica* L., *Balanites aegyptiaca* (L.) Delile, and *Ximenia americana* L. among others (Ojelel et al., 2019). The Wasambaa people of Tanzania consume 92 WEPs including *Amaranthus spp*., *Corchorus olitorius*

L., and *Lantana camara* L. (Powell et al., 2013). These studies suggest wide usage of WEPs in Africa including East African region where this study was done.

In Kenya, culinary relevance of WEPs cannot be overemphasized. Almost every community has their special WEPs that they regard precious in their traditional diets. The Luhya, Kisii, Luo, and Mijikenda people of Kenya highly value their traditional indigenous vegetables harvested from the wild; though some are currently cultivated such as *Cleome gynandra* L. and *Amaranthus hybridus* L. (Maundu et al., 1999). WEPs are equally important among the nomadic pastoral communities who live in arid and semi-arid lands with negligible food crop cultivation. Apart from livestock products that give them proteins, WEPs provide for their vegetarian diets (Gradé, 2012). The Maasai people of Kenya highly value *X. americana*, *Carissa spinarum* L.*,* and *Grewia bicolor* Juss. for their nutritional benefits (Bussmann et al., 2006). Turkana people of northwestern Kenya feed on a range of WEPs to supplement, complement, and as 'safety nets' to cushion during lean season (Otieno, 2016a; Sarfo, 2018). WEPs and orphan crops portray huge potential in providing local solutions for sustainable food systems (Borelli, Hunter, Padulosi, et al., 2020).

Lists of available WEPs in Turkana have been compiled in various studies (Bender, 2017; Ng'asike, 2019; Sarfo et al., 2017; Watkins, 2010), which is an important step in identifying the WEPs consumed in the county. However, little has been done in understanding how the communities perceive their availability, threats and management options and their potential suitable habitat across space and time; an effort which would support their conservation and management for sustainable use. The studies have been largely concentrating in listing the available WEPs without necessarily unravelling how they can be used sustainably to support alleviation of hunger and malnutrition in the region.

Previous studies have reported the WEPs within Turkana to be culturally important in the livelihood of Turkana people not only due to their edible fruits but also due to their use as livestock fodder, ethno-pharmacology uses, trade, and construction among others (Sarfo, 2017). The distribution range of the WEPs is not restricted only to Turkana County alone, for example, *Ziziphus mauritiana* Lam. spans from India (Anshuman Singh et al., 2020) to Sudan Savanna ecological zones of Nigeria (Ambursa et al., 2019). On the other hand, *Salvadora persica* L. is a halophyte that can grow under extreme conditions from very dry environments to highly saline soils (Falasca et al., 2015). It also thrives in dry bushland and wooded grassland (Najma, 2011) and is largely distributed within tropical East Africa, Sudano-Sahelian border in West Africa, Namibia border with Angola, and northwestern parts of India (Ma'Ayergi et al., 1984). The plant further prefers hot and moist localities that characterize riparian areas in Turkana County. *Balanites rotundifolia* Blatt on the other hand is a species occupying parts of Kenya and Djibouti-Somalia border. It survives well in arid and semi-arid environments and not restricted to riverine areas (October 2020 own field observation). It is an evergreen shrub/small tree in life form growing to a height of 6 to 8 m. It is having a low bushy habit, densely branched with trunk up to 40 cm diameter (Sands et al., 2003).

The government of Turkana County is supporting sustainable use of natural resources in the county for the well-being of the inhabitants (CHSS-CAT, 2018). There are also efforts being made to educate the people on the available WEPs and their preparation and consumption as such knowledge is rapidly facing erosion by adoption of more westernized culture. The county is also the most food insecure and records the highest poverty levels nationally (KER, 2020, 2021) hence dire need for assessing its WEPs.

Dependence on and consumption of livestock products and cultivated crops alone may not sufficiently fight malnutrition especially in arid and semi-arid areas of Africa where cultivated crops and livestock products hardly yield optimally (Borelli, Hunter, Padulosi, et al., 2020; Hunter et al., 2019). WEPs offer opportunity to reduce food and nutrition insecurity globally in the face of climate variability that is claimed to pose comparatively greater threat to cultivated crops than WEPs (Gradé, 2012; Ojelel et al., 2019). Accordingly, in order to realize optimal exploitation of priority WEPs, it is important to understand their ecology and threats at local scales that make sense to specific dependent communities (Gaoue et al., 2017). For understanding of their sustainability, mapping out of their current occurrence sites and modeling their potential distribution in non-sampled sites is imperative especially in the face of climate and land use changes (Shumsky et al., 2014; Vári et al., 2020).

2.3 Availability of wild edible plants

A comprehensive list of 17 theories and major hypotheses within the field of Ethnobotany have been put forward to provide insights into the understanding of human-plant relationships in ethnobotanical realm (Gaoue et al., 2017). These hypotheses have evolved over time, being borrowed from various related disciplines to Ethnobotany such as Ecology, Anthropology, and Botany (Gaoue et al., 2017, 2021). Among these hypotheses, chapter three of this thesis focuses on one in particular, the availability hypothesis, that features measurable parameters that could help understand how the Turkana communities regard WEPs as available to them or not. The availability hypothesis posits that people are more likely to incorporate WEPs into their diets or employ them for medicinal purposes when these plants are readily available within their immediate vicinity (Albuquerque, 2006; Gaoue et al., 2017). It is assessed using such variables as physical distance to harvest sites, price of WEPs, availability in the market, availability in home gardens, and access to natural areas where the WEPs occur (Gaoue et al., 2017; Voeks, 2004) among other context dependent parameters. For instance, WEPs that are closer to inhabited areas or easily accessible harvesting sites are more likely to be utilized due to the reduced effort required for their collection or foraging.

WEPs that are lowly priced in the markets could also attract more usage since the efforts to get them are generally less. This is closely associated with presence of the WEPs in the market. The WEPs that are present in the local markets and are affordable have been reported to be largely used for dietary diversity among communities in the neighboring Ethiopia (Tahir et al., 2023) and Uganda (Akankwasah et al., 2012), for instance. Cultivation/domestication or caring for the WEPs in the home gardens has also been documented to contribute to the perception of availability of WEPs as already proposed in Mediterranean basin (Ceccanti et al., 2018) and western Himalaya (Aryal et al., 2018) among other places. In this regard, the WEPs that exist within the inhabited zones or homesteads of the specific communities are regarded as more available to them for use in diversifying their diets than those distributed outside the homesteads. While such plants within homesteads are still considered wild, they normally receive disproportionately better care from humans than those in the wilderness (Aryal et al., 2018; Cruz-Garcia & Struik, 2015; Kujawska & Łuczaj, 2015).

There has been a number of studies across the globe trying to explain availability of WEPs to communities by paying close attention to varied parameters or indicators, such as seasonal availability (Kiran et al., 2019), local abundance (Peduruhewa et al., 2021), physical distance and access to harvest sites (Albuquerque, 2006). The choice of parameters used to assess availability of WEPs to some communities is not standardized to date and thus remain context dependent and at discretion of the specific researchers (Gaoue et al., 2017). This is therefore posing a challenge in making comparison across the globe or even some cases regionally on how communities perceive availability of their respective WEPs. In that regard, this study assembles most of the parameters that have been used elsewhere including distance to harvest sites, seasons, abundance, access to harvest sites, ease of harvesting, portability, availability in the market, size of household to feed, and price in the market, to assess how the local communities in Turkana County consider WEPs as available to them or not.

Consumption preferences in the modern society is making WEPs "unavailable" to several people as the youths from indigenous communities consider consumption of cultivated crops like mangoes, apples, oranges while shunning their traditional WEPs (L. Kidane & Kejela, 2021). This could be a result of taste and preferences as some people prefer specific WEPs due to their tastes (Termote et al., 2010). This is also happening when indigenous knowledge of WEPs is being eroded at a very high rate (Luczaj et al., 2012; Muhammad et al., 2020), and hence the need to rekindle the use of these plants. It could be important not only to mention and identify the WEPs present within communities but also delve into how the concerned communities perceive their availability for use in dietary diversification among themselves. This is the phenomena that can help us demystify the paradox of why some communities endowed with WEPs still suffer extreme hunger and malnutrition as observed in biodiverse areas of Burkina Faso (Termote et al., 2012) .

Perceiving availability of WEPs in terms of access to harvest sites has also gained traction in the literature as well as ease of harvesting and processing prior to consumption. Some WEPs are located in areas that are not freely accessed by communities such as protected areas (Barreau et al., 2016; Blanco-Salas et al., 2019) and culturally important places like shrines (Marpa et al., 2020) as well as within private lands (Barreau et al., 2016; Ginger et al., 2012). These WEPs may not be easily accessed by local communities unless after acquiring specific access rights (Barreau et al., 2016). Further, one might be able to access them but still find it difficult to harvest (Tebkew et al., 2018), say thorny trees or difficult to climb and process them for consumption, such as boiling of *Dobera glabra* (Forssk.) Juss. ex Poir (Oduor et al., 2023) that takes over half a day and needs specific skills to render the product edible.

Studies that have assessed availability hypothesis with regards to WEPs have emphasized on examining the locations where individual communities collect their wild medicinal and food plants and by correlating local abundance with use values of specific WEPs (Gaoue et al., 2017). However, the differences in specific context in which studies are conducted and the kinds of WEPs being studied call for context dependent conceptualization of availability hypothesis as efforts to have universal concept is faced with a range of criticisms (de Oliveira Trindade et al., 2015; Gonçalves et al., 2016). To ensure that the availability of WEPs is better captured in the context of Turkana County, this study added several parameters such as portability, ease of harvesting, and ease of processing that are specific to the kinds of woody WEPs of interest to the study in the context of the study area. For instance, some of the WEPs studied grow taller than average human height, towering above 13 m, for example, *Hyphaene compressa* H. Wendl (Omire, Budambula, et al., 2020). For such WEPs, ease of harvesting thus becomes crucial parameter to consider before generalization on its availability can be deduced.

Understanding of availability of WEPs in Turkana is very timely in this thesis since the county has several WEPs that have helped the residents withstand hunger and drought in the past (W. T. W. Morgan, 1981) but are continually being neglected in the contemporary diets. With the continued challenges posed by climate variability and change, it is important to ensure that the communities leverage their locally available resources to adapt to the climate change as they offer huge potential for the future (Peduruhewa et al., 2021).

2.4 Threats and management options to wild edible plants

Environmental changes across landscape are contributing to biodiversity loss worldwide including WEPs (Borelli, Hunter, Powell, et al., 2020). WEPs are facing a number of threats that are ranging from natural and anthropogenic in nature and a mix of the two in which case anthropogenic activities aggravate the natural threats (Guzo et al., 2023; Suwardi, Navia, Harmawan, Seprianto, et al., 2022). However, studies involving WEPs rarely dwell on the threats facing them even though such understanding could be important in devising conservation strategies. In this section, we shall look into some of the scarcely identified threats facing WEPs with more emphasis in Eastern Africa as some of the threats could be region-specific.

One of the threats facing WEPs is agricultural expansion (L. Kidane & Kejela, 2021; Suwardi et al., 2020). Pieces of land are being converted to cultivated agriculture at the expense of WEPs (Muhammad et al., 2020; Pawera et al., 2020; D. R. Williams et al., 2021). This interferes with natural regeneration of the WEPs and destroys their habitats (Liu et al., 2019). Expansion of agriculture has been reported as a notable threat to WEPs in several countries across the globe such as Indonesia (Pawera et al., 2020), Ethiopia (L. Kidane & Kejela, 2021) and Uganda (Masters, 2021; Ssenku et al., 2022) among other places. Conversion of land from WEPs to cultivated crops is normally followed by mono-cropping where one species of crops is grown in large scale (B. A. Williams et al., 2020). This is thus narrowing dietary diversity while at the same time interfering with ecosystem services that were being offered by the previously existing diverse WEPs.

Apart from expansion of agriculture, wild fires also threaten WEPs (Garcia et al., 2021). Use of fire as an ecosystem service to manage pasture has been practiced for a long time across the globe (Pausas & Keeley, 2019). The relevance has been to ensure that the old grasses give way for new fresh sprouts that better develop for the use by livestock (Colantoni et al., 2020; Fidelis, 2020). This can lead to loss of WEPs in the vicinity of the area especially when it follows prolonged dry season when the plants are dry (Haque et al., 2021; Ojeda, 2020). This is an example of a scenario where anthropogenic activity could be aggravating climate change as the plants that are already overstressed by prolonged drought could easily yield into the veracity of the fire (Mariani et al., 2019; Pontes-Lopes et al., 2021; Richardson et al., 2022).

In addition to the above, invasive species have also been reported to threaten native WEPs (Duenas et al., 2021; Siddiqui et al., 2021). This has been witnessed in many spheres where introduced alien species outcompete the native species and push the native species into extinction (Carboni et al., 2021). Some invasive species could be having better adaptation characteristics to survive in the invaded lands and maximize use of resources at the expense of the original species in the region (Carboni et al., 2021; Cheng et al., 2020). This could be in terms of access to solar or soil nutrients and water (Linders et al., 2019). The invasive species could also be having some harmful allelopathic properties against the native species (Kalisz et al., 2021; Qu et al., 2021) as is reported for *Imperata cylindrica* (Kato-Noguchi, 2022) and *L. camara* (Kato-Noguchi & Kurniadie, 2021) among other species. Examples of invasive species outcompeting native species have been reported for *P. juliflora* in northern Kenya (Tadros et al., 2020).

Within the nomadic pastoral communities like the case of most parts of Africa, overstocking or overgrazing has been reported as a threat to WEPs (Guzo et al., 2023; L. Kidane & Kejela, 2021). While nomadic pastoral communities have lived with WEPs throughout their history, transition from nomadic pastoralism to sedentary lifestyle is putting more pressure on land and tending to exceed the carrying capacity of such lands hence reducing chances of seedlings or propagules to develop into adult plants (Ganie et al., 2019). Organized nomadism could give WEPs enough time to regenerate as the livestock could be moved from one place to another for several months allowing enough time for WEPs to regenerate (Mohammadi et al., 2023; Moradi et al., 2022). This phenomenon is witnessed even in the wild such as seasonal pasture regeneration following migration of wildebeest in Kenya (Msoffe et al., 2019). However, as land management starts to change from communal to private ownership and several development projects get established, there is limited freedom for people to move with their livestock (Greiner, 2017). While the desire/culture to have more livestock still lags, the size of land to raise them diminishes at a high rate (Galaty, 2013; Greiner, 2017). This could lead to the toppling above the carrying capacity of the land and rendering any regenerating WEPs difficult to survive to maturity.

Other extractive human activities such as charcoal burning and collection of timber for construction is also putting more pressure on the plants, especially woody WEPs (Luczaj et al., 2012). For instance, leaves of *H. compressa* are used in making a lot of handicrafts that are sold in the market (Omire, Neondo, et al., 2020). On the other hand, extraction of timber for building of houses from WEPs have been noted in some regions of Africa (Guzo et al., 2023; Tebkew et al., 2018). Use of WEPs for fuel and charcoal is another extractive activity that could push some WEPs out of production (Akall, 2021; Owino et al., 2021). As urban population grows in most parts of Africa, need for charcoal also increases as the most affordable fuel for cooking (Doggart & Meshack, 2017; Santos et al., 2017). The trade on charcoal should thus be regulated in a manner that WEPs are not included in the business (Wekesa et al., 2023). Some communities are already controlling for this by ensuring that no WEPs are harvested for charcoal while others allow for using WEPs that have naturally dried out (Hazarika & Pongener, 2018; Yiblet et al., 2023).

Another important threat on WEPs is linked to climate change. Through its various indicators such as prolonged drought and related extreme events like flash floods, WEPs are becoming more vulnerable (Powell et al., 2023; Reyes-García et al., 2015). Some WEPs that preferentially grow in riparian areas find it difficult to continue surviving under changing climate (Tonkin et al., 2018). Extreme droughts and heat compound water stress on them and when this is followed by flash floods, they easily topple and get washed away (Bejarano et al., 2018). Further, with climate change, some species are moving towards cooler areas in higher altitudes as observed in South Africa (Wessels et al., 2021). In that regard, WEPs that are slow in dispersal ability might be exposed to more threats (Barber et al., 2016; Mo & Polly, 2022; Zhang et al., 2017).

It is also important to mention that localized infrastructural developments in biodiverse areas also pose threat to WEPs (Liu et al., 2019; Yangdon et al., 2022). These include industries, roads and, the case of oil prospect in Turkana (Mkutu et al., 2019; Mullins & Wambayi, 2017; Obongo, 2018) that have necessitated clearing of WEPs and hence decline in their richness (Jigme & Yangchen, 2023). While environmental impact assessments are normally done prior to establishment of such industries, it is always a huge tag of war between the investors and environmental conservationists; with investors winning in most cases as the values of the WEPs are not readily quantifiable.

2.5 Species distribution modeling of wild edible plants

Species distribution modeling (SDM) involves prediction and mapping of the potential geographic distribution of a species depending on environmental factors and its known occurrence data (Escobar et al., 2018; Franklin & Miller, 2010; Guisan et al., 2017; Peterson et al., 2011). The concept depends on the ecological niche theory that was first put forward by Grinnell in the early 20th century (Grinnell, 1917b, 1917a). The theory suggests that each species occupies a unique ecological niche defined by its interactions with environmental variables (Grinnell, 1917b). The niche has been conceptualized as a function of biotic, abiotic, and movement parameters (Peterson et al., 2011). The biotic components include all physical characteristics of an environment that are suitable for a species (Franklin & Miller, 2010; Guisan et al., 2017). On the other hand, the biotic components involve the interactions within and among species in the same geographic region (Guisan & Zimmermann, 2000). Lastly, the movement component is pegged on the ability of the species to disperse and reach locations with favorable biotic and abiotic conditions (Feng, Park, Walker, et al., 2019).

The two major approaches in building SDMs include those that are correlative and the mechanistic ones (Chapman et al., 2017; Rougier et al., 2015; Shabani et al., 2016). The correlative approaches use species occurrence records over space, normally a large area of land, and environmental predictor variables to determine the niche of such species (Journé et al., 2020; Shabani et al., 2016). This is the most common kind of SDMs done for example in assessing suitable habitats of plant communities (Gaisberger et al., 2017; Henderson et al., 2014; Pellissier et al., 2010), wild medicinal plants (Bariotakis et al., 2019; Mkala et al., 2022), and WEPs (Wessels et al., 2021) among many others. The mechanistic SDMs are normally based on controlled environmental studies. They tend to be rather costly to establish and to run successfully (Shabani et al., 2016). The advantage of the mechanistic SDM is that the researcher has the freedom to assess tolerance of a species to specific environmental conditions that can be adjusted until the maximum or minimum tolerance level is achieved (Chapman et al., 2017; Shabani et al., 2016).

Since its inception in the early 20th century, SDM has gained traction in scientific community and been applied to model potentially suitable habitats of most organisms. Further, developments in the domain has seen various models developed being dominated by MaxEnt (Phillips et al., 2006) and today more than 91 open source packages are available to run SDMs (Helixcn, 2017). This has seen a boost in the adoption of SDMs and efforts have been made to ensure reproducibility and adherence to modeling protocols that make the work more reliable.

Advancements in machine learning techniques and computation capacity have also boosted the growth of the domain (Guisan et al., 2017). Various concepts like range shift (Bocedi et al., 2021) and niche evolution verses niche conservatism (Culumber & Tobler, 2016; Salariato et al., 2022; Vieira et al., 2023) have been tested and many more stretches in the domain remain to be fully unearthed especially those linking genetics information of modelled species (Cacciapaglia & van Woesik, 2018; McCluskey et al., 2022). As technology advances rapidly, occasional publication of classical books reminds users to stay grounded in the fundamental principles of the domain amid the fast-paced development of hardware and software(Franklin & Miller, 2010; Guisan et al., 2017; Peterson et al., 2011; Tikhonov et al., 2020).

For most machine learning models to be trained well, there is need to have training data of different classes from which machines "learn" patterns. When these are applied in SDM, one would normally have occurrence records, that is, locations where a given species has been observed (Guisan et al., 2017; Tikhonov et al., 2020). Obtaining absence data (locations where the species is not found) is challenging due to various complex reasons, such as the species not having dispersed there or lack of observation and reporting in that location. (Peterson et al., 2011). Accordingly, methodologies have been developed to generate pseudo-absences (false absence) and background points from which models can be built to help predict the potentially suitable habitats of a given species (Feng, Park, Walker, et al., 2019; Zurell et al., 2020). A lot of advancements have also been made on how such background points should be generated including using convex hulls as well as doughnut and circular buffers around presence points (Kass et al., 2021; Pebesma & Bivand, 2023).

Given the occurrence records (presence and pseudo-absence/background), researchers then obtained appropriate predictor variables (normally in raster file formats) which are important in explaining the ecology of a specific species (Petitpierre et al., 2017; Pratt et al., 2022). The occurrence records are then used to extract corresponding predictor variables and used to build the predictive models. This process normally involves tuning of the model until a useful model is obtained which can then be projected over the whole spatial extent of interest (Bernabo et al., 2022; Brownscombe et al., 2021; Kass et al., 2021). Additionally, the model can be applied in hindcasting the potentially suitable habitats of the species in question in the past (Hodel et al., 2022; Regos et al., 2018) or future (Jarvie & Svenning, 2018; Messina et al., 2019). This is done with care to ensure that the environmental characteristics of the regions where the models are being transferred are comparable with where the model was trained (Márcia Barbosa et al., 2013).

This is therefore a well-established modeling workflow in distribution ecology that fits well in the present work to determine the potentially suitable habitats of WEPs in Turkana County, Kenya. Throughout the globe very few studies, however, have used the workflow in understanding the potentially suitable habitats of WEPs (Vincent et al., 2019) although it can be helpful in informing conservation strategies of species over regions especially where there are adequate training data. Some of the studies that have employed the protocol include a global study (Vincent et al., 2019), North America (Khoury et al., 2019), and that specific to southern Africa (Wessels et al., 2021). Other studies have given emphasis on medicinal plants for example Mediterranean medicinal plants in Crete (Bariotakis et al., 2019) and medicinal plants such as Aloe species spanning north eastern Tanzania and south eastern Kenya (Mkala et al., 2022). This study will be the first of a kind to apply SDM on WEPs of eastern Africa.

Chapter 3: Methods and Study Area

3.1 Study Area

3.1.1 Description of the study area

This thesis is part of an on-going project "*Improving dietary quality and livelihoods using farm and wild biodiversity through an integrated community-based approach in Kenya*" (2019-2023) by The Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT). The project involved collaborators from The University of Nairobi, Kenya (Project Monitoring and Evaluation), University of Hohenheim, Germany (Socio-Cultural aspects of WEPs' use), University of Goettingen, Germany (Nutrition analysis of WEPs), and this study from the University of Bonn, Germany on availability and sustainable harvesting of WEPs in Turkana County, Kenya. The study area is located in Turkana County in northwestern Kenya (Appendix 2). It spans longitudes 33.99°E to 36.72°E and latitudes 0.92°N to 5.50°N, covering an area of about 68,253 km^2. The area features low-lying plains with occasional hills depicting the physical landscape (Opiyo et al., 2015). Altitude ranges from 370 m towards the east at the shores of Lake Turkana to 2285 m above the sea level on top of Loima Hills to the west. River Turkwel drains from South Western parts towards center of the study area and curves its way eastwards into Lake Turkana. Numerous seasonal tributaries that experience occasional flash floods join the river and characterize potentially suitable habitats of the WEPs (according to field visit in October 2020).

Climate and Soils

Rainfall pattern is bimodal with high variability leading to regular drought events with a long term mean annual rainfall of 216 mm (Opiyo et al., 2015). This varies highly within the study area (Appendix 1). Maximum temperature range within Turkana County is normally between 23^oC and 38^oC with a mean of 30.5^oC (Opiyo et al., 2015). The county is hot and dry most of the year hence classified under agro-ecological zone IV which is semi-humid to semi-arid as well as zone V which is semi-arid (Jaetzold & Schmidt, 1983). Soils of the area comprise coarse alluvial deposits and coarse sand, gravels and boulders as well as exposed bedrocks following erosion events

(Coughenour & Ellis, 1993). The alluvial soils of the area are deep, sandy loams that are poorly differentiated with low water holding capacity, nutrients, organic matter, and cation exchange capacity (Reid & Ellis, 1995).

Vegetation cover

Vegetation comprise bush species and dwarf shrubs (Opiyo et al., 2015). However, there is evident high variability and annual patchy grassland, herbaceous plants, woody shrubs as well as riverine vegetation (Kariuki et al., 2008; Opiyo et al., 2015). Generally, numerous Vachellia species dominate the landscape and are of relevance to the livestock, people, and ecosystem (Coughenour & Ellis, 1993; Kariuki et al., 2008; Opiyo et al., 2015). Potential natural vegetation of the study area depicts vegetation of the class Acacia-Commiphora stunted bushland and Somalia-Masai Acacia-Commiphora deciduous bushland and thicket that occupy 49.21% and 40.82% of the study area, respectively (van Breugel et al., 2015).

The people

The county consists primarily of Turkana people who are traditionally nomadic pastoralists (keeping cattle, camels, donkeys, sheep, and goats) and their livelihoods is pegged on livestock products such as meat, milk, and blood (Otieno, 2016a). They live in arid and semi-arid area where crop farming is poorest nationally (Watete et al., 2016; Yoda et al., 2020). Population of their livestock is also dwindling attributable to negative effects of extreme drought events, diseases and exceedance of land carrying capacity (Otieno, 2020). WEPs serve as supplements, complements, or substitutes to traditional livestock products in the diets of Turkana people. They are crucial during lean seasons to cushion hunger, boost dietary diversity, and alleviate malnutrition (Bhatia et al., 2018; Sarfo, 2018).

Turkana is the poorest county in Kenya (Kuper et al., 2015) with poverty headcount rate of 79.4% compared to the national average of 36.1% and the best scenario of 16.7% in Nairobi County (KER, 2020). The county also leads, nationally, in food poverty at 66.1%. Against the national hardcore poverty line of 8.6%, the county is at 52.7%, depicting worst scenario in the nation (KER, 2020). The county, however, has tourism potential (regarded the cradle of modern man)

(Harmand et al., 2015), has the largest desert lake in the world (Lake Turkana), oil deposits (Mkutu et al., 2019), wind power plants (Cormack & Kurewa, 2018), and about 60 WEPs reported by several researchers (W. T. W. Morgan, 1981; Sarfo, 2017). The WEPs comprise vegetables, tubers, mushrooms, and fruit trees that cushion dietary needs of locals (Sarfo et al., 2017).

Land uses

The vegetation, climate, and geography of the county support nomadic pastoralism as a traditional means of livelihood for majority of the people. Further, the existing vegetation feature some WEPs which support food security, nutritional requirements, and economic needs of the local residents (Bender, 2017; W. T. W. Morgan, 1981; Sarfo et al., 2017). There are also small towns in the county such as Lodwar where trade is taking place. Communities located astride river banks, such as along River Turkwel conduct irrigated agriculture. They sustain their livelihoods by harvesting palm leaves and using them in the crafting of items such as baskets and mats.

3.2 Research Methods

The data collection and analysis approaches used in the thesis are summarized in Table 3.1. In chapter four, the study used FGD to understand how local communities perceived availability of their WEPs and analyzed the data using both qualitative and quantitative techniques, (see section 4.3.3). FGD 'is a type of group discussion about a topic under the guidance of a trained group moderator' (Sim & Waterfield, 2019). The method allows for interaction between the moderator and the participants thus ease of getting in-depth understanding of the topic as narrated by the participants (Nyumba et al., 2018; Stewart & Shamdasani, 1998; Wong, 2008). Chapter five, included field surveys on top of FGDs to achieve field observation of threats facing WEPs within the study communities. The data were analyzed quantitatively by assaying the scores of both threats and management options (see section 5.3.3).

Chapter six involved data collection from a range of sources including online databases, museum collections and field surveys (Table 3.1). These were analyzed quantitatively using maximum entropy modeling approach as detailed in section 6.3.6. These methods enabled collection of relevant data and applied relevant analytical methods to address the objectives of the thesis.

Table 3.1: Summary of the methods of data collection and analysis used in this thesis

Chapter	Data sources	Analysis methods	Chapter section
Four	Focus Group Discussion	Quantitative and qualitative (Bayesian regression and mixed content analysis)	4.3.3
Five	Focus Group Discussion and Field Surveys	Quantitative (Friedman aligned rank tests)	5.3.3
Six	Online databases, Museum collections, and Field Surveys	Quantitative (Maximum Entropy modeling)	6.3.6

Chapter 4: Integrated Participatory Approach Reveals Perceived Local Availability of Wild Edible Plants in Northwestern Kenya

This chapter has been published as Oluoch, W. A., Whitney, C. W., Termote, C., Borgemeister, C. and Schmitt, C. B. 2023. Integrated Participatory Approach Reveals Perceived Local Availability of Wild Edible Plants in Northwestern Kenya. Hum Ecol 51, 59 – 74. https://doi.org/10.1007/s10745-022-00370-0

4.1 Abstract

Availability is a crucial aspect of wild edible plants (WEPs) consumption by indigenous communities. Understanding the local perception of this availability helps to determine, which contribution WEPs can make to rural communities. We used an integrated participatory approach to investigate important parameters and themes that influenced the perception of availability of woody WEPs. We demonstrate the approach in three communities in Turkana County, Kenya. By availability, we referred to the ease of accessing, harvesting, transporting, and processing WEPs for consumption. We conducted three focus group discussions (FGDs). We asked FGD participants to list, score, and discuss availability. We used logistic regression and mixed-content analysis to identify important parameters and themes, respectively. The most important WEPs were the toothbrush tree (*Salvadora persica* L.), Indian jujube (*Ziziphus mauritiana* Lam.), and mbamba ngoma (*Balanites rotundifolia* (Tiegh.) Blatt.). Distance, seasonality, price, and adequacy of harvested WEPs for household consumption were important parameters. Culture and tradition, distribution of WEPs, seasonality, and climate change emerged as important themes. We showed the importance of using an integrated participatory approach when assessing the perception of WEPs' availability by local communities and could be used in comparable arid and semi-arid areas with semi-nomadic pastoralists across Africa.

Keywords Wild edible plants · Non-cultivated fruits · Focus group discussion · Mixed-content analysis · Ethnobotany · Bayesian modeling · Integrated participatory research · Northwestern Kenya

4.2 Introduction

Availability of wild edible plants (WEPs) alone is not expected to translate directly into their inclusion into the diet by indigenous communities (Termote et al., 2012). However, assessing how such communities perceive availability of their WEPs could inform management and foster inclusion in dietary diversification programs. That is especially true for woody WEPs used by semi-nomadic pastoral communities in arid and semi-arid lands such as Turkana of northwestern Kenya. There, crop cultivation is curtailed by unfavorable climatic conditions (Otieno, 2020) and traditional pastoralism is becoming more unsustainable due to surpassed carrying capacity of land leading to such issues as cross-border conflicts, pests, diseases, and pasture degradation (Njeri, 2020; Nyabuto, 2017; D. O. Ouma, 2017).

Northwestern Kenya is characterized by arid and semiarid environments. The region is home to the Turkana people (hereinafter called Turkanas) whose main livelihood strategy is largely based on livestock keeping (Akuja & Kandagor, 2019; Ratemo et al., 2020). The region's tropical plant life includes 60 wild species that are edible (Sarfo et al., 2017). The Turkanas have depended on WEPs throughout their history (W. T. W. Morgan, 1981) though their contemporary diets contain less WEPs (Bender, 2017). Malnutrition and hunger rates in the County are the highest in Kenya with food poverty at about 66.1% against a national average of 32% (KER, 2020). The County also faces poverty rate of 52.7%, well above the national average of 8.6% (KER, 2020). According to the Kenya Integrated Household Budget Survey 2015/16 Well Being Report "a household is in hardcore or extreme poverty if their monthly adult equivalent total consumption expenditure per person is less than Kshs 1,954 (about $20 as of 2016) in rural and peri-urban areas and less than Kshs 2,551 (about $25 as of 2016) in core-urban areas" (KER, 2020).

The availability hypothesis, see Gaoue et al. (2017), posits that more accessible or locally abundant plants are preferred for use (Albuquerque, 2006; Gaoue et al., 2017; Hart et al., 2017; Voeks, 2004) and communities tend to utilize more plant resources which are easier to reach or more abundant within their locality. The hypothesis, however, has been criticized on the basis that some native plants are used regardless of their abundance and/or limited accessibility thus posing mixed support to the hypothesis (de Oliveira Trindade et al., 2015; Estomba et al., 2006;

Gonçalves et al., 2016). While availability is generally perceived as the physical distance to resource locations (Albuquerque et al., 2019; Hart et al., 2017), it can also be assessed in terms of seasonality, abundance, price, market access, and access to harvesting sites (Gaoue et al., 2017). Seasonality of resources availability, for example, can explain many of the patterns of resource utilization within arid and semiarid areas (Albuquerque, 2006; Estomba et al., 2006) where maturity of WEPs follow seasonal patterns.

We aimed to better understand the main determinants that influence perception of availability of WEPs. We worked with indigenous groups, conducting FGDs in three Turkana communities that are characterized by different environmental and socio-economic settings (Appendix 1). We first applied integrated participatory methods (Boedecker et al., 2019) for scoring pre-defined parameters of WEP availability derived from the literature. Second, we stimulated discussions amongst the participants with a focus on selected three priority WEPs to gain more specific insights into their perceived availability. In the next step, we analyzed the findings with Bayesian logistic regression models and by coding and extracting themes from FGDs text data in a mixed content analysis protocol. Our results illustrate important parameters and themes determining how communities perceive availability of their WEPs.

4.3 Materials and Methods

4.3.1 Study Area Description

We conducted this study within Loima and Turkana South Sub-Counties of Turkana County, northwestern Kenya, in April 2021 within three selected community units (Nasiger, Atala Kamusio, and Lopur). These three community units were representative of the socio-economic and environmental heterogeneity (see Appendix 1) of the study region (Figure 4.1). The community units were located in arid and semi-arid lands with annual rainfall of 290 mm, 557 mm, and 670 mm at Nasiger, Lopur, and Atala Kamusio, respectively (Appendix 1). The major rainy season in the County spans March to June and is locally termed '*akiporo'* while the rest of the year is normally dry or '*akamu'* (Ng'asike, 2019).

The Turkanas dominate the County though Luo, Kikuyu, Somali, Luhya among other ethnic groups of Kenya, are also present in low numbers especially within scattered town centers (Otieno, 2016a). Livelihood strategies are distinct among community units within the study area (Food Economy Group, 2016). Besides keeping livestock, those who live along River Turkwel (such as at Lopur) also farm crops on the banks of the river (Emuria, 2018; Stevenson, 2018) (Figure 4.1). Communities on the hilly borders with Uganda (such as Atala Kamusio) keep livestock like goats, camels, and cows due to relatively good pastures and rainfall (Chelang'a & Chesire, 2020; Njeri, 2020). Other communities in the flat plains (such as Nasiger) keep livestock like goats, sheep, and camels that are better adapted to the prevailing environmental conditions (Joly, 2020; Lojock, 2021; Ratemo et al., 2020).

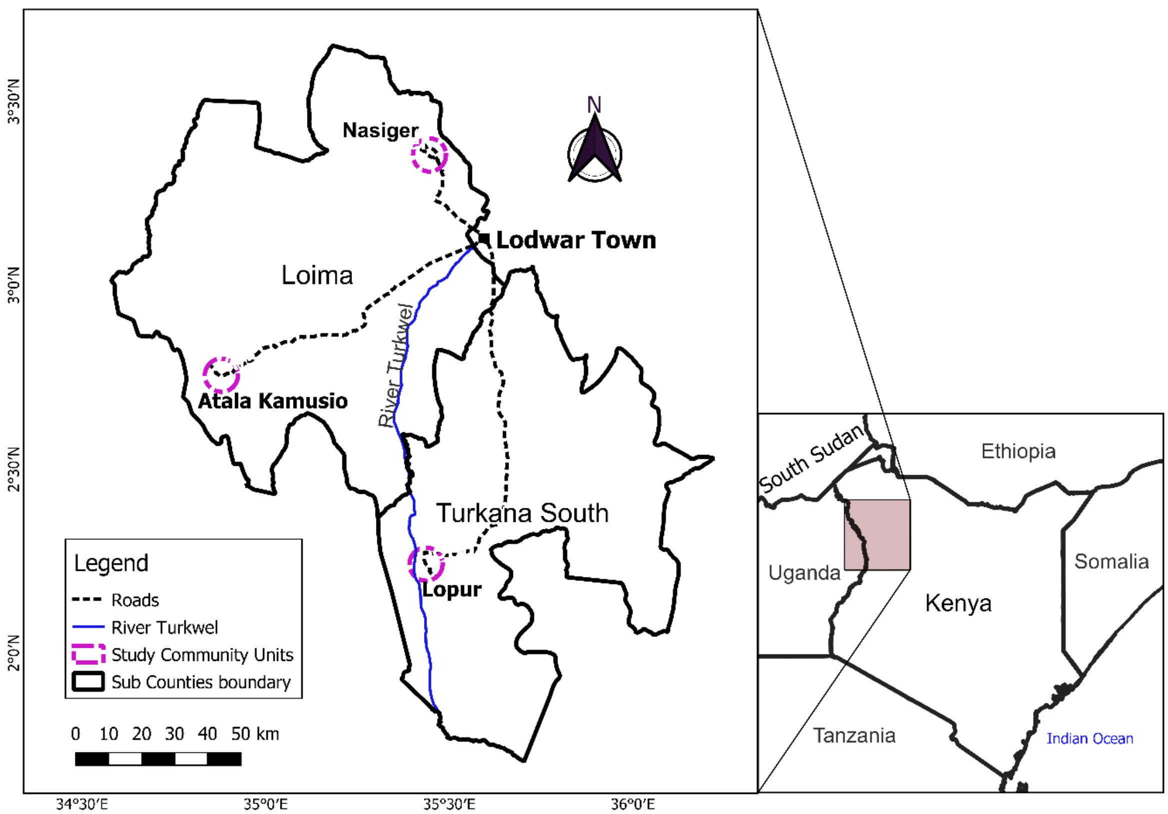


Figure 4.1: Study area map showing the three study community units (Nasiger, Atala Kamusio, and Lopur), River Turkwel and connecting roads leading to the three community units. We obtained administrative boundary data from the Database of Global Administrative Areas (GADM) using version 3.5.15 of raster package (Hijmans, 2023), we obtained roads data from

Open Street Map (OpenStreetMap contributors, 2017), and we digitized River Turkwel from Google Earth pro 7.3.3.7786. We captured community units' location data using handheld GPS Garmin 64s. We created the map in QGIS software (QGIS Development Team, 2023) version 3.20.1

4.3.2 Data collection

4.3.2.1 Scoring Predictor Parameters for Availability Modeling

To identify important parameters influencing perceptions on availability, we conducted focus group discussions (FGDs) in each of the study community units adapting the protocol by Nyumba et al. (2018) to suit our present study. Each FGD comprised 14 adult participants (male and female) not less than 18 years old. We purposively sampled participants from community members with the help of administrators (chiefs and assistant chiefs) to include key knowledge holders/informants. We included community nutritionists, community health extension workers, community health volunteers, administration representatives (Chiefs/Assistant Chiefs), and other selected community members knowledgeable of WEPs. We only included participants who consented verbally to take part in the study and we covered their transport costs to and from FGD sites. The FGDs were moderated by two research assistants drawn from the communities with good command of both Turkana and English languages. We provided these assistants with two days of training prior to conducting the FGDs.

We commenced every FGD by having participants freely list all woody (fruit trees) WEPs available and used within respective community units. We understand that WEPs can include vegetables, seeds, nuts, underground tubers, and mushrooms (Mishra et al., 2021) and diverse lifeforms like shrubs, forbs, herbs, grass, climbers, trees (Ojelel et al., 2019; Porcher et al., 2022; Rashid et al., 2008; Tiwari et al., 2010). Here, we considered only wild woody fruit trees. We assumed they have longer lifespans thus the participants would interact, know, and use them better to warrant informative discussion in addressing objectives of our study. Subsequently, we engaged participants in scoring the listed WEPs (Appendix 4) using a predefined 'topic list' (Cotton, 1996) of eleven parameters that we gathered from literature (physical distance to harvest sites, seasonality, abundance, price, market access, and access to harvest sites of the WEPs, ease of harvesting, ease of portability, ease of processing, adequacy of harvest, and regeneration potential) (Albuquerque et al., 2019; Feitosa et al., 2018; Gaoue et al., 2017; Gonçalves et al., 2016; Soldati et al., 2017).

Discussions on scoring of each of the listed WEPs under each of our parameters resulted in consensus on one of three possible ordinal response levels. For instance, if the WEP under discussion was the toothbrush tree (Salvadora persica), possible ordinal/categorical responses under distance to harvest sites parameter would be 1: Near, 2: Average and 3: Far depending on what participants consensually agreed (Appendix 4). We did that for all listed WEPs across the 11 categorical predictor parameters. Finally, we asked participants to consensually decide on the overall binary perception of availability of the WEPs (1: Yes; 0: No, Appendix 4), which was then included as response parameter in our model.

4.3.2.2 Discussion Statements on Availability of Wild Edible Plants

From the list of available WEPs generated by FGD participants in each community unit, the participants discussed and consensually settled on three (priority) WEPs. These three priority WEPs were those that, from the list, were consensually considered by the participants to be most important as food, fodder, medicine, and all other aspects of usage they knew. The priority WEPs were similar for all three community units (see Overview of Wild Edible Plants" regardless of socio-economic and environmental differences (Appendix 1). We then held in-depth discussions under each of the 'topic list' parameters for each of the priority WEPs to reveal the community perceptions on their availability. We narrowed on the three priority WEPs that were best known by all community members since this increased comparability between the three study sites. It also allowed us to maximize on use of time.

While discussing priority WEPs against the 11 predictor parameters, we noted down statements from the participants and appended unique codes to denote the speaker to enable traceability of the statements and subsequent clarification(s) wherever necessary (D. L. Morgan, 1996; Olsson et al., 2005). The prefix three letters of the code (NAS, ATA, and LOP) represented the first three letters of the respective community unit name while the suffix digit(s) denoted unique number assigned to the participant (between 1 and 14). For example, NAS1 code referred to first

FGD participant from Nasiger community unit, ATA5 was the fifth participant from Atala Kamusio community unit, and LOP14 referred to the 14th FGD participant from Lopur community unit. We conducted FGDs in Turkana language that enabled every participant to follow through the discussions and clarify their points. We allotted every FGD participant ample time to express themselves by allowing only one speaker at a time. We then translated the FGD notes (those captured in Turkana language) into English language and verified with the local research assistants to ensure no loss of meaning occurred during translation. The FGDs lasted not more than two hours at every community unit. We summarized the whole research process in Appendix 3.

4.3.3 Data Analysis

4.3.3.1 Bayesian Logistic Regression Analysis

We used Bayesian regression methods because of their reliability (Etz & Vandekerckhove, 2016), accuracy in small and noisy samples (Kruschke et al., 2012), possibility of introducing prior knowledge into the model (Andrews & Baguley, 2013; Kruschke et al., 2012), and intuitive nature of their results as well as straightforward interpretation (Kruschke, 2010; Wagenmakers et al., 2018). We subjected non-correlated predictor parameters to the test for relationships between different levels of categorical predictor parameters and response parameter using the stan_glm Bayesian generalized linear regression function in rstanarm (Goodrich et al., 2022) package version 2.21.4 in (R Core Team, 2023) version 4.3.1. To ensure that the model handled our response parameter as logical, we specified binomial argument to the 'family' parameter within the function call. We programmed our model to regress two parameter levels against the first with the first being the desirable situation. For example, in the case of distance to harvest site parameter, we regressed distance_average and distance_far levels against distance_near, with distance_near being the desired situation. We built four probabilistic models, one for all the three community units combined and for each community unit separately.

We then assessed contribution of the predictor parameter levels in explaining variation in the response parameter in order to identify the most important parameters. We did that by plotting posterior distributions of regression coefficients of the model output at second and third parameter levels against the first (desirable) parameter level. All analyses were performed in the R programming language (R Core Team, 2023) version 4.3.1. We opted to visualize model output for ease of interpretation (Kastellec & Leoni, 2007) and comparison of within parameter variation in explaining availability. For tabulated model output results see Appendix 8, Appendix 9, Appendix 8 and Appendix 9.

To prepare our data for the Bayesian logistic regression modeling procedures we checked the FGD scored data for multi-collinearity among the 11 predictor parameters (Appendix 4). We dropped two highly correlated ($r >= 0.7$) parameters, notably abundance and market, and retained the non-collinear ones ($r < 0.7$) (Appendix 10 and Appendix 11). To check multi-collinearity among predictor parameters we used the vifcor function in the usdm (Naimi et al., 2015) package version 2.1.6 in R (R Core Team, 2023) version 4.3.1. The function is useful in determining and eliminating collinear parameters among predictors at user specified correlation threshold before further statistical analyses (Aggemyr et al., 2018; Petanidou et al., 2018; Tuset et al., 2021). We repeated that procedure for the data from all the three community units combined and with the data partitioned specific to each community unit (Appendix 6, Appendix 7, Appendix 8, and Appendix 9).

4.3.3.2 Mixed Content Analysis of Qualitative Data

We used a mixed content analysis approach (D. L. Morgan, 1996) to extract both quantitative and qualitative information from FGDs statements about the agreed priority WEPs. The approach enables systematic coding of data into categories to discover patterns undetectable by mere listening to recordings or going through the transcripts or FGD notes alone (Gaur & Kumar, 2018; Renz et al., 2018). We followed the "three-element coding framework" protocol described by Nyumba et al. (2018) yielding quantitative and qualitative results from iterative content and ethnographic analytic techniques, respectively. During the content analysis, we used a deductive approach to obtain code categories from the statements to show linkages with Bayesian regression model results. By iteratively looking through each of the FGDs statements, we obtained codes that captured key ideas. We then grouped the codes that captured related ideas together to form themes. We did this iteratively until we ended up with a set of themes surrounding major ideas of the participants on how availability of the priority WEPs are perceived. We highlighted how the major themes were related to the model output results for insights into the perception of availability by the community units.

4.4 Results

4.4.1 General Characteristics of Focus Group Discussion Participants

The proportions of female to male participants were 5:9, 5:9, and 7:7 in Nasiger, Atala Kamusio, and Lopur community units, respectively. Considering our selection criteria for participants (see section on Scoring Predictor Parameters for Availability Modeling), the roles such as chiefs, nutritionists, village elders, health workers and volunteers, were male dominated in the study region and that could explain the disproportionate male representation. Overall, 40% and 60% of the participants identified themselves as female and male, respectively. Up to 45% of the statements from the FGDs were contributed by female participants (see section on Content Themes on the Availability of Priority Wild Edible Plants). As participants included people knowledgeable about WEPs, we did not expect gender disproportionality to affect the results of this study. Their ages ranged from 20 to 66 years. The majority (n = 16) had primary level of formal education, followed by no formal education (n = 11), diploma (n = 8) and lastly secondary (n = 7).

4.4.2 Overview of Wild Edible Fruit Plants

We observed similarities in woody WEPs listed across the three community units (Appendix 4). However, Atala Kamusio recorded almost twice (n = 23) as many WEPs as the other two community units (n = 13 each). All WEPs listed in both Lopur and Nasiger were also listed in Atala Kamusio with 10 more uniquely cited in Atala Kamusio (Appendix 4). Of all the listed WEPs, we observed consistent selection of Indian jujube (Ziziphus mauritiana), the toothbrush tree (*Salvadora persica*), and mbamba ngoma (*Balanites rotundifolia*) as the three priority WEPs in every FGD. Table 4.1 shows how these three WEPs were scored against the 11 parameters and by the three community units. For a full list of cited WEPs see Appendix 4.

Table 4.1: Scoring of the three priority wild edible plants across the three community units and 11 parameters. NAS = Nasiger, ATA = Atala Kamusio, and LOP = Lopur community units. Grayed columns indicated where all the WEPs received similar scores. For full scores of all WEPs see Appendix 4

SITE	Wild edible plant	Abundance	Distance	Harvesting	Portability	Processing	Seasonality	Market	Price	Access	Adequacy	Regeneration	AVAILABILITY
NAS	*Ziziphus mauritiana*	1	1	1	1	1	2	3	1	1	3	3	1
NAS	*Salvadora persica*	1	1	1	1	1	2	3	1	1	3	3	1
NAS	*Balanites rotundifolia*	2	1	1	3	3	1	3	1	1	3	1	1
ATA	*Ziziphus mauritiana*	1	1	1	1	1	2	3	1	1	3	3	1
ATA	*Salvadora persica*	2	3	1	1	1	2	3	1	1	3	3	1
ATA	*Balanites rotundifolia*	1	1	1	3	3	2	3	1	1	3	1	1
LOP	*Ziziphus mauritiana*	1	1	1	1	1	2	3	1	1	3	3	1
LOP	*Salvadora persica*	1	1	1	1	1	2	3	1	1	3	3	1
LOP	*Balanites rotundifolia*	2	1	1	3	3	2	3	1	1	3	1	1

While deciding on priority WEPs the participants did not rely on scoring alone but also considered other uses of the WEPs such as food, fodder, medicine, brews, religion, among others (Table 4.1). All three priority WEPs were scored similarly under harvesting, market, price, access, adequacy, and were all considered available. For harvesting and portability, only Balanites rotundifolia differed, being hard to process and heavy to carry, respectively. All priority WEPs were found near the communities except Salvadora persica at Atala Kamusio. Further, all WEPs matured during dry season except Balanites rotundifolia at Nasiger that matured in both wet and dry seasons.

4.4.3 Bayesian Logistic Regression Results on Availability of Wild Edible Plants

Multi-collinearity among predictor parameters differed across community units hence we used different predictor parameters in different community units (Appendix 12). Our models indicated that variations in different predictor parameter levels were associated differently with variations in participants' perceptions on availability. Of all the parameters in our models, only variation in seasonality showed consistent importance across all the four models: the overall model and one for each of the three community units.

For all models combined, variations in distance to harvest sites, seasonality, price, access, and adequacy of harvested WEPs were important in explaining variability in availability of the listed WEPs (Figure 4.2A). We did not consider the access parameter since all WEPs were freely accessible except one data-point of a non-priority WEP, Tamarindus indica, at Lopur that required permission to access. As distance to harvest sites got further from the community units, WEPs became less available to the participants (Figure 4.2A). With seasonality, WEPs that matured in the dry season were considered more available to the people than those that matured in both dry and wet or wet season alone. More expensive WEPs were also less available to the participants. Lastly, WEPs with little or average adequacy per harvest session for individual and household use were considered more available by our model.

In Nasiger community unit (Figure 4.2B), only variations in seasonality and adequacy were important in explaining variation in perceived availability. The importance followed the same pattern as that of the overall model at least for seasonality. However, for adequacy, average adequacy contributed negatively to availability. At Atala Kamusio community unit (Figure 4.2C), however, apart from seasonality, variations in both portability and market were important in explaining availability. As WEPs get heavier, they became less available according to the model. Lastly, at Lopur community unit (Figure 4.2D), both distance to harvest sites and seasonality variations were important factors in explaining variation in availability. The kind of seasonality importance here followed the pattern of the combined model for all the community units, but not for average distance.

4.4.4 Content Themes on the Availability of Priority Wild Edible Plants

We obtained 348 statements from the FGDs with 42 participants throughout the three study community units. Out of the 348 statements, the least contributing participant had two statements while the most contributing participant had 17 statements. Overall, however, there were balanced contributions of statements from Nasiger and Atala Kamusio (n = 120 each) and

Lopur contributed the remaining 108 statements to this study. From the statements, we derived 17 (codes) that captured key ideas that we grouped, based on our own consensual judgements, into 13 themes. Of the 348 statements, female and male participants contributed 158 and 190 statements, respectively (Appendix 13).

4.4.5 Bayesian Model Outputs and Focus Group Discussion Themes

Here, we highlight themes from FGDs that followed the parameters investigated in the model. Specifically, we put more emphasis on the four important parameters (distance, seasonality, price, and adequacy) that were obtained from the overall model output (Figure 4.2A) as highlighted in the red bounding box (Figure 4.3). We further give highlights of some contradicting findings between model outputs and themes we generated from FGDs. It should however, be noted that for these discussion statements we used only the three priority WEPs while modeling relied on all listed WEPs per community unit.

By iteratively looking through each of the 348 statements, we obtained a total of 17 codes that captured key ideas in the statements. We then grouped the codes into 13 themes surrounding major ideas of the participants on how availability of priority WEPs is perceived (Appendix 13). Culture and traditions strongly influenced the view of whether WEPs were available or not, with 126 statements supporting (Appendix 13), with seasonality coming second with 62 supporting statements. These two themes alone were supported by about 54% of all statements with the remaining 11 themes sharing the remaining 46% of the statements.

Overall, most statements from the FGDs captured aspects of culture and traditions, seasonality, and conservation and management (Appendix 13). This suggests that they were important factors when participants consider availability of their WEPs. For the distance parameter, the top three extracted themes included culture and traditions, distribution of WEPs, and seasonality (Figure 4.3). On the other hand, seasonality, climate change, and culture and tradition occurred sequentially in top three in that order under seasonality parameter. This further suggests that the communities looked at seasonality from the point of view of changing climate and their own inherent culture and traditions. With regards to the price parameter, culture and traditions, seasonality, and distribution of WEPs followed that order. Distribution of WEPs could be important theme regarding how much a WEP costs, as it would inform the costs involved in acquiring the WEPs and possibly selling it to the end users. Lastly, seasonality, culture and traditions, and population pressure followed the sequence under the adequacy parameter (Figure 4.3). It was clear from the FGDs that adequacy of WEPs relates significantly to the number of people who are to be fed at home. More mouths demand more WEPs.

In Table 4.2, we show some of the statements from the FGDs that contributed to the top three themes under each of our important parameters from the model. We then put into context the themes that we developed from important model parameters. While the model outputs gave important insights into how each of the studied parameters contributed to the perception of availability, discussions on the priority WEPs went even further to unravel more locally inherent themes surrounding such measured model outputs. For instance, while model outputs showed farther distance to inhibit perception of availability, discussions showed that such distances are seen from the cultural and traditional way of life.

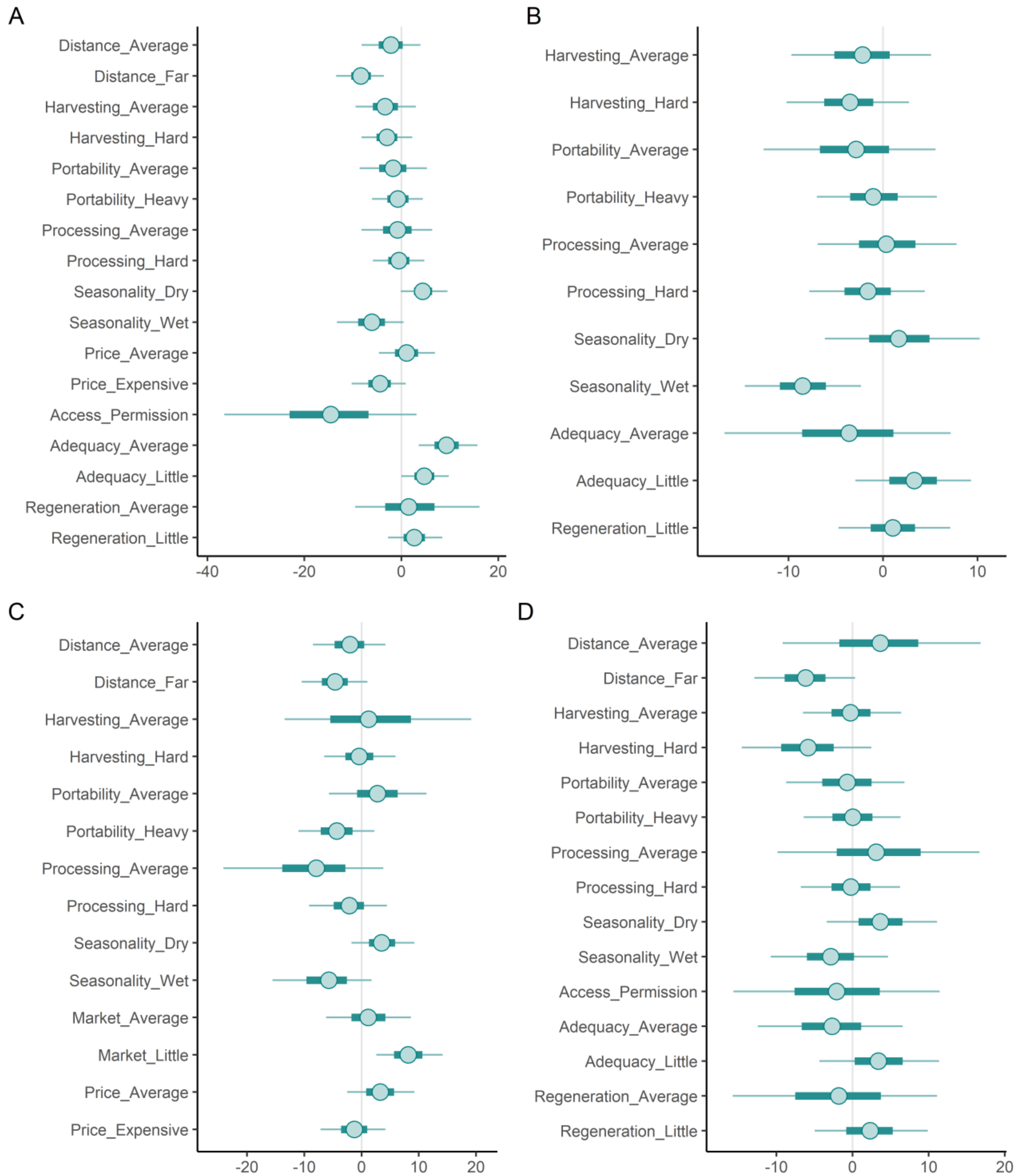


Figure 4.2: Contributions of predictor parameter levels on availability of wild edible plants. A. overall model for the three community units (n = 49), B. Nasiger community unit (n = 13), C. Atala Kamusio community unit (n = 23), and D. Lopur community unit (n = 13). The central small circles represent median coefficient point estimate of the association while the horizontal lines depict

95% credible intervals. The range of parameter coefficient estimates is on the x-axis while the predictor levels are plotted on the y-axis. Parameters with same first part of names before underscore (_) are of the same group (predictor). The vertical line through 0 point on the x-axis (null effect) enables easier magnitude comparison of positive, negative, and null effects coefficients. Non-overlapping horizontal bars under same parameter level group indicate significant difference. Horizontal bars touching the vertical 0 line indicate null effect, that is, effect not different from zero

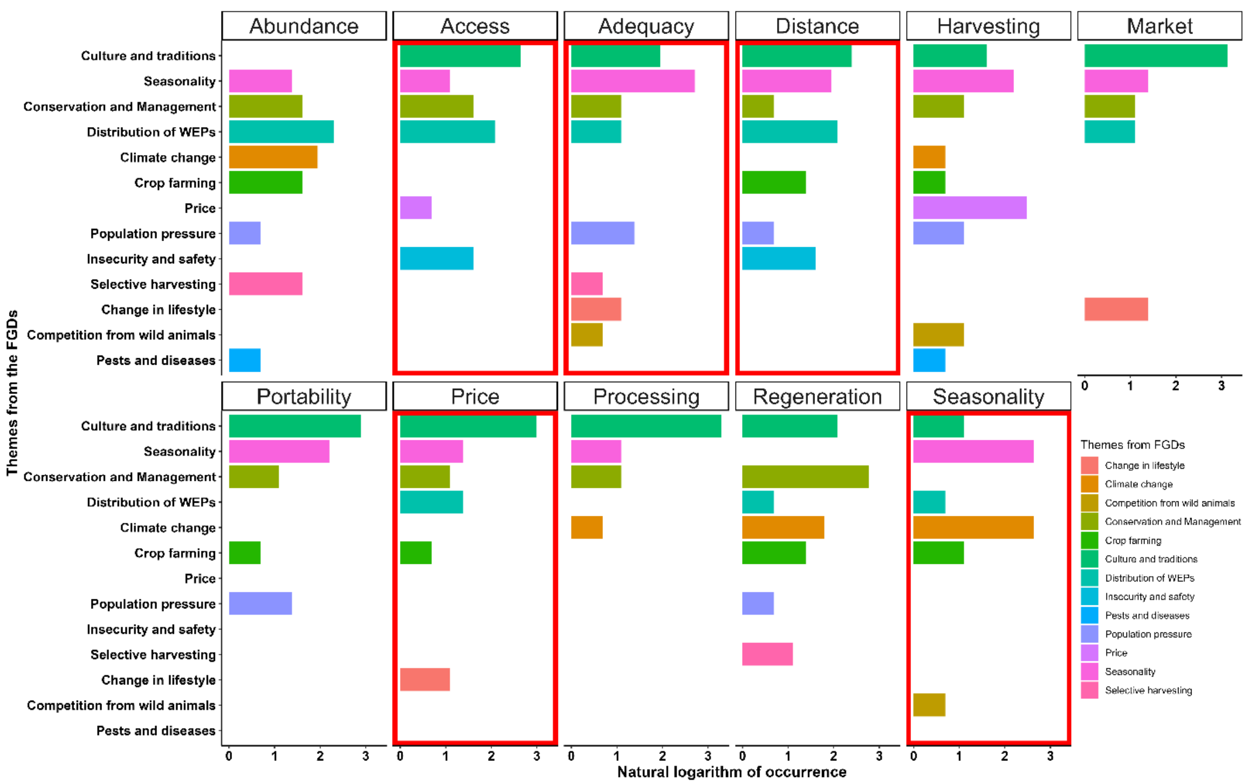


Figure 4.3: Distribution of themes (n = 13) derived from statements (n = 348) obtained during Focus Group Discussions (FGDs) conducted in Nasiger, Atala Kamusio, and Lopur community units of Turkana County, Kenya. The distributions are faceted by parameters used in model building and those within the red boxes were important in explaining availability

4.4.5.1 Cultural and Traditions on Availability

Our combined FGD and model results provided insights linking culture and traditions of the Turkanas to the distances that they cover to harvest sites of their WEPs. While the overall model results indicated that WEPs located far away were considered less available, individual FGD statements suggested that people were willing to walk longer distances to get particular WEPs for specific uses. For instance, an informant suggested that “People making and selling local brews using *Balanites rotundifolia* fruits normally travel longer distances to harvest the fruits. Such distances can be longer than the distance they travel when the aim is only to eat the fruits” (ATA9). Our model also showed that those WEPs that matured in the dry seasons were more available to the local communities. However, this might be changing since the traditional movement with livestock over space is declining due to adoption of more sedentary lifestyle.

Our model and FGD results indicated that as WEPs got more expensive, their availability declined. Indeed, the FGD participants reiterated that as part of their tradition, they were well aware of harvesting sites of the WEPs and would rather obtain them from nature than spend any money in buying them from the market. We further noted that adequacy of harvest was associated with the youth who spent more time with livestock in the grazing fields. The youth ended up getting more adequate amounts of WEPs than those who remained in the homesteads. This could not be seen from the model findings alone that only indicated that averagely adequate WEPs were more available to the communities. Such model result could be due to the fact that almost all WEPs were scored as averagely available.

4.4.5.2 Seasonality

Seasonal availability is another theme we derived from FGDs that shed more light into our observed patterns from the model results on distance, seasonality, price, and adequacy. While the model output showed that WEPs located farther away were less available (see section on Culture and Traditions on Availability), FGD findings revealed that such distances to be covered depended on seasonality of the WEPs’ maturity. The participants were willing to cover greater distances during lean seasons to obtain WEPs. Further, going beyond the model results that only regarded WEPs maturing in dry season to be more available, FGD statements revealed that in good seasons the WEPs can be available throughout. This could mean that WEPs that were maturing in both dry and wet seasons were regarded as more available than what our model indicated or that those maturing during dry season were more important to the study communities.

We further found that seasons were linked to price of WEPs in the market. While the model specifically showed that more expensive WEPs were less available, the FGDs indicated that such price effects were season driven. It was whether the WEP was in season or not that influenced its price in the market. Such price could also be seen as the effort involved in obtaining the fruit, as is the case of overcoming the thorny features of particular WEPs. It generally required less effort/cost to get the WEPs during plenty seasons. It also became clearer from the FGDs that the contribution of adequacy of the WEPs to availability was season based. The communities would find WEPs in season to be more adequate than those off season.

Table 4.2: Overview of contributions of focus group discussion statements on themes under important parameters from regression model. The first three letters of the codes at the end of each statement represent the community unit and the digit(s) part denote participant number, for example, ATA9 is participants number nine from Atala Kamusio community unit

Model important parameter	Top three themes per important parameter	Selected statements from focus group discussions supporting the themes
Distance	Culture and traditions	"People making and selling local brews using *Balanites rotundifolia* fruits normally travel longer distance to harvest the fruits. Such distances can be longer than the distance they travel when the aim is only to eat the fruits." ATA9
	Seasonality	"When the fruits are in season we do not travel long distance from this village." ATA14
	Distribution of WEPs	"Harvest sites are scattered. It depends on where a fruit tree grows so the distance to such places vary." LOP6
Seasonality	Seasonality	"In good season, they can mature twice a year due to the short rains benefit." NAS4
	Climate change	"It is no longer distinct when the plants will be producing fruits probably due to climate change issues. People could depend on the fruits in the past because their availability could be easily predicted but is no longer the case." LOP14
	Culture and traditions	"Seasons used to play a big role in our migration with animals and where we could get ready fruits to harvest. However, in the recent past things have changed and it is hard to tell when the season starts and ends." NAS11

Model important parameter	Top three themes per important parameter	Selected statements from focus group discussions supporting the themes
Price	Culture and traditions	"For us who know how the fruits taste and where they are located, we would rather go for them than to pay any money to get them. This makes them free of cost." LOP2
	Seasonality	"When the population of ripe fruits starts to decline from the trees, those who spend energy to search for them can sell. Such is normally during extreme hunger periods." ATA14
	Distribution of WEPs	"No costs are involved in getting the fruits for consumption because we get them from the riverbanks and away from riverine in case of *Balanites rotundifolia* for free. Those taking care of livestock easily access them. Homesteads where these fruits grow also make it easy to access them for free." LOP13
Adequacy	Seasonality	"Whether what we harvest is adequate or not depends on harvesting site and season/time. When the fruits are ready, one will get enough fruits even from one plant. During other times, you cannot find even one fruit." NAS1
	Culture and traditions	"While taking care of livestock in the field, it is very easy for one to get enough fruits for their consumption in the field. In case there is need to bring some home, then the challenge arises." ATA10
	Population pressure	"When harvesting the fruits for a household use, then large families may not get enough fruits for their consumption. Unless if every member of the large household sets out to harvest the fruits." NAS10

4.4.5.3 Distribution of Wild Edible Plants

From the FGDs, we learned that the priority WEPs were not distributed evenly within the three communities. Across all the three community units, some WEPs (like *Salvadora persica* and *Ziziphus mauritiana*) were said to be located along riverine areas while others (like *Balanites rotundifolia*) occurred in the open lands and thickets. This pattern of distribution could be linked with the four important model output parameters. For instance, the distance that one covers to harvest the WEPs depended on distribution over land. WEPs that were clustered together would likely require less distance to harvest than those that were scattered over land. Even the price parameter from the model was harmonized by the fact that participants could get the WEPs distributed along riverine areas for free while watering their livestock (except for one case of *Tamarindus indica* that required permission). The question of where and how the WEPs were distributed was thus critical for the availability concerns to the communities.

4.4.5.4 Climate change

This is another theme that emanated from the FGDs. It drew from such impacts as extended drought periods, flashfloods along the riverine areas, and emergence of invasive plants such as Mathenge tree (*Prosopis juliflora*). Participants mentioned that as opposed to the past when seasons were distinct and predicting fruiting periods were more accurate, the current pattern was quite unpredictable; and they attributed that to climate change and variability. Further, climate change effects have allowed for invasion by plants such as *Prosopis juliflora* that have the potential to outcompete native plants including some WEPs and degrade the land.

4.4.5.5 Population Pressure

Population pressure, especially household size, was mentioned as an important factor with regards to adequacy of harvest for consumption. Smaller household sizes could easily get more adequate WEPs for consumption than large household sizes. This complements the model results that showed that WEPs in adequate quantities per harvest session were more available to the communities. Those who looked after livestock in the field were mentioned to be more exposed to the WEPs and could get them in adequate quantities, however, when they had to carry some home for the whole household use, then the WEPs were likely to be inadequate. This indicated that whether the harvest would be adequate or not was subject to the number of mouths to

be fed.

4.5 Discussion

4.5.1 Priority Wild Edible Plants

Different communities cited and scored different WEPs, but shared the same three priority WEPs (*Ziziphus mauritiana*, *Salvadora persica*, and *Balanites rotundifolia*). This could be due to the long history of knowledge, relevance, and use of these particular plants beyond food consumption among Turkanas (W. T. W. Morgan, 1981). Related studies have also shown the importance of these WEPs in neighboring regions. *S. persica* is used in Ethiopia for treating respiratory infections and tuberculosis and several Ziziphus species for their edible fruits (Duguma, 2020). The fruits of

B. rotundifolia are also consumed and used for medicine within the region (Duguma, 2020). Both *S. persica* and *B. rotundifolia* are used for several purposes including food in Eastern Baringo District (Termote et al., 2014). In neighboring country South Sudan *S. persica* is used for medicine (AbdELRahman et al., 2003). The three priority WEPs appeared to be useful beyond the current study area and thus call for enhanced assays that will culminate into their sustainable use to fight malnutrition and hunger in the region.

4.5.2 Important Factors on Availability of Wild Edible Plants in Turkana County, Kenya

Our results showed that distance to harvest sites, seasonality, price, and adequacy of harvested WEPs were important in explaining availability of the WEPs to the communities. WEPs located farther away from the community units were considered less available compared to those that were nearer. In terms of seasonality, WEPs that matured during dry season were the most available group to the communities. Moreover, as the WEPs got more expensive, they became less available to the communities. Lastly, WEPs of more adequate quantity of fruits per harvest session were considered more available. There are reports of similar patterns, with regards to distance to harvest sites, among studies on medicinal plants (Gonçalves et al., 2016). The observed patterns could be a result of the high hunger and poverty rates within the county (KER, 2020; Kuper et al., 2015). Turkanas rely on their available WEPs for nutrition, especially in the lean season.

The need to cover longer distances from the residential places to harvest WEPs lowered perceived availability. Similar patterns had been witnessed in harvesting of wild edible ferns in Japan (Matsuura et al., 2014; Ochoa & Ladio, 2014) and neighboring Ethiopia (Kebede et al., 2017). We are however, cognizant of the fact that we obtained distance parameter in ordinal scale (near, average, and far) during the FGDs hence only interpretable to the three subjective levels from the point of view of the FGD participants. Promoting WEPs for dietary diversification should consider distance to harvest sites, since this relates strongly to how communities perceive availability.

In addition to the above, the model revealed that seasonal availability of the edible parts of the WEPs was also important in explaining the variation in perceived availability. WEPs that matured in the dry season were strongly related to availability according to our model. Previous studies in the region showed that in dry seasons most locals face extreme hunger (Opiyo et al., 2015; Otieno, 2020). Our findings showed that WEPs could be considered safety nets for communities facing hunger and drought. This is supported by research related studies that have also found WEPs to be regarded as safety nets by communities especially during lean seasons (Carr & Carr, 2017; Otieno, 2020; Sarfo, 2017). Studies in neighboring Ethiopia, South Sudan, and Uganda have also revealed the contribution of WEPs, especially fruit trees, in substituting for cultivated food crops during shortage seasons (Addis et al., 2005; Dejene et al., 2020; Dragicevic, 2017; Ojelel et al., 2019). Relevance of seasonal availability was beneficial in providing food security and an income source to rural communities in Maharshtara, India (Kiran et al., 2019) and in Punjab (Atri et al., 2010). The question of which WEPs mature in which seasons was beyond the scope of our study, but could be an important point for further research. Our model further revealed the importance of market price of the WEPs. As costs increased from average to expensive, perception of availability decreased. Similar findings were reported in Mapuche, South America (Estomba et al., 2006) and in Turkey and neighboring Ethiopia (Dougan et al., 2013; Duguma, 2020). Even though we noticed infrastructural improvements in road networks within our present study area that could have potentially improved penetration of the WEPs into the market, the WEPs were still largely being obtained from the wild with minimal monetary exchanges if any (FGD deliberations). Ways to stabilize price of WEPs like traditional sun-drying of the fruits during plenty to provide for lean seasons could improve availability of the WEPs to the people throughout the year.

When adequacy of harvested WEPs for consumption was scored average, perception of availability increased, counterintuitively. Most of the WEPs that the communities regard as available to them yielded average fruits. It was interesting to note that not all WEPs that yielded plenty fruits were cited as adequate. It could be possible that other properties of the fruits like mass, amount of edible parts, size of seeds contributed to this effect. However, this adequacy factor was augmented by the size of household. WEPs that could be adequate for individual consumption were inadequate for a large household size (see Table 4.2 on adequacy)

4.5.3 Important Themes Behind Availability of Wild Edible Plants

The FGD findings enriched our understanding of regression model results. The major themes from FGD statements (culture and traditions, distribution of WEPs, seasonality, climate change, and population pressure) overlapped with important factors from the regression model. These themes were consistent with the literature too. For example, cultural/traditional knowledge was highlighted in the detailed review by Chakravarty et al. (2016) as important in understanding rural communities' linkages with their wild edible fruits. Elsewhere, in a study on wild edible fungi in Mexico, Castro-Sánchez et al. (2019) indicated decreasing consumption among youth due to livestock raising and agricultural intensification.

Seasonality was important in understanding how the local communities perceive availability, especially during the dry season. Studies elsewhere in Kenya (Shumsky et al., 2014), Ethiopia (Tebkew et al., 2018), and Vietnam (Ogle et al., 2003) have also reported that WEPs are used to cushion hunger during lean seasons. Communities have been shown to put a lot of effort into harvesting WEPs during lean periods and use them as supplementary foods in other seasons with reports from Rwanda, India and Uganda (Janvier et al., 2019; Sharma et al., 2018; Tabuti et al., 2004).

The distribution of WEPs was also important theme in line with important factors in our regression model. The FGD participants emphasized that differential distribution of WEPs over the landscape informed how far one would travel to access them. Further, such distribution also informed whom the WEPs would be more available to. Children and youth taking care of livestock in the open fields and along riverine areas were more exposed to diverse WEPs compared to elderly adults back home. Comparable findings have been reported in two neighboring countries of Ethiopia (Addis et al., 2005, 2013) and Uganda (Tabuti, 2007). In their traditional movement with livestock from one place to another, Turkanas encountered and consumed diverse WEPs (Ladio & Lozada, 2004) possibly translating into nutrition adequacy (Lachat et al., 2018) depending on their abundance within a locality (Termote et al., 2012). WEPs occurring more closely together rendered adequate harvests per session compared to scattered WEPs as revealed by FGD deliberations hence calling for optimal management and conservation efforts.

Climate change also emerged as a theme from FGDs, including prolonged droughts, flashfloods and invasive species such as *Prosopis juliflora* (Nadio et al., 2020; Ng et al., 2016). The recent (2020) devastation by swarming desert locusts in the whole of north eastern Africa, including Turkana region, could also be attributed to changes/variabilities in climate (Peng et al., 2020; Zhongming et al., 2020). Efforts to mitigate the negative impacts of climate change and variability on the WEPs in this arid and semi-arid environment should thus be heightened. This will ensure enhanced availability of the WEPs with potential inclusion in fight against malnutrition and hunger in Turkana County.

We also obtained an important theme on population pressure. Households with more mouths to feed would need more of harvested fruits from WEPs to achieve adequate quantity. This was of concern especially in lean seasons when the fruits were hardly available in the fields. Ensuring nutrition security for everyone by relying on WEPs was, therefore, a big concern (Lachat et al., 2018). Indeed, the whole globe is concerned about how agricultural systems could be improved to ensure increasing population is nutritionally secure from a range of research works (Gerten et al., 2020; Plesse, 2020; von Braun et al., 2021). It calls for concerted efforts to ensure that Turkana County is nutritionally secure amidst its growing population and optimized conservation of already evolutionarily suited WEPs could offer a solution.

Beyond the themes that we derived across the parameters we used in modeling, the FGDs also revealed other crucial themes that we did not include in the Bayesian model. For instance, use value of the priority WEPs emerged with some participants suggesting that they could travel longer distances to obtain WEPs of high use values. Food aid from both government and non-governmental organizations during extreme hunger and drought in the study region was also highlighted, especially so in the event of extreme drought when even livestock succumbed. The communities normally called for an intervention from the government to salvage the dire situation. To this end, we noted that even though parameters in our predefined 'topic list' were important in helping us understand the availability perception, still some ideas emerged beyond our predefined list. Hence, the importance of conducting an integrated participatory study that contributes to co-development of knowledge and understanding with the communities under study.

We combined both stochastic modeling protocols and theme extraction from FGDs to gain insights into the WEPs availability to local communities in Turkana County. Mere tabulated figures of regression results may not show the reasons behind the statistics. On the other hand, mere statements with no magnitude and direction of effects may not yield much actionable findings. However, by bringing together the two and co-developing knowledge with the communities in an integrated participatory approach, where the key stakeholders (local communities) contribute actively, we managed to better understand what informs perception of availability of WEPs to the Turkanas of northwestern Kenya.

4.6 Conclusion

In our novel approach of integrating Bayesian regression results and focus group discussion findings in an integrated participatory approach, we gained important insights about the perceived availability of WEPs in northwestern Kenya. Our findings showed the relevance of involving local communities in understanding how their perception regarding their WEPs is structured. Overall, we found that distance to harvest sites, seasonal availability, market price, and adequacy of harvest were important parameters in explaining variation in perceived availability. With the integrated participatory approach, we revealed that perceived availability of WEPs was enshrined in culture and tradition and in the WEPs seasonality and distribution patterns within Turkana County. Factors such as climate change and population pressure as well as changing lifestyles were expected to change the perceived availability and use of WEPs and consequently their importance as a food source. As factors such as climate change continue to lower perceived availability, it would be important to document threats and subsequently potentially suitable habitats of the WEPs for their sustainable use in future. These findings may be used in formulating programs and policies to include WEPs in the fight against hunger and malnutrition in comparable arid and semi-arid pastoral communities in Africa.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10745-022-00370-0.

Acknowledgements We sincerely thank participants from Nasiger, Atala Kamusio, and Lopur community units who hosted us and shared their knowledge about their wild edible plants.

Authors' Contributions Wyclife Agumba Oluoch, Cory W. Whitney, Celine Termote, and Christine B. Schmitt conceptualized the study. Wyclife Agumba Oluoch, Cory W. Whitney, and Christine B. Schmitt composed methodology for the study. Formal analysis and investigation of the study were done by Wyclife Agumba Oluoch and Cory W. Whitney. Writing–original draft preparation was done by Wyclife Agumba Oluoch. Further review and editing were done by Wyclife Agumba Oluoch, Cory W. Whitney, Celine Termote, Christian Borgemeister, and Christine B. Schmitt. Funding acquisition was done by Celine Termote and Christine B. Schmitt. Supervision of the study was done by Cory W. Whitney and Christine B. Schmitt.

Funding Open Access funding enabled and organized by Projekt DEAL. This study received financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ) commissioned and administered through the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) Fund for International Agricultural Research (FIA), grant number: 81235248.

Data Availability The datasets and R scripts are publicly available in the GitHub repository (https://github.com/Wycology/wild_edible_plants_availability) for use with correct citation of the source. However, we will not make FGD data available as some contain information that can identify the speaker individually, except those provided in (Table 4.1).

4.7 Declarations

Ethical Approval This study was approved by Center for Development Research – ZEF ethical review committee, Bonn, Germany and National Commission for Science, Technology and Innovation (NACOSTI), Nairobi, Kenya under license number NACOSTI/P/20/7052.

Consent to Participate Prior informed verbal consent was obtained from all participants before their participation in the study.

Research Involving Human and Animal Ethics The research was conducted under Center for Development Research – ZEF, Bonn Germany, research ethics framework and that of National Commission for Science, Technology and Innovation, Nairobi Kenya research ethics guideline.

Consent for Publication All participants in the study consented verbally

to have their data published.

Competing Interests The authors have no conflict of interest to declare.

Chapter 5: Indigenous communities' perceptions reveal threats and management options of wild edible plants in semiarid lands of northwestern Kenya

This chapter has been published as Oluoch, W. A., Whitney, C. W., Termote, C., Borgemeister C. and Schmitt, C. B. (2023). Indigenous communities' perceptions reveal threats and management options of wild edible plants in semiarid lands of northwestern Kenya. Journal of Ethnobiology and Ethnomedicine, 19(13): 15. https://doi.org/10.1186/s13002-023-00584-6

5.1 Abstract

Background Understanding how local communities perceive threats and management options of wild edible plants (WEPs) is essential in developing their conservation strategies and action plans. Due to their multiple use values, including nutrition, medicinal, construction, and cultural as well as biotic and abiotic pressures, WEPs are exposed to overexploitation, especially within arid and semi-arid lands hence the need to manage and conserve them. We demonstrate how an understanding of indigenous communities' perceptions could be achieved through an integrated participatory approach involving focus group discussions (FGDs) and field plot surveys.

Methods We conducted three FGDs between October 2020 and April 2021 within three community units in northwestern Kenya with different socio-economic and environmental characteristics. We subsequently surveyed 240 field plots of size 1 ha each to assess threats facing WEPs within a 5 km buffer radius in every study community. We compared ranks of threats and management options across community units.

Results Rankings of threats and management options differed across the three study communities. We obtained strong positive linear relationships between field and FGD rankings of threats facing WEPs. Climate change, overstocking, overharvesting, and invasive species were the highest-ranked threats. Mitigation of climate change, local knowledge preservation, selection, propagation, processing, and marketing of WEPs ranked high among possible management options irrespective of the socioeconomic and environmental characteristics of the community unit.

Conclusions Our approach emphasizes the relevance of leveraging indigenous communities' perceptions and conducting field plot surveys to assess threats and management options for WEPs. Evaluating the effectiveness and cost-benefit implications of implementing the highly ranked management options could help determine potentially suitable habitats of the WEPs for conservation and management purposes, especially for priority WEPs.

Keywords: conservation; sustainable use; wild food plants; integrated participatory approach; field survey; focus group discussion; local knowledge; Kenya.

5.2 Introduction

Wild edible plants (WEPs) are 'safety nets' for many communities during lean seasons (Nkem et al., 2010; Shackleton et al., 2011; Shumsky et al., 2014) and in conflict situations (Redžić & Ferrier, 2014; Sulaiman et al., 2022). They are and have been essential assets in the fight against malnutrition and hunger in many societies (Giraud et al., 2021; Hunter et al., 2019; Shaheen et al., 2017), and stand to benefit modern communities and those in the future (Baldermann et al., 2016; Dempewolf et al., 2017). However, WEPs have witnessed continued localized habitat destruction and overexploitation (Kideghesho, 2009; Vinceti et al., 2018), attributable to various anthropogenic and natural factors (Y. O. Kidane et al., 2012; Schunko et al., 2022). Such factors compromise the sustainable use of WEPs as safety nets for many communities across the globe (Schunko et al., 2022)

Within Africa, threats to WEPs pose challenges to about 80% of the rural populations that derive food from the wild (Hickey et al., 2016). The threats inhibit the optimal regeneration of WEPs and their use as food by such communities (Balemie & Kebebew, 2006; Devi Thakur et al., 2016). While some threats have adverse effects on the local abundance of WEPs, changes in lifestyle and consumption patterns, among other socio-economic and cultural reasons, also explain the declining use of WEPs (Bender, 2017; Pawera et al., 2020). The impacts from such threats are primarily felt by poor rural people (Angelsen et al., 2014; Hickey et al., 2016), thus negatively affecting the role of WEPs as 'safety nets' for rural African populations vulnerable to malnutrition and hunger (Bélanger & Pilling, 2019; Paumgarten et al., 2018).

Turkana County in northwestern Kenya is one of the affected regions in Africa. It is inhabited by the Turkana people, among others, whose traditional livelihood strategy is nomadic pastoralism (Opiyo et al., 2015; Otieno, 2016b). Accordingly, their primary diet comprises animal products like meat, milk, and blood. They derive plant-based vitamins and herbal medicines primarily from WEPs (Bender, 2017; Ng’asike & Blue Swadener, 2015; Ratemo et al., 2020). Some communities have diversified their livelihood strategies into trade, such as the sale of Aloe vera (C. Ouma et al., 2012; Watson & Binsbergen, 2006), honey harvesting (Akall, 2021; Opiyo et al., 2015), artisanal gold mining (Odero, 2015), poultry keeping (Bett et al., 2008), basket weaving (Ejore et al., 2020; Lokuruka, 2008; Omire, Neondo, et al., 2020), hide processing (Wayua et al., 2014), local brewing (Akujah, 2011), fishing (Carr & Carr, 2017; B. D. Smith, 2018), and crop cultivation (Juma, 2009; Opiyo et al., 2015).

Of the 47 counties in Kenya, Turkana County has the highest poverty and malnutrition rates (KER, 2020). Only 3.2% of its population hold food stocks that can last more than one month (KER, 2021). Against the national poverty headcount rate of 36.1%, it has the highest poverty rate of 79.4% (about 80% of Turkana people are considered poor) (KER, 2021). The county also has the highest food poverty rate at 66.1%, compared to the national average of 32% (KER, 2021). With WEPs known to aid in food and nutritional security (Sarfo, 2018), assessing their threats and management options could be a significant step in sustainably utilizing them in such a setting as Turkana County.

Turkana people have relied on locally constituted management methods like seasonal grazing (via migration with livestock) and clear designation grazing fields (W. T. W. Morgan, 1981). These, however, could not be sufficient in countering contemporary threats, including those of anthropogenic climate change. Managing valuable resources such as WEPs for sustainable use is crucial to local communities. We define ‘sustainable use’ as the case when WEPs are harvested within the limits of their carrying capacity for self-renewal and the manner of harvest does not degrade the environment in other ways (Hamilton, 2005, p. 1).
We sought to understand the threats and management options that could aid the sustainable use of WEPs in northwestern Kenya. To achieve this, we used an integrated participatory

approach to combine FGDs results with field plot surveys guided by three research questions: (i) What threats face WEPs in Turkana County, and how do they vary across different socio-economic and environmental settings? (ii) How do indigenous communities' perceptions of these threats compare with field survey results? (iii) What are possible effective management options and how do they differ across socio-economic and environmental settings?

5.3 Materials and Methods

5.3.1 Study Area Description

We conducted the study in three community health units (Nasiger, Atala Kamusio, and Lopur), reflecting the socio-economic and environmental differences in Turkana County (Figure 5.1). A community health unit, hereinafter called a community unit, is a designated geographical zone with approximately 1000 households and served by ten community health volunteers and one health extension worker (Hossain, 2020). Nasiger community is located in the dry plains about 40 km north of Lodwar town, the headquarter of Turkana County. It receives an annual rainfall of about 166 mm (average 1981 - 2022) (C. Funk et al., 2015). The vegetation consists of scanty scrubs with occasional trees along the riparian areas (normally dry riverbeds) (W. T. W. Morgan, 1981). According to the Food Economy Group, the community unit falls under the Turkana Central Pastoral livelihood zone, an "exceptionally hot, dry, and arid environment" Food Economy Group (2016).

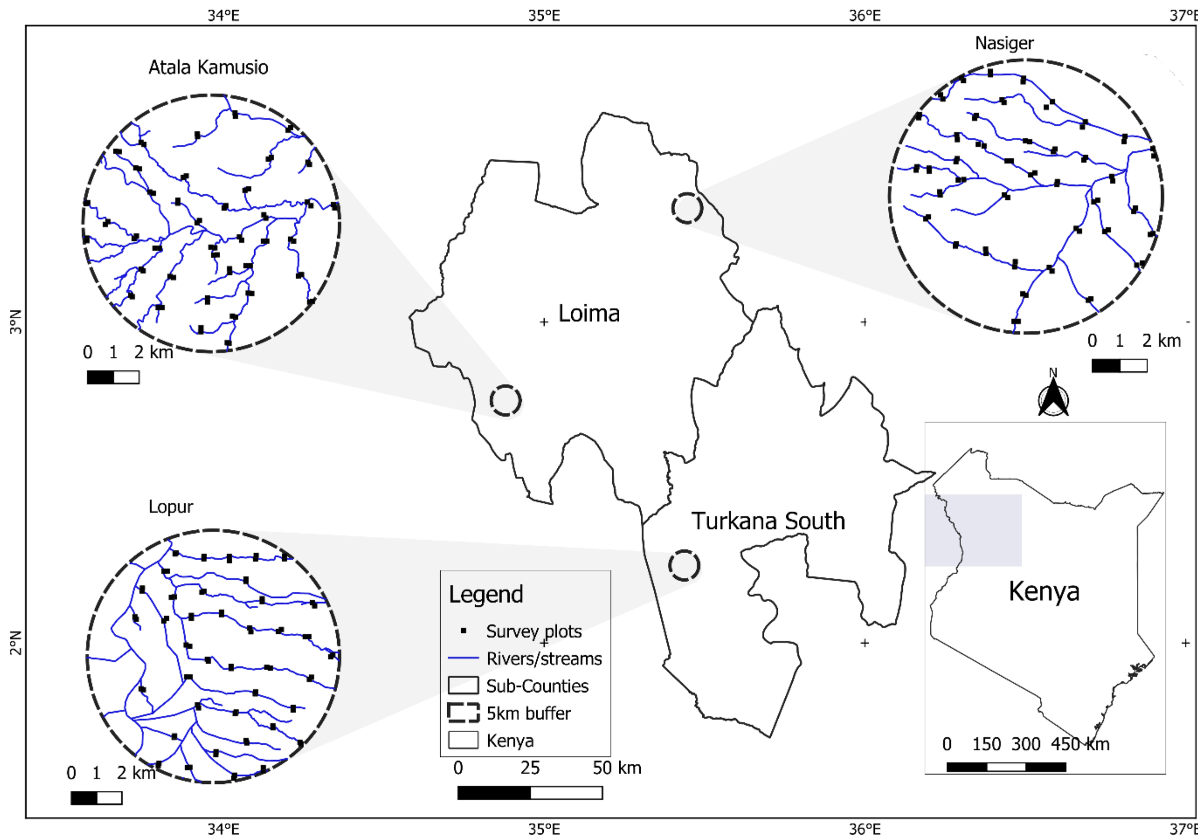


Figure 5.1: Study area map showing the distribution of the study plots within the three community units of Nasiger, Atala Kamusio, and Lopur within Loima and Turkana South sub-counties of Turkana County, Kenya

Atala Kamusio community is situated in the Turkana Border Pastoral livelihood zone (Food Economy Group, 2016), about 100 km west of Lodwar town (Figure 5.1). The landscape undulates between mid- and lowland elevations, and woody and shrubby plants dominate the landscape (W. T. W. Morgan, 1981). It receives an annual rainfall of 371 mm (average 1981 - 2022) (C. Funk et al., 2015). The Lopur community is in the Turkwel Riverine-Agro Pastoral livelihood zone (Food Economy Group, 2016), about 118 km south of Lodwar town (Figure 5.1), along the only permanent river in Turkana County, the Turkwel River. The area receives 327 mm of rainfall per year (average 1981 - 2022) (C. Funk et al., 2015) and has intensive crop cultivation with irrigation water from the river (Emuria, 2018). Inhabitants grow crops such as maize, beans, tomatoes, and pawpaw and keep livestock such as cattle, sheep, goats, camels, and donkeys (Emuria, 2018; Stevenson, 2018).

5.3.2 Data collection

We obtained threats and management options data on WEPs from the literature and discussed these with each of the three community units in FGDs. We also conducted field observations of threats. The research activities were carried out from October 2020 to April 2021.

5.3.2.1 Extraction of threats and management option categories from the literature

We extracted threats and management options for WEPs from published literature using a snow-balling approach (Wohlin, 2014). We went through as many literature sources as possible (n = 23) that featured either threat or management reports. The list of threats and management options with their corresponding reviewed sources are in Appendix 14 and Appendix 16, respectively. We also obtained threat categories from the threats classification scheme version 3.2 by the International Union for Conservation of Nature (IUCN) (IUCN, 2012). We then went through all threat categories in the obtained literature. We grouped categories referring to similar threats, e.g., by placing “expansion of agriculture” and “expansion of agricultural land” into the same category (Appendix 15).

5.3.2.2 Focus group discussions

We held FGDs with 14 adults (age >= 18 years) participants in each of the three study community units (Oluoch et al., 2022). With the help of local administrators, we included participants in the study who were involved in the WEPs value chain, including harvesting, use, and conservation efforts. They included, among other community members, village elders, community health volunteers, church leaders, community nutritionists, public health officers, community health workers, and teachers.

Village elders, for example, oversee matters concerning the use and conservation of community resources, including WEPs. Local administrators maintain peace and ensure adherence to rules, such as settling disputes whenever they arise, including those concerning WEPs. They are also the main entry points to the communities for government or non-government programs. Teachers instill knowledge in the young generation in school settings, including nutrition skills that could involve the use of WEPs. Health workers, such as health extension officers, nutritionists, public health officers, and community health volunteers at the community level, support the improvement of the health and well-being of local people, including advocating for the use of WEPs in their diets. Lastly, other members of the FGDs were drawn from residents who participated in harvesting and use of WEPs for food and medicine, among others. We thus considered all the participants very resourceful in discussing threats and management options for WEPs.

We used three woody WEPs, i.e., *Salvadora persica*, *Ziziphus mauritiana*, and *Balanites rotundifolia, considered* priority (Oluoch et al., 2022) due to their high use values in the region for detailed FGDs with the local participants. We opted for woody species as their longer lifespan in the field implied that participants interacted with them more and could discuss them more exhaustively. Further, the trees were also present in the field during our plot surveys.

We commenced every FGD by allowing participants to free list and discuss threats facing the three priority woody WEPs. We then consensually co-grouped the listed threats into the nine pre-defined (cf. Appendix 15) categories with the participants. We added a tenth category for all mentioned threats that were not in our nine pre-selected categories (Appendix 15). We did preference ranking (Cotton, 1996; Martin, 1995, 2010) that involved asking the participants to score each of the ten threat categories on a scale of 10 (threat of greatest concern) to 1 (threat of least concern) according to their perceived magnitude of effects on the three priority woody WEPs. We gave each participant 10 white circular pieces of cardboard, and they raised a card after concluding the discussion on each threat category. We took note of the number on the raised cardboard by each participant. We repeated that for all ten threat categories as we expounded on the indicators under each threat category. We ranked management options in the same manner.

5.3.2.3 Focus group discussions

We obtained geographic coordinates of the FGD venue in each of the three community units using a handheld Global Positioning System (GPS). Treating this as the central point of the community unit, we created a virtual buffer zone of a five km radius (Figure 5.1) as buffers, within which we traced all rivers/streams using QGIS software (QGIS Development Team, 2023) and Google Earth base layers. Though there were no distinct boundary maps of the community units to help derive the centers, the local communities considered our FGD sites central. None of our five km buffers overlapped with neighboring community units. Based on prior informal discussions with local administrators, we assumed that the participants, and other community members in general, resided within that radius, and their scored threats would be represented within that spatial extent. We then generated 40 random survey plots and established 100 m by 100 m (1 ha) plots at each point along the digitized streams such that no two plots were closer than 1 km (Figure 5.1). For every random riverine plot, we generated a corresponding off-riverine plot at least 100 m from the river bank. That resulted in 80 survey plots per community unit and 240 survey plots for the three community units. We chose to include 'riverine' as a factor since our study area was largely arid. We assumed occasional higher relative moisture levels confined within riverine areas could explain some variations. Both *S. persica* and *Z. mauritiana* have also been reported to prefer riverine sites (Falasca et al., 2015; Ma'Ayergi et al., 1984; Anshuman Singh et al., 2020).

Using nine of our ten threat categories (we dropped 'climate change' as it was impractical to observe indicators of climate change in a single field visit), we scored observable threats to WEPs in each survey plot. Each threat category could receive a score between 1 (least threat) and 9 (highest threat). Scoring was based on the consensus of the threat categories by three observers (two trained research assistants and the corresponding author). Observed indicators of threats included fire scars to denote fire threat, over-browsed seedlings/lower branches of priority woody WEPs to denote overstocking/overgrazing, and plowed land to characterize agriculture expansion threat, among others that were obtained from FGDs (Appendix 15).

5.3.3 Data analysis

We calculated score-sums (Cotton, 1996; Martin, 2010) for all threat and management scores from all participants to obtain an overall ranking of each threat and management category for all community units combined and individually. We then tested for differences in the scores within and between community units for management options and scores from threats we observed from field plot surveys. We ran the test using non-parametric *friedmanAlignedRanksTest* and *friedmanAlignedRanksPost* functions in the *scmamp* (Calvo & Santafé Rodrigo, 2016) package version 0.3.2 in R (R Core Team, 2023) version 4.2.2. The test is well suited for non-parametric, non-normally distributed, and ranked or ordinal data. To compare FGD and field plot survey ranking of threats to woody WEPs, we ran pairwise correlation tests on the resulting rankings.

5.4 Results

5.4.1 General description of FGD participants

Participants in the FGDs were individuals knowledgeable about WEPs (cf. **Error! Reference source not found.**) within Turkana County, Kenya. Their representation is summarized in Table 5.1.

Table 5.1: Proportion of participants in the FGDs

Participants	Number included in the study	Proportion (%)
Village elders	7	17
Chiefs/Assistants chiefs	5	12
Teachers	5	12
Health workers	8	19
Nutritionists	3	7
Public health officers	1	2
Other community members	13	31
Total	**42**	**100**

Table 5.1 indicates that the majority of the participants, 31% (n = 13), were ordinary community members, followed by health workers, village elders, and a public health officer. Up to 60% (n = 25) of the participants were female, while 40% (n = 17) were male. The participants were considered diverse and knowledgeable enough to give detailed discussions on the WEPs needed for the study.

5.4.2 Threats to woody wild edible plants from focus group discussions

Climate change, invasive species, and overstocking/overgrazing ranked highest among the threats facing priority woody WEPs according to scores by FGD participants (Table 5.2). We observed similar patterns in the Nasiger and Atala Kamusio community units but not in Lopur. Agriculture expansion, selective harvesting/overharvesting, and overstocking/overgrazing were ranked the highest here. We then tested for possible differences in threat scores.

At least one community unit was significantly different ($\alpha < 5\%$) from the other(s) in the ranking of each threat category except for invasive species, pests and diseases, and others (Figure 5.2).

Table 5.2: Rank summaries of threat categories in each community unit and across all community units combined (Nasiger, Atala Kamusio, and Lopur) in Turkana County, Kenya

Threat Categories	**Nasiger**		**Atala Kamusio**		**Lopur**		**All communities**	
	Score	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Climate change	117	1	111	1	57	8	285	1
Invasive species	88	2	104	2	89	6	281	2
Overstocking/overgrazing	65	3	93	3	102	3	260	3
Selective harvesting/Overharvesting	61	4	76	4	110	2	247	4
Fuelwood collection/charcoal burning	43	5	69	5	97	5	209	5
Agricultural expansion	23	9	38	7	130	1	191	6
Uncontrolled fire	40	6	25	9	101	4	166	7
Infrastructural development	31	7	62	6	72	7	165	8
Pests and diseases	30	8	33	8	41	9	104	9
Others	16	10	19	10	17	10	52	10

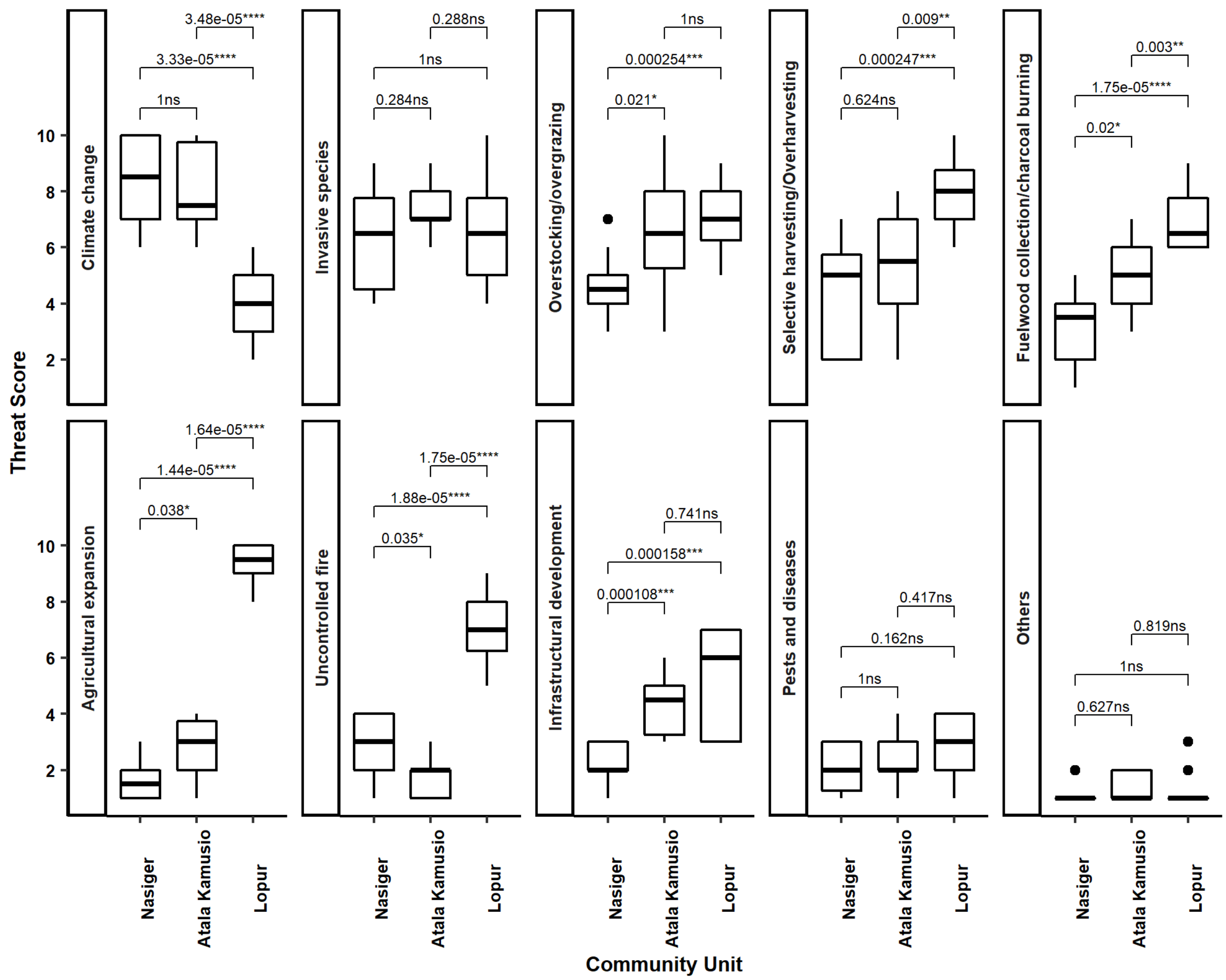


Figure 5.2: Comparison of scores on threats across the three study community units in Turkana County, Kenya. ns, *, **, ***, and **** represent not significant, significant at α = 5%, 1%, 0.1% and 0.01%, respectively

5.4.3 Threats to woody wild edible plants from field observations

We observed no significant differences in threat scores between riverine and off-riverine field survey plots; hence we formed a composite of the two datasets resulting in 80 survey plots per community unit. Overstocking/overgrazing, invasive species, and selective harvesting/overharvesting were the top three threats we observed in the field at Nasiger (Table 5.3). At Atala Kamusio, top three threats were overstocking/overgrazing, selective harvesting/overharvesting, and fuelwood collection/charcoal burning. Agricultural expansion was the top-ranked threat to WEPs at Lopur, followed by invasive species and uncontrolled fire (Table 5.3). In field plot observations overstocking/overgrazing was the highest-ranked threat, followed by selective harvesting/overharvesting and invasive species (Table 5.3). The same threats were identified in the FGDs.

Table 5.3: Sum of scores and ranks of threats categories from field plot observations (n = 80) in three community units (Nasiger, Atala Kamusio, and Lopur and all combined) in Turkana County, Kenya

Threat Categories	**Nasiger**		**Atala Kamusio**		**Lopur**		**All communities**	
	Score	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Overstocking/overgrazing	581	1[2]	635	1[2]	615	4[3]	1831	1[2]
Selective harvesting/Overharvesting	471	3[3]	557	2[3]	442	5[2]	1470	2[3]
Invasive species	483	2[1]	332	4[1]	628	2[6]	1443	3[1]
Fuelwood collection/charcoal burning	269	4[4]	448	3[4]	387	6[5]	1104	4[4]
Agricultural expansion	80	9[8]	168	6[6]	658	1[1]	906	5[5]
Uncontrolled fire	105	7[5]	160	7[8]	617	3[4]	882	6[6]
Infrastructural development	168	6[6]	154	8[5]	282	7[7]	604	7[7]
Pests and diseases	197	5[7]	204	5[7]	129	8[8]	530	8[8]
Others	102	8[9]	83	9[9]	82	9[9]	267	9[9]

Our rankings of threats categories facing woody WEPs from the field plots surveys varied significantly among the study community units (Figure 5.3). We, however, observed some similarities in the rankings, as were the cases for overstocking/overgrazing at all communities, selective harvesting/overharvesting at Atala Kamusio and Lopur, infrastructural development at Nasiger and Lopur, pests and diseases at Nasiger and Lopur, and others at Nasiger and Atala Kamusio.

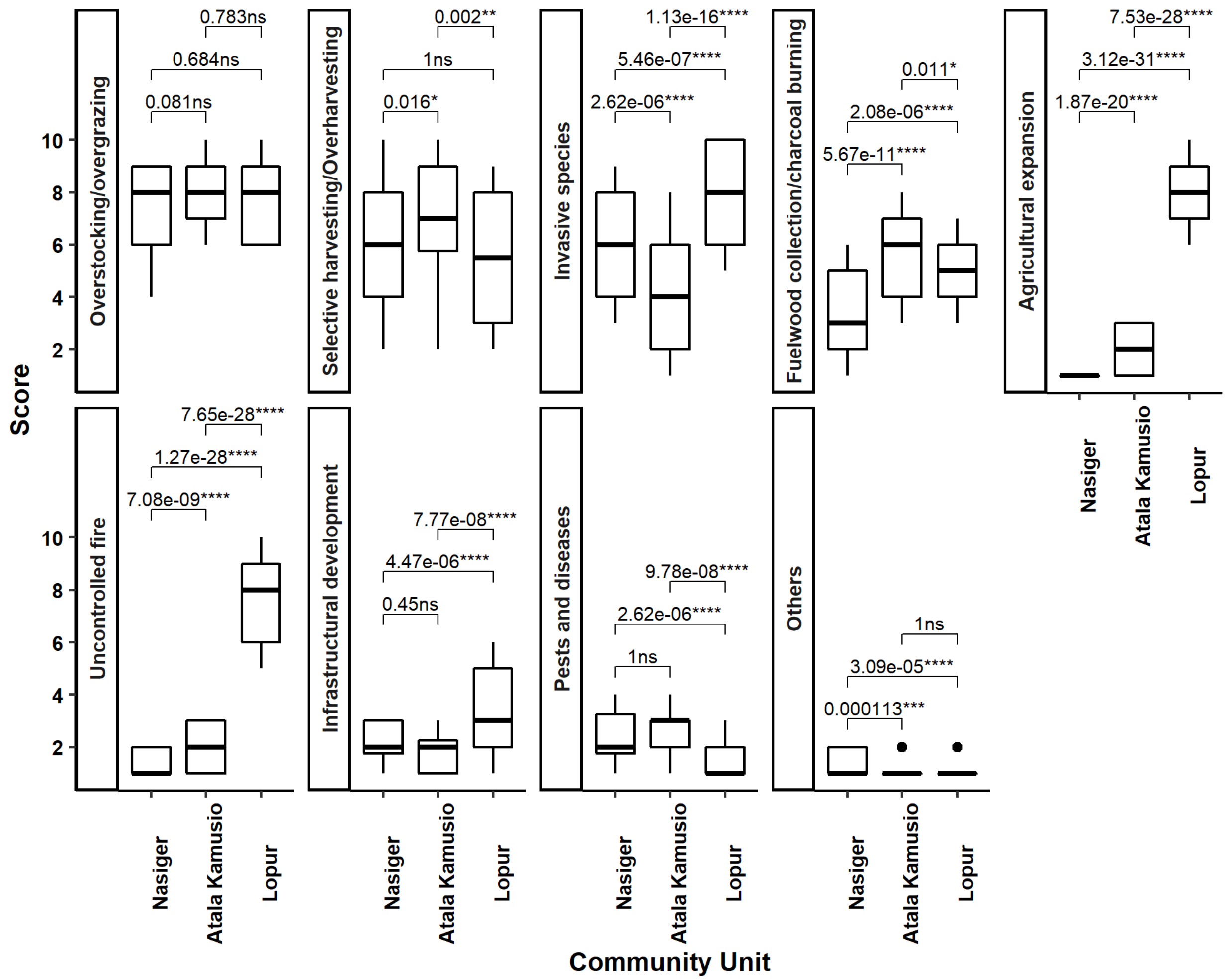


Figure 5.3: Comparison of rankings of threat categories observed in the field across three study community units in Turkana County, Kenya. ns, *, **, ***, and **** represent not significant, significance at α = 5%, 1%, 0.1% and 0.01%, respectively

To spatially visualize variations in scores among threats facing priority WEPs in all the 240 surveyed plots and community units, we developed a graduated gray scale map (Figure 5.4). For example, overstocking/overgrazing ranked similarly high in almost all three community units. At the same time, the agricultural expansion was least in Nasiger and highest in Lopur.

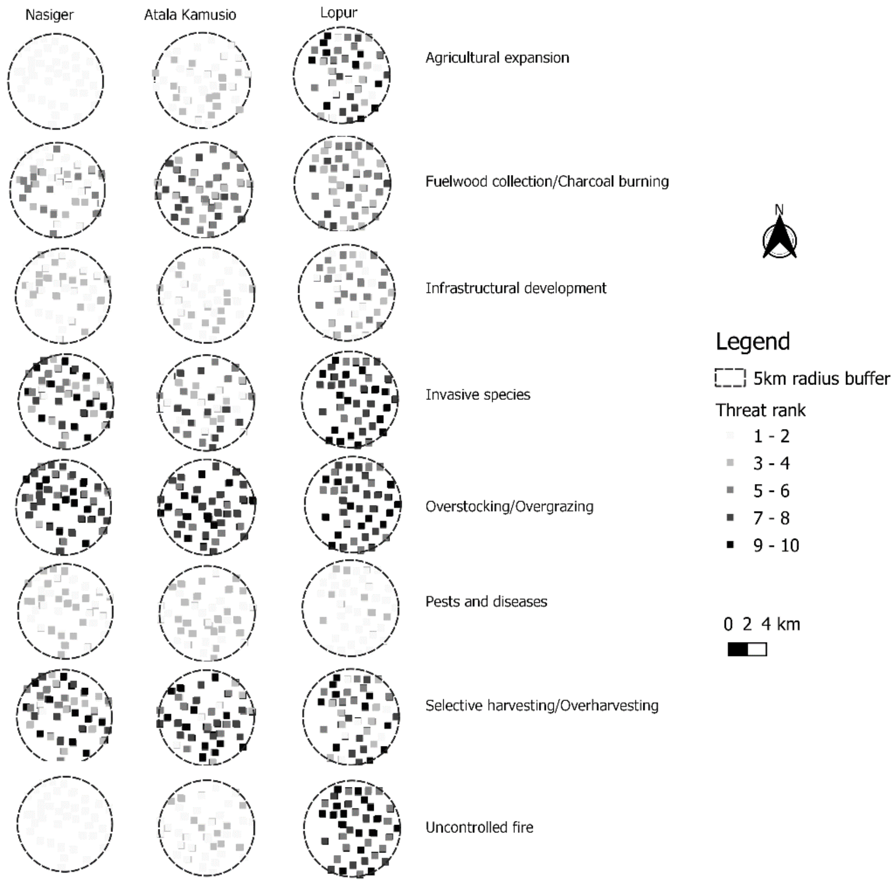


Figure 5.4: Map showing the variation in the ranking of threat categories facing priority woody wild edible plants within three study community units (Nasiger, Atala Kamusio, and Lopur) in Turkana County, Kenya. We did not include the 'Others' category in the figure as it had negligible rankings, while climate change indicators were not assessed in the field

Figure 5.5 shows how the scores for threats (except climate change) in FGDs are associated with that of field plot surveys. Strong positive linear associations existed between FGD rankings and field plot survey rankings of threats facing priority woody WEPs in Turkana County, similar to the one-to-one ranking in Table 5.3.

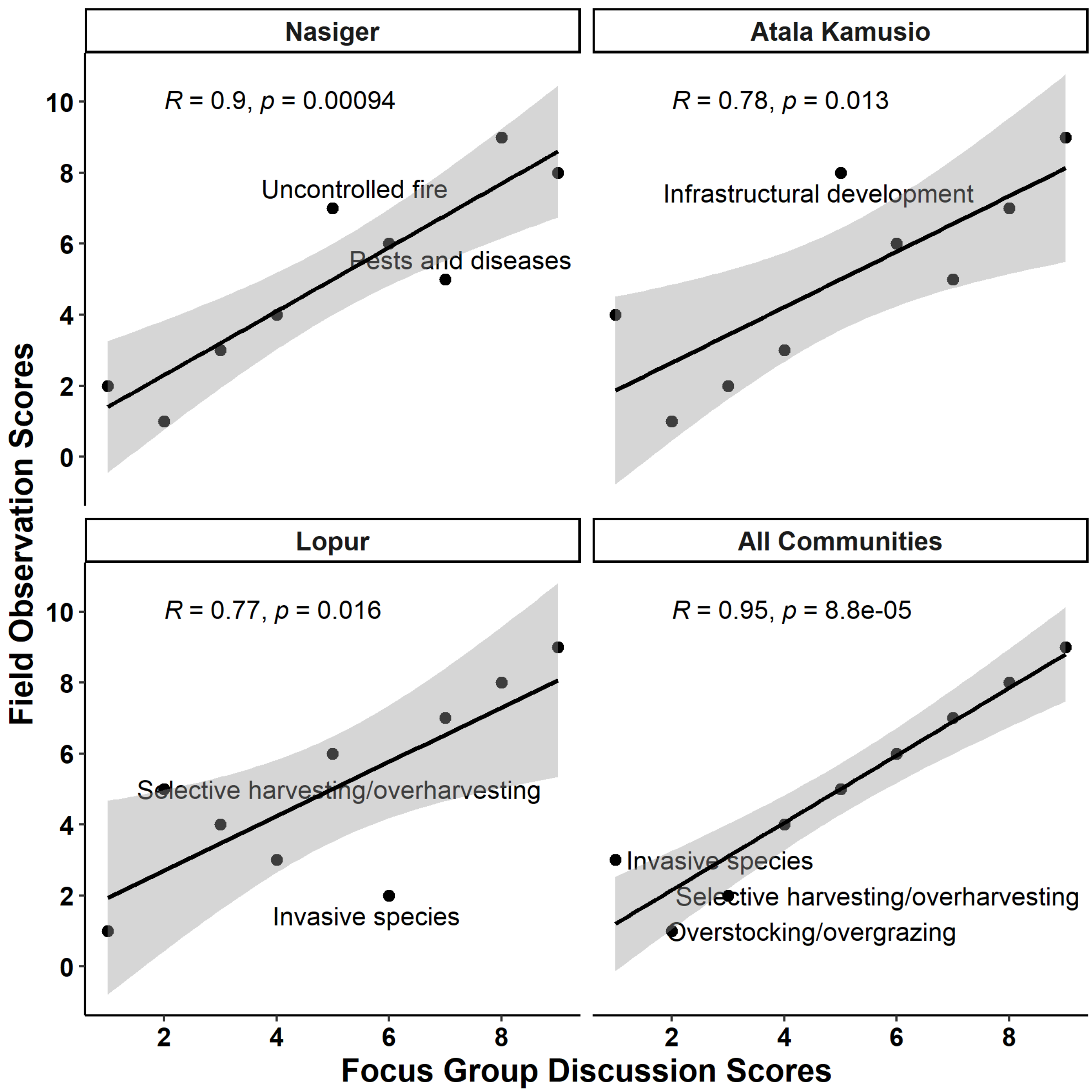


Figure 5.5: Association between focus group discussion and field plot survey ranking of studied threat categories (except climate change) facing wild edible plants within Nasiger, Atala Kamusio, and Lopur community units in Turkana County, Kenya. The gray margin area around the best line of fit (black line) represents the 95% confidence interval. Points outside that margin are labeled by their threat category names

5.4.4 Management options for threats to priority woody wild edible plants

Overall, the three study communities mentioned mitigation of climate change, preservation of local knowledge about WEPs, and selection, propagation, processing, and marketing as the highest-ranked management options for threats facing WEPs (Table 5.4). At least two of these top three management options appeared among the top three for each community unit individually. However, no two community units attained similarity for the top-ranked management option per community unit. Nasiger, Atala Kamusio, and Lopur community units ranked control harvesting for food and fodder, cultivating WEPs, and mitigating climate change as their top-ranked management options, respectively. We thus checked for possible similarities and differences in the ranked management options.

Table 5.4: Scores and ranks of management options by participants (n = 14 in each community unit and n = 42 for all the three community units combined) for threats to wild edible plants in Turkana County, Kenya. Scoring was done by each participant at a scale of 1 (least ranked management option) to 12 (highest ranked management option) and summed for every community unit individually and all community units combined

Management Categories	**Nasiger**		**Atala Kamusio**		**Lopur**		**All communities**	
	Score	**Rank**	**Score**	**Rank**	**Score**	**Rank**	**Score**	**Rank**
Mitigate climate change	113	3	138	2	133	1	384	1
Preserve local knowledge about the WEPs	115	2	137	3	130	5	382	2
Selection, propagation, processing and marketing	110	4	136	4	132	2	378	3
Cultivate WEPs	100	6	139	1	131	3	370	4
Control harvesting for food and fodder	122	1	121	6	119	7	362	5
Prohibit charcoal burning	86	7	136	4	131	3	353	6
Assess nutrition and toxicity	110	4	107	8	114	8	331	7
Create public awareness on WEPs	72	9	109	7	124	6	305	8
Conserve in sacred areas	80	8	102	9	76	10	258	9
Establish protected areas	62	10	46	10	102	9	210	10
Monitor and inventor	38	12	35	12	43	11	116	11
Others (home gardens, pruning and pollarding, enhance participatory planning, alternative livelihood for local people)	39	11	38	11	31	12	108	12

Out of the 12 scored management options, there were seven with significant differences in at least two compared community units (Figure 5.6). The four management options, control harvesting for food and fodder, assess nutrition and toxicity, monitor and inventor, and others, ranked similarly across the community units, suggesting commonality in how the FGD participants from the study communities perceived the management options.

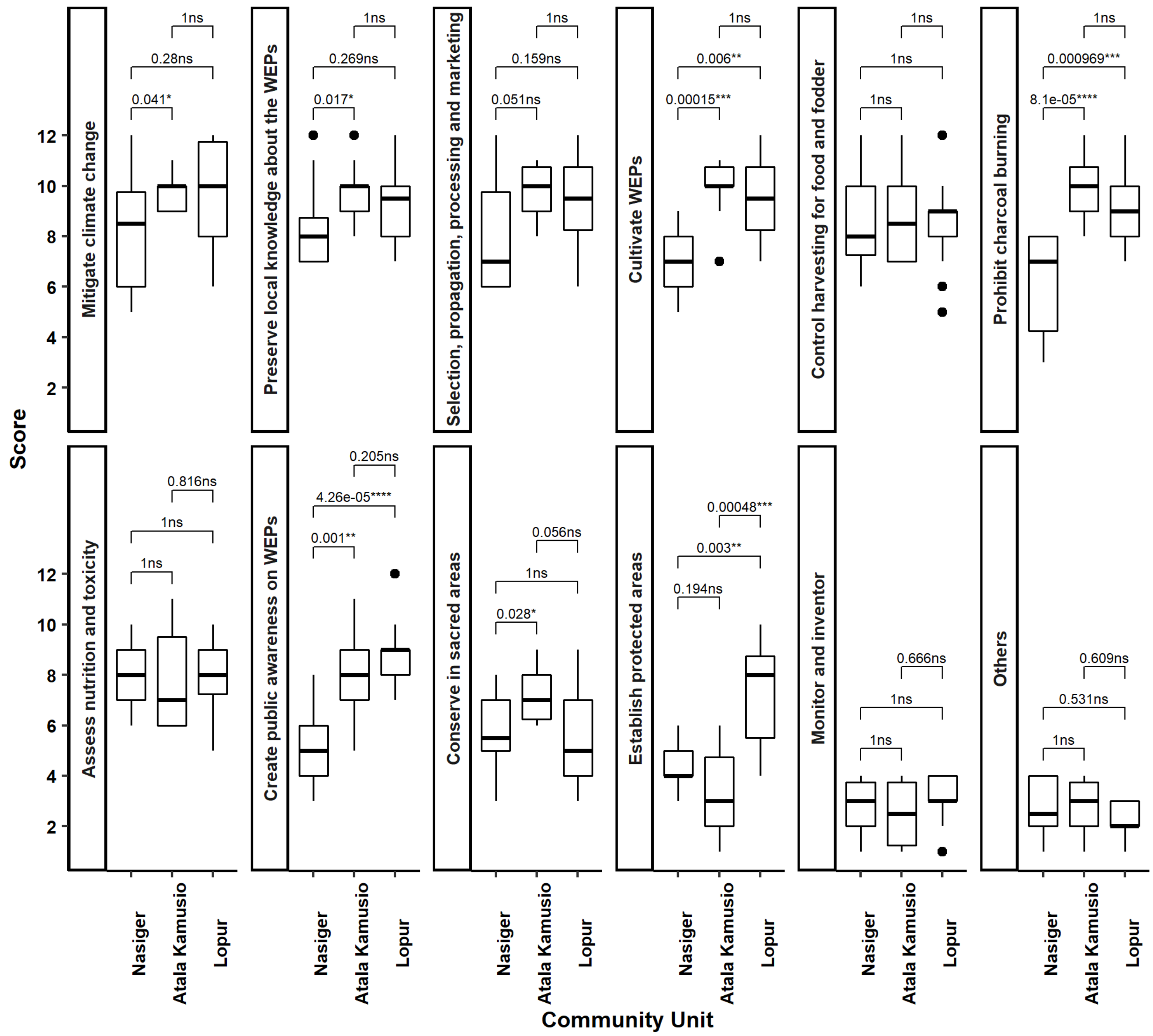


Figure 5.6: Mean comparisons of management options in three community units in Turkana County, Kenya. ns, *, **, ***, and **** represent not significant, significant at α = 5%, 1%, 0.1%, and 0.01%, respectively

5.5 Discussions

We assessed threats facing priority woody WEPs from local community perspectives involving FGDs and field plot surveys in an integrated participatory approach. We also assessed management options with the potential to counter the adverse effects of these threats from the point of view of FGD participants. From the FGDs, we most importantly found climate change, invasive species, and overstocking/overgrazing to be among the highest-ranking threats facing WEPs in Turkana County. Our findings from the field plot surveys revealed that overstocking/overgrazing, selective harvesting/overharvesting, and invasive species were the top-ranking threats. Field plot surveys and FGD rankings of threats showed strong positive linear relationships. We found mitigation of climate change, preservation of local knowledge, and selection, propagation, processing, and marketing to be the highest-ranking management options for the priority woody WEPs.

Our FGDs and field observations results on threats correspond to those from similar studies conducted in southern Ethiopia that put agricultural land expansion, fuelwood collection, uncontrolled fire setting, overgrazing, and overharvesting as highly ranked threats to WEPs (Balemie & Kebebew, 2006; Berihun & Molla, 2017; L. Kidane & Kejela, 2021; Regassa et al., 2015). The different socio-economic and environmental settings of the studied community units can explain the observed differences in the scoring of threats facing WEPs: For example, inhabitants of the three community units derived their livelihoods differently. While livestock keeping was predominant in Nasiger and Atala Kamusio, crop farming dominated in Lopur (Food Economy Group, 2016). The extensive irrigated croplands astride the banks of River Turkwel in Lopur partly explained why this community scored the threat of agricultural expansion highest. Efforts by the Kenyan government to expand agricultural land for irrigated crop farming since 2015 (Food Economy Group, 2016) could jeopardize the future of WEPs in the region.

In terms of invasive species, although receiving average to high scores across the communities, no differences among the community units could be detected. By far the most dominating invasive species in northwestern Kenya, *Prosopis juliflora* (Maundu et al., 2009; Mwangi et al., 2005), possibly was perceived by all three community units similarly as a threat to the priority woody WEPs. This species was highlighted by the FGDs as highly invasive, a fodder to livestock although known to destroy teeth of goats, and is used for charcoal to try and manage its spread. We also observed the species in the field surveys.

Even though WEPs could potentially cushion a community against the negative impacts of climate change (Feyssa et al., 2011; Gradé, 2012; Tebkew, 2015), climate change can also threaten their sustainable use (L. Kidane & Kejela, 2021; Schunko et al., 2022). Climate change was perceived by the FGD participants in terms of a range of indicators that they experienced in the region (Appendix 15). We acknowledge that these could be subjective, and that structured scientific investigations could help reveal the extent of the impact of climate change or variability on WEPs in the region. Further, overstocking/overgrazing could also inhibit optimal production of WEPs while at the same time inhibiting the regeneration potential as the seedlings or propagules get stampeded, over-grazed/over-browsed (T. Singh et al., 2016; Teketay et al., 2016).

Our results on the potential management options for priority woody WEPs indicated that mitigation of climate change, preservation of local knowledge about WEPs, and carrying out selection, propagation, processing, and marketing of WEPs in the region were perceived as plausible. While the communities called for documenting local knowledge about the WEPs and passing that knowledge to current generations, they also understood that climate change should be mitigated and that scientists could help in selecting WEPs, propagating them on a large scale, processing/improving on traditional preservation methods to add value, and availing them in the market for sustainable income generation.

Implementing management options such as mitigation of climate change (Mabhaudhi et al., 2018, 2019), controlling harvesting (Hanazaki et al., 2018), establishing protected areas (Heywood, 2019; Valderrábano et al., 2018; Vincent et al., 2019), and nutritional and genetic profiling (Fongnzossie et al., 2020) have been proposed to protect WEPs, and some places implemented with notable successes (Feyssa, 2012; Tebkew et al., 2018). In particular, Feyssa (2012) in Ethiopia showed how important indigenous knowledge and its intergenerational transfer could aid the management and conservation of WEPs. Marketing has also been reported as a potential management strategy of WEPs elsewhere (Sundriyal & Sundriyal, 2004) because communities that derive an income from the sale of fruits from WEPs will also consider them more valuable and worthy of conservation. Moreover, propagation and cultivation are also reported elsewhere as potential ways to use WEPs sustainably (Pant & Pant, 2011; Tuncer, 2020; Zulu et al., 2020).

In more recent work, Borelli (2020) emphasized the need for an integrated conservation approach to better manage WEPs. This would entail cooperation across sectors and diverse stakeholders in the WEP's value chain(s). Indeed, we noted that local communities knew the threats facing their WEPs, as indicated by a strong positive linear correlation with our field plot survey scores, and should, accordingly, be integrated into the formulation of WEP management options. Their voice in the implementation of management options should be borne in mind by scientific communities and policymakers alike since they have used their management options to sustainably utilize their resources throughout history.

Among the possible management options mentioned by FGD participants, some could be implemented through local community initiatives, while others would require interventions from external bodies. For instance, the conservation of WEPs in sacred areas (cemeteries, churches, cultural gathering sites), controlling harvesting for food and fodder, cultivation of WEPs, regulation of charcoal burning, and preservation of local knowledge about WEPs could fit within local community action plans (personal communication from FGD participant). On the other hand, the assessment of nutritional value and toxicity, the establishment of protected areas, selection, propagation, processing, and marketing require external intervention but with local collaboration. Some measures, such as raising public awareness about the benefits of WEPs, mitigation of climate change, and monitoring and inventorying WEPs, can only be achieved by closely engaging with local communities, policymakers, and any actors attempting to influence the management of WEPs. Involving local communities in implementing any management option is imperative.

We understand that cost implications always play a big role in implementing any management options for threats facing biodiversity (Pienkowski et al., 2021). However, it is beyond the scope of our study to address the question of cost implications in deploying any of the management options to ensure sustainability in the conservation efforts of WEPs. It is important to map the extent of potentially suitable habitats for the WEPs so that conservation and management options can be implemented site-specific. How future climate change scenarios might exacerbate the already existing threats would also be important to determine moving forward.

Even though these findings agreed well with most studies on threats to biodiversity across the region, it is important to note that the relative significance varied with environmental and socio-economic gradients at local scales. Local differences in threats and management options are therefore worth considering in developing sustainable management solutions for WEPs to bring them back into dietary diversification programs sustainably (Schunko et al., 2022; Visseren-Hamakers et al., 2021).

5.6 Conclusion

Climate change, invasive species, and overstocking/overgrazing threaten the sustainable use of WEPs in Turkana County, Kenya. How threats are perceived to affect WEPs depends on socio-economic and environmental gradients across communities. Our integrated participatory approach, combining local community perceptions and field plot assessments, revealed close links, but some threats were ranked strikingly differently across the three study community units.

Across all the study communities, the most plausible management options for the WEPs were mitigation of climate change, preservation of local knowledge, and selection, propagation, processing, and marketing. We propose a detailed cost-benefit analysis of the assessed management options, bringing on-board all stakeholders in the WEP value chain, which should be a prerequisite before conservation plans are implemented. It is also important to establish the extent of the suitable habitats of the WEPs. Such an overview could improve the success of conservation and management interventions.

5.7 Acknowledgements

This work received financial support from the German Federal Ministry for Economic Cooperation and Development (BMZ) commissioned and administered through the Deutsche Gesellschaft für

Internationale Zusammenarbeit (GIZ) Fund for International Agricultural Research (FIA), grant number: 81235248. We would also wish to acknowledge the local community of Turkana County who participated in the study and generously offered to give detailed information about their taboos with respect to plant use. I equally acknowledge the support from my family which made this study a success.

Chapter 6: Predicted changes in distribution and richness of wild edible plants under climate change scenarios in northwestern Kenya

This chapter has been submitted for publication as Oluoch, W. A., Borgemeister, C., Vidal Junior, J. D., Fremout, T., Gaisberger, H., Whitney, C. W., and Schmitt, C. B. (nd). Predicted changes in distribution and richness of wild edible plants under climate change scenarios in northwestern Kenya. Journal of Regional Environmental Change, XX(X): XXX – XXX.

6.1 Abstract

Wild edible plants (WEPs) can provide diverse and nutrient-rich food sources that contribute to the health and well-being of communities worldwide. In northwestern Kenya, WEPs are vital dietary components for nomadic pastoral communities with limited access to diverse cultivated food crops. However, the increasing impact of climate change poses a threat to these valuable food resources, and their sustainable utilization remains precarious. Here, we assessed the potentially suitable habitats and richness of 23 selected WEPs in the region using a species distribution modeling (SDM) approach. We used species occurrence points from global databases, a national herbarium, and field surveys and made predictions spanning two future time intervals, 2041-2070 and 2071-2100, across three shared socio-economic pathways (126, 370, and 585) using bioclimatic variables from five global circulation models. We also included soil and topographic variables in our models. We calibrated maximum entropy models using individually-tuned parameters. Our future predictions showed a predominant decline in habitat suitability for half the studied WEPs. The richness of the selected WEPs are predicted to remain rather stable under projected future climates concentrating in southern parts of Turkana County. Conservation and management measures need to consider the changing availability of these valuable resources in order to underpin the dietary diversification of local communities.

Key-words: wild food plants; ecological niche modeling; regional climate change; biodiversity loss

6.2 Introduction

Northwestern Kenya is characterized by vast arid and semi-arid lands inhabited by nomadic pastoralist communities, many of whom are from the Turkana ethnic group (Ejore et al. 2020;

Ratemo et al. 2020). The Turkana people depend on animal products for their protein requirements and wild edible plants (WEPs), especially their fruits, for macro and micro-nutrients (Twine et al. 2003; Agol et al. 2020; Oduor et al. 2023). The majority of Turkana communities do not have immediate access to cultivated crops and hence rely on WEPs (Ngoye et al. 2021; Shanguhyia 2021); the few strips of irrigated crop farming astride streams in the region are insufficient (Akuja and Kandagor 2019; Mbugua et al. 2020; Akall 2021). Intermittent rains within Turkana, accompanied by low flows of the Turkwel River, undermine the productivity of the irrigated riverbank strips (Korobe 2022). Occasional flash floods also devastate riparian crop farms (Chilambe et al. 2022), further increasing the nutritional insecurity problems.

Turkana is the most food-insecure county in Kenya, Kenya Economic Report (2020). The county has high levels of malnutrition among children and adults (Kuper et al. 2015; Bhavnani et al. 2023) attributable to the high food poverty rate of 66%, which is higher than the national average of 32% (Mbogori and Murimi 2017). Turkana has a low infrastructural development (Kihu et al. 2015) with low accessibility to remote areas hindering trade and markets. Turkana residents rely on WEPs as “safety nets”, including herbs, vegetables, and fruit trees (Oduor et al. 2023). The nutritional value of regional WEPs is similar to or superior to cultivated crops (Sarfo 2018). WEPs can support local communities to alleviate hunger and malnutrition challenges. For these resources to be used sustainably to meet the future food demands in Turkana, it is important to quantify their present and potential future spatial coverage and richness in the face of anthropogenic climate change.

We trained correlative species distribution models (SDMs) to predict the potentially suitable habitats and species richness of selected woody WEPs. Such models have been used to assess the potential distribution of socio-economically important non-timber plants and tree species across Africa (Amoussou et al. 2022), priority multipurpose tree species in Central Africa (Ceccarelli et al. 2022) and Burkina Faso (Gaisberger et al. 2017), wild food crops in southern Africa (Wessels et al. 2021) and medicinal plants like Aloe species in East Africa (Mkala et al. 2022), among others.

Impacts of climate change on the Turkana pastoral communities have been reported, particularly in terms of livestock losses (Otieno 2020; Anno and Ameripus 2022; Imana and Zenda 2023). However, little is known about the climate change impact on the distribution and richness of nutritionally valuable WEPs. To address this gap, we adopted an SDM approach and analyzed both present and projected future climate scenarios for the years 2041-2070 and 2071-2100 under three shared socioeconomic pathways (SSPs) - SSP126, SSP370, and SSP585 (O'Neill et al. 2017). The aim of our study was to shed light on the dynamics of valuable WEPs in the face of climate change and to provide insights for policymakers and stakeholders committed to sustainable use of WEPs in northwestern Kenya. We focused on answering the following research questions:

i. What is the current extent of suitable habitats for selected woody WEPs in Turkana County, Kenya?
ii. How will future (2041-2070 and 2071-2100) climatic conditions under the three shared socioeconomic pathways (SSP126, SSP370, and SSP585) affect the distribution and extent of potentially suitable habitats of selected woody WEPs in Turkana County, Kenya?
iii. How will the species richness of selected woody WEPs respond to projected climate change scenarios in Turkana County, Kenya?

6.3 Materials and Methods

6.3.1 Study area

We conducted the study in Turkana County, northwestern Kenya, (Figure 6.1). It covers an area of about 68,253 km^2. The human population in the county is 926,976 (KNBS 2019), hence a density of about 13 people per km^2. Literacy level is low (< 20%) according to Opiyo et al., (2015) and the county has the highest poverty rate in Kenya, about 66% (KER, 2020). We used a wider geographical area spanning eastern Africa and parts of central and southern Africa (see the light green highlighted region in the inset Africa map in Figure 6.1), to calibrate the models. This ensured that we obtained an adequate number of occurrence points for the studied species and captured most of the environmental conditions under which the modeled species could thrive.

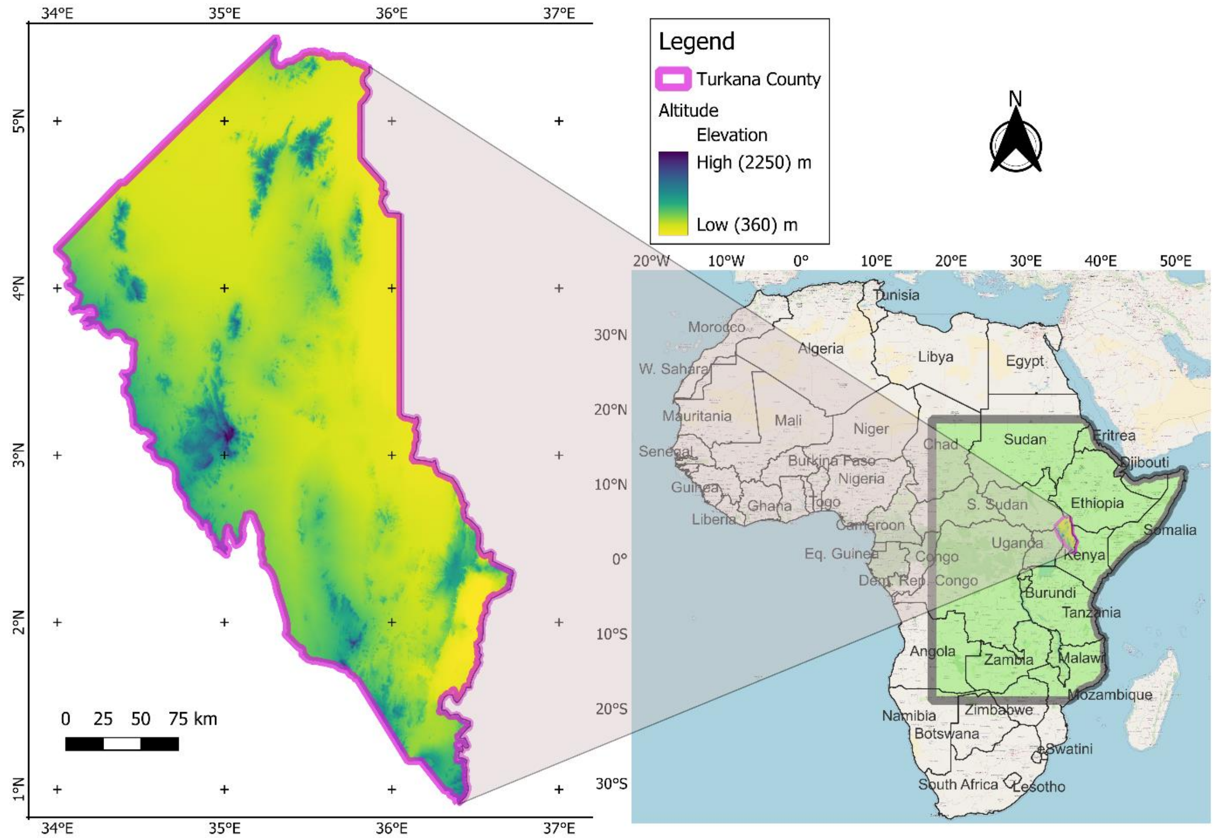


Figure 6.1: The study area (Turkana County). The model calibration area is shown in the light green with a gray border spanning countries in eastern Africa and parts of southern and central African countries in the inset map (bottom right)

During the period in which the species distribution models were calibrated, 1950 to 2022, the minimum ranged from 20.0°C (1968) to 22.5°C (2022) and maximum temperatures ranged from 32.6°C (1968) to 35.3°C (2022) within Turkana County according to Abatzoglou et al. (2018), as shown in Appendix 17. Total annual precipitation ranged from 244 mm (1984) to 886 mm (1961).

6.3.2 Selection of WEPs

We obtained a list of 23 woody WEPs from two recent studies focusing on the availability of WEPs (Oluoch et al. 2022), and threats facing the WEPs and management options (Oluoch et al. 2023) in Turkana County. The inventory consisted of woody plant species with two key attributes: well known by the local communities and producing edible fruits consumed by the local communities. We performed taxonomic validation for these WEPs by cross-referencing their names with the Plants of the World Online database (POWO 2022) (https://powo.science.kew.org/) (accessed in October 2022), checking for alternative spelling and reconciling synonyms with accepted names.

6.3.3 Occurrence records of the WEPs

We obtained occurrence points of the WEPs from five sources: Global Biodiversity Information Facility (GBIF; https://www.gbif.org, (GBIF.org 2020), accessed October 2022), Botanical Information and Ecology Network (BIEN; https://bien.nceas.ucsb.edu/bien/, (Enquist et al. 2016), accessed October 2022), Response And Impacts of Natural and anthropogenic factors on BIOdiversity in tropical forests (RAINBIO; https://gdauby.github.io/rainbio/index.html, (Dauby et al. 2016), accessed October 2022), East African Herbarium at the National Museums of Kenya (EAH; visited in January 2023), and from field surveys within Turkana County (between April and May 2021). The field surveys were carried out in 240 plots, each 1 ha in size, for three species; *Balanites rotundifolia*, *Ziziphus mauritiana*, and *Salvadora persica*, within a 5 km radius of three communities in Turkana; Nasiger (dry lowlands, 35.437877°E 3.361547°N), Atala Kamusio (relatively less arid high altitude, 34.878133°E 2.756355°N), and Lopur (irrigated riverbanks, 35.433488°E 2.239970°N) (Oluoch et al. 2023). These three species were considered priority by the local communities for their nutrition values.

We retained occurrence points collected after 1950 to ensure congruence with the temporal resolution of our predictor variables. Further, we removed duplicated occurrence points and kept those that fell within our predetermined calibration area, see Figure 6.1. This helped us minimize potential problems in our models related to the potential local genetic adaptation to environmental conditions (Kadu et al., 2013; Vinceti et al., 2013).

Finally, we spatially thinned the occurrence points using a radius of 10 km to minimize potential spatial bias. The retained occurrence points ranged from *Vatovaea pseudolablab* and *Sterculia stenocarpa* (n = 26 each) to *Vachellia tortilis* (n = 337) (Table 6.1), which we considered to be a sufficient number of occurrence points for our models (Wisz et al. 2008). The 23 WEPs comprised woody species from 11 families, mainly producing edible fruits. Fabaceae family had the highest representation (*n* = 5), followed by Malvaceae (*n* = 4) and Zygophyllaceae (*n* = 3) (Table 6.1). These species are primarily distributed from southern Arabia to northern South Africa and across the west to east of Africa.

Table 6.1: Wild edible plants modeled in Turkana County, Kenya, their families, number of occurrence points used in model building (n), threshold used for binary maps generation (Maximum Sensitivity + Specificity), and performance metrics of the models: area under the receiver operating characteristic (ROC) curve (Mean AUC) ± standard deviation (sd) and Continuous Boyce Index (CBI)

Wild edible plant	Family	*n*	Threshold	AUC ± sd	CBI ± sd
Balanites aegyptiaca	Zygophyllaceae	258	0.531	0.82±0.08	0.80±0.15
Balanites pedicellaris	Zygophyllaceae	29	0.531	0.72±0.17	0.77±0.17
Balanites rotundifolia	Zygophyllaceae	43	0.585	0.73±0.03	0.59±0.09
Berchemia discolor	Rhamnaceae	72	0.487	0.68±0.18	0.25±0.61
Boscia coriacea	Capparaceae	89	0.599	0.57±0.16	0.05±0.59
Cordia sinensis	Boraginaceae	167	0.405	0.79±0.17	0.83±0.08
Dobera glabra	Salvadoraceae	60	0.685	0.77±0.04	0.69±0.11
Ficus sycomorus	Moraceae	177	0.510	0.73±0.10	0.71±0.26
Grewia mollis	Malvaceae	139	0.514	0.74±0.08	0.51±0.19
Grewia tenax	Malvaceae	79	0.617	0.78±0.05	0.79±0.04
Grewia villosa	Malvaceae	127	0.423	0.84±0.09	0.70±0.29
Hyphaene compressa	Arecaceae	50	0.704	0.74±0.10	0.48±0.16
Lannea triphylla	Anacardiaceae	40	0.685	0.61±0.22	0.34±0.35
Maerua subcordata	Capparaceae	40	0.661	0.67±0.08	0.63±0.16
Salvadora persica	Salvadoraceae	188	0.500	0.82±0.06	0.82±0.09
Senegalia senegal	Fabaceae	320	0.499	0.75±0.17	0.55±0.70
Sterculia stenocarpa	Malvaceae	26	0.714	0.69±0.21	0.61±0.36
Tamarindus indica	Fabaceae	241	0.454	0.75±0.05	0.77±0.12
Vachellia oerfota	Fabaceae	134	0.274	0.74±0.10	0.74±0.13
Vachellia tortilis	Fabaceae	337	0.309	0.76±0.08	0.61±0.38
Vatovaea pseudolablab	Fabaceae	26	0.719	0.57±0.14	0.38±0.30
Ximenia americana	Olacaceae	155	0.594	0.71±0.11	0.82±0.15
Ziziphus mauritiana	Rhamnaceae	167	0.346	0.85±0.15	0.78±0.23

6.3.4 Background points generation

We generated background points within a convex hull around occurrence points for each species. We extended the hull by 10% of the length of the longest axis from its centroid to the vertices to allow for the extraction of background points slightly beyond the presence points. We used the default number of 10,000 background points for each WEP within our extended convex hull.

6.3.5 Environmental predictors

We used 13 bioclimatic predictor variables from the CHELSA database (Karger et al. 2019) (Table 6.2) for present and future (2041-2070 and 2071-2100) climate conditions from all the five global circulation models (GCMs) of CHELSA database. For each of the five GCMs, we used three shared socioeconomic pathways (SSPs): SSP126 (optimistic), SSP370 (regional rivalry), and SSP585 (pessimistic) (O'Neill et al. 2014; Riahi et al. 2017). The spatial resolution of the predictor variables was 30 arc seconds (ca. 0.9 km at the equator).

We also obtained eight soil variables (Table 6.2) from the International Soil Reference and Information Center (ISRIC) (Hengl et al. 2017) at a spatial resolution of 250 m. We resampled them to match the extent and resolution of the bioclimatic variables. Finally, we obtained six topographic predictor variables (Table 6.2), topographic variables, from the Shuttle Radar Topography Mission (SRTM 2013) and the Multi-Error-Removed Improved Terrain Digital Elevation Model (MERIT DEM) (Yamazaki et al. 2017).

Table 6.2: Environmental predictor variables used in modeling potentially suitable habitats of wild edible plants in Turkana County, Kenya

Data	Code	Description	units	Source
Climatic variables used in modeling	bio_2	Mean Diurnal Range (Mean of monthly [max temp - min temp])	°C	CHELSA V2.1 (Karger et al., 2019)
	bio_3	Isothermality (BIO2/BIO7) (×100)	°C	
	bio_4	Temperature Seasonality (standard deviation ×100)	°C/100	
	bio_5	Maximum Temperature of Warmest Month	°C	
	bio_7	Temperature Annual Range (BIO5-BIO6)	°C	
	bio_8	Mean Temperature of Wettest Quarter	°C	
	bio_9	Mean Temperature of Driest Quarter	°C	
	bio_12	Annual Precipitation	kg m^{-2} $year^{-1}$	
	bio_13	Precipitation of Wettest Month	kg m^{-2} $month^{-1}$	
	bio_14	Precipitation of Driest Month	kg m^{-2} $month^{-1}$	
	bio_15	Precipitation Seasonality (Coefficient of Variation)	kg m^{-2}	
	bio_18	Precipitation of Warmest Quarter	kg m^{-2} $month^{-1}$	
	bio_19	Precipitation of Coldest Quarter	kg m^{-2} $month^{-1}$	
Climatic variables removed	bio_1	Mean annual air temperature	°C	
	bio_6	Mean daily minimum daily air temperature of the coldest month	°C	
	bio_10	Mean daily mean air temperatures of the warmest quarter	°C	
	bio_11	Mean daily mean air temperatures of the coldest quarter	°C	
	bio_16	Mean monthly precipitation amount of the wettest quarter	kg m^{-2} $month^{-1}$	
	bio_17	Mean monthly precipitation amount of the driest quarter	kg m^{-2} $month^{-1}$	
Soil variables	bdod	Bulk density of the fine earth fraction	cg/cm^3	ISRIC SoilGrids250m version 2.0 (Hengl et al., 2017)
	cec	Cation Exchange Capacity of the soil	mmol(c)/kg	
	cfvo	Volumetric fraction of coarse fragments (> 2 mm)	cm3/dm3 (vol‰)	

Data	Code	Description	units	Source
	clay	Proportion of clay particles (< 0.002 mm) in the fine earth fraction	g/kg	
	phh2o	Soil pH	pHx10	
	sand	Proportion of sand particles (> 0.05 mm) in the fine earth fraction	g/kg	
	silt	Proportion of silt particles (≥ 0.002 mm and ≤ 0.05 mm) in the fine earth fraction	g/kg	
	soc	Soil organic carbon content	dg/kg	
Topographic variables	HLI	Heat Load Index	W	Derived from Shuttle Radar Topography Mission (SRTM) elevation data (available at http://srtm.csi.cgiar.org/) and calculated with the 'raster' package version 3.6.20 (Hijmans, 2023) in R version 4.3.1 (R Core Team, 2023).
	NO	Negative Openness	°	Derived from MERIT DEM (Yamazaki et al., 2017)
	PO	Positive Openness	°	
	SLO	Slope	°	
	TPI	Topographic position index	m	
	TWI	Topographic wetness index	NA	

6.3.6 Species distribution modeling

We used MaxEnt (Phillips et al. 2006) algorithm version 3.4.3 to build the models since it is appropriate for presence-only data and robust against potential geo-referencing errors (Graham et al. 2008). We tuned the MaxEnt algorithm across four feature classes (linear, quadratic, hinge, and product; we tested four combinations (linear-quadratic, hinge, linear-quadratic-hinge, and linear-quadratic-hinge-product), three regularization multipliers (1, 3, and 5), and their combinations in the *ENMeval* package version 2.0.4 (Kass et al. 2021) in R version 4.3.1 (R Core

Team 2023) for ease of reproducibility of the workflow. We used a spatial block cross-validation method with four folds to calibrate the models. To obtain the best model amongst the tuned models, we first picked the four models with the highest Area Under the receiver operating characteristic Curve (AUC) (using testing data), and then chose the model with the smallest difference between training and testing AUC (AUC_{diff}), which is a measure for overfitting. We then used this model to make predictions over geographic space for current and future times. For transparency and reproducibility, we adhered to the Overview, Data, Model fitting, Assessment, and Predictions (ODMAP) protocol by Zurell et al. (Zurell et al. 2020), Fitzpatrick (2021) and the checklist by Feng et al. (2019) during the modeling process.

6.3.7 Model output analysis

To assess the performance of our models, we used two suitable widely used metrics for presence-only models, AUC and Continuous Boyce Index (CBI) (Manzoor et al. 2018). AUC is a measurement of discriminatory capacity of classification models (Jiménez-Valverde 2012; Shabani et al. 2018) with values close to 0.5 being close to random classification while those approaching 1 are better classification capacity (Hao et al. 2020; Lissovsky and Dudov 2021). Positive values of CBI indicate that the predicted distribution by the model is congruent with the occurrence points data. Values approaching 0 indicate random model prediction, while negative values imply counter-predictions (Manzoor et al. 2018; Maruthadurai et al. 2023). We converted the predicted suitability values to binary presence-absence maps using the suitability threshold that maximized the sum of sensitivity (true positive rate) and specificity (true negative rate) (Table 6.1).

From the five GCM binary outputs for each time interval and SSP, we used a majority vote rule (that is, conditions were deemed suitable when three out of the five GCMs predicted suitable conditions) to generate a single output for the future projections. We used these maps to determine the potentially suitable habitats for future climate scenarios by calculating the areas of pixels with value 1 (present) and those with value 0 (absence). We also compared the pixel values of the present binary with the future binaries for each species to obtain change maps. This enabled us to estimate potential suitable habitats' persistence, loss, absence, and gain.

To estimate changes in species richness, we summed the presence-absence maps for all WEPs to obtain a layer that expresses species richness for the present and future scenarios separately. We then calculated the change in species richness by subtracting the present richness layer from the future richness layer and expressed it as a percentage change.

6.4 Results

6.4.1 Present and future climate of Turkana County

The climate conditions of CHELSA dataset used in this study fell within the conditions previously experienced by the WEPs in Turkana County (Appendix 17) (Table 6.3; see Appendix 18 for means of the climatic variables and Appendix 20 for their standard deviations across all the five GCMs of CHELSA). Hence, we considered the models appropriate for predicting into the future climate change scenarios.

Table 6.3: Average climatic variables values and deviations about the averages for the present and projected future climate scenarios for Turkana County, Kenya. The future values are averaged from five global circulation models (GFDL, IPSL, MPI, MRI, and UKESM1) of the CHELSA database. The description of the abbreviated columns is shared in Table 6.2

Metric	SSPs and times	bio_12	bio_13	bio_14	bio_15	bio_18	bio_19	bio_2	bio_3	bio_4	bio_5	bio_7	bio_8	bio_9
Mean	Present	369.82	66.06	08.97	55.40	63.63	95.55	9.57	75.76	82.92	34.99	12.54	28.79	29.07
	SSP126_2041-2070	405.47	78.61	10.31	59.38	81.03	100.67	9.11	74.85	85.48	31.92	12.09	30.28	30.32
	SSP126_2071-2100	414.83	75.39	10.96	57.71	90.59	101.98	9.11	74.98	83.45	30.91	12.07	30.33	30.35
	SSP370_2041-2070	421.15	77.46	10.53	57.18	86.84	108.31	8.77	71.21	94.89	32.21	12.25	30.46	30.54
	SSP370_2071-2100	458.27	84.17	11.56	57.61	102.60	118.93	8.32	70.24	94.37	31.09	11.77	30.53	30.55
	SSP585_2041-2070	434.17	80.04	10.44	57.69	92.11	112.46	8.77	72.93	87.78	32.14	11.93	30.53	30.55
	SSP585_2071-2100	486.08	92.97	12.95	58.89	108.74	122.36	8.85	71.92	94.11	31.15	12.18	30.59	30.60
±Standard deviations	Present	113.50	15.58	3.26	10.02	20.90	49.88	1.41	3.89	11.16	1.72	1.43	2.07	1.76
	SSP126_2041-2070	123.97	19.01	4.15	10.40	25.64	51.88	1.42	4.55	10.09	0.49	1.42	0.55	0.48
	SSP126_2071-2100	128.19	18.22	4.62	10.78	29.14	52.38	1.40	4.44	10.22	0.17	1.43	0.19	0.17
	SSP370_2041-2070	130.61	18.86	4.24	10.55	27.30	55.53	1.40	5.20	10.47	0.49	1.37	0.60	0.51
	SSP370_2071-2100	141.61	21.01	4.89	10.55	32.50	58.20	1.37	5.77	10.29	0.18	1.37	0.20	0.18
	SSP585_2041-2070	132.85	18.98	4.08	10.76	27.88	55.83	1.39	4.75	9.75	0.50	1.41	0.59	0.49
	SSP585_2071-2100	151.79	22.60	5.64	11.04	35.43	58.38	1.42	5.31	9.17	0.18	1.44	0.20	0.18

6.4.2 Model performance

The predictive power of the MaxEnt models was very good (0.8 < AUC <= 0.9) for four WEPs, good (0.7 < AUC <= 0.8) for 13 WEPs, moderate (0.6 < AUC <= 0.7) for four WEP species, and low for two species (AUC = 0.57) (Table 6.1). The six WEPs with AUC < 0.7, primarily due to their small number of occurrence records, included in descending order of their AUC values *S. stenocarpa*, *Berchemia discolor*, *Maerua subcordata*, *Lannea triphylla*, *Boscia coriacea*, and *V. pseudolablab*, and hence their predictions should be interpreted cautiously (Table 6.1). Values of CBI were also positive and ranged between 0.05 (± 0.59 sd) for *B. coriacea* and 0.83 (±0.08 sd) for *Cordia sinensis* (Table 6.1). Given these metrics we considered the models appropriate for making predictions on the potential suitable habitats of WEPs under current and projected future climates. The threshold values that maximized sensitivity and specificity ranged from 0.274 for *Vachellia oerfota* to 0.719 for *V. pseudolablab* (Table 6.1).

6.4.3 Current extents of potential suitable habitats of priority WEPs

Under the present climatic conditions, the proportions of potential suitable habitats for the studied WEPs within Turkana County ranged from 2.8% for *Grewia mollis* to 99.9% for *B. rotundifolia* with an average potentially suitable habitat for the species being 64.5% of Turkana County land area (see Appendix 20 for areal values of presence and absence for the WEPs). About 74% (*n* = 17) of the studied WEPs had a current potentially suitable habitat of at least 50% of the area of Turkana County (Figure 6.2).

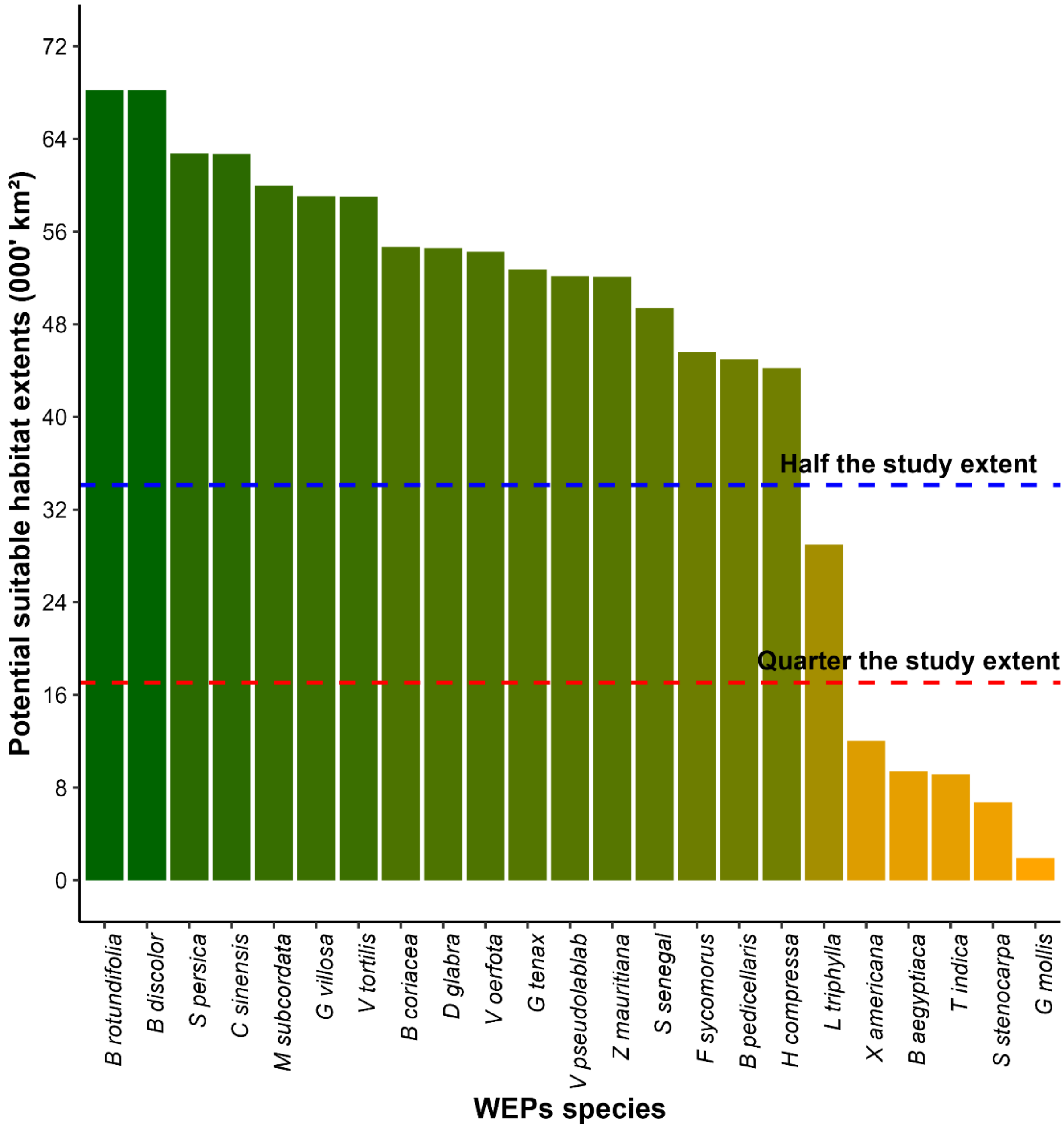


Figure 6.2: Predicted potentially suitable habitat (km^2) of the studied 23 wild edible plants in Turkana County, Kenya. Bars representing plants with larger area cover are darker green, while those with smaller area cover are orange. The blue and red dashed horizontal lines depict half and quarter the area of Turkana County, respectively

The southern part of the county was potentially suitable for most of the WEPs during current climate conditions (Appendix 21). Generally, the high elevation areas in the South, Southeast and

Northwest of the county (Figure 6.1) showed higher suitability for the selected WEPs, while the central part, with low altitude areas up to Lake Turkana, was less suitable, though this varied among the WEPs.

6.4.4 Change in potentially suitable habitat for selected WEPs in Turkana County

6.4.4.1 The period 2041-2070

Under SSP126, our models predicted that by 2041-2070, up to 39% (n = 9) of the WEPs will experience a reduction in their current potentially suitable habitats (Figure 6.3 a). About 61% (n = 14) of the WEPs maintained or expanded their current potentially suitable habitats. During the same period but under SSP370, we predicted a decrease in potentially suitable habitats of up to 43% (n = 10) of the WEPs (Figure 6.3 b). Similarly, under SSP585 for the same period, 43% (n = 10) of the studied WEPs are predicted to experience a decrease in their potentially suitable habitat (Figure 6.3 c). This indicated a progressive decline in the size of potentially suitable habitat for about 50% of the studied WEPs with about three WEPs losing their potential suitable habitats by over 40% of the current suitable habitat under the SSP585 for the period of 2041-2070. Spatial distributions, corroborating the predicted changes (persistence, suitability loss, suitability gain, and absence) for the period are shown in Appendix 22 a - c.

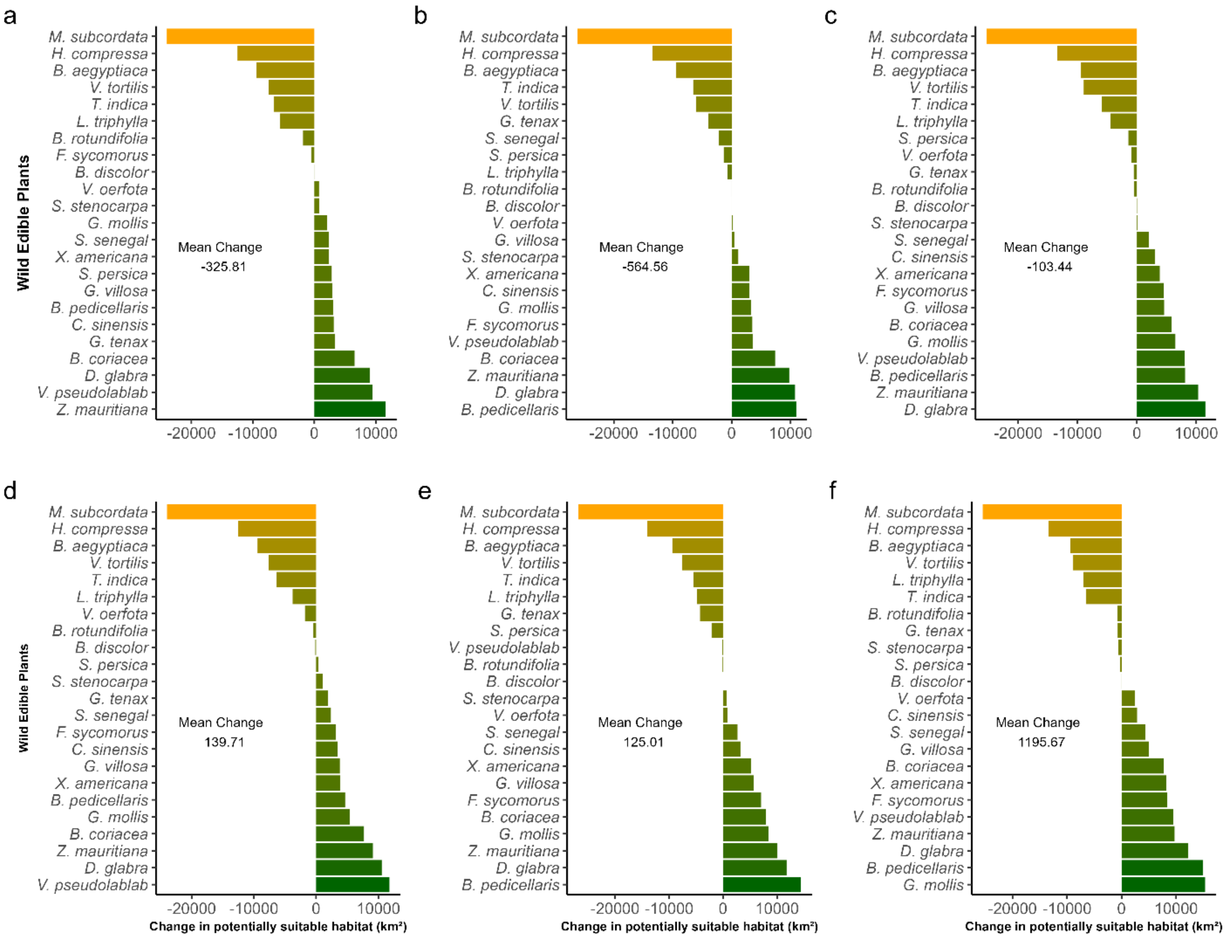


Figure 6.3: a-f Change in potentially suitable habitat of 23 wild edible plants species during two time intervals (2041-2070 and 2071-2100) for three shared socioeconomic pathways (SSP126, SSP370, and SSP585). (a) is 2041-2070 for SSP126, (b) is 2041-2070 for SSP370, (c) is 2041-2070 for SSP585, (d) is 2071-2100 for SSP126, (e) is 2071-2100 for SSP370, and (f) is 2071-2100 for SSP585. Brighter shades of orange indicate more decline while darker shades of green colors represent more gain in potentially suitable habitat. Mean changes for all the species under each time and SSP are indicated on the respective plots

6.4.4.2 The period 2071-2100

For SSP126 of this period, 39% (*n* = 9) of the WEPs were predicted to experience a decline in their potentially suitable habitats, similar to 2041-2070 under the same SSP. For SSP370, however, 48% (*n* = 11) of the WEPs were predicted to shrink their potentially suitable habitats (Figure 6.3

e) which was one more species as compared to the same SSP under the 2041-2070 period. Under SSP585, a similar number of the studied WEPs as SSP370 showed a decline in their potentially suitable habitats by the end of the century (Figure 6.3 f). Among the species that expanded their potentially suitable habitats, most of the expansions did not exceed 40% of their present suitable habitat. This was comparable to the decline, where we observed a localized complete loss of potentially suitable habitat for one WEP while most WEPs did not lose more than 40% of their suitable habitats (Figure 6.3 a - f). The observed spatial changes in habitat suitability of the WEPs are shown in Appendix 22 d - f.

6.4.5 Current richness of woody WEPs in Turkana County, Kenya and future changes

6.4.5.1 The period 2041-2070

Under SSP126, about 27,900 km^2 of Turkana County was predicted to undergo a decline in the richness of the studied WEPs by 2041-2070. The average slight decline in the studied WEPs' richness over Turkana County was predicted to be 0.2% of the current number of species per pixel (spatial resolution is ~0.9 km). For SSP370 and the same time period, the decline was predicted to be an average 1.13%. Under SSP585 for the same period, our models predicted an average slight gain in species richness by up to 0.16% of the current number of species per pixel (Appendix 23 a - c).

During this time period and irrespective of the SSPs, the species richness was predicted to concentrate in the southern part of the county that is relatively elevated as well as the western border with Uganda and parts of the Northeast (Figure 6.4 a - d). Despite the small average changes in potentially suitable habitats reported in previous sections, individual pixels still showed large changes in species richness such as increase in southern parts of the county (Figure 6.4 b - d).

6.4.5.2 The period 2071-200

During this period and under SSP126, our models predicted an average gain in WEPs' richness by about 0.79% of the current number of species per pixel though 41% (28,000 km^2) of the area was predicted to record a decline in richness. Recoveries were predicted to continue for SSP370 with an average rise in richness by 0.64% of the current number of species per pixel (Appendix 23 d - f). The recovery in richness continued under SSP585 by 3.47% of the current number of species per pixel, for the period. Over 2071-2100, the 23 WEPs' richness showed a similar trend as 2041-2070 and can be generally termed stable with respect to current richness values (Figure 6.4 e - g).

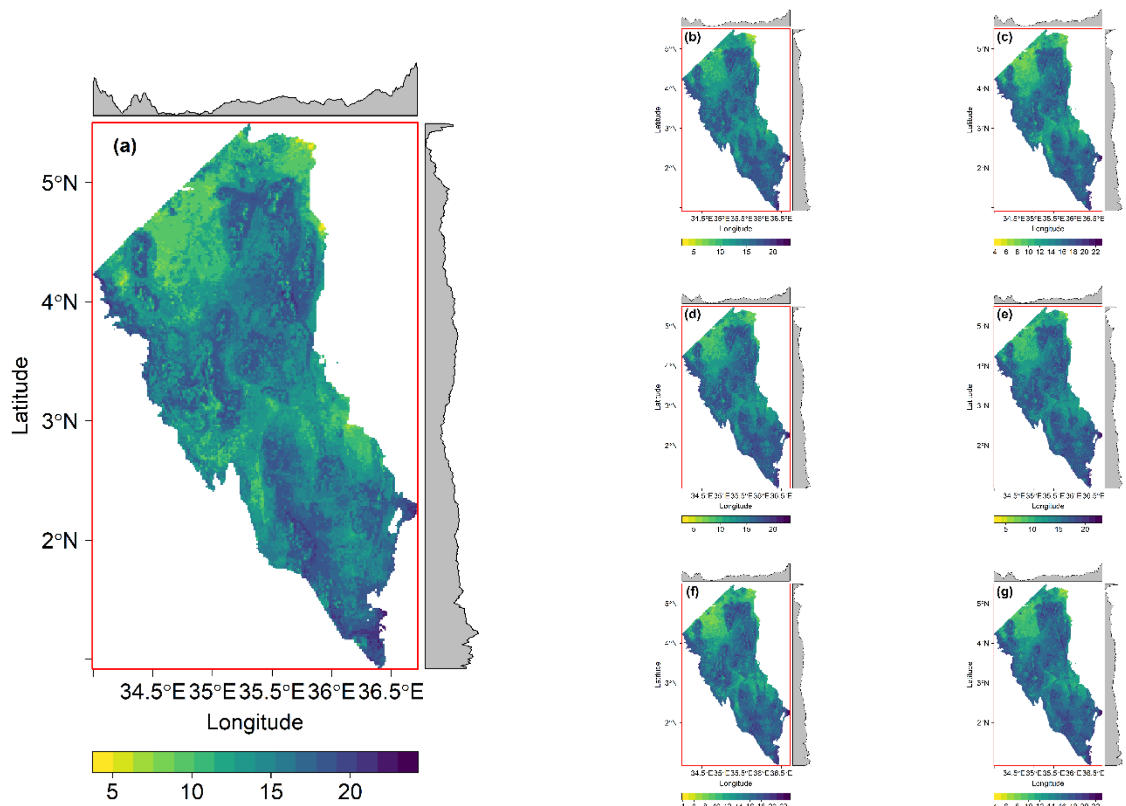


Figure 6.4: a - g Species richness of the 23 wild edible plants in Turkana County (area size: 68,253 km^2), Kenya, under present and projected future climates. **a** represents the current climate, **b** the period 2041-2070 under SSP126, **c** 2041-2070 under SSP370, **d** 2041-2070 under SSP585, **e** 2071-

2100 under SSP126, **f** 2071-2100 under SSP370, and **g** 2071-2100 under SSP585. Gray margin plots show distribution of the richness values along both latitudinal and longitudinal gradients

6.5 Discussion

6.5.1 Variability in climatic parameters in northwestern Kenya

Total annual precipitation (bio_12) in Turkana County is projected to increase over the two time intervals (2041-2070 and 2071-2100) and across the three SSPs (SSP126, SSP370, and SSP585). A similar pattern was reported by (Omolo 2010; Gebrechorkos et al. 2019) for parts of Ethiopia and Kenya especially during the short rainy seasons. There is also a projected corresponding increase in variability in the annual rainfall as indicated by the rising rainfall seasonality values (bio_15) (Appendix 18). However, increasing variability of the rainfall could imply prolonged drought periods and shorter but more intense rainy episodes (Gebrechorkos et al. 2019; Palmer et al. 2023). Projecting the future climate of eastern Africa as a whole is faced with a lot of challenges including limited rainfall stations for calibrations, the El Niño–Southern Oscillation and the Indian Ocean Dipole (Gebrechorkos et al. 2019; Palmer et al. 2023). The future maximum precipitation of the wettest (bio_13), and the driest (bio_14) months are within their present ranges, but the combined CHELSA models shows a general rise in their means. This should be interpreted cautiously as previous findings acknowledge the difficulties inherent in predicting future rainfall variabilities in eastern Africa (Nicholson 2017; Palmer et al. 2023). As with other precipitation related variables we used, precipitation of the warmest (bio_18) and the coldest (bio_19) quarters of the year showed an increasing pattern. While we could not determine the trend since the time intervals were not linear, visual appraisal of the plots indicated a stronger rise in precipitation of the warmest than that of the coldest quarter.

Regarding temperature variables, we observed future distributions of ranges overlap with those of the present, hence suited their use in building our models. However, under future times and SSPs, we observed varied distribution trends as reported in other studies (Gebrechorkos et al. 2019) . Diurnal range in temperature first declined then plateaued over time and SSPs. Similar trends emerged for isothermality (bio_3), which corresponds to the increasing trend for temperature seasonality (bio_4). This indicated a rise in variability among the observed temperature values, implying intermittent heat stress imposed on the WEPs regardless of the increasing seasonal or annual precipitation. We observed declining maximum temperature values for the warmest month (bio_5). In contrast, annual temperature ranges for the area remained rather stable over the study period and SSPs (Appendix 18). Both mean temperature of the wettest (bio_8) and driest (bio_9) quarters showed an increasing trend relative to the current climatic conditions. These warming quarters, coupled with the increasing rainfall seasonality, could negatively impact habitat suitability and richness of the studied WEPs.

We observed varied trends of the major climate variables guiding the distribution of the WEPs over space. The difficulties in explaining the variability of the climate conditions in East Africa is well documented (Nicholson 2017). This is even more challenging when making future projections (Cook et al. 2020; Palmer et al. 2023). This is because most of the observed seasonal variabilities cannot be fully explained by the known drivers of climate in the region. This calls for enhanced monitoring of the patterns to enable more accurate future predictions (Palmer et al. 2023). We visually appraised that the ranges of the variables under future scenarios fell within those of the calibration sets.

6.5.2 Current potentially suitable habitats for selected WEPs in Turkana County, Kenya

Up to 17 WEPs currently have potentially suitable habitat areas that cover more than half of Turkana County (Appendix 21). However, we are aware that our predictions only reflect Turkana County rather than the full distribution range of the species which stretches well beyond the county. For suitability maps for the whole model calibration area see Appendix 24. All of the 23 studied WEPs have potentially suitable habitats beyond the borders of Turkana County.

For five species, the potentially suitable habitat covered less than 25% of the study area. Out of those, *B. aegyptiaca* showed a complete loss of its local suitable habitat within Turkana County for future climate scenarios. The species has been reported to thrive in rain-fed conditions with 400-800 mm per annum and mean temperature of 20°C (Hall 1992) that could be rare under current and future climate conditions. About 50% of the WEPs showed a decline in potentially suitable habitat, with their distribution concentrated in the South end of the county, the western edge bordering Uganda, and in some parts of the Northeast (Appendix 22). These areas are at relatively higher elevations (about 900m in altitude) areas and have been characterized by conflicts with neighboring communities over pasture and livestock in the past (Shanguhyia 2021; Anno and Ameripus 2022). Hence, for communities to better utilize WEP resources at present and in the future, fostering peace in the area could be essential (Omolo 2010) as the plants are more distributed adjacent to the shared borderlands.

6.5.3 Future changes in potentially suitable habitats of selected WEPs in Turkana County, Kenya

Our models show that the size of potentially suitable habitat for half of the studied WEPs could experience considerable decline in the future and across SSPs, with *Balanites aegyptiaca* losing local (within the county) suitable habitat even under SSP126 of 2041-2070 period. Some species that will expand their current ranges within the county include *Dobera glabra*, *G. mollis,* and *V. pseudolablab*. These species are largely native to arid and semi-arid conditions, and could possess a high degree of heat stress tolerance as reports from South Africa suggest (Midgley and Thuiller 2007; Wessels et al. 2021).

Several studies on the impact of climate change on the distribution of plants in East Africa pointed out that most species will likely narrow the area of their current suitable habitat (Kalisa et al. 2019; Kidane et al. 2019). However, some localized studies, for example, within a 50 by 50 m plot in Tigray region of Ethiopia, showed likely expansion of the range of *Tamarindus indica* under future climate scenarios (Gufi et al. 2022), while the species showed steady decline in potentially suitable habitat in this study. Further, decline in potentially suitable habitats of some species in this study could be exacerbated by impacts of land cover and land use changes (Powers and Jetz 2019). For example, an earlier study showed that human activities such as overgrazing and crop irrigation in riparian areas are threatening the survival of WEPs in Turkana County (Oluoch et al. 2023) and neighboring countries (Bahru et al. 2013; Kidane and Kejela 2021). These additional threats were not assessed in this study but could worsen the negative effects of climatic changes on WEPs.

6.5.4 Changes in WEPs species richness under the future climate conditions in Turkana County, Kenya

In scarcely sampled areas, species richness can be derived from stacking binary outputs of species distribution models as shown for instance in studying endemic flora for conservation (Hoveka et al. 2020) and wild food plants in southern Africa (Wessels et al. 2021). Our aggregated model outputs suggest stability or gain in the richness of about half of the studied WEPs within our study area. The WEPs could be already existing in conditions comparable to projected future climates in the region. Although other studies have reported climate change in East Africa as serious threat to WEPs (Kidane et al. 2019; Schipper et al. 2020), such studies did not consider wider environmental conditions under which the species existed as achieved in this study. Nonetheless, we are aware that this study did not include other factors that could further limit the potential suitable habitats of the WEPs such as anthropogenic activities on land and dispersal ability of the WEPs to reach new suitable areas under future climates.

6.5.5 Beyond the abiotic

While we have only considered abiotic factors in the present analysis, there are also biotic and mobility/dispersal factors that influence distribution of species over space and time, as described in the biotic, abiotic, and mobility Venn diagram by Peterson et al. (2011). Interactions among the studied WEPs and competition between the WEPs and other plants over land could also influence the size of potentially suitable habitat and species richness. Additionally, the dispersal rates of different WEPs differ and their efficiency in following the shifting area size of potentially suitable habitats might also vary, hence we cannot claim occupancy of the predicted potentially suitable pixels in future. Seeds of some WEPs are dispersed by birds such as *Z. mauritiana* (Grice 1996) while others by water like *Hyphaene compressa* (Sullivan et al. 1995; Stave et al. 2006). Dynamics among and within these agents could drive the success of a WEP in colonizing new potentially suitable regions beyond the current habitats. Land use activities, such as overstocking and expansion of agriculture, could also influence the ranges of the WEPs in the future and their richness. Overstocking and overgrazing, for instance, reduce regeneration of WEPs (Oluoch et al.

2023), hence could limit range expansion as well as persistence of the WEPs within their current ranges. It is thus crucial to consider these factors when designing any management and conservation efforts and strategies for WEPs.

6.6 Conclusion

Our results reveal a decline in potentially suitable habitat for half the selected woody WEPs in Turkana County, Kenya, from the current climatic conditions to 2041-2070 and 2071-2100 periods across all three SSPs. Importantly, our models may overestimate the potentially suitable habitat for the WEPs because we did not consider anthropogenic factors that could further negatively influence the habitats and richness of the WEPs. Nonetheless, our findings contribute to improving the understanding of the influence of climate variability on the potential distribution and richness of WEPs in northwestern Kenya. The use of SDMs is criticized for their assumption of state of equilibrium between species and environment which is not always the case as complete sampling of species records is hardly achievable. Further, the models assume that we have included all major predictor variables governing the distribution of a species. Our use of SDMs in predicting potentially suitable habitat of WEPs, however, provides valuable insights for conservation and sustainable management of WEPs for use in improving dietary diversity of local communities. Both mitigation of climate change on a global scale and local management strategies such as controlled livestock farming and improving education and awareness for WEPs could help to better manage and sustainably conserve these valuable resources.

6.7 Acknowledgements

We sincerely thank institutions hosting online datasets used in the manuscript and individual original collectors of such data. Special thanks to East African Herbarium for allowing us to access their collections and to Dr. Céline Termote from Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT), Nairobi, Kenya for coordinating this study. This work was supported by the German Federal Ministry for Economic Cooperation and Development (BMZ) commissioned and administered through the Deutsche Gesellschaft für

Internationale Zusammenarbeit (GIZ) Fund for International Agricultural Research (FIA), grant number: 81235248.

Chapter 7: Synthesis

This synthesis highlights the intricate relationships among perception of availability of WEPs (see Chapter 4), threats and management options to WEPs (see Chapter 5), and potential suitable habitats of WEPs (see Chapter 6) in Turkana County, Kenya. Although the three chapters focused on different aspects of WEPs, some parameters featured throughout them. Notably, climate change emerged as a pervasive factor, intricately woven into each of the three facets of the study, revealing its influence on the socio-cultural and ecological dimensions of WEPs.

7.1 Availability of wild edible plants in Turkana County, Kenya

The study revealed multifaceted determinants influencing the perception of availability of WEPs by the local communities in Turkana County, Kenya. These ranged from distance they had to cover to harvest WEPs, seasonality of harvesting, price dynamics, and socio-cultural relevance of the WEPs. With the context of the study area being arid and semi-arid (see section 3.1.1), the WEPs are scattered in their distribution pattern and the local communities need to occasionally cover long distances to harvest them. This scattered distribution pattern is also revealed in Chapter 6 where potential suitable habitats of the WEPs are modeled (see Appendix 21).

The aspect of seasonality also played a significant role in influencing the perception of availability of WEPs. Being a nomadic pastoral community, movement with livestock in search of pasture following seasons is an aspect enshrined in their culture (Opiyo et al., 2015). This could explain why they retained mental maps of availability of WEPs in terms of seasonality. With climate change being revealed in Chapter 5 as an important threat to the WEPs (see Table 5.2), seasonality patterns of harvesting WEPs could be altered further swaying availability of WEPs to the local communities.

Cultural and traditional aspects also influenced the perception of availability of WEPs in Turkana County (see Figure 4.3 and Section 4.4.5.1). The aspect of culture underscores what the people consider edible and even how to prepare them as well as sharing of this knowledge across generations. The communities emphasized the relevance of culture and knowledge further in Chapter 5 by considering preservation of local knowledge about the WEPs as an important management option against threats after mitigation of climate change (see Table 5.4). The study thus found close link between major factors influencing how availability of WEPs is perceived and the threats as well as management options. With climate change projected to reduce the potential suitable habitats of half the studied WEPs (see Section 6.4.4), availability of WEPs to the local communities could be influenced in ways yet to be determined.

7.2 Threats to wild edible plants and management options in Turkana County, Kenya

Climate change, invasive species, and overstocking/overgrazing were the major threats facing priority woody WEPs in Turkana County (Table 5.2 and Table 5.3). The factors create conditions that hinder optimal regeneration of the WEPs. For example, climate change could be threatening the WEPs through a range of its indicators such as prolonged drought, inconsistent seasonality, and flashfloods among others. This could be drawing from the finding on perception of availability of WEPs where seasonality was mentioned as an important factor (Section 4.4.5.2). Additionally, subsequent investigations in Chapter 6 also showed climate change to reduce the extent of potential suitable habitats of half the WEPs (Section 6.4.4). Other threats are associated with culture and traditions of the people such as overstocking that follow from the nomadic pastoralism way of life of the Turkana people. With predicted reductions in the potential suitable habitats of half the studied WEPs (Section 6.4.4), overstocking, as a threat, could continue to pile pressure on the regeneration potential of WEPs in the Turkana County. This is thus calling for implementation of management practices as highlighted in Table 5.4.

In order to mitigate the threats facing WEPs, the findings of this thesis showed mitigation of climate change, preservation of local knowledge about WEPs, and selection, propagation, processing, and marketing as the highest-ranked management options (Table 5.4). The need for these management options is further revealed by the changes in the potential suitable habitats of WEPs in the county as presented in Chapter 6. Some of the management options could be strategized and executed at local community levels like preservation of local knowledge about the WEPs so that generations to come will appreciate the significance of the WEPs. Others, however, may need address beyond the study communities and even to the global scale such as initiatives to mitigate climate change. Policies in line with mitigating climate change from global to regional levels should be implemented and monitored. While the study did not evaluate efficacy of the management options, it remains an important area of inquiry to address the threats facing WEPs in the context of Turkana County.

7.3 Potentially suitable habitats of wild edible plants in Turkana County, Kenya

The need to find out the potentially suitable habitats of the WEPs followed from the findings in the previous chapters, perception of availability of WEPs (Chapters 4) and threats facing WEPs (Chapter 5). It determined the potentially suitable habitats of the WEPs within Turkana County under current as well as projected future climate scenarios. With climate change being considered one of the most important threats to the WEPs (Table 5.2), the study included climatic parameters in building models to predict the potentially suitable habitats for the WEPs in Turkana County.

7.3.1 Current potentially suitable habitat for the WEPs

The distribution of the modeled 23 WEPs (see Appendix 4 for the names) under current climate conditions showed varied distributions of potentially suitable habitats within the county (Appendix 21). The some WEPs such as *Dobera glabra* and *Vatovaea pseudolablab* showed uniform distribution within the area while others like *Grewia mollis* and *Sterculia stenocarpa* were sparsely distributed. Although these potentially suitable habitats are not necessarily occupied by the individual WEPs, they help to explain some of the observed parameters influencing availability of WEPs in Chapter 4. For instance, the sparsely distributed potentially suitable habitats of some WEPs could imply that the users need to travel longer distances to harvest them, and hence making distance to harvest sites an important parameter in perception of availability of WEPs to the Turkana communities (Table 4.2).

7.3.2 Future potentially suitable habitat for the WEPs

Seasonality, which is an aspect of climate, was considered one of the important parameters influencing the perception of availability of WEPs in Turkana County in Chapter 4 (Figure 4.2 and Section 4.4.5.2). Further, Chapter 5 also presented climate change as one of the important threats facing WEPs within Turkana County (Table 5.2). The findings from Chapter 6 also showed that with climate change into the future, up to half the studied WEPs will reduce their potentially suitable habitats (see Section 6.5.3). Even though the prediction of future climates in East Africa is complex and not unified, the findings are quite compelling as they resonate well with the discussions from FGDs and ranking of threats facing WEPs within the county. Further, there are several other important threats listed including overstocking and invasive species that were not included in the model. An interaction of climate change impacts and these anthropogenic factors can influence the availability of the WEPs in directions yet to be shown.

With predicted changes in the habitat suitability following climate change scenarios into the future, some WEPs will persist, others lose while others gain (Appendix 22) potentially suitable habitats. WEPs such as *Balanites aegyptiaca* may be out of reach of the Turkana people following their complete loss of suitable habitat within the county (Appendix 22). As the nomadic pastoralism way of life of the Turkana people becomes more sedentary (Ganie et al., 2019), it is important that new approaches of managing their ecosystem be devised since their movement with livestock in search of pasture is getting less practiced. Their ability to traverse the county and access diverse WEPs especially following the shifts in distribution of potentially suitable habitats of the WEPs could get more difficult.

7.3.3 Synergy among availability of wild edible plants, their threats and suitable habitats

The synergy among the perception of availability of WEPs by Turkana communities, threats and management of WEPs, and distribution of potential suitable habitats of the WEPs under climate change is intricate. Although climate change fueled most of the observed interplay, other factors such as distance to harvest sites and nomadic cultural practices, significantly influenced the dynamics. Understanding and addressing these interlinked factors in an integrated participatory approach is crucial for sustainable management and harvesting of WEPs in arid and semi-arid setting of Turkana County, Kenya.

Chapter 8: Outlook

This thesis gives important insights into integrated participatory research, bringing together both traditional ecological knowledge of WEPs and scientific methods among traditional Turkana communities in remote arid and semi-arid lands of northwestern Kenya. In the succeeding subsections, important aspects that need further investigations are highlighted in order to realize better utilization of WEPs in Turkana County sustainably. The knowledge gained from the local communities on availability, threats and management options of the WEPs as well as habitat suitability concerns are highlighted.

8.1 Availability of Wild Edible Plants in Turkana County, Kenya

While the thesis gained important insights about the perceived availability of WEPs in Turkana County Kenya, there remained several questions that still beg investigations. For instance, this study only looked at fruit-bearing woody WEPs yet there are several wild edible herbs/vegetables that are also very important in the daily diets of the Turkana people. More detailed investigations into the herbs such as *C. gynandra*, *Solanum americanum* Mill., *C. olitorius, Amaranthus graecizans* Cutanda among other herbs within the county would be important. Further research could also emphasize on documenting traditional ethnobotanical knowledge of the Turkana people so that the knowledge can be better incorporated into management and conservation plans for the WEPs. Cultural significance of WEPs to the Turkana community is also an area that needs further research and documentation especially with regard to how the knowledge can be transferred from one generation to another. This will help in execution of investigations of the potential loss of cultural heritage associated with declining plant resources.

Turkana community are known to interact with their neighboring communities while searching for pasture, water for their livestock, and through inter-marriages. Cross-community engagement and understanding of availability perception of WEPs would thus be important. This would make it possible to do cross-regional comparisons on availability of WEPs so that wider perspective is attained regarding the perceptions of the communities on their WEPs. Wider study covering the neighboring nomadic pastoral communities from South Sudan, eastern Uganda, southern Ethiopia and neighboring communities in Kenya like the Pokot to the south and Samburu to the east should be designed and executed. This will provide wider regional understanding and comparison of perceptions on availability of WEPs, threats, management options, distributions, and traditional ecological knowledge, as most of the WEPs are distributed and used beyond Turkana borders.

8.2 Threats and management options of Wild Edible Plants in Turkana County, Kenya

Very importantly, the thesis reported major threats facing woody WEPs within the arid and semi-arid lands of Turkana County. While the current study dwelt less on local traditional conservation strategies, this would be very important component to investigate further so that community-based conservation action plans can be designed. For sustainability of the management and conservation plans within the communities, the study recommends establishment of long term monitoring strategies of the important WEPs within the county so that the relevance of conservation efforts can be evaluated.

Very importantly, this study calls for multi-stakeholder effort on management of one specific invasive species, *P. juliflora*. Combining different stakeholders in understanding the invasive species could help in coming up with appropriate measures of controlling its spread and negative effects on existing WEPs and other biodiversity within the county. Such investigations would help key stakeholders to coin policies and governance strategies for the species in order to ensure better ecosystem balance within the county for persistence of both agro- and wild biodiversity.

The findings of the thesis highlighted a number of management options that could be helpful in cushioning the impact of threats on WEPs within Turkana County. However, the economic valuation is lacking. To begin with, it would be important to have economic valuation of WEPs as whole plants in terms of their medicinal values and nutrition values as well as ecosystem and cultural significance. This will be helpful in the second stage of evaluating the costs and benefits of executing various management options. Some management options could seem quite expensive, however, if the values of the WEPs are known then they might be considered worthwhile ventures.

8.3 Potentially suitable habitats of Wild Edible Plants in Turkana County, Kenya

The thesis achieved its objective of quantifying the potentially suitable habitats of WEPs in Turkana County Kenya. In this endeavor, however, a number of important knowledge gaps that would be worth investigating emerged. While the thesis modeled each WEP individually, this is not what normally happens in nature, as species interact with other organisms within landscape to determine where they can establish successfully. For instance, the WEPs that are outcompeted by *P. juliflora* would have reduced potentially suitable habitat within the study area. It would therefore be important to conduct further studies to reveal the dynamic interactions among the WEPs as well as with other organisms over land to refine the established potentially suitable habitats.

The current models of potentially suitable habitats assumed that the landscape is devoid of significant human activities and infrastructural developments. However, some developments are cropping in the county already including establishment and growth of towns and road networks as well as recent discovery and drilling of oil. These land use activities, as revealed under threats to WEPs (Table 5.2), could reduce further the potentially suitable habitats of the WEPs. Establishment of these layers and using them in masking the current potentially suitable habitats for the WEPs could be important in improving the accuracy of established extents. The refining of spatial modeling should also encompass ensemble of several machine learning methods such as random forest, xgboost, support vector machines, among others to come up with improved consensus on model performance. Additionally, as precise climate data is crucial for understanding ecological patterns, enhancing climate prediction models for East Africa is imperative to aid conservation and mitigate the impacts of climate change on biodiversity in the region.

Lastly, an important outlook from this study entails engaging the local Turkana communities to reconsider their traditional ways of environmental management and conservation. Most of the aspects that guide their perception of availability of WEPs have roots within their traditional ways of life. Evolving developments such infrastructure, changes in land ownership, more westernized education system, and climate change could distort the delicate fabric of traditional lifestyle.

Closer collaboration among the Turkana communities and stakeholders from research spheres should be more integrated in order to find harmonized ways of dealing with new challenges impeding the availability and sustainable harvesting of wild edible plants in Turkana County, Kenya.

References

Abatzoglou, J. T., Dobrowski, S. Z., Parks, S. A., & Hegewisch, K. C. (2018). TerraClimate, a high-resolution global dataset of monthly climate and climatic water balance from 1958--2015. *Scientific Data*, *5*(1), 1–12. https://doi.org/10.1038/sdata.2017.191

Abbasi, A. M., Khan, M. A., Khan, N., & Shah, M. H. (2013). Ethnobotanical survey of medicinally important wild edible fruits species used by tribal communities of Lesser Himalayas-Pakistan. *Journal of Ethnopharmacology*, *148*(2), 528–536. https://doi.org/10.1016/J.JEP.2013.04.050

AbdELRahman, H. F., Skaug, N., Whyatt, A. M., & Francis, G. W. (2003). Volatile compounds in crude Salvadora persica extracts. *Pharmaceutical Biology*, *41*(6), 399–404. https://doi.org/10.1076/phbi.41.6.399.17826

Achaglinkame, M. A., Aderibigbe, R. O., Hensel, O., Sturm, B., & Korese, J. K. (2019). Nutritional characteristics of four underutilized edible wild fruits of dietary interest in Ghana. *Foods*. https://doi.org/10.3390/foods8030104

Addis, G., Asfaw, Z., & Woldu, Z. (2013). *Ethnobotany of wild and semi-wild edible plants of Konso ethnic community, South Ethiopia*.

Addis, G., Urga, K., & Dikasso, D. (2005). Ethnobotanical study of edible wild plants in some selected districts of Ethiopia. *Human Ecology*, *33*(1), 83–118. https://doi.org/10.1007/s10745-005-1656-0

Aggemyr, E., Auffret, A. G., Jädergård, L., & Cousins, S. A. O. (2018). Species richness and composition differ in response to landscape and biogeography. *Landscape Ecology*, *33*(12), 2273–2284. https://doi.org/10.1007/s10980-018-0742-9

Agol, D., Angelopoulos, K., Lazarakis, S., Mancy, R., & Papyrakis, E. (2020). *Voices of the Turkana People*. Friends of Lake Turkana. https://eprints.gla.ac.uk/223900/1/223900.pdf

Akall, G. (2021). Effects of development interventions on pastoral livelihoods in Turkana County, Kenya. *Pastoralism*, *11*(1), 1–15. https://doi.org/10.1186/s13570-021-00197-2

Akankwasah, B., Tabuti, J. R. S., Van Damme, P., Agea, J. G., & Muwanika, V. (2012). *Potential for commercialization and value chain improvement of wild food and medicinal plants for livelihood enhancement in Uganda*.

Akuja, T. E., & Kandagor, J. (2019). A review of policies and agricultural productivity in the arid and semi-arid lands (ASALS), Kenya: the case of Turkana County. *Journal of Applied Biosciences*, *140*, 14304–14315. https://doi.org/10.4314/jab.v140i1.9

Akujah, P. E. (2011). *Interaction of coping strategies as determined by rainfall: The case of Turkana Riverine smallholders, Kenya*. Wageningen, The Netherlands: Van Hall Larenstein

University of Applied Sciences.

Alarcón, R., Pardo-de-Santayana, M., Priestley, C., Morales, R., & Heinrich, M. (2015). Medicinal and local food plants in the south of Alava (Basque Country, Spain). *Journal of Ethnopharmacology*, *176*, 207–224. https://doi.org/10.1016/j.jep.2015.10.022

Albuquerque, U. P. (2006). Re-examining hypotheses concerning the use and knowledge of medicinal plants: A study in the Caatinga vegetation of NE Brazil. *Journal of Ethnobiology and Ethnomedicine*, *2*(30), 1–10. https://doi.org/10.1186/1746-4269-2-30

Albuquerque, U. P., de Medeiros, P. M., Júnior, W. S. F., da Silva, T. C., da Silva, R. R. V., & Gonçalves-Souza, T. (2019). Social-ecological theory of maximization: basic concepts and two initial models. *Biological Theory*, *14*(2), 73–85. https://doi.org/10.1007/s13752-019-00316-8

Alemayehu, G., Asfaw, Z., & Kelbessa, E. (2015). Plant diversity and ethnobotany in Berehet District, North Shewa Zone of Amhara Region (Ethiopia) with emphasis on wild edible plants. *Journal of Medicinal Plants Studies*, *3*(6), 93–105.

Ali-Shtayeh, M. S., Jamous, R. M., Al-Shafie', J. H., Elgharabah, W. A., Kherfan, F. A., Qarariah, K. H., Khdair, I. S., Soos, I. M., Musleh, A. A., Isa, B. A., Herzallah, H. M., Khlaif, R. B., Aiash, S. M., Swaiti, G. M., Abuzahra, M. A., Haj-Ali, M. M., Saifi, N. A., Azem, H. K., & Nasrallah, H. A. (2008). Traditional knowledge of wild edible plants used in Palestine (Northern West Bank): A comparative study. *Journal of Ethnobiology and Ethnomedicine*, *4*(1), 13. https://doi.org/10.1186/1746-4269-4-13

Ambursa, S. A., Muhammad, A., Tijjani, A., Sanda, H. Y., & Hamidat, M. M. (2019). Effect of Seed Priming Methods on Germination of Sweet Dattock (Detarium microcarpum) and Indian Jujube (Ziziphus mauritiana) in Sudan Savanna Ecological Zone of Nigeria. *Asian Journal of Advances in Agricultural Research*. https://doi.org/10.9734/ajaar/2019/v10i230025

Amoussou, B. E. N., Idohou, R., Glèlè Kakai, R., Dauby, G., & Couvreur, T. L. P. (2022). Impact of end-of-century climate change on priority non-timber forest product species across tropical Africa. *African Journal of Ecology*, *60*(4), 1120–1132. https://doi.org/10.1111/aje.13034

Andrews, M., & Baguley, T. (2013). *Prior approval: The growth of Bayesian methods in psychology*. Wiley Online Library.

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N. J., Bauch, S., Börner, J., Smith-Hall, C., & Wunder, S. (2014). Environmental Income and Rural Livelihoods: A Global-Comparative Analysis. *World Development*, *64*(S1), S12–S28. https://doi.org/10.1016/J.WORLDDEV.2014.03.006

Anno, E. F., & Ameripus, M. E. (2022). Effects of Internal and Cross-Border Resource-Based Conflicts on Livestock Market Performance in Pastoral Areas of Karamoja, Uganda and Turkana, Kenya. *American Journal of Environmental and Resource Economics*, *7*(3), 87–96.

https://doi.org/10.11648/j.ajere.20220703.14

Aryal, K. P., Poudel, S., Chaudhary, R. P., Chettri, N., Chaudhary, P., Ning, W., & Kotru, R. (2018). Diversity and use of wild and non-cultivated edible plants in the Western Himalaya. *Journal of Ethnobiology and Ethnomedicine*. https://doi.org/10.1186/s13002-018-0211-1

Asfaw, Z. (2008). The future of wild food plants in southern Ethiopia: ecosystem conservation coupled with enhancement of the roles of key social groups. *International Symposium on Underutilized Plants for Food Security, Nutrition, Income and Sustainable Development 806*, 701–708. https://doi.org/10.17660/ActaHortic.2009.806.87

Ashagre, M., Asfaw, Z., & Kelbessa, E. (2016). Ethnobotanical study of wild edible plants in Burji District, Segan Area Zone of Southern Nations, Nationalities and Peoples Region (SNNPR), Ethiopia. *Journal of Ethnobiology and Ethnomedicine*, *12*(1). https://doi.org/10.1186/s13002-016-0103-1

Assefa, A., & Abebe, T. (2011). Wild edible trees and shrubs in the semi-arid lowlands of southern Ethiopia. *J Sci Dev*, *1*(1), 5–19.

Atri, N. S., Gupta, A. K., Kaur, A., Kour, H., & Saini, S. S. (2010). Documentation of wild edible mushrooms and their seasonal availability in Punjab. In K. G. Mukerji & C. Manoharachary (Eds.), *Taxonomy and ecology of Indian fungi* (pp. 161–169). I. K. International Publishing House.

Badimo, D., Lepetu, J., & Teketay, D. (2015). Utilization of edible wild plants and their contribution to household income in Gweta Village, central Botswana. *Afr J Food Sci Technol*, *6*(7), 220–228. https://doi.org/10.14303/ajfst.2015.074

Bahar, N. H. A., Lo, M., Sanjaya, M., Van Vianen, J., Alexander, P., Ickowitz, A., & Sunderland, T. (2020). Meeting the food security challenge for nine billion people in 2050: What impact on forests? *Global Environmental Change*. https://doi.org/10.1016/j.gloenvcha.2020.102056

Bahru, T., Asfaw, Z., & Demissew, S. (2013). Wild edible plants: sustainable use and management by indigenous communities in and the buffer area of Awash national park, Ethiopia. *SINET: Ethiopian Journal of Science*, *36*(2), 93–108.

Baldermann, S., Blagojević, L., Frede, K., Klopsch, R., Neugart, S., Neumann, A., Ngwene, B., Norkeweit, J., Schröter, D., Schröter, A., Schweigert, F. J., Wiesner, M., & Schreiner, M. (2016). Are Neglected Plants the Food for the Future? *Critical Reviews in Plant Sciences*, *35*(2). https://doi.org/10.1080/07352689.2016.1201399

Balemie, K., & Kebebew, F. (2006). Ethnobotanical study of wild edible plants in Derashe and Kucha Districts, South Ethiopia. *Journal of Ethnobiology and Ethnomedicine*, *2*, 1–9. https://doi.org/10.1186/1746-4269-2-53

Barber, Q. E., Nielsen, S. E., & Hamann, A. (2016). Assessing the vulnerability of rare plants using climate change velocity, habitat connectivity, and dispersal ability: a case study in Alberta, Canada. *Regional Environmental Change*, *16*, 1433–1441. https://doi.org/10.1007/s10113-015-0870-6

Bariotakis, M., Georgescu, L., Laina, D., Oikonomou, I., Ntagounakis, G., Koufaki, M.-I., Souma, M., Choreftakis, M., Zormpa, O. G., Smykal, P., Sourvinos, G., Lionis, C., Castanas, E., Karousou, R., & Pirintsos, S. A. (2019). From wild harvest towards precision agriculture: Use of Ecological Niche Modelling to direct potential cultivation of wild medicinal plants in Crete. *Science of The Total Environment*. https://doi.org/10.1016/j.scitotenv.2019.133681

Barreau, A., Ibarra, J. T., Wyndham, F. S., Rojas, A., & Kozak, R. A. (2016). How Can We Teach Our Children if We Cannot Access the Forest? Generational Change in Mapuche Knowledge of Wild Edible Plants in Andean Temperate Ecosystems of Chile. *Journal of Ethnobiology*, *36*(2), 412–432. https://doi.org/10.2993/0278-0771-36.2.412

Bejarano, M. D., Jansson, R., & Nilsson, C. (2018). The effects of hydropeaking on riverine plants: a review. *Biological Reviews*, *93*(1), 658–673. https://doi.org/10.1111/brv.12362

Bélanger, J., & Pilling, D. (2019). *The state of the world's biodiversity for food and agriculture*. FAO Commission on Genetic Resources for Food and Agriculture Assessments.

Bender, L. (2017). *The use of indigenous knowledge in nutrition communication: The example of pastoralist communities in Turkana County, Kenya*. University of Hohenheim. Masters Thesis.

Berihun, T., & Molla, E. (2017). Study on the diversity and use of wild edible plants in Bullen District Northwest Ethiopia. *Journal of Botany*, *2017*, 10. https://doi.org/10.1155/2017/8383468

Bernabo, I., Biondi, M., Cittadino, V., Sperone, E., & Iannella, M. (2022). Addressing conservation measures through fine-tuned species distribution models for an Italian endangered endemic anuran. *Global Ecology and Conservation*, *39*, e02302. https://doi.org/10.1016/j.gecco.2022.e02302

Bett, B. K., Jost, C., & Mariner, J. C. (2008). Participatory investigation of important animal health problems amongst the Turkana pastoralists: Relative incidence, impact on livelihoods and suggested interventions. *ILRI Targeting and Innovation Discussion Paper*.

Bhatia, H., Sharma, Y. P., Manhas, R. K., & Kumar, K. (2018). Traditionally used wild edible plants of district Udhampur, J&K, India. *Journal of Ethnobiology and Ethnomedicine*. https://doi.org/10.1186/s13002-018-0272-1

Bhavnani, R., Schlager, N., Donnay, K., Reul, M., Schenker, L., Stauffer, M., & Patel, T. (2023). Household behavior and vulnerability to acute malnutrition in Kenya. *Humanities and Social Sciences Communications*, *10*(1), 1–14. https://doi.org/10.1057/s41599-023-01547-8

Birhanu, A. (2023). *Study on Wild Edible Plant Used by Shinasha Ethnic Community at Metekel Zone, Northwest Ethiopia*. https://doi.org/10.21203/rs.3.rs-3116261/v1

Blanco-Salas, J., Gutierrez-Garcia, L., Labrador-Moreno, J., & Ruiz-Tellez, T. (2019). Wild plants potentially used in human food in the Protected Area" Sierra Grande de Hornachos" of Extremadura (Spain). *Sustainability*, *11*(2), 456. https://doi.org/10.3390/su11020456

Bocedi, G., Palmer, S. C. F., Malchow, A.-K., Zurell, D., Watts, K., & Travis, J. M. J. (2021). RangeShifter 2.0: an extended and enhanced platform for modelling spatial eco-evolutionary dynamics and species' responses to environmental changes. *Ecography*, *44*(10), 1453–1462. https://doi.org/10.1111/ecog.05687

Boedecker, J., Odhiambo Odour, F., Lachat, C., Van Damme, P., Kennedy, G., & Termote, C. (2019). Participatory farm diversification and nutrition education increase dietary diversity in Western Kenya. *Maternal & Child Nutrition*, *15*(3), e12803. https://doi.org/10.1111/mcn.12803

Borelli, T., Hunter, D., Padulosi, S., Amaya, N., Meldrum, G., de Oliveira Beltrame, D. M., Samarasinghe, G., Wasike, V. W., Güner, B., Tan, A., Dembélé, Y. K., Lochetti, G., Sidibé, A., & Tartanac, F. (2020). Local solutions for sustainable food systems: The contribution of orphan crops and wild edible species. In *Agronomy*. https://doi.org/10.3390/agronomy10020231

Borelli, T., Hunter, D., Powell, B., Ulian, T., Mattana, E., Termote, C., Pawera, L., Beltrame, D., Penafiel, D., Tan, A., Taylor, M., & Engels, J. (2020). Born to Eat Wild: An Integrated Conservation Approach to Secure Wild Food Plants for Food Security and Nutrition. In *Plants* (Vol. 9, Issue 10). https://doi.org/10.3390/plants9101299

Brownscombe, J. W., Midwood, J. D., & Cooke, S. J. (2021). Modeling fish habitat: model tuning, fit metrics, and applications. *Aquatic Sciences*, *83*, 1–14. https://doi.org/10.1007/s00027-021-00797-5

Bussmann, R. W., Gilbreath, G. G., Solio, J., Lutura, M., Lutuluo, R., Kunguru, K., Wood, N., & Mathenge, S. G. (2006). Plant use of the Maasai of Sekenani Valley, Maasai Mara, Kenya. *Journal of Ethnobiology and Ethnomedicine*, *2*, 1–7. https://doi.org/10.1186/1746-4269-2-22

Cacciapaglia, C., & van Woesik, R. (2018). Marine species distribution modelling and the effects of genetic isolation under climate change. *Journal of Biogeography*, *45*(1), 154–163. https://doi.org/10.1111/jbi.13115

Calvo, B., & Santafé Rodrigo, G. (2016). scmamp: Statistical comparison of multiple algorithms in multiple problems. *The R Journal, Vol. 8/1, Aug. 2016*. https://hdl.handle.net/2454/23209

Carboni, M., Livingstone, S. W., Isaac, M. E., & Cadotte, M. W. (2021). Invasion drives plant diversity loss through competition and ecosystem modification. *Journal of Ecology*, *109*(10), 3587–3601. https://doi.org/10.1111/1365-2745.13739

Carr, C. J., & Carr, C. J. (2017). Turkana Survival Systems at Lake Turkana: Vulnerability to Collapse from Omo Basin Development. In *River Basin Development and Human Rights in Eastern Africa — A Policy Crossroads*. https://doi.org/10.1007/978-3-319-50469-8_9

Carvalho, A. M., & Barata, A. M. (2016). The Consumption of Wild Edible Plants. In *Wild Plants, Mushrooms and Nuts: Functional Food Properties and Applications*. https://doi.org/10.1002/9781118944653.ch6

Castro-Sánchez, E. I., Moreno-Calles, A. I., Meneses-Eternod, S., Farfán-Heredia, B., Blancas, J., & Casas, A. (2019). Management of Wild Edible Fungi in the Meseta Purépecha Region, Michoacán, México. *Sustainability*, *11*(14), 3779. https://doi.org/10.3390/su11143779

Ceccanti, C., Landi, M., Benvenuti, S., Pardossi, A., & Guidi, L. (2018). Mediterranean wild edible plants: weeds or "new functional crops"? *Molecules*, *23*(9), 2299. https://doi.org/10.3390/molecules23092299

Ceccarelli, V., Ekué, M., Fremout, T., Gaisberger, H., Kettle, C., Taedoumg, H., Wouters, H., Vanuytrecht, E., De Ridder, K., & Thomas, E. (2022). Vulnerability mapping of 100 priority tree species in Central Africa to guide conservation and restoration efforts. *Biological Conservation*, *270*, 109554. https://doi.org/10.1016/j.biocon.2022.109554

Chakravarty, S., Bhutia, K. D., Suresh, C. P., Shukla, G., & Pala, N. A. (2016). A review on diversity, conservation and nutrition of wild edible fruits. *Journal of Applied and Natural Science*, *8*(4), 2346–2353. https://doi.org/10.31018/jans.v8i4.1135

Chapman, D. S., Scalone, R., Štefanić, E., & Bullock, J. M. (2017). Mechanistic species distribution modeling reveals a niche shift during invasion. *Ecology*, *98*(6), 1671–1680. https://doi.org/10.1002/ecy.1835

Chelang'a, J. K., & Chesire, M. (2020). Analysis of Conflict Resolution Strategies among Pastoralist Communities of Kenya. *Journal of African Interdisciplinary Studies*, *4*(4), 4–21.

Cheng, J., Yang, X., Xue, L., Yao, B., Lu, H., Tian, Z., Li, J., Zhou, X., Zhang, Y., Zia Ul Haq, M., & others. (2020). Polyploidization contributes to evolution of competitive ability: a long term common garden study on the invasive Solidago canadensis in China. *Oikos*, *129*(5), 700–713. https://doi.org/10.1111/1365-2745.13739

Chilambe, P., Denje, T., Arum, S., Vyas, S., Jalang'o Anyango, D., Awola, D., Girvetz, E. H., & Wamukoya, G. (2022). *Situational analysis of the Karamoja-Turkana/West Pokot-Easter Equatoria Cluster*. CGIAR Initiative on Climate Resilience.

CHSS-CAT. (2018). *The Turkana County Community Health Services Bill*. The Government Printer, Nairobi.

Colantoni, A., Egidi, G., Quaranta, G., D'Alessandro, R., Vinci, S., Turco, R., & Salvati, L. (2020). Sustainable land management, wildfire risk and the role of grazing in Mediterranean urban-rural interfaces: A regional approach from Greece. *Land*, *9*(1), 21. https://doi.org/10.3390/land9010021

Cook, K. H., Fitzpatrick, R. G. J., Liu, W., & Vizy, E. K. (2020). Seasonal asymmetry of equatorial East African rainfall projections: Understanding differences between the response of the long rains and the short rains to increased greenhouse gases. *Climate Dynamics*, *55*, 1759–1777. https://doi.org/10.1007/s00382-020-05350-y

Cormack, Z., & Kurewa, A. (2018). The changing value of land in Northern Kenya: the case of Lake Turkana Wind Power. *Critical African Studies*. https://doi.org/10.1080/21681392.2018.1470017

Cotton, C. M. (1996). *Ethnobotany: principles and applications.* John Wiley & Sons.

Coughenour, M. B., & Ellis, J. E. (1993). Landscape and Climatic Control of Woody Vegetation in a Dry Tropical Ecosystem: Turkana District, Kenya. *Journal of Biogeography*. https://doi.org/10.2307/2845587

Cruz-Garcia, G. S., & Struik, P. C. (2015). Spatial and seasonal diversity of wild food plants in home gardens of Northeast Thailand. *Economic Botany*, *69*, 99–113.

Culumber, Z. W., & Tobler, M. (2016). Ecological divergence and conservatism: spatiotemporal patterns of niche evolution in a genus of livebearing fishes (Poeciliidae: Xiphophorus). *BMC Evolutionary Biology*, *16*(1), 1–16. https://doi.org/10.1186/s12862-016-0593-4

D'iaz, S., Settele, J., Brond'izio, E. S., Ngo, H. T., Agard, J., Arneth, A., Balvanera, P., Brauman, K. A., Butchart, S. H. M., Chan, K. M. A., & others. (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science*, *366*(6471), eaax3100.

Dauby, G., Zaiss, R., Blach-Overgaard, A., Catarino, L., Damen, T., Deblauwe, V., Dessein, S., Dransfield, J., Droissart, V., Duarte, M. C., Engledow, H., Fadeur, G., Figueira, R., Gereau, R. E., Hardy, O. J., Harris, D. J., De Heij, J., Janssens, S., Klomberg, Y., … Couvreur, T. L. P. (2016). RAINBIO: A mega-database of tropical African vascular plants distributions. *PhytoKeys*. https://doi.org/10.3897/phytokeys.74.9723

De Merode, E., Homewood, K., & Cowlishaw, G. (2004). The value of bushmeat and other wild foods to rural households living in extreme poverty in Democratic Republic of Congo. *Biological Conservation*. https://doi.org/10.1016/j.biocon.2003.10.005

de Oliveira Trindade, M. R., Jardim, J. G., Casas, A., Guerra, N. M., & de Lucena, R. F. P. (2015). Availability and use of woody plant resources in two areas of Caatinga in Northeastern Brazil. *Ethnobotany Research and Applications*, *14*, 313–330. https://doi.org/10.17348/era.14.0.313-330

Dejene, T., Agamy, M. S., Agúndez, D., & Martin-Pinto, P. (2020). Ethnobotanical survey of wild edible fruit tree species in lowland areas of Ethiopia. *Forests*. https://doi.org/10.3390/f11020177

Delang, C. O. (2006). The role of wild food plants in poverty alleviation and biodiversity conservation in tropical countries. *Progress in Development Studies*. https://doi.org/10.1191/1464993406ps143oa

Dempewolf, H., Baute, G., Anderson, J., Kilian, B., Smith, C., & Guarino, L. (2017). Past and future use of wild relatives in crop breeding. *Crop Science*, *57*(3), 1070–1082. https://doi.org/10.2135/cropsci2016.10.0885

Devi Thakur, S., Kapoor, K. S., & Samant, S. S. (2016). Diversity, distribution and Indigenous uses of some threatened medicinal plants in Kullu district of Himachal Pradesh, Northwestern Himalaya. *Asian Journal of Advanced Basic Sciences*, *9*(1), 42–45. https://doi.org/DOI:10.15520/.v1i0.6

Doggart, N., & Meshack, C. (2017). The marginalization of sustainable charcoal production in the policies of a modernizing African nation. *Frontiers in Environmental Science*, *5*, 27. https://doi.org/10.3389/fenvs.2017.00027

Dougan, Y., Uugulu, I., & Durkan, N. (2013). Wild edible plants sold in the local markets of Izmir, Turkey. *Pakistan Journal of Botany*, *45*(1), 177–184.

Dragicevic, H. (2017). *Everything except the soil: understanding wild food consumption during the lean season in South Sudan*.

Duenas, M.-A., Hemming, D. J., Roberts, A., & Diaz-Soltero, H. (2021). The threat of invasive species to IUCN-listed critically endangered species: A systematic review. *Global Ecology and Conservation*, *26*, e01476. https://doi.org/10.1016/j.gecco.2021.e01476

Duguma, H. T. (2020). Wild edible plant nutritional contribution and consumer perception in Ethiopia. *International Journal of Food Science*, *2020*, 16. https://doi.org/10.1155/2020/2958623

Ejore, E., Ongugo, R., Kemboi, J., Ojunga, S., Mwenja, P., & Owino, J. (2020). Plant species and their importance to housing in the Turkana community, Kenya. *Journal of Horticulture and Forestry*, *12*(3), 101–108. https://doi.org/10.5897/jhf2020.0634

Emuria, W. H. (2018). *Factors Affecting Farm-level Efficiency in Irrigation Schemes: a Case of Turkana South Sub-county*. University of Nairobi.

Enquist, B. J., Condit, R., Peet, R. K., Schildhauer, M., & Thiers, B. M. (2016). Cyberinfrastructure for an integrated botanical information network to investigate the ecological impacts of global climate change on plant biodiversity. *PeerJ*, 33. https://doi.org/10.7287/peerj.preprints.2615v2

Erskine, W., Ximenes, A., Glazebrook, D., da Costa, M., Lopes, M., Spyckerelle, L., Williams, R., & Nesbitt, H. (2020). Wild Foods and Food Security: The Case of Timor-Leste. In *Food Security in Small Island States*. https://doi.org/10.1007/978-981-13-8256-7_15

Escobar, L. E., Qiao, H., Cabello, J., & Peterson, A. T. (2018). Ecological niche modeling re-examined: A case study with the Darwin's fox. *Ecology and Evolution*. https://doi.org/10.1002/ece3.4014

Estomba, D., Ladio, A., & Lozada, M. (2006). Medicinal wild plant knowledge and gathering patterns in a Mapuche community from North-western Patagonia. *Journal of Ethnopharmacology*, *103*(1), 109–119. https://doi.org/10.1016/j.jep.2005.07.015

Etz, A., & Vandekerckhove, J. (2016). A Bayesian perspective on the reproducibility project: Psychology. *PloS One*, *11*(2), 1–12. https://doi.org/10.1371/journal.pone.0149794

Falasca, S., Pitta-Alvarez, S., & del Fresno, C. M. (2015). Salvadora persica agro-ecological suitability for oil production in Argentine dryland salinity. *Science of the Total Environment*, *538*, 844–854. https://doi.org/10.1016/j.scitotenv.2015.08.082

Farr, T. G., & Kobrick, M. (2000). Shuttle Radar Topography Mission produces a wealth of data. *Eos Trans. AGU*, *81*(48), 583–585. https://doi.org/10.1029/EO081i048p00583

Feitosa, I. S., Monteiro, J. M., Araújo, E. L., Lopes, P. F. M., & Albuquerque, U. P. (2018). Optimal Foraging Theory and Medicinal Bark Extraction in Northeastern Brazil. *Human Ecology*, *46*(6), 917–922. https://doi.org/10.1007/s10745-018-0037-4

Feng, X., Park, D. S., Liang, Y., Pandey, R., & Papes, M. (2019). Collinearity in ecological niche modeling: Confusions and challenges. *ECOLOGY AND EVOLUTION*, *9*(18), 10365–10376. https://doi.org/10.1002/ece3.5555

Feng, X., Park, D. S., Walker, C., Peterson, A. T., Merow, C., & Papeş, M. (2019). A checklist for maximizing reproducibility of ecological niche models. *Nature Ecology & Evolution*, *3*(10), 1382–1395. https://doi.org/10.1038/s41559-019-0972-5

Feyssa, D. H. (2012). Comparative analysis of indigenous knowledge on use and management of wild edible plants: the case of central east Shewa of Ethiopia. *Ethnobotany Research and Applications*, *10*, 287–304. https://doi.org/10.17348/era.10.0.287-304

Feyssa, D. H., Njoka, J. T., Asfaw, Z., & Nyangito, M. M. (2011). Seasonal availability and consumption of wild edible plants in semiarid Ethiopia: Implications to food security and climate change adaptation. *Journal of Horticulture and Forestry*, *3*(5), 138–149. http://www.academicjournals.org/jhf/PDF/pdf2011/May/Feyssa et al.pdf

Feyssa, D. H., Njoka, J. T., Asfaw, Z., & Nyangito, M. M. (2012). Uses and management of Ximenia americana, Olacaceae in semi-arid East Shewa, Ethiopia. *Pakistan Journal of Botany*, *44*(4), 1177–1184.

Fidelis, A. (2020). Is fire always the "bad guy"? *Flora*, *268*, 151611. https://doi.org/10.1016/j.flora.2020.151611

Fitzpatrick, M. C., Lachmuth, S., & Haydt, N. T. (2021). The ODMAP protocol: a new tool for standardized reporting that could revolutionize species distribution modeling. *Ecography*, *44*(7), 1067–1070. https://doi.org/10.1111/ECOG.05700

Flyman, M. V, & Afolayan, A. J. (2006). The suitability of wild vegetables for alleviating human dietary deficiencies. *South African Journal of Botany*, *72*(4), 492–497. https://doi.org/10.1016/j.sajb.2006.02.003

Fongnzossie, E. F., Nyangono, C. F. B., Biwole, A. B., Ebai, P. N. B., Ndifongwa, N. B., Motove, J., & Dibong, S. D. (2020). Wild edible plants and mushrooms of the Bamenda Highlands in Cameroon: ethnobotanical assessment and potentials for enhancing food security. *Journal of Ethnobiology and Ethnomedicine*, *16*(1), 1–10. https://doi.org/10.1186/s13002-020-00362-8

Fonjong, L. N., & Gyapong, A. Y. (2021). Plantations, women, and food security in Africa: Interrogating the investment pathway towards zero hunger in Cameroon and Ghana. *World Development*. https://doi.org/10.1016/j.worlddev.2020.105293

Food Economy Group. (2016). *Livelihood Profiles Baseline Update: Six Livelihood Zones in Turkana County, Kenya*.

Franklin, J., & Miller, J. A. (2010). Mapping species distributions: Spatial inference and prediction. In *Mapping Species Distributions: Spatial Inference and Prediction*. https://doi.org/10.1017/CBO9780511810602

Friedl, M., & Sulla-Menashe, D. (2019). *MCD12Q1 MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V006. NASA EOSDIS Land Processes DAAC.* https://doi.org/10.5067/MODIS/MCD12Q1.006

Funk, C. C., Peterson, P. J., Landsfeld, M. F., Pedreros, D. H., Verdin, J. P., Rowland, J. D., Romero, B. E., Husak, G. J., Michaelsen, J. C., Verdin, A. P., & others. (2014). A quasi-global precipitation time series for drought monitoring. *US Geological Survey Data Series*, *832*(4), 1–12. https://doi.org/10.3133/ds832

Funk, C., Pete, P., Landsfeld, M., Diego, P., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A., & Michaelsen, J. (2015). The climate hazards infrared precipitation with stations-a new environmental record for monitoring extremes. *Sci. Data*, *2*, 1–21. https://doi.org/10.1038/sdata.2015.66

Gaisberger, H., Kindt, R., Loo, J., Schmidt, M., Bognounou, F., Da, S. S., Diallo, O. B., Ganaba, S., Gnoumou, A., Lompo, D., & others. (2017). Spatially explicit multi-threat assessment of food tree species in Burkina Faso: A fine-scale approach. *PLoS One*, *12*(9), e0184457. https://doi.org/10.1371/journal.pone.0184457

Galaty, J. G. (2013). The collapsing platform for pastoralism: Land sales and land loss in Kajiado County, Kenya. *Nomadic Peoples*, *17*(2), 20–39. https://doi.org/10.3167/np.2013.170204

Ganie, A. H., Tali, B. A., Khuroo, A. A., Reshi, Z. A., & Nawchoo, I. A. (2019). Impact assessment of anthropogenic threats to high-valued medicinal plants of Kashmir Himalaya, India. *Journal for Nature Conservation*, *50*, 125715. https://doi.org/10.1016/j.jnc.2019.125715

Gaoue, O. G., Coe, M. A., Bond, M., Hart, G., Seyler, B. C., & McMillen, H. (2017). Theories and Major Hypotheses in Ethnobotany. In *Economic Botany*. https://doi.org/10.1007/s12231-017-9389-8

Gaoue, O. G., Moutouama, J. K., Coe, M. A., Bond, M. O., Green, E., Sero, N. B., Bezeng, B. S., & Yessoufou, K. (2021). Methodological advances for hypothesis-driven ethnobiology. *Biological Reviews*. https://doi.org/10.1111/brv.12752

Garcia, L. C., Szabo, J. K., de Oliveira Roque, F., Pereira, A. de M. M., da Cunha, C. N., Damasceno-Júnior, G. A., Morato, R. G., Tomas, W. M., Libonati, R., & Ribeiro, D. B. (2021). Record-breaking wildfires in the world's largest continuous tropical wetland: Integrative fire management is urgently needed for both biodiversity and humans. *Journal of Environmental Management*, *293*, 112870. https://doi.org/10.1016/j.jenvman.2021.112870

GBIF.org. (2020). *GBIF Home Page*. https://www.gbif.org

Gebrechorkos, S. H., Hülsmann, S., & Bernhofer, C. (2019). Regional climate projections for impact assessment studies in East Africa. *Environmental Research Letters*, *14*(4), 44031. https://doi.org/10.1088/1748-9326/ab055a

Gerten, D., Heck, V., Jägermeyr, J., Bodirsky, B. L., Fetzer, I., Jalava, M., Kummu, M., Lucht, W., Rockström, J., Schaphoff, S., & Schellnhuber, H. J. (2020). Feeding ten billion people is possible within four terrestrial planetary boundaries. *Nature Sustainability*, *3*, 200–208. https://doi.org/10.1038/s41893-019-0465-1

Ginger, C., Emery, M. R., Baumflek, M. J., & Putnam, D. E. (2012). Access to natural resources on private property: Factors beyond right of entry. *Society \& Natural Resources*, *25*(7), 700–715. https://doi.org/10.1080/08941920.2011.633596

Giraud, N. J., Kool, A., Karlsen, P., Annes, A., & Teixidor-Toneu, I. (2021). From trend to threat? Assessing the sustainability of wild edible plant foraging by linking local perception to ecological inference. *BioRxiv*. https://doi.org/10.1101/2021.09.27.461499

Gonçalves, P. H. S., Albuquerque, U. P., & Medeiros, P. M. de. (2016). The most commonly available woody plant species are the most useful for human populations: A meta-analysis. *Ecological Applications*, *26*(7), 2238–2253. https://doi.org/10.1002/eap.1364

Goodrich, B., Gabry, J., Ali, I., & Brilleman, S. (2022). *rstanarm: {Bayesian} applied regression modeling via {Stan}.* https://mc-stan.org/rstanarm

Gradé, J. T. (2012). Karamojong (Uganda) pastoralists' use of wild edible plants: A traditional coping mechanism towards climate change. In G. B. Mulugeta & J.-B. Butera (Eds.), *Climate Change and Pastoralism: Traditional Coping Mechanisms and Conflict in the Horn of Africa* (pp. 34-55.). Institute for Peace and Security Studies and University for Peace. https://espace.library.uq.edu.au/view/UQ:337443/UQ337443_OA.pdf#page=166

Graham, C. H., Elith, J., Hijmans, R. J., Guisan, A., Townsend Peterson, A., Loiselle, B. A., & Group, N. P. S. D. W. (2008). The influence of spatial errors in species occurrence data used in distribution models. *Journal of Applied Ecology*, *45*(1), 239–247. https://doi.org/10.1111/j.1365-2664.2007.01408.x

Greiner, C. (2017). Pastoralism and land-tenure change in Kenya: the failure of customary institutions. *Development and Change*, *48*(1), 78–97. https://doi.org/10.1111/dech.12284

Grice, A. C. (1996). Seed production, dispersal and germination in Cryptostegia grandiflora and Ziziphus mauritiana, two invasive shrubs in tropical woodlands of northern Australia. *Australian Journal of Ecology*, *21*(3), 324–331. https://doi.org/10.1111/j.1442-9993.1996.tb00615.x

Grinnell, J. (1917a). Field Tests of Theories Concerning Distributional Control. *The American Naturalist*. https://doi.org/10.1086/279591

Grinnell, J. (1917b). The niche-relationships of the California Thrasher. *The Auk*, *34*(4), 427–433.

Guarino, L., & Lobell, D. B. (2011). A walk on the wild side. *Nature Climate Change*, *1*(8), 374–375. https://doi.org/10.1038/nclimate1272

Gufi, Y., Manaye, A., Tesfamariam, B., Abriha, H., Tesfaye, M., & Hintsa, S. (2022). Modeling Impacts of Climate Change on the Geographic Distribution and Abundances of Tamarindus Indica in Tigray Region, Ethiopia. *Heliyon*. https://doi.org/10.2139/ssrn.4268120

Guinand, Y., & Lemessa, D. (2000). Wild food plants in Southern Ethiopia: Reflections on the role of 'famine foods' at a time of drought. In *UNDP-EUE Field Mission Report, Addis Ababa*.

Guisan, A., Thuiller, W., & Zimmermann, N. E. (2017). Habitat suitability and distribution models: With applications in R. In *Habitat Suitability and Distribution Models: With Applications in R*. Cambridge University Press. https://doi.org/10.1017/ 9781139028271

Guisan, A., & Zimmermann, N. E. (2000). Predictive habitat distribution models in ecology. *Ecological Modelling*. https://doi.org/10.1016/S0304-3800(00)00354-9

Guzo, S., Lulekal, E., & Nemomissa, S. (2023). Ethnobotanical study of underutilized wild edible plants and threats to their long-term existence in Midakegn District, West Shewa Zone, Central Ethiopia. *Journal of Ethnobiology and Ethnomedicine*, *19*(1), 30.

Hall, J. B. (1992). Ecology of a key African multipurpose tree species, Balanites aegyptiaca

(Balanitaceae): the state-of-knowledge. *Forest Ecology and Management*, *50*(1), 1–30. https://doi.org/10.1016/0378-1127(92)90311-V

Hamilton, A. (2005). Resource assessment for sustainable harvesting of medicinal plants. *A Side-Event at the International Botanical Congress on Source to Shelf: Sustainable Supply Chain Management of Medicinal and Aromatic Plants, Vienna*, 21–22.

Hanazaki, N., Zank, S., Fonseca-Kruel, V. S., & Schmidt, I. B. (2018). Indigenous and traditional knowledge, sustainable harvest, and the long road ahead to reach the 2020 Global Strategy for Plant Conservation objectives. *Rodriguesia*, *69*, 1587–1601. https://doi.org/10.1590/2175-7860201869409

Hao, T., Elith, J., Lahoz-Monfort, J. J., & Guillera-Arroita, G. (2020). Testing whether ensemble modelling is advantageous for maximising predictive performance of species distribution models. *Ecography*, *43*(4), 549–558. https://doi.org/10.1111/ecog.04890

Haque, M. K., Azad, M. A. K., Hossain, M. Y., Ahmed, T., Uddin, M., & Hossain, M. M. (2021). Wildfire in Australia during 2019-2020, Its impact on health, biodiversity and environment with some proposals for risk management: a review. *Journal of Environmental Protection*, *12*(6), 391–414. https://doi.org/10.4236/jep.2021.126024

Harmand, S., Lewis, J. E., Feibel, C. S., Lepre, C. J., Prat, S., Lenoble, A., Boës, X., Quinn, R. L., Brenet, M., Arroyo, A., Taylor, N., Clément, S., Daver, G., Brugal, J. P., Leakey, L., Mortlock, R. A., Wright, J. D., Lokorodi, S., Kirwa, C., … Roche, H. (2015). 3.3-million-year-old stone tools from Lomekwi 3, West Turkana, Kenya. *Nature*. https://doi.org/10.1038/nature14464

Hart, G., Gaoue, O. G., de la Torre, L., Navarrete, H., Muriel, P., Mac\'\ia, M. J., Balslev, H., León-Yánez, S., Jørgensen, P., & Duffy, D. C. (2017). Availability, diversification and versatility explain human selection of introduced plants in Ecuadorian traditional medicine. *PloS One*, *12*(9), 1–16. https://doi.org/10.1371/journal.pone.0184369

Harumi, I. J., Fernandes, Â., Calhelha, R. C., Alves, M. J., Ferreira, F. D., Barros, L., Amaral, J. S., & Ferreira, I. C. F. R. (2019). Nutritional composition and bioactivity of Umbilicus rupestris (Salisb.)Dandy: An underexploited edible wild plant. *Food Chemistry*. https://doi.org/10.1016/j.foodchem.2019.05.139

Hazarika, T. K., & Pongener, M. (2018). Potential wild edible fruits of Nagaland, North-east India and its significance in the livelihood and nutritional security of rural, indigenous people. *Genetic Resources and Crop Evolution*, *65*(1). https://doi.org/10.1007/s10722-017-0523-3

Helixcn. (2017). *A curated list of R packages for species distribution modelling*. https://github.com/helixcn/sdm_r_packages

Henderson, E. B., Ohmann, J. L., Gregory, M. J., Roberts, H. M., & Zald, H. (2014). Species distribution modelling for plant communities: stacked single species or multivariate modelling approaches? *Applied Vegetation Science*, *17*(3), 516–527.

https://doi.org/10.1111/avsc.12085

Hengl, T., de Jesus, J., Heuvelink, G. B. M., Ruiperez Gonzalez, M., Kilibarda, M., Blagotić, A., Shangguan, W., Wright, M. N., Geng, X., Bauer-Marschallinger, B., & others. (2017). SoilGrids250m: Global gridded soil information based on machine learning. *PLoS One*, *12*(2), e0169748. https://doi.org/10.1371/journal.pone.0169748

Heywood, V. H. (1999). *Use and potential of wild plants in farm households* (No. 15). Food & Agriculture Organization.

Heywood, V. H. (2019). Conserving plants within and beyond protected areas – still problematic and future uncertain. *Plant Diversity*, *41*(2), 36–49. https://doi.org/10.1016/J.PLD.2018.10.001

Hickey, G. M., Pouliot, M., Smith-Hall, C., Wunder, S., & Nielsen, M. R. (2016). Quantifying the economic contribution of wild food harvests to rural livelihoods: A global-comparative analysis. *Food Policy*, *62*, 122–132. https://doi.org/10.1016/J.FOODPOL.2016.06.001

Hijmans, R. J. (2023). *raster: Geographic Data Analysis and Modeling*. https://cran.r-project.org/package=raster

Hodel, R. G. J., Soltis, D. E., & Soltis, P. S. (2022). Hindcast-validated species distribution models reveal future vulnerabilities of mangroves and salt marsh species. *Ecology and Evolution*, *12*(9), e9252. https://doi.org/10.1002/ece3.9252

Hossain, S. (2020). *Kenya's Community Health Volunteer Program*. CHWCentral. https://chwcentral.org/kenyas-community-health-volunteer-program/#:~:text=Kenya's community-based health workers,served by approximately 10 CHVs.

Hoveka, L. N., van der Bank, M., Bezeng, B. S., & Davies, T. J. (2020). Identifying biodiversity knowledge gaps for conserving South Africa's endemic flora. *Biodiversity and Conservation*, *29*, 2803–2819. https://doi.org/10.1007/s10531-020-01998-4

Hunter, D., Borelli, T., Beltrame, D. M. O., Oliveira, C. N. S., Coradin, L., Wasike, V. W., Wasilwa, L., Mwai, J., Manjella, A., Samarasinghe, G. W. L., Madhujith, T., Nadeeshani, H. V. H., Tan, A., Ay, S. T., Güzelsoy, N., Lauridsen, N., Gee, E., & Tartanac, F. (2019). The potential of neglected and underutilized species for improving diets and nutrition. In *Planta* (Vol. 250, Issue 3, pp. 709–729). Springer Verlag. https://doi.org/10.1007/s00425-019-03169-4

Imana, C. A., & Zenda, M. (2023). Impact of climate change on sustainable pastoral livelihoods in Loima Sub-County, Turkana County, Kenya. *South African Journal of Agricultural Extension*, *51*(1), 13–33. https://doi.org/10.17159/2413-3221/2023/v51n1a11367

IUCN. (2012). *IUCN-CMP Unified Classification of Direct Threats*. SSC/IUCN Gland & Cambridge. https://www.iucnredlist.org/resources/threat-classification-scheme (Accessed on 10th August 2020)

Jaetzold, R., & Schmidt, H. (1983). *Farm management handbook of Kenya. Volume II. Parts A, B and C. Ministry of Agriculture in Cooperation with German Agency for Technical Cooperation* (II).

Janvier, H., Muhizi, T., Ndayambaje, J. B., & Akenga, T. A. (2019). Nutritional value assessment of umufumba: A Rwandan wild edible plant Mondia whytei (Hook. F). *Food Science and Nutrition*. https://doi.org/10.1002/fsn3.796

Jarvie, S., & Svenning, J.-C. (2018). Using species distribution modelling to determine opportunities for trophic rewilding under future scenarios of climate change. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1761), 20170446. https://doi.org/10.1098/rstb.2017.0446

Jigme, J., & Yangchen, K. (2023). Ethnobotanical study of the wild edible plants used by the indigenous people of Merak in Bhutan. *Asian Journal of Ethnobiology*, *6*(1).

Jiménez-Valverde, A. (2012). Insights into the area under the receiver operating characteristic curve (AUC) as a discrimination measure in species distribution modelling. *Global Ecology and Biogeography*, *21*(4), 498–507. https://doi.org/10.1111/j.1466-8238.2011.00683.x

Joly, F. (2020). Conquering Deserts. In F. Joly & G. Bourrie (Eds.), *Mankind and Deserts 1: Deserts, Aridity, Exploration and Conquests* (pp. 11–64). Wiley Online Library. https://doi.org/10.1002/9781119801771.ch2

Joshi, S. K., Ballabh, B., Negi, P. S., & Dwivedi, S. K. (2018). Diversity, Distribution, Use Pattern and Evaluation of Wild Edible Plants of Uttarakhand, India. *Defence Life Science Journal*. https://doi.org/10.14429/dlsj.3.12579

Journé, V., Barnagaud, J.-Y., Bernard, C., Crochet, P.-A., & Morin, X. (2020). Correlative climatic niche models predict real and virtual species distributions equally well. *Ecology*, *101*(1), e02912. https://doi.org/10.1002/ecy.2912

Ju, Y., Zhuo, J., Liu, B., & Long, C. (2013). Eating from the wild: diversity of wild edible plants used by Tibetans in Shangri-la region, Yunnan, China. *Journal of Ethnobiology and Ethnomedicine*, *9*(1), 1–22.

Juma, R. O. (2009). *Turkana livelihood strategies and adaptation to drought in Kenya* [Victoria University of Wellington]. http://researcharchive.vuw.ac.nz/bitstream/handle/10063/1063/thesis.pdf?sequence=1

Kadu, C. A. C., Konrad, H., Schueler, S., Muluvi, G. M., Eyog-Matig, O., Muchugi, A., Williams, V. L., Ramamonjisoa, L., Kapinga, C., Foahom, B., & others. (2013). Divergent pattern of nuclear genetic diversity across the range of the Afromontane Prunus africana mirrors variable climate of African highlands. *Annals of Botany*, *111*(1), 47–60. https://doi.org/10.1093/aob/mcs235

Kalisa, W., Igbawua, T., Henchiri, M., Ali, S., Zhang, S., Bai, Y., & Zhang, J. (2019). Assessment of climate impact on vegetation dynamics over East Africa from 1982 to 2015. *Scientific Reports*, *9*(1), 16865. https://doi.org/10.1038/s41598-019-53150-0

Kalisz, S., Kivlin, S. N., & Bialic-Murphy, L. (2021). Allelopathy is pervasive in invasive plants. *Biological Invasions*, *23*, 367–371. https://doi.org/10.1007/s10530-020-02383-6

Kallas, J. (2010). *Edible Wild Plants: Wild Foods From Dirt to Plate* (p. 416). http://books.google.com/books?hl=en&lr=&id=Q-AZur2fNUwC&oi=fnd&pg=PA7&dq=Edible+Wild+Plants:+Wild+Foods+From+Dirt+To+Plate&ots=yFSI2rCo3F&sig=77zE5VY4jcg68_cMfnnUHt-8F5I

Karger, D. N., Conrad, O., Böhner, J., Kawohl, T., Kreft, H., Soria-Auza, R. W., Zimmermann, N. E., Linder, P., & Kessler, M. (2019). Climatologies at high resolution for the Earth land surface areas. *Scientific Data*, *4*(170122). https://doi.org/10.1038/sdata.2017.122

Kariuki, J. G., Machua, J. M., Luvanda, A. M., & Kigomo, J. N. (2008). *Baseline survey of woodland utilization and degradation around Kakuma efugee camp*.

Kass, J. M., Muscarella, R., Galante, P. J., Bohl, C. L., Pinilla-Buitrago, G. E., Boria, R. A., Soley-Guardia, M., & Anderson, R. P. (2021). ENMeval 2.0: Redesigned for customizable and reproducible modeling of species' niches and distributions. *Methods in Ecology and Evolution*, *12*(9), 1602–1608. https://doi.org/10.1111/2041-210X.13628

Kastellec, J. P., & Leoni, E. L. (2007). Using graphs instead of tables in political science. *Perspectives on Politics*, *5*(4), 755–771. https://doi.org/10.1017/S1537592707072209

Kato-Noguchi, H. (2022). Allelopathy and allelochemicals of Imperata cylindrica as an invasive plant species. *Plants*, *11*(19), 2551. https://doi.org/10.3390/plants11192551

Kato-Noguchi, H., & Kurniadie, D. (2021). Allelopathy of Lantana camara as an invasive plant. *Plants*, *10*(5), 1028. https://doi.org/10.3390/plants10051028

Katoch, R., & Katoch, R. (2020). Prospects of Underutilized Crops in Combating Poverty, Malnutrition, and Hunger. In *Ricebean*. https://doi.org/10.1007/978-981-15-5293-9_3

Kebede, A., Tesfaye, W., Fentie, M., & Zewide, H. (2017). An ethnobotanical survey of wild edible plants commercialized in Kefira Market, Dire Dawa City, eastern Ethiopia. *Plant*, *5*(2), 42–46.

Kenya Population and Housing. (2019). 2019 Kenya Population and Housing Census. In *Republic of Kenya*.

Kenya Soil Survey. (1980). *Information Base for the Exploratory Soil Map and Agro-Climatic Zone Map of Kenya. Appendix 4 to Report no. E1*. https://esdac.jrc.ec.europa.eu/content/information-base-exploratory-soil-map-and-agro-climatic-zone-map-kenya-appendix-4-report-no

KER. (2020). *Kenya Economic Report 2020: Creating an Enabling Environment for Inclusive Growth in Kenya*. https://kippra.or.ke/index.php/publications?task=download.send&id=226&catid=4&m=0

KER. (2021). *Kenya Economic Report 2021: Kenya in COVID-19 Era: Fast-Tracking Recovery and Delivery of the "Big Four" Agenda*. https://kippra.or.ke/download/kenya-economic-report-2021/?wpdmdl=10678&ind=1645175207803

Khoury, C. K., Amariles, D., Soto, J. S., Diaz, M. V., Sotelo, S., Sosa, C. C., Ramírez-Villegas, J., Achicanoy, H. A., Velásquez-Tibatá, J., Guarino, L., León, B., Navarro-Racines, C., Castañeda-Álvarez, N. P., Dempewolf, H., Wiersema, J. H., & Jarvis, A. (2019). Comprehensiveness of conservation of useful wild plants: An operational indicator for biodiversity and sustainable development targets. *Ecological Indicators*. https://doi.org/10.1016/j.ecolind.2018.11.016

Khoury, C. K., Bjorkman, A. D., Dempewolf, H., Ramirez-Villegas, J., Guarino, L., Jarvis, A., Rieseberg, L. H., & Struik, P. C. (2014). Increasing homogeneity in global food supplies and the implications for food security. *Proceedings of the National Academy of Sciences*, *111*(11), 4001–4006.

Kidane, B., van der Maesen, L. J. G., Asfaw, Z., Sosef, M. S. M., & van Andel, T. (2015). Wild and semi-wild leafy vegetables used by the Maale and Ari ethnic communities in southern Ethiopia. *Genetic Resources and Crop Evolution*, *62*(2), 221–234. https://doi.org/10.1007/s10722-014-0147-9

Kidane, L., & Kejela, A. (2021). Food security and environment conservation through sustainable use of wild and semi-wild edible plants: a case study in Berek Natural Forest, Oromia special zone, Ethiopia. *Agriculture & Food Security*, *10*(1), 1–16. https://doi.org/10.1186/s40066-021-00308-7

Kidane, Y. O., Stahlmann, R., & Beierkuhnlein, C. (2012). Vegetation dynamics, and land use and land cover change in the Bale Mountains, Ethiopia. *Environmental Monitoring and Assessment*. https://doi.org/10.1007/s10661-011-2514-8

Kidane, Y. O., Steinbauer, M. J., & Beierkuhnlein, C. (2019). Dead end for endemic plant species? A biodiversity hotspot under pressure. *Global Ecology and Conservation*, *19*, e00670. https://doi.org/10.1016/j.gecco.2019.e00670

Kideghesho, J. R. (2009). The potentials of traditional African cultural practices in mitigating overexploitation of wildlife species and habitat loss: experience of Tanzania. *International Journal of Biodiversity Science & Management*, *5*(2), 83–94. https://doi.org/10.1080/17451590903065579

Kihu, S. M., Gitao, G. C., Bebora, L. C., John, N. M., Wairire, G. G., Maingi, N., & Wahome, R. G. (2015). Economic losses associated with Peste des petits ruminants in Turkana County Kenya. *Pastoralism*, *5*(1), 1–8. https://doi.org/10.1186/s13570-015-0029-6

King, F. B. (1994). Interpreting wild food plants in archaeological record. In *Eating on the wild side*.

Kiran, K. C., Dhanush, C., Gajendra, C. V, & Reddy, B. M. (2019). Diversity and Seasonal Availability of Potential Wild Edible Plants from Vidarbha Region of Maharashtra State, India. *International Journal of Current Microbiology and Applied Sciences*, *8*(2), 2019. https://doi.org/10.20546/ijcmas.2019.802.xx

KNBS. (2019). *Kenya Population and Housing Census (Volume III)*.

Korobe, B. L. (2022). Comparative Analysis of the Turkana Ethnoecological Calendar and Gregorian Dating System: Prospects and Potential for History and Ethnographic Preservation. *Journal of African Interdisciplinary Studies*, *6*(7), 89–117.

Kruschke, J. K. (2010). What to believe: Bayesian methods for data analysis. *Trends in Cognitive Sciences*, *14*(7), 293–300. https://doi.org/10.1016/j.tics.2010.05.001

Kruschke, J. K., Aguinis, H., & Joo, H. (2012). The time has come: Bayesian methods for data analysis in the organizational sciences. *Organizational Research Methods*, *15*(4), 722–752. https://doi.org/10.1177/1094428112457829

Kujawska, M., & Łuczaj, Ł. (2015). Wild edible plants used by the Polish community in Misiones, Argentina. *Human Ecology*, *43*, 855–869. https://doi.org/10.1007/s10745-015-9790-9

Kuper, H., Nyapera, V., Evans, J., Munyendo, D., Zuurmond, M., Frison, S., Mwenda, V., Otieno, D., & Kisia, J. (2015). Malnutrition and Childhood Disability in Turkana, Kenya: Results from a Case-Control Study. *PLoS ONE*, *10*(12), 1–13. https://doi.org/10.1371/journal.pone.0144926

Lachat, C., Raneri, J. E., Smith, K. W., Kolsteren, P., Van Damme, P., Verzelen, K., Penafiel, D., Vanhove, W., Kennedy, G., Hunter, D., & others. (2018). Dietary species richness as a measure of food biodiversity and nutritional quality of diets. *Proceedings of the National Academy of Sciences*, *115*(1), 127–132. https://doi.org/10.1073/pnas.1709194115

Ladio, A. H., & Lozada, M. (2004). Summer Cattle Transhumance and Wild Edible Plant Gathering in a Mapuche Community of Northwestern Patagonia. *Human Ecology*, *32*(2), 225–240. https://doi.org/10.1023/B:HUEC.0000019764.62185.99

Le Page, M. (2021). How climate change hits nature. *New Scientist*, *250*(3329), 41–45. https://doi.org/10.1016/S0262-4079(21)00615-1

Li, F., Zhuo, J., Liu, B., Jarvis, D., & Long, C. (2015). Ethnobotanical study on wild plants used by Lhoba people in Milin County, Tibet. *Journal of Ethnobiology and Ethnomedicine*. https://doi.org/10.1186/s13002-015-0009-3

Li, H., Tian, Y., Menolli Jr, N., Ye, L., Karunarathna, S. C., Perez-Moreno, J., Rahman, M. M., Rashid,

M. H., Phengsintham, P., Rizal, L., & others. (2021). Reviewing the world's edible mushroom species: A new evidence-based classification system. *Comprehensive Reviews in Food Science and Food Safety*, *20*(2), 1982–2014. https://doi.org/10.1111/1541-4337.12708

Linders, T. E. W., Schaffner, U., Eschen, R., Abebe, A., Choge, S. K., Nigatu, L., Mbaabu, P. R., Shiferaw, H., & Allan, E. (2019). Direct and indirect effects of invasive species: Biodiversity loss is a major mechanism by which an invasive tree affects ecosystem functioning. *Journal of Ecology*, *107*(6), 2660–2672. https://doi.org/10.1111/1365-2745.13268

Lissovsky, A. A., & Dudov, S. V. (2021). Species-distribution modeling: advantages and limitations of its application. 2. MaxEnt. *Biology Bulletin Reviews*, *11*(3), 265–275. https://doi.org/10.1134/S2079086421030087

Liu, J., Coomes, D. A., Gibson, L., Hu, G., Liu, J., Luo, Y., Wu, C., & Yu, M. (2019). Forest fragmentation in China and its effect on biodiversity. *Biological Reviews*, *94*(5), 1636–1657. https://doi.org/10.1111/brv.12519

Logan, A. L. (2015). Archaeology of African plant use. *Azania: Archaeological Research in Africa*. https://doi.org/10.1080/0067270x.2014.977538

Lojock, L. J. (2021). *Resource mobilization strategies and sustainable livelihoods among the pastoral communities in Turkana, Kenya*. Moi Univesity.

Lokuruka, M. (2008). Fatty acids in the nut of the Turkana Doum Palm (Hyphaene Coriacea). *African Journal of Food, Agriculture, Nutrition and Development*, *8*(2), 118–132.

Luczaj, L., Pieroni, A., Tard\'\io, J., Pardo-de-Santayana, M., Sõukand, R., Svanberg, I., & Kalle, R. (2012). Wild food plant use in 21 st century Europe, the disapperance of old traditions and the search for new ciusines involving wild edibles. *Acta Societatis Botanicorum Poloniae*, *81*(4). https://doi.org/10.5586/asbp.2012.031

Ma'Ayergi, H. A., Ismail, S. I., Batanouny, K. H., & Rizik, A. M. (1984). Ecological and phytochemical studies on the "Miswak", Salvadora persica l. *Qatar Univ. Sci. Bull.*, *4*, 37–44.

Mabhaudhi, T., Chibarabada, T. P., Chimonyo, V. G. P., Murugani, V. G., Pereira, L. M., Sobratee, N., Govender, L., Slotow, R., & Modi, A. T. (2018). Mainstreaming underutilized indigenous and traditional crops into food systems: A South African perspective. In *Sustainability (Switzerland)* (Vol. 11, Issue 1). https://doi.org/10.3390/su11010172

Mabhaudhi, T., Chimonyo, V. G. P., Hlahla, S., Massawe, F., Mayes, S., Nhamo, L., & Modi, A. T. (2019). Prospects of orphan crops in climate change. *Planta*, *250*(3), 695–708. https://doi.org/10.1007/s00425-019-03129-y

Manzoor, S. A., Griffiths, G., & Lukac, M. (2018). Species distribution model transferability and model grain size--finer may not always be better. *Scientific Reports*, *8*(1), 7168. https://doi.org/10.1038/s41598-018-25437-1

Márcia Barbosa, A., Real, R., Muñoz, A.-R., & Brown, J. A. (2013). New measures for assessing model equilibrium and prediction mismatch in species distribution models. *Diversity and Distributions*, *19*(10), 1333–1338. https://doi.org/10.1111/ddi.12100

Mariani, M., Fletcher, M.-S., Haberle, S., Chin, H., Zawadzki, A., & Jacobsen, G. (2019). Climate change reduces resilience to fire in subalpine rainforests. *Global Change Biology*, *25*(6), 2030–2042. https://doi.org/10.1111/gcb.14609

Maroyi, A., & Cheikhyoussef, A. (2017). Traditional knowledge of wild edible fruits in southern Africa: A comparative use patterns in Namibia and Zimbabwe. *Indian Journal of Traditional Knowledge*.

Marpa, S., Samant, S. S., Tewari, A., & Paul, S. (2020). Diversity and indigenous uses of plants in Naina Devi Sacred Shrine Rewalsar, Himachal Pradesh, North Western Himalaya, India. *Int J Chem Stud*, *8*(2), 1265–1276. https://doi.org/10.22271/chemi.2020.v8.i2s.8939

Martin, G. J. (1995). *Ethnobotany: a methods manual* (First). Chapman and Hall.

Martin, G. J. (2010). *Ethnobotany: a methods manual (people and plants conservation series)*. Earthscan Publications.

Maruthadurai, R., Das, B., & Ramesh, R. (2023). Predicting the invasion risk of rugose spiraling whitefly, Aleurodicus rugioperculatus, in India based on CMIP6 projections by MaxEnt. *Pest Management Science*, *79*(1), 295–305. https://doi.org/10.1002/ps.7199

Masters, E. T. (2021). Traditional food plants of the upper Aswa River catchment of northern Uganda—a cultural crossroads. *Journal of Ethnobiology and Ethnomedicine*, *17*(1), 1–21.

Matsuura, T., Sugimura, K., Miyamoto, A., Tanaka, H., & Tanaka, N. (2014). Spatial characteristics of edible wild fern harvesting in mountainous villages in Northeastern Japan using GPS tracks. *Forests*, *5*(2), 269–286. https://doi.org/10.3390/f5020269

Maundu, P. M., Kibet, S., Morimoto, Y., Imbumi, M., & Adeka, R. (2009). Impact of Prosopis juliflora on Kenya's semi-arid and arid ecosystems and local livelihoods. *Biodiversity*, *10*(2–3), 33–50. https://doi.org/10.1080/14888386.2009.9712842

Maundu, P. M., Ngugi, W. G., & Kabuye, H. S. C. (1999). *Traditional Food Plants of Kenya*. National Museums of Kenya.

Mbogori, T., & Murimi, M. (2017). Determinants of maternal and child malnutrition among low income households in Turkana County, Kenya. *The FASEB Journal*, *31*, 754–786. https://doi.org/10.1096/fasebj.31.1_supplement.786.54

Mbugua, J., Touge, Y., & Kazama, S. (2020). Basin Scale Analysis of Land Surface Hydrological Processes for Water Management in the Lake Turkana Basin. *AGU Fall Meeting Abstracts*, *2020*, 1.

McCluskey, E. M., Lulla, V., Peterman, W. E., Stryszowska-Hill, K. M., Denton, R. D., Fries, A. C., Langen, T. A., Johnson, G., Mockford, S. W., & Gonser, R. A. (2022). Linking genetic structure, landscape genetics, and species distribution modeling for regional conservation of a threatened freshwater turtle. *Landscape Ecology*, *37*(4), 1017–1034. https://doi.org/10.1007/s10980-022-01420-0

Messina, J. P., Brady, O. J., Golding, N., Kraemer, M. U. G., Wint, G. R. W., Ray, S. E., Pigott, D. M., Shearer, F. M., Johnson, K., Earl, L., & others. (2019). The current and future global distribution and population at risk of dengue. *Nature Microbiology*, *4*(9), 1508–1515. https://doi.org/10.1038/s41564-019-0476-8

Midgley, G. F., & Thuiller, W. (2007). Potential vulnerability of Namaqualand plant diversity to anthropogenic climate change. *Journal of Arid Environments*, *70*(4), 615–628. https://doi.org/10.1016/j.jaridenv.2006.11.020

Mishra, A., Laxmana Swamy, S., Thakur, T. K., Bhat, R., Bijalwan, A., Kumar, A., & Vinson, J. (2021). Use of Wild Edible Plants: Can They Meet the Dietary and Nutritional Needs of Indigenous Communities in Central India. *Foods*, *10*(7), 1–22. https://doi.org/10.3390/foods10071453

Mkala, E. M., Mutinda, E. S., Wanga, V. O., Oulo, M. A., Oluoch, W. A., Waswa, E. N., Odago, W., Nanjala, C., Mwachala, G., Hu, G.-W., & others. (2022). Modeling impacts of climate change on the potential distribution of three endemic Aloe species critically endangered in East Africa. *Ecological Informatics*, *71*, 101765. https://doi.org/10.1016/j.ecoinf.2022.101765

Mkutu, K., Mkutu, T., Marani, M., & Ekitela, A. L. (2019). New Oil Developments in a Remote Area: Environmental Justice and Participation in Turkana, Kenya. *Journal of Environment and Development*. https://doi.org/10.1177/1070496519857776

Mo, J., & Polly, P. D. (2022). The role of dispersal, selection intensity, and extirpation risk in resilience to climate change: A trait-based modelling approach. *Global Ecology and Biogeography*, *31*(6), 1184–1193. https://doi.org/10.1111/geb.13495

Mohammadi, K. A., Mousavi, S. A., Soltani Koupaei, S., & Kiani, G. H. (2023). Analysis of externality costs of livestock grazing enterprise in semi-arid rangelands. *Environment, Development and Sustainability*, 1–20. https://doi.org/10.1007/s10668-023-03106-2

Mokganya, M. G., & Tshisikhawe, M. P. (2019). Medicinal uses of selected wild edible vegetables consumed by Vhavenda of the Vhembe District Municipality, South Africa. *South African Journal of Botany*. https://doi.org/10.1016/j.sajb.2018.09.029

Moradi, M., Jorfi, M. R., Basiri, R., Yusef Naanaei, S., & Heydari, M. (2022). Beneficial effects of livestock exclusion on tree regeneration, understory plant diversity, and soil properties in semiarid forests in Iran. *Land Degradation \& Development*, *33*(2), 324–332. https://doi.org/10.1002/ldr.4154

Morgan, D. L. (1996). *Focus groups as qualitative research* (Vol. 16). Sage publications.

Morgan, W. T. W. (1981). Ethnobotany of the Turkana: Use of plants by a pastoral people and their livestock in Kenya. *Economic Botany*, *35*(1), 96–130. https://doi.org/10.1007/BF02859220

Msoffe, F. U., Ogutu, J. O., Said, M. Y., Kifugo, S. C., de Leeuw, J., Van Gardingen, P., Reid, R. S., Stabach, J. A., & Boone, R. B. (2019). Wildebeest migration in East Africa: Status, threats and conservation measures. *BioRxiv*, 546747. https://doi.org/10.1101/546747

Muhammad, A. A., Abbasi, A. M., Ullah, Z., & Pieroni, A. (2020). Shared but threatened: The heritage of wild food plant gathering among different linguistic and religious groups in the Ishkoman and Yasin Valleys, North Pakistan. *Foods*, *9*(5), 601. https://doi.org/10.3390/foods9050601

Mullins, D., & Wambayi, J. (2017). *Testing community Consent: Tullow oil project in Kenya*.

Mwangi, E., Swallow, B., & others. (2005). Invasion of Prosopis juliflora and local livelihoods: Case study from the lake Baringo area of Kenya. In *Nairobi, Kenya: World Agroforestry Centre* (Vol. 22). https://hdl.handle.net/10535/4277

N'Danikou, S., Achigan-Dako, E. G., & Wong, J. L. G. (2011). Eliciting Local Values of Wild Edible Plants in Southern Bénin to Identify Priority Species for Conservation1. *Economic Botany*, *65*(4), 381–395. https://doi.org/10.1007/s12231-011-9178-8

Nadio, E. C., Agevi, H., & Obiri, J. (2020). *Impacts of Prosopis juliflora on Abundance and Species Diversity of Forage Species in Turkana County, Kenya*.

Naimi, B., Ham, A. S. N., Groen, T. A., Skidmore, A. K., & Toxopeus, A. G. (2015). Where is positional uncertainty a problem for species distribution modeling. *Ecograph*, *37*, 191–203. https://doi.org/10.1111/j.1600-0587.2013.00205.x

Najma, D. (2011). *Field guide to common trees and shrubs of East Africa*. Hirt and Cartner Cape Ltd.

Ng'asike, J. T. (2019). Indigenous knowledge practices for sustainable lifelong education in pastoralist communities of Kenya. *International Review of Education*, *65*, 19–46. https://doi.org/10.1007/s11159-019-09767-4

Ng'asike, J. T., & Blue Swadener, B. (2015). Turkana indigenous knowledge: Environmental sustainability and pastoralist lifestyle for economic survival. In *Indigenous Innovation: Universalities and Peculiarities*. https://doi.org/10.1007/978-94-6300-226-4_7

Ng, W.-T., Immitzer, M., Floriansitz, M., Vuolo, F., Luminari, L., Adede, C., Wahome, R., & Atzberger, C. (2016). Mapping Prosopis spp. within the Tarach water basin, Turkana, Kenya using Sentinel-2 imagery. *Remote Sensing for Agriculture, Ecosystems, and Hydrology XVIII*, *9998*, 99980L.

Ngome, P. I. T., Shackleton, C., Degrande, A., Tieguhong, J. C., Tata Ngome, P. I., Shackleton, C., Degrande, A., & Tieguhong, J. C. (2017). Addressing constraints in promoting wild edible plants' utilization in household nutrition: Case of the Congo Basin forest area. *Agriculture and Food Security*, *6*(1), 1–10. https://doi.org/10.1186/s40066-017-0097-5

Ngoye, B. O., Saado, H., & Gachari, C. W. (2021). Who could have seen this coming? The Kenya red cross society and the drought appeal of 2019. *Emerald Emerging Markets Case Studies*, *11*(2), 1–20. https://doi.org/10.1108/EEMCS-03-2020-0069

Nicholson, S. E. (2017). Climate and climatic variability of rainfall over eastern Africa. *Reviews of Geophysics*, *55*(3), 590–635. https://doi.org/10.1002/2016RG000544

Njeri, B. S. (2020). *Effect Of Cross-border Ethnic Conflicts On Social Economic Security Of Pastoralist Living Along Kenya-uganda Border: A Case Of Turkana Community 2000-2018*. University of Nairobi.

Nkem, J., Kalame, F. B., Idinoba, M., Somorin, O. A., Ndoye, O., & Awono, A. (2010). Shaping forest safety nets with markets: Adaptation to climate change under changing roles of tropical forests in Congo Basin. *Environmental Science & Policy*, *13*(6), 498–508. https://doi.org/10.1016/J.ENVSCI.2010.06.004

Nyabuto, B. K. (2017). *Conflict And Environmental Security Among The Pastoral Communities In Northern Kenya: The Case Study Of Turkana*. United States International University-Africa.

Nyumba, O. T., Wilson, K., Derrick, C. J., & Mukherjee, N. (2018). The use of focus group discussion methodology: Insights from two decades of application in conservation. *Methods in Ecology and Evolution*, *9*(1), 20–32. https://doi.org/10.1111/2041-210X.12860

O'Neill, B. C., Kriegler, E., Ebi, K. L., Kemp-Benedict, E., Riahi, K., Rothman, D. S., Van Ruijven, B. J., Van Vuuren, D. P., Birkmann, J., Kok, K., & others. (2017). The roads ahead: Narratives for shared socioeconomic pathways describing world futures in the 21st century. *Global Environmental Change*, *42*, 169–180. https://doi.org/10.1016/j.gloenvcha.2015.01.004

O'Neill, B. C., Kriegler, E., Riahi, K., Ebi, K. L., Hallegatte, S., Carter, T. R., Mathur, R., & Van Vuuren, D. P. (2014). A new scenario framework for climate change research: the concept of shared socioeconomic pathways. *Climatic Change*, *122*, 387–400. https://doi.org/10.1007/s10584-013-0905-2

Obongo, J. O. (2018). *The influence of oil exploration on the livelihoods of the Turkana community: A study of Tullow Oil Company in Lokichar Location of Turkana South Sub-County* [University of Nairobi]. http://erepository.uonbi.ac.ke/handle/11295/105011

Ochoa, J. J., & Ladio, A. H. (2014). Ethnoecology of Oxalis adenophylla Gillies ex Hook. & Arn. *Journal of Ethnopharmacology*, *155*(1), 533–542. https://doi.org/10.1016/j.jep.2014.05.058

Odero, F. O. (2015). *Challenges of foreign direct investment within Turkana county, Kenya*.

University of Nairobi.

Oduor, F. O., Kaindi, D. W. M., Abong, G. O., Thuita, F., & Termote, C. (2023). Diversity and utilization of indigenous wild edible plants and their contribution to food security in Turkana County, Kenya. *Frontiers in Sustainable Food Systems*, *7*(1113771), 14. https://doi.org/10.3389/fsufs.2023.1113771

Ogle, B. M., Tuyet, H. T., Duyet, H. N., & Dung, N. N. X. (2003). Food, feed or medicine: The multiple functions of edible wild plants in Vietnam. *Economic Botany*, *57*, 103–117. https://doi.org/10.1663/0013-0001(2003)057[0103:FFOMTM]2.0.CO;2

Ojeda, F. (2020). Pine afforestation, herriza and wildfire: a tale of soil erosion and biodiversity loss in the Mediterranean region1. *International Journal of Wildland Fire*, *29*(12), 1142–1146. https://doi.org/10.1071/WF20097

Ojelel, S., Mucunguzi, P., Katuura, E., Kakudidi, E. K., Namaganda, M., & Kalema, J. (2019). Wild edible plants used by communities in and around selected forest reserves of Teso-Karamoja region, Uganda. *Journal of Ethnobiology and Ethnomedicine*, *15*(1), 1–14. https://doi.org/10.1186/s13002-018-0278-8

Olsson, A., Lundqvist, M., Faxelid, E., & Nissen, E. (2005). Women's thoughts about sexual life after childbirth: focus group discussions with women after childbirth. *Scandinavian Journal of Caring Sciences*, *19*(4), 381–387. https://doi.org/10.1111/j.1471-6712.2005.00357.x

Oluoch, W. A., Whitney, C., Termote, C., Borgemeister, C., & Schmitt, C. B. (2023). Indigenous communities' perceptions reveal threats and management options of wild edible plants in semiarid lands of northwestern Kenya. *Journal of Ethnobiology and Ethnomedicine*, *19*(1), 13. https://doi.org/10.1186/s13002-023-00584-6

Oluoch, W. A., Whitney, C. W., Termote, C., Borgemeister, C., & Schmitt, C. B. (2022). Integrated participatory approach reveals perceived local availability of wild edible plants in northwestern Kenya. *Human Ecology*, 16. https://doi.org/10.1007/s10745-022-00370-0

Omire, A., Budambula, N. L. M., Neondo, J., Gituru, R., & Mweu, C. (2020). Phenotypic Diversity of Doum Palm (Hyphaene compressa), a Semi-Domesticated Palm in the Arid and Semi-Arid Regions of Kenya. *Scientifica*, *2020*, 1–13. https://doi.org/10.1155/2020/4920830

Omire, A., Neondo, J. O., Budambula, N., Gituru, R., & Mweu, C. (2020). Hyphaene compressa, an important palm in the arid and semi-arid regions of Kenya. *Ethnobotany Research and Applications*, *20*(4). https://doi.org/10.32859/era.20.4.1-15

Omolo, N. A. (2010). Gender and climate change-induced conflict in pastoral communities: Case study of Turkana in northwestern Kenya. *African Journal on Conflict Resolution*, *10*(2). https://doi.org/10.4314/ajcr.v10i2.63312

OpenStreetMap contributors. (2017). *Planet dump retrieved from https://planet.osm.org* .

Opiyo, F., Wasonga, O., Nyangito, M., Schilling, J., & Munang, R. (2015). Drought Adaptation and Coping Strategies Among the Turkana Pastoralists of Northern Kenya. *International Journal of Disaster Risk Science*, *6*, 295–309. https://doi.org/10.1007/s13753-015-0063-4

Otieno, J. R. (2016a). Live hood Strategies in North-Western Kenya: A Study of Turkana People's Customary Response to Famine. *International Journal of Science and Research*, *5*(11), 1357–1361. https://doi.org/10.21275/ART20162920

Otieno, J. R. (2016b). Role of Livelihood Platform in Adaptation and Poverty Alleviation Case Study of Turkana District, Kenya. *International Journal of Advances in Social Science and Humanities*, *04*(12). http://www.ijassh.com/index.php/IJASSH/article/view/261

Otieno, J. R. (2020). Drought impact evaluation and perception model: a systems approach in Turkana County, Kenya. *Journal Of Humanities And Social Science*, *25*(1), 8. https://doi.org/10.9790/0837-2501083542

Ouma, C., Obando, J., & Koech, M. (2012). Post Drought recovery strategies among the Turkana pastoralists in Northern Kenya. *Scholarly Journals of Biotechnology*, *1*(5), 90–100.

Ouma, D. O. (2017). *Assessing the Factors Influencing Food and Livelihood Security Among Pastoral Communities in Turkana County, Kenya*. University of Nairobi.

Owino, J. O., Kemboi, J., & Muturi, G. M. (2021). Rangeland rehabilitation using micro-catchments and native species in Turkana County, Kenya. *Journal of Ecology and The Natural Environment*, *13*(2), 30–40. https://doi.org/10.5897/JENE2020.0833

Palmer, P. I., Wainwright, C. M., Dong, B., Maidment, R. I., Wheeler, K. G., Gedney, N., Hickman, J. E., Madani, N., Folwell, S. S., Abdo, G., & others. (2023). Drivers and impacts of Eastern African rainfall variability. *Nature Reviews Earth & Environment*, *4*(4), 254–270. https://doi.org/10.1038/s43017-023-00397-x

Pant, S., & Pant, V. S. (2011). Status and conservation management strategies for threatened plants of Jammu and Kashmir. *Journal of Phytology*, *3*(7), 50–56.

Paumgarten, F., Locatelli, B., & Witkowski, E. T. F. (2018). Wild Foods: Safety Net or Poverty Trap? A South African Case Study. *Human Ecology*, *46*(2), 183–195. https://doi.org/10.1007/s10745-018-9984-z

Pausas, J. G., & Keeley, J. E. (2019). Wildfires as an ecosystem service. *Frontiers in Ecology and the Environment*, *17*(5), 289–295. https://doi.org/10.1002/fee.2044

Pawera, L., Khomsan, A., Zuhud, E. A. M., Hunter, D., Ickowitz, A., & Polesny, Z. (2020). Wild food plants and trends in their use: From knowledge and perceptions to drivers of change in West Sumatra, Indonesia. *Foods*, *9*(9), 22. https://doi.org/10.3390/foods9091240

Pebesma, E., & Bivand, R. (2023). *Spatial Data Science with R*. CRC Press: Boca Raton, FL, USA.

Peduruhewa, P., Jayathunge, L., & Liyanage, R. (2021). Potential of Underutilized Wild Edible Plants as the Food for the Future – A Review. *Journal of Food Security*, *9*, 136–147. https://doi.org/10.12691/jfs-9-4-1

Peeters, L. E. A., & Maxwell, D. G. (2011). Characteristics and strategies favouring sustained food access during Guinea's food-price crisis. *Development in Practice*, *21*(4–5), 613–628. https://doi.org/10.1080/09614524.2011.561285

Pellissier, L., Anne Bråthen, K., Pottier, J., Randin, C. F., Vittoz, P., Dubuis, A., Yoccoz, N. G., Alm, T., Zimmermann, N. E., & Guisan, A. (2010). Species distribution models reveal apparent competitive and facilitative effects of a dominant species on the distribution of tundra plants. *Ecography*, *33*(6), 1004–1014. https://doi.org/10.1111/j.1600-0587.2010.06386.x

Peng, W., Ma, N. L., Zhang, D., Zhou, Q., Yue, X., Khoo, S. C., Yang, H., Guan, R., Chen, H., Zhang, X., & others. (2020). A review of historical and recent locust outbreaks: Links to global warming, food security and mitigation strategies. *Environmental Research*, *191*, 110046. https://doi.org/10.1016/j.envres.2020.110046

Petanidou, T., Kallimanis, A. S., Lazarina, M., Tscheulin, T., Devalez, J., Stefanaki, A., Hanlidou, E., Vujić, A., Kaloveloni, A., & Sgardelis, S. P. (2018). Climate drives plant--pollinator interactions even along small-scale climate gradients: the case of the Aegean. *Plant Biology*, *20*, 176–183. https://doi.org/10.1111/plb.12593

Peterson, A. T., Soberón, J., Pearson, R. G., Anderson, R. P., Martínez-Meyer, E., Nakamura, M., Araújo, M. B., Mart'inez-Meyer, E., Nakamura, M., Araújo, M. B., Peterson, A. T., Soberón, J., Pearson, R. G., Anderson, R. P., Martínez-Meyer, E., Nakamura, M., & Araújo, M. B. (2011). *Ecological Niches and Geographic Distributions*. Princeton University Press.

Petitpierre, B., Broennimann, O., Kueffer, C., Daehler, C., & Guisan, A. (2017). Selecting predictors to maximize the transferability of species distribution models: Lessons from cross-continental plant invasions. *Global Ecology and Biogeography*, *26*(3), 275–287. https://doi.org/10.1111/geb.12530

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological Modelling*, *190*(3–4), 231–259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Pienkowski, T., Cook, C., Megha Verma, |, Luis, |, & Carrasco, R. (2021). *Conservation cost-effectiveness: a review of the evidence base*. https://doi.org/10.1111/csp2.357

Plesse, M. (2020). *Global Food and Water Security in 2050: Demographic Change and Increased Demand*. Future Directions International.

Pontes-Lopes, A., Silva, C. V. J., Barlow, J., Rincón, L. M., Campanharo, W. A., Nunes, C. A., de Almeida, C. T., Silva Júnior, C. H. L., Cassol, H. L. G., Dalagnol, R., & others. (2021). Drought-driven wildfire impacts on structure and dynamics in a wet Central Amazonian forest.

Proceedings of the Royal Society B, *288*(1951), 20210094. https://doi.org/10.1098/rspb.2021.0094

Porcher, V., Carrière, S. M., Gallois, S., Randriambanona, H., Rafidison, V. M., & Reyes-García, V. (2022). Growing up in the Betsileo landscape: Children's wild edible plants knowledge in Madagascar. *PLoS ONE*, *17*(2 February). https://doi.org/10.1371/JOURNAL.PONE.0264147

Powell, B., Bhatt, I. D., Mucioki, M., Rana, S., Rawat, S., & Kerr, R. B. (2023). The need to include wild foods in climate change adaptation strategies. *Current Opinion in Environmental Sustainability*, *63*, 101302. https://doi.org/10.1016/j.cosust.2023.101302

Powell, B., Maundu, P., Kuhnlein, H. V., & Johns, T. (2013). Wild Foods from Farm and Forest in the East Usambara Mountains, Tanzania. *Ecology of Food and Nutrition*, *52*(6), 451–478. https://doi.org/10.1080/03670244.2013.768122

Powers, R. P., & Jetz, W. (2019). Global habitat loss and extinction risk of terrestrial vertebrates under future land-use-change scenarios. *Nature Climate Change*, *9*(4), 323–329. https://doi.org/10.1038/s41558-019-0406-z

POWO. (2022). *Plants of the World Online*. Facilitated by the Royal Botanic Gardens, Kew. http://www.plantsoftheworldonline.org/

Pratt, C. J., Denley, D., & Metaxas, A. (2022). Selection of predictor variables for species distribution models: a case study with an invasive marine bryozoan. *Oecologia*, *198*(2), 319–336. https://doi.org/10.1007/s00442-022-05110-1

QGIS Development Team. (2023). QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org. In *Qgisorg* (3.30.0).

Qu, T., Du, X., Peng, Y., Guo, W., Zhao, C., & Losapio, G. (2021). Invasive species allelopathy decreases plant growth and soil microbial activity. *PloS One*, *16*(2), e0246685. https://doi.org/10.1371/journal.pone.0246685

R Core Team. (2023). *R: A Language and Environment for Statistical Computing* (4.3.2). R Foundation for Statistical Computing. https://www.r-project.org/

Rashid, A., Anand, V. K., & Serwar, J. (2008). Less known wild edible plants used by the Gujjar tribe of district Rajouri, Jammu and Kashmir State. *International Journal of Botany*.

Rasingam, L. (2012). Ethnobotanical studies on the wild edible plants of Irula tribes of Pillur Valley, Coimbatore district, Tamil Nadu, India. *Asian Pacific Journal of Tropical Biomedicine*, *2*(3 SUPPL.), S1493–S1497. https://doi.org/10.1016/S2221-1691(12)60443-2

Ratemo, C. M., Ogendi, G. M., Huang, G., & Ondieki, R. N. (2020). Application of Traditional Ecological Knowledge in Food and Water Security in the Semi-Arid Turkana County, Kenya. *Open Journal of Ecology*, *10*(6), 321–340. https://doi.org/10.4236/oje.2020.106020

Ray, A., Ray, R., & Sreevidya, E. A. (2020). How Many Wild Edible Plants Do We Eat—Their Diversity, Use, and Implications for Sustainable Food System: An Exploratory Analysis in India. *Frontiers in Sustainable Food Systems*. https://doi.org/10.3389/fsufs.2020.00056

Redžić, S., & Ferrier, J. (2014). The use of wild plants for human nutrition during a war: Eastern Bosnia (Western Balkans). In *Ethnobotany and Biocultural Diversities in the Balkans: Perspectives on Sustainable Rural Development and Reconciliation*. https://doi.org/10.1007/978-1-4939-1492-0_9

Regassa, T., Kelbessa, E., & Asfaw, Z. (2015). Ethnobotany of wild and semi-wild edible plants of Chelia District, West-Central Ethiopia. *Science, Technology and Arts Research Journal*, *3*(4), 122–134. https://doi.org/10.4314/star.v3i4.18

Regos, A., Imbeau, L., Desrochers, M., Leduc, A., Robert, M., Jobin, B., Brotons, L., & Drapeau, P. (2018). Hindcasting the impacts of land-use changes on bird communities with species distribution models of Bird Atlas data. *Ecological Applications*, *28*(7), 1867–1883. https://doi.org/10.1002/eap.1784

Reid, R. S., & Ellis, J. E. (1995). Impacts of pastoralists on woodlands in South Turkana, Kenya: Livestock-mediated tree recruitment. *Ecological Applications*. https://doi.org/10.2307/2269349

Reyes-García, V., Menendez-Baceta, G., Aceituno-Mata, L., Acosta-Naranjo, R., Calvet-Mir, L., Domínguez, P., Garnatje, T., Gómez-Baggethun, E., Molina-Bustamante, M., Molina, M., Rodríguez-Franco, R., Serrasolses, G., Vallès, J., & Pardo-de-Santayana, M. (2015). From famine foods to delicatessen: Interpreting trends in the use of wild edible plants through cultural ecosystem services. *Ecological Economics*, *120*, 303–311. https://doi.org/10.1016/j.ecolecon.2015.11.003

Riahi, K., Van Vuuren, D. P., Kriegler, E., Edmonds, J., O'neill, B. C., Fujimori, S., Bauer, N., Calvin, K., Dellink, R., Fricko, O., & others. (2017). The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. *Global Environmental Change*, *42*, 153–168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

Richardson, D., Black, A. S., Irving, D., Matear, R. J., Monselesan, D. P., Risbey, J. S., Squire, D. T., & Tozer, C. R. (2022). Global increase in wildfire potential from compound fire weather and drought. *NPJ Climate and Atmospheric Science*, *5*(1), 23. https://doi.org/10.1038/s41612-022-00248-4

Rougier, T., Lassalle, G., Drouineau, H., Dumoulin, N., Faure, T., Deffuant, G., Rochard, E., & Lambert, P. (2015). The combined use of correlative and mechanistic species distribution models benefits low conservation status species. *PLoS One*, *10*(10), e0139194. https://doi.org/10.1371/journal.pone.0139194

Salariato, D. L., Trinidad, H., Cano, A., Zuloaga, F. O., & Al-Shehbaz, I. A. (2022). Interplay between conservatism and divergence in climatic niche evolution of Brassicaceae tribe Eudemeae shaped their distribution across the different environments of the Andes. *Botanical Journal of the Linnean Society*, *200*(3), 314–343. https://doi.org/10.1093/botlinnean/boac031

Salih, N. K. E. M., & Hassan Ali, A. (2014). Wild food trees in Eastern Nuba mountains, Sudan: Use, diversity, and threatening factors. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, *115*(1), 1–7.

Sands, M. J., Beentje, H., & Ghazanfar, S. A. (2003). *Flora of Tropical East Africa: Prepared at the Royal Botanic Gardens, Kew in Cooperation with the East African Herbarium, the National Herbarium of Tanzania and the Herbaria of Makerere University and Dar Es Salaam University. Balanitaceae/cby Martin JS S*. A.A.Balkema Publishers.

Santos, M. J., Dekker, S. C., Daioglou, V., Braakhekke, M. C., & van Vuuren, D. P. (2017). Modeling the effects of future growing demand for charcoal in the tropics. *Frontiers in Environmental Science*, *5*, 28. https://doi.org/10.3389/fenvs.2017.00028

Sarfo, J. (2017). Effects of wild foods and food interventions in reducing the minimum cost of diet using linear programming modelling: a case study of Turkana in Kenya. In *3rd International Congress Hidden Hunger: Post-2015 Agenda and Sustainable Developmental Goals (SDG): Where are we now? Strategies to improve nutrition quality and combat hidden hunger*. Georg-August-University of Göttingen, Germany.

Sarfo, J. (2018). *Effects of Wild Foods and Food Interventions in reducing the Minimum Cost of Diet using Linear Programming Modelling: A case study of Turkana in Kenya*. George-August-University of Göttingen, Germany.

Sarfo, J., Termote, C., Keding, G., Boedecker, J. and, & Pawelzik, E. (2017). *The Impact of Wild Plant Foods in reducing the minimum Cost of a Nutritious Diet in Turkana , Kenya using Linear Programming Modelling*.

Šarić-Kundalić, B., Dobeš, C., Klatte-Asselmeyer, V., & Saukel, J. (2011). Ethnobotanical survey of traditionally used plants in human therapy of east, north and north-east Bosnia and Herzegovina. *Journal of Ethnopharmacology*. https://doi.org/10.1016/j.jep.2010.11.033

Schipper, A. M., Hilbers, J. P., Meijer, J. R., Antão, L. H., Ben\'\itez-López, A., de Jonge, M. M. J., Leemans, L. H., Scheper, E., Alkemade, R., Doelman, J. C., & others. (2020). Projecting terrestrial biodiversity intactness with GLOBIO 4. *Global Change Biology*, *26*(2), 760–771. https://doi.org/10.1111/gcb.14848

Schunko, C., Li, X., Klappoth, B., Lesi, F., Porcher, V., Porcuna-Ferrer, A., & Reyes-García, V. (2022). Local communities' perceptions of wild edible plant and mushroom change: A systematic review. *Global Food Security*, *32*, 100601.

Searchinger, T., Waite, R., Hanson, C., & Ranganathan, J. (2019). Creating a sustainable food future: A menu of solutions to feed nearly 10 billion people by 2050. *World Resources*

Report.

Shabani, F., Kumar, L., & Ahmadi, M. (2016). A comparison of absolute performance of different correlative and mechanistic species distribution models in an independent area. *Ecology and Evolution*, *6*(16), 5973–5986. https://doi.org/10.1002/ece3.2332

Shabani, F., Kumar, L., & Ahmadi, M. (2018). Assessing accuracy methods of species distribution models: AUC, specificity, sensitivity and the true skill statistic. *Global Journal of Human-Social Science*, *18*(1), 1–13. https://globaljournals.org/GJHSS_Volume18/2-Assessing-Accuracy-Methods.pdf

Shackleton, S., Delang, C. O., & Angelsen, A. (2011). From subsistence to safety nets and cash income: exploring the diverse values of non-timber forest products for livelihoods and poverty alleviation. In *Non-timber forest products in the global context* (pp. 55–81). Springer. https://doi.org/10.1007/978-3-642-17983-9_3

Shaheen, S., Ahmad, M., & Haroon, N. (2017). Edible Wild Plants: An alternative approach to food security. In *Edible Wild Plants: An alternative approach to food security*. https://doi.org/10.1007/978-3-319-63037-3

Shanguhyia, M. S. (2021). Insecure borderlands, marginalization, and local perceptions of the state in Turkana, Kenya, circa 1920--2014. *Journal of Eastern African Studies*, *15*(1), 85–107. https://doi.org/10.1080/17531055.2020.1868195

Sharma, L., Samant, S. S., Kumar, A., Lal, M., Devi, K., & Tewari, L. M. (2018). Diversity, distribution pattern, endemism and indigenous uses of wild edible plants in Cold Desert Biosphere Reserve of Indian Trans Himalaya. *Indian Journal of Traditional Knowledge*.

Shumsky, S., Hickey, G. M., Pelletier, B., & Johns, T. (2014). Understanding the contribution of wild edible plants to rural Socialecological resilience in semi-arid Kenya. *Ecology and Society*, *19*(4), 34. https://doi.org/10.5751/ES-06924-190434

Siddiqui, J. A., Bamisile, B. S., Khan, M. M., Islam, W., Hafeez, M., Bodlah, I., & Xu, Y. (2021). Impact of invasive ant species on native fauna across similar habitats under global environmental changes. *Environmental Science and Pollution Research*, *28*, 54362–54382. https://doi.org/10.1007/s11356-021-15961-5

Sim, J., & Waterfield, J. (2019). Focus group methodology: some ethical challenges. *Quality and Quantity*. https://doi.org/10.1007/s11135-019-00914-5

Singh, Ajeet, Dubey, P. K., & Abhilash, P. C. (2018). Food for thought: Putting wild edibles back on the table for combating hidden hunger in developing countries. In *Current Science*. https://doi.org/10.18520/cs/v115/i4/611-613

Singh, Anshuman, Singh, R. K., Kumar, A., Kumar, A., Kumar, R., Kumar, N., Sheoran, P., Yadav, R. K., & Sharma, D. K. (2020). Adaptation to social-ecological stressors: a case study with Indian jujube (Ziziphus mauritiana Lam.) growers of north-western India. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-020-00717-x

Singh, T., Singh, A., & Dangwal, L. R. (2016). Impact of overgrazing and documentation of wild fodder plants used by Gujjar and Bakerwal tribes of district Rajouri (J&K), India. *Journal of Applied and Natural Science*, *8*(2), 804–811. https://doi.org/10.31018/jans.v8i2.876

Smith, B. D. (2018). Hunting in yellow waters: an ethnoarchaeological perspective on selective fishing on Lake Turkana. *Quaternary International*, *471*, 241–251. https://doi.org/10.1016/j.quaint.2017.11.038

Smith, E., Ahmed, S., Dupuis, V., Crane, M. R., Eggers, M., Pierre, M., & Shanks, C. B. (2019). Contribution of wild foods to diet, food security, and cultural values amidst climate change. *Journal of Agriculture, Food Systems, and Community Development*, *9*(B), 1–24. https://doi.org/10.5304/jafscd.2019.09B.011

Soldati, G. T., de Medeiros, P. M., Duque-Brasil, R., Coelho, F. M. G., & Albuquerque, U. P. (2017). How do people select plants for use? Matching the ecological apparency hypothesis with optimal foraging theory. *Environment, Development and Sustainability*, *19*(6), 2143–2161.

SRTM. (2013). *NASA Shuttle Radar Topography Mission (SRTM) Global. Distributed by OpenTopography*. URL: Https://Www. Fdsn. Org/Networks/Detail/GH/, Doi: Doi. Org/10.5069/G9445JDF. https://www.earthdata.nasa.gov/sensors/srtm#:~:text=The Shuttle Radar Topography Mission,global dataset of land elevations.

Ssenku, J. E., Okurut, S. A., Namuli, A., Kudamba, A., Tugume, P., Matovu, P., Wasige, G., Kafeero, H. M., & Walusansa, A. (2022). Medicinal plant use, conservation, and the associated traditional knowledge in rural communities in Eastern Uganda. *Tropical Medicine and Health*, *50*(1), 39. https://doi.org/10.1186/s41182-022-00428-1

Stave, J., Oba, G., Nordal, I., & Stenseth, N. C. (2006). Seedling establishment of Acacia tortilis and Hyphaene compressa in the Turkwel riverine forest, Kenya. *African Journal of Ecology*, *44*(2), 178–185. https://doi.org/10.1111/j.1365-2028.2006.00614.x

Stevenson, E. G. J. (2018). Plantation Development in the Turkana Basin: The Making of a New Desert? *Land*, *7*(1), 16. https://doi.org/10.3390/land7010016

Stewart, D. W., & Shamdasani, P. N. (1998). Focus group research: Exploration and discovery. In *Handbook of Applied Social Research Methods*.

Sulaiman, N., Pieroni, A., Sõukand, R., & Polesny, Z. (2022). Food Behavior in Emergency Time: Wild Plant Use for Human Nutrition during the Conflict in Syria. *Foods*, *11*(2), 177. https://doi.org/10.3390/foods11020177

Sullivan, S., Konstant, T. L., & Cunningham, A. B. (1995). The impact of utilization of palm products on the population structure of the vegetable ivory palm (Hyphaene petersiana, Arecaceae) in north-central Namibia. *Economic Botany*, *49*, 357–370. https://doi.org/10.1007/BF02863085

Sundriyal, M., & Sundriyal, R. C. (2004). Wild edible plants of the Sikkim Himalaya: Marketing, value addition and implications for management. *Economic Botany*, *58*(2), 300–315. https://doi.org/10.1663/0013-0001(2004)058[0300:WEPOTS]2.0.CO;2

Sundriyal, M., Sundriyal, R. C., & Sharma, E. (2004). Dietary use of wild plant resources in the Sikkim Himalaya, India. *Economic Botany*. https://doi.org/10.1663/0013-0001(2004)058[0626:DUOWPR]2.0.CO;2

Suwardi, A. B., Navia, Z. I., Harmawan, T., & Mukhar, E. (2020). Ethnobotany and conservation of indigenous edible fruit plants in South Aceh, Indonesia. *Biodiversitas Journal of Biological Diversity*, *21*(5).

Suwardi, A. B., Navia, Z. I., Harmawan, T., Seprianto, S., Syamsuardi, S., & Mukhtar, E. (2022). Diversity of wild edible fruit plant species and their threatened status in the Aceh Province, Indonesia. *Biodiversitas Journal of Biological Diversity*, *23*(3). https://doi.org/10.13057/biodiv/d230315

Suwardi, A. B., Navia, Z. I., Harmawan, T., Syamsuardi, S., & Mukhtar, E. (2022). Importance and local conservation of wild edible fruit plants in the East Aceh region, Indonesia. *International Journal of Conservation Science*, *13*(1), 221–232.

Tabuti, J. R. S. (2007). Status of non-cultivated food plants in Bulamogi County, Uganda. *African Journal of Ecology*. https://doi.org/10.1111/j.1365-2028.2007.00745.x

Tabuti, J. R. S., Dhillion, S. S., & Lye, K. A. (2004). The status of wild food plants in Bulamogi County, Uganda. *International Journal of Food Sciences and Nutrition*, *55*(6), 485–498. https://doi.org/10.1080/09637480400015745

Tadros, M. J., Al-Assaf, A., Othman, Y. A., Makhamreh, Z., & Taifour, H. (2020). Evaluating the effect of Prosopis juliflora, an alien invasive species, on land cover change using remote sensing approach. *Sustainability*, *12*(15), 5887. https://doi.org/10.3390/su12155887

Tahir, M., Abrahim, A., Beyene, T., Dinsa, G., Guluma, T., Alemneh, Y., Van Damme, P., Geletu, U. S., & Mohammed, A. (2023). The traditional use of wild edible plants in pastoral and agro-pastoral communities of Mieso District, eastern Ethiopia. *Tropical Medicine and Health*, *51*(1), 1–15. https://doi.org/10.1186/s41182-023-00505-z

Tebkew, M. (2015). Wild and semi-wild edible plants in Chilga District , Northwestern Ethiopia : Implication for food security and climate change adaptation. *Global Journal of Wood Science, Forestry and Wildlife*, *3*(3), 72–82.

Tebkew, M., Asfaw, Z., & Zewudie, S. (2014). Underutilized wild edible plants in the Chilga District, northwestern Ethiopia: Focus on wild woody plants. *Agriculture and Food Security*, *3*(12),

16. http://www.agricultureandfoodsecurity.com/content/3/1/12

Tebkew, M., Gebremariam, Y., Mucheye, T., Alemu, A., Abich, A., & Fikir, D. (2018). Uses of wild edible plants in Quara district, northwest Ethiopia: Implication for forest management. *Agriculture and Food Security*, *7*(1), 1–14. https://doi.org/10.1186/s40066-018-0163-7

Teketay, D., Geeves, G., Kopong, I., Mojeremane, W., Sethebe, B., & Smith, S. (2016). Diversity, stand structure and regeneration status of woody species, and spatial cover of herbaceous species in Mokolodi Nature Reserve, Southeastern Botswana. *International Journal of Biodiversity and Conservation*, *8*(8), 180–195.

Termote, C., Bwama Meyi, M., Dhed'a Djailo, B., Huybregts, L., Lachat, C., Kolsteren, P., & van Damme, P. (2012). A biodiverse rich environment does not contribute to a better diet: A case study from DR Congo. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0030533

Termote, C., Raneri, J., Deptford, A., & Cogill, B. (2014). Assessing the potential of wild foods to reduce the cost of a nutritionally adequate diet: an example from eastern Baringo District, Kenya. *Food and Nutrition Bulletin*, *35*(4), 458–479. https://doi.org/10.1177/156482651403500408

Termote, C., Van Damme, P., & Dhed'a Djailo, B. (2010). Eating from the wild: Turumbu indigenous knowledge on noncultivated edible plants, Tshopo District, DRCongo. *Ecology of Food and Nutrition*, *49*(3), 173–207. https://doi.org/10.1080/03670241003766030

Tikhonov, G., Opedal, Ø. H., Abrego, N., Lehikoinen, A., de Jonge, M. M. J., Oksanen, J., & Ovaskainen, O. (2020). Joint species distribution modelling with the r-package Hmsc. *Methods in Ecology and Evolution*. https://doi.org/10.1111/2041-210X.13345

Tiwari, J. K., Ballabha, R., & Tiwari, P. (2010). Some promising wild edible plants of Srinagar and its adjacent area in Alaknanda valley of Garhwal Himalaya, India. *Journal of American Science*, *6*(4), 167–174.

Tonkin, J. D., Merritt, D. M., Olden, J. D., Reynolds, L. V, & Lytle, D. A. (2018). Flow regime alteration degrades ecological networks in riparian ecosystems. *Nature Ecology \& Evolution*, *2*(1), 86–93. https://doi.org/10.1038/s41559-017-0379-0

Tuncer, B. (2020). In vitro germination and bulblet and shoot propagation for wild edible Eremurus spectabilis M. Bieb. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *48*(2), 814–825. https://doi.org/10.15835/nbha48211883

Tuset, V. M., Otero-Ferrer, J. L., Siliprandi, C., Manjabacas, A., Marti-Puig, P., & Lombarte, A. (2021). Paradox of otolith shape indices: routine but overestimated use. *Canadian Journal of Fisheries and Aquatic Sciences*, *78*(6), 681–692. https://doi.org/10.1139/cjfas-2020-0369

Twine, W., Moshe, D., Netshiluvhi, T., & Siphugu, V. (2003). Consumption and direct-use values of savanna bio-resources used by rural households in Mametja, a semi-arid area of Limpopo province, South Africa. *South African Journal of Science*, *99*(9), 467–473.

Ulian, T., Diazgranados, M., Pironon, S., Padulosi, S., Liu, U., Davies, L., Howes, M.-J. R., Borrell, J. S., Ondo, I., Pérez-Escobar, O. A., & others. (2020). Unlocking plant resources to support food security and promote sustainable agriculture. *Plants, People, Planet*, *2*(5), 421–445. https://doi.org/10.1002/ppp3.10145

United Nations. (2017). The Sustainable Development Goals Report. *United Nations Publications*. https://doi.org/10.18356/3405d09f-en

Valderrábano, E. M., Gil, T., Heywood, V., & Montmollin, B. De. (2018). Conserving wild plants in the south and east Mediterranean region. In *Conserving wild plants in the south and east Mediterranean region*. https://doi.org/10.2305/iucn.ch.2018.21.en

van Breugel, P., Kindt, R., Lillesø, J.-P. B., Bingham, M., Demissew, S., Dudley, C., Friis, I., Gachathi, F., Kalema, J., Mbago, F., Moshi, H., Mulumba, J., Ndangalasi, H., Namaganda, M., Ruffo, C., Védaste, M., Jamnadass, R., & Graudal, L. (2015). *Potential Natural Vegetation Map of Eastern Africa (Burundi, Ethiopia, Kenya Malawi, Rwanda, Tanzania, Uganda and Zambia). Version 2.0*. Forest and Landscape (Denmark) and World Agroforestry Centre (ICRAF). https://www.forskningsdatabasen.dk/en/catalog/2398337079

Vári, Á., Arany, I., Kalóczkai, Á., Kelemen, K., Papp, J., & Czúcz, B. (2020). Berries, greens, and medicinal herbs - Mapping and assessing wild plants as an ecosystem service in Transylvania (Romania). *Journal of Ethnobiology and Ethnomedicine*. https://doi.org/10.1186/s13002-020-0360-x

Vieira, M., Zetter, R., Gr\'\imsson, F., & Denk, T. (2023). Niche evolution versus niche conservatism and habitat loss determine persistence and extirpation in late Neogene European Fagaceae. *Quaternary Science Reviews*, *300*, 107896. https://doi.org/10.1016/j.quascirev.2022.107896

Vincent, H., Amri, A., Castañeda-Álvarez, N. P., Dempewolf, H., Dulloo, E., Guarino, L., Hole, D., Mba, C., Toledo, A., & Maxted, N. (2019). Modeling of crop wild relative species identifies areas globally for in situ conservation. *Communications Biology*, *2*(1), 1–8. https://doi.org/10.1038/s42003-019-0372-z

Vinceti, B., Loo, J., Gaisberger, H., van Zonneveld, M. J., Schueler, S., Konrad, H., Kadu, C. A. C., & Geburek, T. (2013). Conservation priorities for Prunus africana defined with the aid of spatial analysis of genetic data and climatic variables. *PloS One*, *8*(3), e59987. https://doi.org/10.1371/journal.pone.0059987

Vinceti, B., Termote, C., Thiombiano, N., Agundez, D., & Lamien, N. (2018). Food tree species consumed during periods of food shortage in Burkina Faso and their threats. *Forest Systems*, *27*(2), e006--e006. https://doi.org/10.5424/fs/2018272-12157

Visseren-Hamakers, I. J., Razzaque, J., McElwee, P., Turnhout, E., Kelemen, E., Rusch, G. M., Fernández-Llamazares, Á., Chan, I., Lim, M., Islar, M., Gautam, A. P., Williams, M., Mungatana, E., Karim, M. S., Muradian, R., Gerber, L. R., Lui, G., Liu, J., Spangenberg, J. H., & Zaleski, D. (2021). Transformative governance of biodiversity: insights for sustainable development. *Current Opinion in Environmental Sustainability*, *53*, 20–28. https://doi.org/10.1016/J.COSUST.2021.06.002

Voeks, R. A. (2004). Disturbance pharmacopoeias: Medicine and myth from the humid tropics. *Annals of the Association of American Geographers*, *94*(4), 868–888. https://doi.org/10.1111/j.1467-8306.2004.00439.x

von Braun, J., Afsana, K., Fresco, L. O., & Hassan, M. (2021). *Food systems: seven priorities to end hunger and protect the planet*. Nature Publishing Group.

Wagenmakers, E.-J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., Love, J., Selker, R., Gronau, Q. F., Šmira, M., Epskamp, S., & others. (2018). Bayesian inference for psychology. Part I: Theoretical advantages and practical ramifications. *Psychonomic Bulletin & Review*, *25*(1), 35–57. https://doi.org/10.3758/s13423-017-1343-3

Watete, P. W., Makau, W. K., Njoka, J. T., MacOpiyo, L. A., & Wasonga, O. V. (2016). Moving in and out of poverty: A case of the Somali and Turkana of Northern Kenya. *Nomadic Peoples*. https://doi.org/10.3197/np.2016.200108

Watkins, T. Y. (2010). The Prevalence of Wild Food Knowledge Among Nomadic Turkana of Northern Kenya. *Journal of Ethnobiology*. https://doi.org/10.2993/0278-0771-30.1.137

Watson, D. J., & Binsbergen, J. van. (2006). Life beyond pastoralism: Livelihood diversification opportunities for pastoralists in Turkana District, Kenya. *ILRI Brief*.

Wayua, F. O., Kuria, S. G., Gudere, A., Golicha, D., Lesuper, J., Walaga, H. K., Adongo, A., & others. (2014). Client satisfaction with livestock improvement technologies in Marsabit, Turkana and Garissa counties of northern Kenya. *Livestock Research for Rural Development*, *26*(5).

Wekesa, C., Mutta, D., Larwanou, M., Kowero, G., & Roos, A. (2023). Effects of charcoal ban on value chains and livelihoods in Kenyan coast--Stakeholders' perceptions. *Environmental Development*, *45*, 100809. https://doi.org/10.1016/j.envdev.2023.100809

Wessels, C., Merow, C., & Trisos, C. H. (2021). Climate change risk to southern African wild food plants. *Regional Environmental Change*, *21*(2), 1–14. https://doi.org/10.1007/s10113-021-01755-5

Williams, B. A., Grantham, H. S., Watson, J. E. M., Alvarez, S. J., Simmonds, J. S., Rogéliz, C. A., Da Silva, M., Forero-Medina, G., Etter, A., Nogales, J., & others. (2020). Minimising the loss of biodiversity and ecosystem services in an intact landscape under risk of rapid agricultural development. *Environmental Research Letters*, *15*(1), 14001.

Williams, D. R., Clark, M., Buchanan, G. M., Ficetola, G. F., Rondinini, C., & Tilman, D. (2021).

Proactive conservation to prevent habitat losses to agricultural expansion. *Nature Sustainability*, *4*(4), 314–322. https://doi.org/10.1038/s41893-020-00656-5

Wisz, M. S., Hijmans, R. J., Li, J., Peterson, A. T., Graham, C. H., Guisan, A., & Group, N. P. S. D. W. (2008). Effects of sample size on the performance of species distribution models. *Diversity and Distributions*, *14*(5), 763–773. https://doi.org/10.1111/j.1472-4642.2008.00482.x

Wohlin, C. (2014). Guidelines for snowballing in systematic literature studies and a replication in software engineering. *Proceedings of the 18th International Conference on Evaluation and Assessment in Software Engineering*, 1–10. https://doi.org/10.1145/2601248.2601268

Wong, L. P. (2008). Focus group discussion: A tool for health and medical research. In *Singapore Medical Journal*.

Yamazaki, D., Ikeshima, D., Tawatari, R., Yamaguchi, T., O'Loughlin, F., Neal, J. C., Sampson, C. C., Kanae, S., & Bates, P. D. (2017). A high-accuracy map of global terrain elevations. *Geophysical Research Letters*, *44*(11), 5844–5853. https://doi.org/10.1002/2017GL072874

Yangdon, P., Araki, T., Rahayu, Y. Y. S., & Norbu, K. (2022). Ethnobotanical study of wild edible fruits in eastern Bhutan. *Journal of Ethnobiology and Ethnomedicine*, *18*(1), 27. https://doi.org/10.1186/s13002-022-00526-8

Yazew, T. (2020). Review on Dietary Contribution of Wild Edible Food Biodiversity to Food Security and Micronutrient Status of Children in Ethiopia. *Journal of Health and Environmental Research*. https://doi.org/10.11648/j.jher.20200601.13

Yeşil, Y., Çelik, M., & Yllmaz, B. (2019). Wild edible plants in Yeşilli (Mardin-Turkey), a multicultural area. *Journal of Ethnobiology and Ethnomedicine*. https://doi.org/10.1186/s13002-019-0327-y

Yiblet, Y., Adamu, E., & others. (2023). An Ethnobotanical Study of Wild Edible Plants in Tach Gayint District, South Gondar Zone, Amhara Region, Northwestern Ethiopia. *Evidence-Based Complementary and Alternative Medicine*, *2023*. https://doi.org/10.1155/2023/7837615

Yoda, L., Anthony, K., & Kihara, P. (2020). Strategies of Households Resilience in Adapting to Challenges in Turkana County. *American Journal of Theoretical and Applied Statistics*. https://doi.org/10.11648/j.ajtas.20200905.16

Zhang, J., Nielsen, S. E., Chen, Y., Georges, D., Qin, Y., Wang, S.-S., Svenning, J.-C., & Thuiller, W. (2017). Extinction risk of North American seed plants elevated by climate and land-use change. *Journal of Applied Ecology*, *54*(1), 303–312. https://doi.org/10.1111/1365-2664.12701

Zhongming, Z., Linong, L., Wangqiang, Z., Wei, L., & others. (2020). *Desert locust threat continues*.

Zulu, D., Ellis, R. H., & Culham, A. (2020). Propagation of lusala (Dioscorea hirtiflora), a wild yam, for in situ and ex situ conservation and potential domestication. *Experimental Agriculture*, *56*(3), 453–468. https://doi.org/10.1017/S0014479720000083

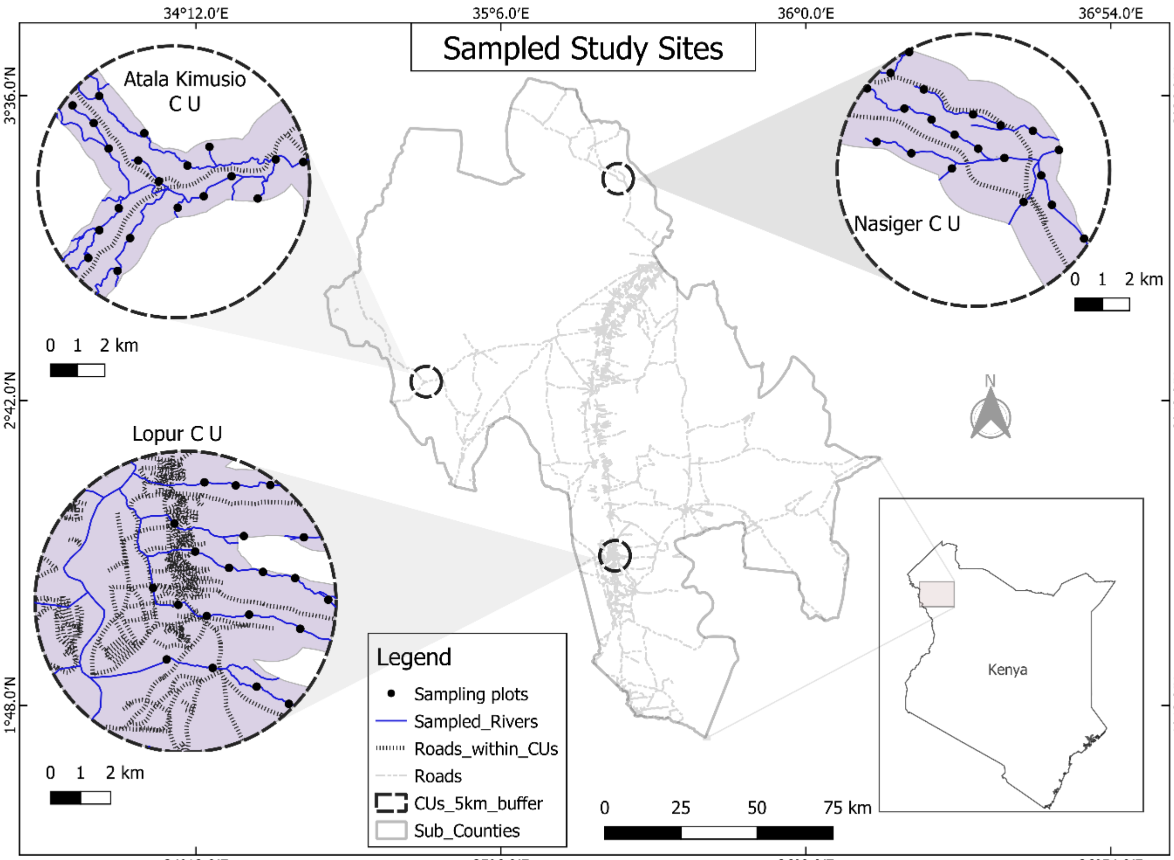
Zurell, D., Franklin, J., König, C., Bouchet, P. J., Dormann, C. F., Elith, J., Fandos, G., Feng, X., Guillera-Arroita, G., Guisan, A., others, Lahoz-Monfort, J. J., Leitão, P. J., Park, D. S., Peterson, A. T., Rapacciuolo, G., Schmatz, D. R., Schröder, B., Serra-Diaz, J. M., … Merow, C. (2020). A standard protocol for reporting species distribution models. *Ecography*, *43*(9), 1261–1277. https://doi.org/10.1111/ecog.04960

APPENDICES

Appendix 1: Variability parameters across the community units in Loima and Turkana South Sub-Counties in Kenya. The three study community units highlighted in green are representative of the different agro-climatic and vegetation zones occurring in the study area. Altitude data were derived from Shuttle Radar Topography Mission (SRTM) (Farr & Kobrick, 2000). Agro-Climatic zones data (Kenya Soil Survey, 1980): VI = Arid and VII = Very Arid. Annual rainfall data from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) (C. C. Funk et al., 2014). For vegetation types: SH = Sparse Herbaceous, B = Barren, DB = Deciduous Broadleaf, and SS = Sparse Shrublands (Friedl & Sulla-Menashe, 2019). For Potential Natural Vegetation of East Africa: Bd = Somalia-Masai Acacia-Commiphora deciduous bushland and thicket, Bds = Acacia-Commiphora stunted bushland, and R = Riverine wooded vegetation (van Breugel et al., 2015). For population density (Kenya Population and Housing, 2019). For livelihood zone: TBP = Turkana Border Pastoral, TCP = Turkana Central Pastoral, and TAP = Turkwel Riverine Agro-Pastoral (Food Economy Group, 2016). For livestock kept: Cam = Camels, S/G = sheep and goats, and Catl = Cattle

Community Unit	Altitude (masl)	Agro-Climatic Zones	Annual Rainfall (mm)	Vegetation types	Potential Natural Vegetation of	Population Density	Livelihood Zone	Livestock kept
Atala Kimusio	889	VI-2	670.15	SH	Bd	7	TBP	Cam, S/G, Catl
Kawalathe	815	VII-1	314.92	B	Bd	12	TCP	Cam, S/G
Lokwatuba	797	VI-1	595.12	SH	Bd	-	TBP	Cam, S/G, Catl
Kamarese	794	VII-1	401.49	B	Bd	-	TCP	Cam, S/G
Lokichar	770	VII-1	401.49	B	Bd	73	TCP	Cam, S/G
Kalemngorok	741	VI-1	555.01	DB	Bds	33	TAP	Cam, S/G, Catl
Lochwa	739	VII-1	344.72	B	Bd	8	TCP	Cam, S/G
Namoruputh	729	VI-1	533.85	DB	R	22	TBP	Cam, S/G, Catl
Lopur	696	VI-1	557.04	DB	R	322	TAP	Cam, S/G, Catl
Lokapel	667	VI-1	489.97	DB	R	96	TAP	Cam, S/G, Catl
Nameyana	643	VII-1	425.03	SS	Bds	-	TCP	Cam, S/G
Lorugum	624	VII-1	316.76	SS	R	11	TCP	Cam, S/G
Napeikar	570	VII-1	273.91	B	R	35	TAP	Cam, S/G, Catl
Kablokor	565	VII-1	292.16	B	R	-	TAP	Cam, S/G, Catl
Nasiger	559	VII-1	290.13	B	Bds	7	TCP	Cam, S/G
Kaapus	557	VII-1	343.33	SS	R	12	TAP	Cam, S/G, Catl
Napusmoru	547	VII-1	288.24	B	Bds	6	TCP	Cam, S/G

Appendix 2: Map of the study community units



Appendix 3: Key Focus Group Discussion questions/discussion items

Sampling CU name: …………………………………………… Date: ………………………

	Participant name	Age (years)	Gender	Contact	Main occupation	Years within CU	Formal education level
1							
2							
3							
4							
5							
6							
7							
8							

1. What are the local names of the pictured WEPs? (*Show pictures of the WEPs*)

WEP	Correctly identified	Not correctly identified
Ekalale		
Esekon		
Ebei		

2. Do you consider the three as the priority woody WEPs in this CU? (*List other woody WEPs they consider priority, if any*)

……………………………………………………………………………………………………..

3. Rank the three species based on the following parameters

WEP	Local abundance	Distance to harvest	Ease of harvesting	Portability	Ease of processing	Seasonal availability	Market availability	Affordability	Access to harvest sites	Adequacy of harvest	Regeneration
Ekalale											
Esekon											
Ebei											
Pick 1 2 3	Little Ave. Plenty	Near Ave. Far	Easy Ave.	Light Ave.	Easy Ave.	Dry Wet.	Little Ave.	Cheap Ave.	Free Permi.	Little Ave.	Little Ave.

			Hard	Heavy	Hard	Both	Plenty	Expe.	Restr.	Plenty	Plenty

4. Where do you normally get the plant? (*List for each WEP*)

WEP	**Harvesting sites**
Ekalale	
Esekon	
Ebei	

5. Apart from food, what are the other uses of these WEPs? (*List as they mention, also note part used*)

WEP	**Part**	**Use(s) *(attention to fodder uses too)***
Ekalale	Roots	
	Bark	
	Stem	
	Leaves	
	Fruits	
Esekon	Roots	
	Bark	
	Stem	
	Leaves	
	Fruits	
Ebei	Roots	
	Bark	
	Stem	
	Leaves	
	Fruits	

6. What are the major threats (things which badly affect the WEPs and might wipe them out) to these WEPs

WEP	**Threats**	**Major threat**
Ekalale		
Esekon		
Ebei		

7. Are there restrictions on harvest place, time, and use of the priority WEPs (*rules, norms, taboos*)

WEP	**Edible parts (who eats which parts)**	**Harvest site**	**Harvest time for food**	**Harvest time for other users (such as fodder)**
Ekalale				
Esekon				
Ebei				

8. Additional remark notes:

……

……

……

……

……

……

……

……

……

……

……

Appendix 4: Focus Group Discussion data for assessment of Wild Edible Plants against 11 predictor parameters and a response parameter in Turkana County, Kenya. Listed wild edible fruit plants per community unit (Nasiger (n = 13), Atala Kamusio (n = 23), and Lopur (n = 13)), their scientific (validated using (Sarfo, 2018) and checked for accepted name using World Flora Online (http://www.worldfloraonline.org/)) and local names (Turkana language). Several WEPs were cited across all or more than one community unit resulting into citations of 49 plants of 24 unique WEPs

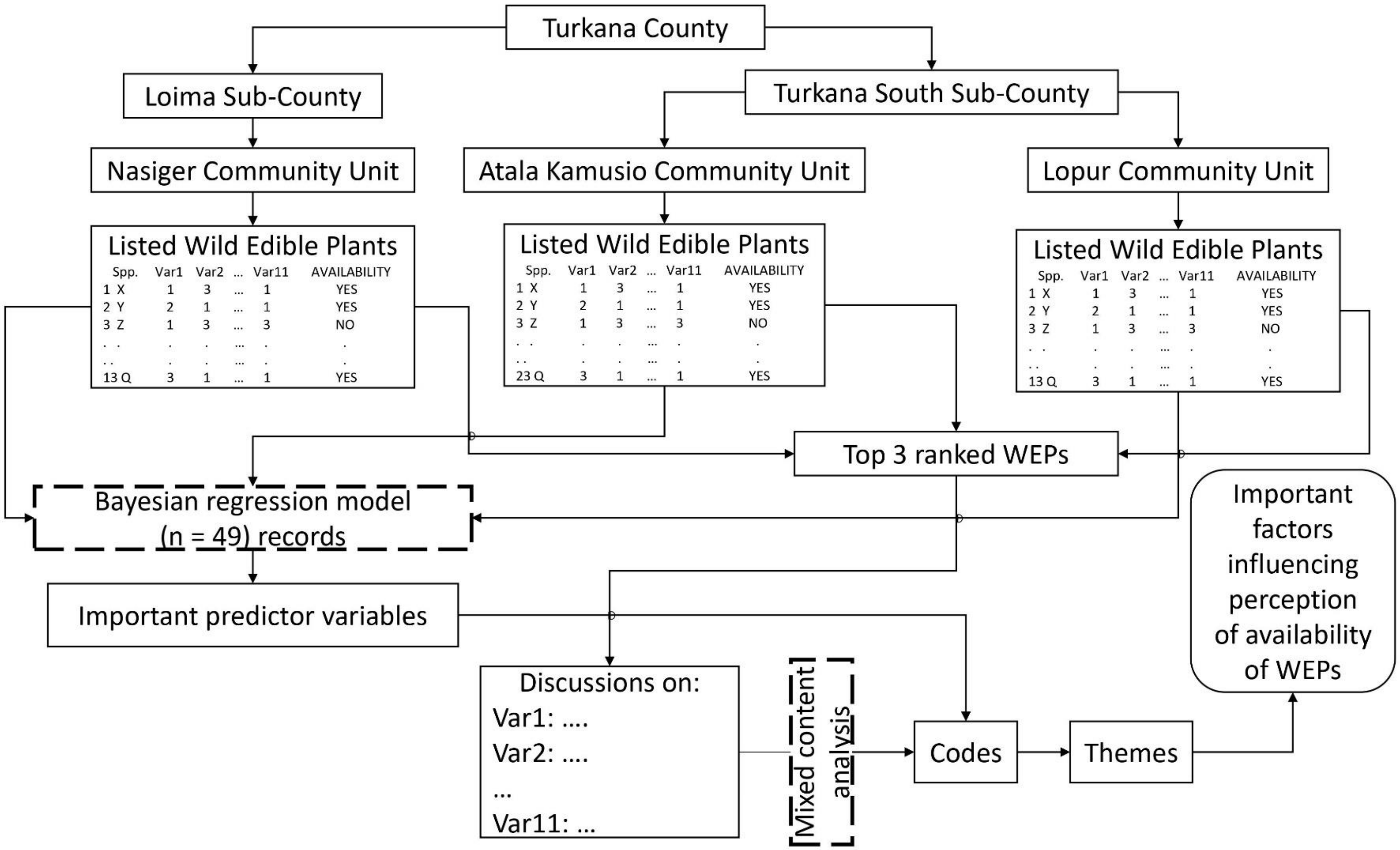
Communtity Unit	Wild Edible Plant	Local name (Turkana)	Abundance	Distance	Harvesting	Portability	Processing	Seasonality	Market	Affordability	Access	Adequacy	Regeneration	AVAILABILITY
Nasiger	*Ziziphus mauritiana* Lam.	Ekalale	1	1	1	1	1	2	3	1	1	3	3	1
Nasiger	*Salvadora persica* L.	Esekon	1	1	1	1	1	2	3	1	1	3	3	1
Nasiger	*Balanites rotundifolia* (Tiegh.) Blatt.	Ebei	2	1	1	3	3	1	3	1	1	3	1	1
Nasiger	*Dobera glabra* Juss. ex Poir.	Edapal	1	2	1	3	1	1	3	1	1	3	3	1
Nasiger	*Cordia sinensis* Lam.	Edome	1	1	1	1	1	1	1	1	1	1	1	1
Nasiger	*Hyphaene compressa* H.Wendl.	Eng'ol	2	2	3	3	2	1	2	2	1	3	3	1
Nasiger	*Boscia coriacea* Pax	Edung	3	3	2	2	3	3	1	3	1	1	1	0
Nasiger	*Balanites pedicellaris* Mildbr. & Schltr.	Elamach	3	3	3	3	1	3	1	3	1	3	1	0
Nasiger	*Vachellia tortilis* (Forssk.) Galasso & Banfi	Ewoi	1	1	2	1	1	2	3	1	1	3	3	1
Nasiger	*Grewia tenax* (Forssk.) Fiori	Eng'omo	3	3	3	2	2	3	1	3	1	1	1	0
Nasiger	*Vatovaea pseudolablab* (Harms) J.B.Gillett	Egilae	2	3	3	3	2	3	1	3	1	2	3	0
Nasiger	*Berchemia discolor* Hemsl.	Emeyen	3	3	2	3	3	3	2	2	1	1	3	0
Nasiger	*Sterculia stenocarpa* H.J.P.Winkl.	Etete	3	3	3	1	3	3	1	3	1	1	1	0
Atala Kamusio	*Ziziphus mauritiana* Lam.	Ekalale	1	1	1	1	1	2	3	1	1	3	3	1
Atala Kamusio	*Salvadora persica* L.	Esekon	2	3	1	1	1	2	3	1	1	3	3	1
Atala Kamusio	*Balanites rotundifolia* (Tiegh.) Blatt.	Ebei	1	1	1	3	3	2	3	1	1	3	1	1
Atala Kamusio	*Balanites pedicellaris* Mildbr. & Schltr.	Elamach	1	1	1	3	1	2	3	1	1	3	3	1
Atala Kamusio	*Boscia coriacea* Pax	Edung'	3	3	1	2	3	3	1	3	1	1	3	0
Atala Kamusio	*Dobera glabra* Juss. ex Poir.	Edapal	1	1	1	2	1	1	1	3	1	2	2	1
Atala Kamusio	*Grewia tenax* (Forssk.) Fiori	Eng'omo	3	2	3	3	3	2	1	3	1	1	1	0
Atala Kamusio	*Vachellia tortilis* (Forssk.) Galasso & Banfi	Ewoi	1	1	2	1	1	2	3	1	1	3	3	1
Atala Kamusio	*Grewia rothii* DC.	Ekali	3	2	3	3	3	1	1	2	1	1	1	1
Atala Kamusio	*Senegalia senegal* (L.) Britton	Ekunoit	3	3	3	3	3	3	1	2	1	1	1	0

Communtity Unit	Wild Edible Plant	Local name (Turkana)	Abundance	Distance	Harvesting	Portability	Processing	Seasonality	Market	Affordability	Access	Adequacy	Regeneration	AVAILABILITY
Atala Kamusio	*Vachellia oerfota* (Forssk.) Kyal. & Boatwr.	Epetet	3	3	3	3	2	1	1	2	1	1	1	0
Atala Kamusio	*Sterculia stenocarpa* H.J.P.Winkl.	Etete	2	3	3	3	3	2	3	3	1	2	1	1
Atala Kamusio	*Grewia villosa* Willd.	Epong'ai	3	3	3	3	3	3	1	1	1	1	1	0
Atala Kamusio	*Ficus sycomorus* L.	Echoke	3	2	3	3	3	1	1	2	1	1	1	0
Atala Kamusio	*Berchemia discolor* Hemsl.	Emeyen	1	1	3	2	3	1	2	2	1	2	1	1
Atala Kamusio	*Cenchrus ciliaris* L.	Ejamaruka	3	3	1	3	3	1	1	1	1	1	1	0
Atala Kamusio	*Lannea triphylla* Engl.	Etopojo	3	3	3	3	3	1	1	3	1	1	1	0
Atala Kamusio	*Balanites aegyptiaca* (L.) Delile	Eroronyit	3	3	3	3	3	1	2	1	1	1	1	0
Atala Kamusio	*Maerua subcordata* (Gilg) DeWolf	Eerut	3	2	3	3	3	1	1	3	1	1	1	0
Atala Kamusio	*Grewia mollis* Juss.	Epat	1	1	3	1	3	2	2	1	1	3	1	1
Atala Kamusio	*Vatovaea pseudolablab* (Harms) J.B.Gillett	Egilae	3	3	3	3	3	1	1	1	1	1	1	0
Atala Kamusio	*Tamarindus indica* L.	Epedur	2	2	3	3	3	1	1	2	1	1	1	0
Atala Kamusio	*Cordia sinensis* Lam.	Edome	2	2	3	3	3	2	3	3	1	3	3	1
Lopur	*Ziziphus mauritiana* Lam.	Ekalale	1	1	1	1	1	2	3	1	1	3	3	1
Lopur	*Salvadora persica* L.	Esekon	1	1	1	1	1	2	3	1	1	3	3	1
Lopur	*Balanites rotundifolia* (Tiegh.) Blatt.	Ebei	2	1	1	3	3	2	3	1	1	3	1	1
Lopur	*Dobera glabra* Juss. ex Poir.	Edapal	1	1	1	3	1	2	3	1	1	3	3	1
Lopur	*Maerua subcordata* (Gilg) DeWolf	Eerut	3	3	3	1	3	2	2	3	1	3	1	0
Lopur	*Balanites pedicellaris* Mildbr. & Schltr.	Elamach	2	1	2	1	3	2	2	3	1	3	1	1
Lopur	*Boscia coriacea* Pax	Edung'	3	3	2	3	3	3	2	3	1	1	1	0
Lopur	*Tamarindus indica* L.	Epedur	2	3	1	3	1	3	3	2	2	2	2	0
Lopur	*Vachellia tortilis* (Forssk.) Galasso & Banfi	Ewoi	1	1	2	1	1	2	3	1	1	3	3	1
Lopur	*Cordia sinensis* Lam.	Edome	2	2	1	2	2	2	3	2	1	3	1	1
Lopur	*Grewia tenax* (Forssk.) Fiori	Eng'omo	3	3	2	2	1	1	1	3	1	2	1	0
Lopur	*Grewia villosa* Willd.	Epong'ai	2	3	2	3	1	3	1	3	1	1	1	0
Lopur	*Vatovaea pseudolablab* (Harms) J.B.Gillett	Egilae	2	3	3	2	1	3	1	3	1	3	1	0

Key	*Abundance (How plenty is the WEP in the community unit?)*	1. Plenty 2. Average 3. Little	Distance (How far do you travel to get the WEP?)	1. Near 2. Average 3. Far
	Harvesting (How easy it is to pick fruit from the WEP?)	1. Easy 2. Average	Portability (How easy is it to carry the harvested fruits of the WEP?)	1. Light 2. Average

Communtity Unit	Wild Edible Plant	Local name (Turkana)	Abundance	Distance	Harvesting	Portability	Processing	Seasonality	Market	Affordability	Access	Adequacy	Regeneration	AVAILABILITY
		3. Hard										3. Heavy		
	Processing (How easy is it to prepare harvested WEP for consumption?)	1. Easy 2. Average 3. Hard	Seasonality (In which seasons are fruits of the WEP plenty?)									1. Both 2. Dry 3. Wet		
	Market (How much of the WEP is sold in the market?)	1. Plenty 2. Average 3. Little	Price (How do you rate the price of the WEP in the market?)									1. Cheap 2. Average 3. Expensive		
	Access (Do you need any permission to access the WEP?)	1. Free 2. With permission 3. No access	Adequacy (How adequate are fruits of the WEP from single harvest?)									1. Plenty 2. Average 3. Little		
	Regeneration (How plenty are young ones of the WEP?)	1. Plenty 2. Average 3. Little	Availability (Do you consider the WEP available or not?)									1. YES 2. NO		

Appendix 5: Summary of research process



Appendix 6: Bayesian regression model output showing contribution of selected predictor variables (n = 9) on the availability of listed wild edible plants (n = 49) to the studied community units (Nasiger, Atala Kamusio, and Lopur) in Turkana County, Kenya. CI means credible interval, pd means probability direction, ROPE means region of practical equivalence, Rhat is the scale reduction factor, and ESS means effective sample size. The affixes_ave, and _perm are abbreviated for average and permission, respectively

Parameter	Median	95% CI	pd	ROPE	% ROPE	Rhat	ESS	Prior	Fit
(Intercept)	3.81	[-1.68, 12.02]	90.95%	[-0.18, 0.18]	2.68%	1.000	4305.73	Normal (0 +- 2.50)	
Distance_ave	-2.18	[-9.16, 5.68]	72.18%	[-0.18, 0.18]	3.18%	1.000	2326.16	Normal (0 +- 6.39)	
Distance_far	-8.28	[-14.24, -2.31]	99.98%	[-0.18, 0.18]	0.00%	0.999	2848.79	Normal (0 +- 4.97)	
Harvesting_ave	-3.24	[-10.80, 4.22]	79.63%	[-0.18, 0.18]	2.97%	1.001	2890.36	Normal (0 +- 6.39)	
Harvesting_hard	-2.92	[-9.35, 3.43]	81.98%	[-0.18, 0.18]	2.97%	1.000	2789.88	Normal (0 +- 4.97)	
Portability_ave	-1.78	[-10.02, 6.89]	67.25%	[-0.18, 0.18]	3.45%	1.000	2652.04	Normal (0 +- 6.69)	
Portability_heavy	-0.85	[-6.82, 5.58]	60.08%	[-0.18, 0.18]	4.29%	1.000	2611.93	Normal (0 +- 4.97)	
Processing_ave	-0.85	[-9.76, 7.74]	58.30%	[-0.18, 0.18]	3.60%	1.000	2527.53	Normal (0 +- 8.17)	
Processing_hard	-0.60	[-7.28, 5.85]	56.58%	[-0.18, 0.18]	4.79%	1.001	2592.45	Normal (0 +- 4.95)	
Seasonality_dry	4.37	[-1.28, 10.19]	94.53%	[-0.18, 0.18]	1.45%	1.000	3276.89	Normal (0 +- 5.03)	
Seasonality_wet	-5.94	[-13.76, 2.20]	93.23%	[-0.18, 0.18]	1.21%	1.000	3321.80	Normal (0 +- 5.60)	
Price_ave	1.03	[-6.06, 7.90]	61.55%	[-0.18, 0.18]	4.13%	1.001	2539.56	Normal (0 +- 6.14)	
Price_expensive	-4.51	[-11.42, 2.09]	90.75%	[-0.18, 0.18]	1.66%	1.001	2562.89	Normal (0 +- 5.13)	
Access_with_perm	-15.05	[-39.31, 6.56]	91.83%	[-0.18, 0.18]	0.55%	1.000	2869.65	Normal (0 +- 17.50)	
Adequacy_ave	9.43	[2.76, 17.52]	99.75%	[-0.18, 0.18]	0.00%	1.000	2497.63	Normal (0 +- 7.55)	
Adequacy_little	4.74	[-1.14, 10.61]	95.00%	[-0.18, 0.18]	1.42%	0.999	3053.65	Normal (0 +- 4.96)	
Regeneration_ave	1.56	[-12.00, 17.42]	58.18%	[-0.18, 0.18]	2.24%	1.000	2990.16	Normal (0 +- 12.51)	
Regeneration_little	2.64	[-3.78, 9.21]	78.68%	[-0.18, 0.18]	4.13%	1.000	3004.53	Normal (0 +- 5.20)	
ELPD									-13.49
LOOIC									26.98
WAIC									19.82
R2									0.88
Sigma									1.00
Log_loss									0.06

Appendix 7: Bayesian logistic regression model output showing contribution of studied predictor variables (n = 6) on the availability of studied listed wild edible plants (n = 13) to Nasiger community unit in Turkana County, Kenya. CI means credible interval, pd means probability direction, ROPE means region of practical equivalence, Rhat is the scale reduction factor, and ESS means effective sample size factor, and ESS means effective sample size

Parameter	Median	95% CI	pd	ROPE	% ROPE	Rhat	ESS	Prior	Fit
(Intercept)	4.43	[-1.98, 13.65]	91.80%	[-0.18, 0.18]	2.13%	1.001	4258.00	Normal (0 +- 2.50)	
Harvesting_ave	-2.18	[-11.68, 5.93]	70.03%	[-0.18, 0.18]	3.34%	1.000	3208.00	Normal (0 +- 5.70)	
Harvesting_hard	-3.51	[-11.17, 4.19]	82.73%	[-0.18, 0.18]	2.45%	1.003	3027.00	Normal (0 +- 4.94)	
Portability_ave	-2.86	[-14.44, 7.01]	71.33%	[-0.18, 0.18]	2.10%	1.002	3457.00	Normal (0 +- 6.66)	
Portability_heavy	-1.05	[-8.43, 6.58]	60.52%	[-0.18, 0.18]	3.87%	1.000	3307.00	Normal (0 +- 4.82)	
Processing_ave	-0.34	[-7.86, 9.45]	52.42%	[-0.18, 0.18]	3.34%	1.001	2962.00	Normal (0 +- 5.70)	
Processing_hard	-1.61	[-8.89, 5.82]	67.75%	[-0.18, 0.18]	3.45%	1.001	3134.00	Normal (0 +- 5.20)	
Seasonality_dry	1.64	[-7.37, 12.03]	64.08%	[-0.18, 0.18]	3.37%	1.000	3687.00	Normal (0 +- 5.70)	
Seasonality_wet	-8.53	[-15.73, -1.13]	99.02%	[-0.18, 0.18]	0.00%	1.000	2834.00	Normal (0 +- 4.82)	
Adequacy_ave	-3.60	[-18.59, 9.64]	69.97%	[-0.18, 0.18]	2.05%	1.000	3352.00	Normal (0 +- 9.01)	
Adequacy_little	3.29	[-3.98, 10.47]	80.23%	[-0.18, 0.18]	2.76%	1.001	3103.00	Normal (0 +- 4.82)	
Regeneration_little	1.03	[-5.79, 8.23]	62.18%	[-0.18, 0.18]	3.89%	1.000	3090.00	Normal (0 +- 4.82)	
ELPD									-3.17
LOOIC									6.35
WAIC									4.31
R2									0.89
Sigma									1.00
Log_loss									0.00269

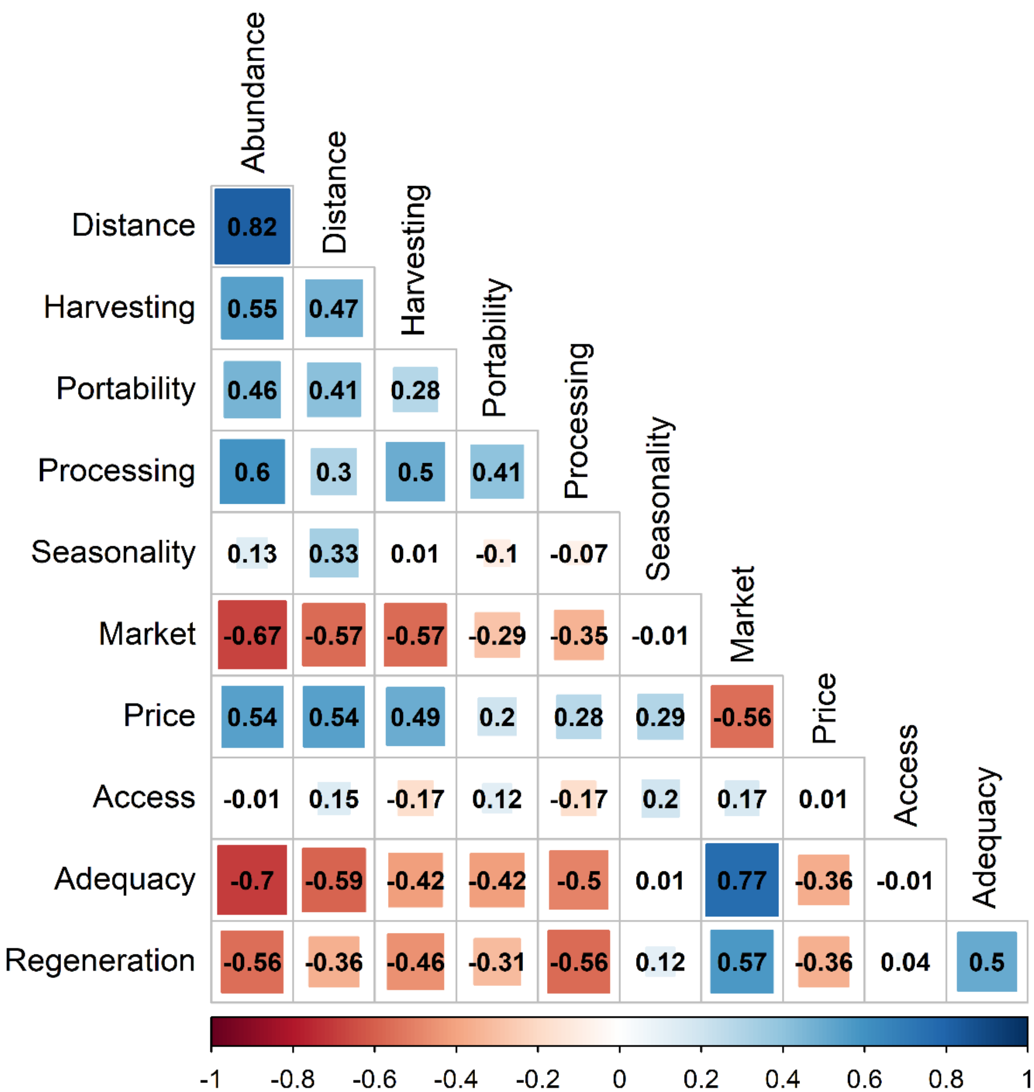
Appendix 8: Bayesian regression model output showing contribution of studied predictor variables (n = 7) on the availability of studied listed wild edible plants (n = 23) to Atala Kamusio community unit in Turkana County, Kenya. CI means credible interval, pd means probability direction, ROPE means region of practical equivalence, Rhat is the scale reduction

Parameter	Median	95% CI	pd	ROPE	% ROPE	Rhat	ESS	Prior	Fit
(Intercept)	4.28	[-5.88, 15.02]	79.67%	[-0.18, 0.18]	2.16%	1.000	3830.00	Normal (0 +- 2.50)	
Distance_ave	-2.04	[-9.73, 5.37]	70.93%	[-0.18, 0.18]	2.74%	1.000	3242.00	Normal (0 +- 5.57)	
Distance_far	-4.64	[-11.34, 2.36]	91.45%	[-0.18, 0.18]	1.58%	1.000	3127.00	Normal (0 +- 4.93)	
Harvesting_ave	1.21	[-16.49, 21.84]	54.62%	[-0.18, 0.18]	1.50%	1.000	4526.00	Normal (0 +- 11.99)	
Harvesting_hard	-0.46	[-7.40, 7.27]	55.25%	[-0.18, 0.18]	4.05%	0.999	3341.00	Normal (0 +- 5.13)	
Portability_ave	2.77	[-7.03, 12.92]	70.50%	[-0.18, 0.18]	2.76%	1.000	3580.00	Normal (0 +- 7.26)	
Portability_heavy	-4.33	[-12.05, 3.71]	85.92%	[-0.18, 0.18]	2.34%	1.002	3427.00	Normal (0 +- 5.31)	
Processing_ave	-7.92	[-26.68, 5.92]	85.60%	[-0.18, 0.18]	1.03%	1.000	3120.00	Normal (0 +- 11.99)	
Processing_hard	-2.15	[-10.84, 5.58]	71.38%	[-0.18, 0.18]	3.37%	1.000	3555.00	Normal (0 +- 5.57)	
Seasonality_dry	3.49	[-2.78, 10.17]	85.82%	[-0.18, 0.18]	2.34%	1.000	3430.00	Normal (0 +- 5.01)	
Seasonality_wet	-5.75	[-16.91, 3.33]	89.60%	[-0.18, 0.18]	1.92%	1.001	3679.00	Normal (0 +- 7.26)	
Market_ave	1.15	[-7.52, 9.93]	60.77%	[-0.18, 0.18]	3.05%	1.000	3312.00	Normal (0 +- 7.26)	
Market_little	8.15	[1.41, 14.95]	99.65%	[-0.18, 0.18]	0.00%	1.000	3380.00	Normal (0 +- 5.31)	
Price_ave	3.26	[-3.94, 10.18]	81.50%	[-0.18, 0.18]	3.03%	1.000	2982.00	Normal (0 +- 5.57)	
Price_expensive	-1.27	[-7.96, 5.30]	64.42%	[-0.18, 0.18]	4.00%	1.000	3145.00	Normal (0 +- 5.31)	
ELPD									-9.37
LOOIC									18.73
WAIC									14.21
R2									0.82
Sigma									1.00
Log_loss									0.10

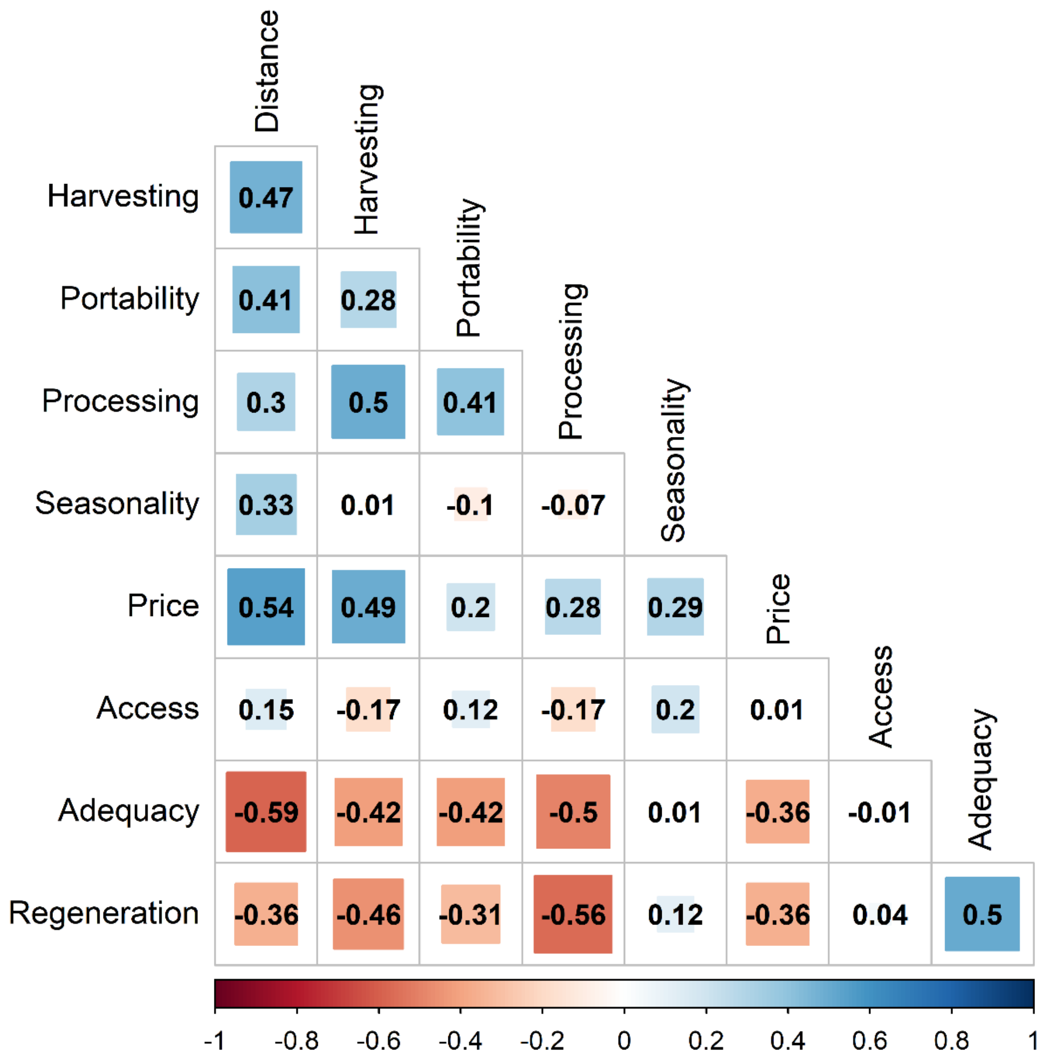
Appendix 9: Bayesian regression model output showing contribution of studied predictor variables (n = 8) on the availability of studied listed wild edible plants (n = 13) to Lopur community unit in Turkana County, Kenya. CI means credible interval, pd means probability direction, ROPE means region of practical equivalence, Rhat is the scale reduction factor, and ESS means effective sample size

Parameter	Median	95% CI	pd	ROPE	% ROPE	Rhat	ESS	Prior	Fit
(Intercept)	-0.16	[-13.99, 13.31]	51.05%	[-0.18, 0.18]	2.21%	1.000	4089.00	Normal (0 +- 2.50)	
Distance_ave	3.63	[-12.13, 19.12]	67.85%	[-0.18, 0.18]	1.42%	1.000	4252.00	Normal (0 +- 9.01)	
Distance_far	-6.15	[-14.44, 1.81]	94.10%	[-0.18, 0.18]	1.16%	1.000	3840.00	Normal (0 +- 4.82)	
Harvesting_ave	-0.28	[-7.57, 7.61]	53.33%	[-0.18, 0.18]	4.58%	1.001	4687.00	Normal (0 +- 4.94)	
Harvesting_hard	-5.84	[-16.08, 3.97]	88.05%	[-0.18, 0.18]	1.45%	1.000	3717.00	Normal (0 +- 6.66)	
Portability_ave	-0.72	[-10.75, 7.99]	56.50%	[-0.18, 0.18]	3.00%	0.999	4339.00	Normal (0 +- 5.70)	
Portability_heavy	0.03	[-7.82, 7.04]	50.52%	[-0.18, 0.18]	3.50%	1.001	4097.00	Normal (0 +- 4.94)	
Processing_ave	3.11	[-11.61, 19.42]	65.67%	[-0.18, 0.18]	1.55%	0.999	4025.00	Normal (0 +- 9.01)	
Processing_hard	-0.22	[-7.72, 7.71]	52.05%	[-0.18, 0.18]	3.79%	1.001	3968.00	Normal (0 +- 5.20)	
Seasonality_dry	3.65	[-4.76, 12.18]	80.58%	[-0.18, 0.18]	2.71%	1.000	4065.00	Normal (0 +- 4.94)	
Seasonality_wet	-2.85	[-11.62, 6.42]	73.47%	[-0.18, 0.18]	2.92%	1.001	3680.00	Normal (0 +- 5.20)	
Access_with_perm	-2.08	[-17.51, 14.72]	59.98%	[-0.18, 0.18]	1.84%	0.999	4583.00	Normal (0 +- 9.01)	
Adequacy_ave	-2.68	[-13.92, 8.82]	67.55%	[-0.18, 0.18]	2.18%	1.001	3804.00	Normal (0 +- 6.66)	
Adequacy_little	3.40	[-5.63, 12.80]	77.18%	[-0.18, 0.18]	2.50%	1.001	4476.00	Normal (0 +- 5.20)	
Regeneration_ave	-1.82	[-17.50, 14.54]	58.95%	[-0.18, 0.18]	1.76%	1.000	4868.00	Normal (0 +- 9.01)	
Regeneration_little	2.31	[-6.62, 10.75]	68.55%	[-0.18, 0.18]	3.18%	0.999	4593.00	Normal (0 +- 5.20)	
ELPD									-2.04
LOOIC									4.07
WAIC									2.74
R2									0.92
Sigma									1.00
Log_loss									0.000649

Appendix 10: Correlation matrix plot of the 11 categorical predictor parameters before removing collinear parameters from three focus group discussions held at Nasiger, Atala Kamusio, and Lopur community units in Turkana County, Kenya



Appendix 11: Correlation matrix plot of the retained 9 categorical predictor parameters after removing collinear parameters (Abundance and Market) from three focus group discussions held at Nasiger, Atala Kamusio, and Lopur community units in Turkana County, Kenya



Appendix 12: Overview of parameters that were retained and dropped in a study of Wild Edible Plants in Turkana County, Kenya. Some parameters were dropped due to multi-collinearity problems (r >= 0.7) with respect to the three communities combined and separately. Dropped parameters are highlighted in gray

No.	Parameter	All Community Units	Nasiger	Atala Kamusio	Lopur
1	Abundance	Dropped	Dropped	Dropped	Dropped
2	Distance	Retained	Dropped	Retained	Retained
3	Harvesting	Retained	Retained	Retained	Retained
4	Portability	Retained	Retained	Retained	Retained
5	Processing	Retained	Retained	Retained	Retained
6	Seasonality	Retained	Retained	Retained	Retained
7	Market	Dropped	Dropped	Retained	Dropped
8	Price	Retained	Dropped	Retained	Dropped
9	Access	Retained	Dropped	Dropped	Retained
10	Adequacy	Retained	Retained	Dropped	Retained
11	Regeneration	Retained	Retained	Dropped	Retained

Appendix 13: Number of statements (n = 348), codes, and themes from Focus Group Discussions (FGDs) held in three community units (Nasiger, Atala Kamusio, and Lopur) regarding Wild Edible Plants in Turkana County, Kenya that contributed to each of the derived codes (n = 17) and themes (n = 13). The statements are partitioned by gender, where F represents female (n = 158) and M represents male (n = 190)

No	Codes	Theme	Number of contributing statements
1	Cultural livelihood strategy	Culture and traditions	126 (F = 55, M = 71)
2	Lean season Dry season	Seasonality	62 (F = 30, M = 32)
3	Conservation and management Overgrazing on seedlings Perishability of the fruits	Conservation and management	36 (F = 15, M = 21)
4	Distribution of WEPs	Distribution of WEPs	32 (F = 15, M = 17)
5	Climate change Invasive species	Climate change	26 (F = 8, M = 18)
6	Agricultural expansion	Crop farming	15 (F = 9, M = 6)
7	Thorny fruit trees	Price	12 (F = 7, M = 5)
8	Population pressure	Population pressure	11 (F = 5, M = 6)
9	Security considerations	Insecurity and safety	8 (F = 2, M = 6)
10	Declining use of WEPs	Change in lifestyle	7 (F = 5, M = 2)
11	Cutting of WEPs	Selective harvesting	7 (F = 4, M = 3)
12	Competition from wild animals	Competition from wild animals	4 (F = 2, M = 2)
13	Pests and diseases	Pests and diseases	2 (F = 1, M = 1)
	TOTAL		**348 (F = 158, M = 190)**

Appendix 14: Threats facing wild edible plants or biodiversity in general mentioned in 23 literature sources and used to guide development of 10 threat categories for both focus group discussions and field plot surveys in Turkana County, Kenya

Number	The threats cited	Reviewed Source
1	Overgrazing, Agricultural land expansion, Over-harvesting, Uncontrolled fire setting, Roads and home construction, Fodder and fuelwood collection	(Abbasi et al., 2013)
2	Construction and tools, Grazing, Charcoal, Agricultural expansions, Firewood,	(Alemayehu et al., 2015)
3	Agricultural land expansion, Over-grazing, Over-harvesting, Uncontrolled fire setting, Fuelwood collection	(Ali-Shtayeh et al., 2008)
4	Habitat conversion due to agricultural expansion, overgrazing, other problems	(Asfaw, 2008)
5	Agricultural expansion, Overgrazing, Fuelwood collection	(Ashagre et al., 2016)
6	Expansion of agriculture, Fire hazards, Overgrazing, Construction of new road, Drought, Collection of firewood and construction materials	(Assefa & Abebe, 2011)
7	Inconsiderate and overexploitation by “outsiders”, Destruction of EWPs by wild animals such as elephants	(Badimo et al., 2015)
8	Overgrazing/over browsing, removal of woody plants for different purposes (e.g. firewood and charcoal production,	(Bahru et al., 2013)

Number	The threats cited	Reviewed Source
	building and construction, fencing materials etc), Human settlement, Agricultural expansion, Burning forests	
9	Agricultural expansion, Fire, Fuelwood collection, Over-stocking, overgrazing, Selective harvesting	(Balemie & Kebebew, 2006)
10	Agricultural land expansion, Uncontrolled fire setting, Fuelwood collection, Overgrazing, Overharvesting	(Berihun & Molla, 2017)
11	Land use change (expansion of agriculture land), Developmental activities (road construction and urbanization), Habitat destruction (Timber harvest, Fuelwood collection, and wildfire), Drought, Overharversting, Overgrazing	(Duguma, 2020)
12	Human population pressure, Land use change, Poverty/hunger, Tribal conflicts, Adverse climate change, Overexploitation of resources, Restriction of mobility, Lack of alternative, High livestock population, Expansion of agriculture.	(Feyssa et al., 2012)
13	Wildfire, Deliberate burning – mostly to get pasture grasses regenerated and control animal exo-parasites like ticks, Deforestation, Bush clearing	(Guinand & Lemessa, 2000)
14	Agriculture, Introducing exotic species, Overgrazing, Construction, Charcoal making, Extended dry seasons	(L. Kidane & Kejela, 2021)

Number	The threats cited	Reviewed Source
15	Agricultural land expansion, Lack of culture of planting, Selective harvesting for other use (house construction, farm implements, household utensils), Drought/shortage of rainfall, Fuelwood collection, Grazing pasture, Wildfire	(B. Kidane et al., 2015)
16	Increase in human population, The increasing logging for charcoal and timber, The heavy harvesting of plants (especially bark, roots and stems) for medicinal use, bush fires, all of which they perceive as leading to soil erosion, drought, and hunger	(N'Danikou et al., 2011)
17	Fuel wood collection, Drought, Selective harvesting, Over-stocking/grazing, Agricultural expansion, Fire hazards	(Regassa et al., 2015)
18	Land use change, Direct exploitation, Climate change, Pollution, Others, Wild fires, Pests	(Schunko et al., 2022)
19	Habitat destruction, Land use change, Over-grazing, Over-harvesting, Invasive species	(Anshuman Singh et al., 2020)
20	Agricultural expansion, Fire, Fuelwood collection, Selective harvesting	(Suwardi et al., 2020)
21	Fire, Agricultural expansion, Deforestation, Free grazing, Fuelwood, Herbicides, Construction, Settlement, Other (farm and household tool)	(Tebkew et al., 2018)
22	Agricultural expansion, Construction, Fuelwood collection and charcoal making, Overgrazing, Fire	(Tebkew et al., 2014)

Number	The threats cited	Reviewed Source
23	Land clearing, Fire, grazing, wood exploitation, fruits/flowers harvest, leaves harvest, back exploitation, charcoal, pests and diseases, drought, ageing, loss soil fertility	(Vinceti et al., 2018)

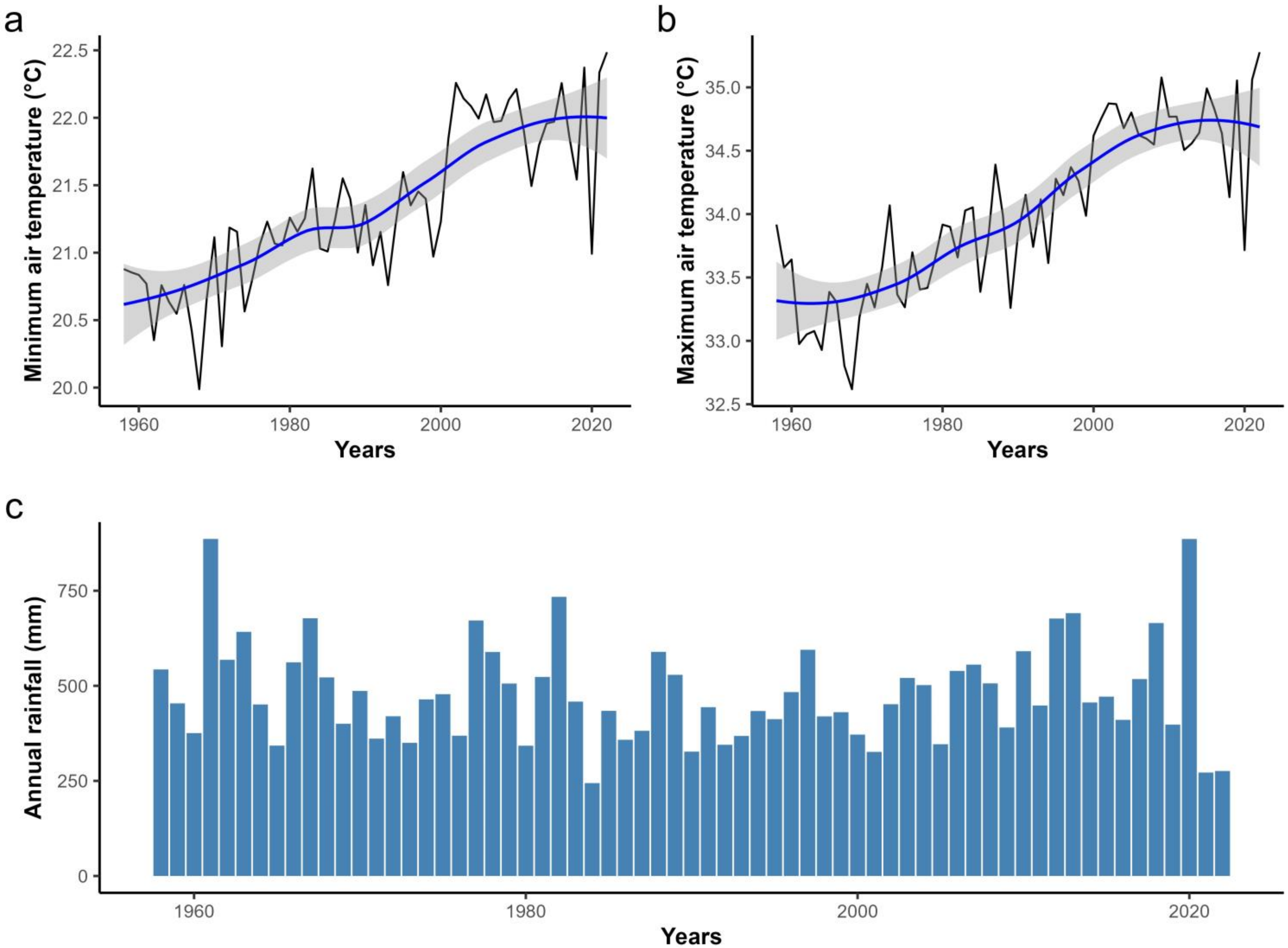
Appendix 15: Indicators derived from the focus group discussions on threats facing priority woody wild edible plants in Turkana County, Kenya. The same indicators were used in field plot surveys except for climate change

Number	Threat category	Threat indicators mentioned by FGD participants
1	Climate change	Severe wilting or drying, *Prosopis juliflora*, loss of surface water sources, extreme precipitation, extreme wind events, reducing population of WEPs, emergence of non-native invasive species, overabundance of some native species
2	Invasive species	Invasive *Prosopis juliflora*, emergence of some harmful microbial organisms
3	Overstocking/overgrazing	Scars of browsed seedlings, browsed branches, cutting of branches for feeding livestock, sedentary ranching
4	Selective harvesting/Overharvesting	Cut stems/branches, stumps identifiable as of WEPs, severely debarked stems, digging of roots of WEPs
5	Fuelwood collection/charcoal burning	Active or used charcoal smoking kiln, Cut stems awaiting charcoal burning, people collecting fuel wood, level of charcoal business in the area
6	Agricultural expansion	Ploughed land, crops or remains of crops, cleared land awaiting ploughing
7	Uncontrolled fire	Fire scars on stems/branches/leaves, burnt piece of land, fire from charcoal burning, fire from honey harvesting,
8	Infrastructural development	New developed structures such as institutions and roads, establishing of homesteads
9	Pests and diseases	Signs of pests on the plant such as locusts, signs of pest damage on leaves, signs of fungal or diseased parts of WEPs
10	Others	Squirrel/woodpecker holes on trunks of WEPs, destruction of land following war/battlefield, riverbank erosion, and sedimentation, use of herbicides and pesticides, pollution from touristic activities, opportunistic harvesting of branches by tourists along the roads

Appendix 16: Management options for wild edible plants mentioned in 9 literature sources and used to guide development of management categories for focus group discussions in selected community units within Turkana County, Kenya

Number	Management options cited	Reviewed Source
1	Cultivation and marketing	(Abbasi et al., 2013)
2	Home gardens, sacred compounds	(Alemayehu et al., 2015)
3	Cultivation and marketing	(Ali-Shtayeh et al., 2008)
4	Domestication and cultivation, studying nutritional values, propagation techniques, marketing and value addition	(Bahru et al., 2013)
5	*In-situ* conservation methods like planting in the form of fences and protected pasture land in different worship areas, and in farm margins	(Berihun & Molla, 2017)
6	Create awareness of WEPs use by indigenous people, Value indigenous knowledge, Enhance participatory planning and implementation of projects, Alternative livelihoods for local people	(Feyssa, 2012)
7	Increasing awareness, agroforestry, garden trees	(Salih & Hassan Ali, 2014)
8	Planting around home gardens, Pruning, Pollarding, Fencing, Protected by culture	(Tebkew et al., 2014)
9	Adoption of longer intervals between fires	(Vinceti et al., 2018)

Appendix 17: Annual mean minimum temperature (a) and maximum temperature (b) for Turkana County between 1958 and 2022. The gray region around the blue solid best line of fit indicates the standard error regions. (c) is the total annual rainfall for the county with each bar representing total rainfall for the respective year



Appendix 18: Mean values of environmental predictor variables used for modeling the potentially suitable habitats of wild edible plants in Turkana County, Kenya. In the title row, gcm_ssp_time represents global circulation model, shared socioeconomic pathway, and time. The abbreviated bio_x refers to bioclimatic variables used in the modeling workflow. Their full definitions and units of measurement are indicated in Table 6.2

gcm_ssp_time	bio_12	bio_13	bio_14	bio_15	bio_18	bio_19	bio_2	bio_3	bio_4	bio_5	bio_7	bio_8	bio_9
present	369.82	66.06	8.97	55.40	63.63	95.55	9.57	75.76	82.92	34.99	12.54	28.79	29.07
gfdl_ssp126_2041-2070	369.81	63.70	9.01	56.15	68.62	88.23	9.65	75.62	93.34	35.97	12.68	30.07	30.22
ipsl_ssp126_2041-2070	389.37	76.34	10.58	59.58	70.91	99.81	8.66	75.03	74.06	30.88	11.47	30.31	30.35
mpi_ssp126_2041-2070	402.10	81.56	9.00	62.95	67.10	96.83	9.02	73.57	92.96	30.88	12.18	30.28	30.33
mri_ssp126_2041-2070	367.10	70.98	9.92	58.07	92.29	97.62	9.59	76.58	80.44	30.93	12.46	30.33	30.32
ukesm1_ssp126_2041-2070	498.99	100.46	13.02	60.16	106.22	120.86	8.64	73.47	86.58	30.96	11.68	30.39	30.38
gfdl_ssp370_2041-2070	376.97	65.17	10.25	53.97	73.01	99.15	9.56	68.61	122.88	37.07	13.85	30.68	31.03
ipsl_ssp370_2041-2070	407.60	80.42	10.70	59.69	71.75	101.45	8.04	73.88	70.31	30.92	10.80	30.40	30.42
mpi_ssp370_2041-2070	409.32	69.77	8.58	55.16	71.88	103.46	8.72	71.12	94.17	30.95	12.18	30.36	30.38
mri_ssp370_2041-2070	370.71	62.95	8.94	53.34	102.37	97.18	9.40	72.43	90.20	31.05	12.91	30.41	30.40
ukesm1_ssp370_2041-2070	541.14	109.01	14.20	63.74	115.21	140.29	8.11	70.00	96.88	31.04	11.49	30.46	30.46
gfdl_ssp585_2041-2070	366.38	56.90	8.47	49.29	72.09	95.61	9.75	73.66	106.58	36.73	13.13	30.99	31.01
ipsl_ssp585_2041-2070	408.04	82.34	10.86	62.42	79.24	112.45	7.91	72.76	67.61	30.95	10.78	30.42	30.46
mpi_ssp585_2041-2070	453.05	82.91	9.34	59.32	73.82	112.34	8.56	69.87	97.17	30.95	12.17	30.34	30.37
mri_ssp585_2041-2070	370.26	63.01	9.96	53.77	108.58	94.58	9.43	76.97	78.19	31.02	12.19	30.44	30.41
ukesm1_ssp585_2041-2070	573.12	115.03	13.59	63.65	126.83	147.32	8.19	71.38	89.36	31.06	11.40	30.48	30.49
gfdl_ssp126_2071-2100	352.42	55.83	8.93	53.16	74.14	92.56	9.82	76.32	93.64	30.92	12.79	30.34	30.37
ipsl_ssp126_2071-2100	419.80	86.73	10.53	62.91	76.49	110.19	8.35	74.11	76.14	30.85	11.19	30.29	30.34
mpi_ssp126_2071-2100	435.56	77.41	9.58	60.26	71.70	105.48	9.01	71.72	97.18	30.90	12.50	30.26	30.32
mri_ssp126_2071-2100	343.16	59.26	9.97	54.36	103.49	84.79	9.77	78.60	68.36	30.93	12.37	30.34	30.32
ukesm1_ssp126_2071-2100	523.20	97.70	15.79	57.87	127.14	116.90	8.59	74.14	81.93	30.96	11.51	30.41	30.39
gfdl_ssp370_2071-2100	375.12	58.77	9.89	50.58	78.44	95.71	9.39	67.38	127.84	31.11	13.87	30.49	30.53
ipsl_ssp370_2071-2100	441.36	93.81	11.19	64.09	81.82	121.43	7.23	71.20	70.37	31.02	10.05	30.54	30.59
mpi_ssp370_2071-2100	443.25	81.99	9.85	59.09	73.52	112.14	8.12	68.62	100.79	31.03	11.74	30.45	30.50
mri_ssp370_2071-2100	377.73	60.35	10.13	50.63	111.07	92.30	9.30	75.48	79.56	31.12	12.26	30.54	30.51
ukesm1_ssp370_2071-2100	653.91	125.95	16.73	63.68	168.15	173.06	7.55	68.52	93.28	31.18	10.92	30.63	30.62
gfdl_ssp585_2071-2100	411.62	68.39	11.67	50.62	84.85	101.02	10.19	70.18	114.74	31.16	14.43	30.50	30.47
ipsl_ssp585_2071-2100	460.14	95.74	12.86	62.88	91.82	128.40	6.80	68.37	67.89	31.11	9.82	30.63	30.68

gcm_ssp_time	bio_12	bio_13	bio_14	bio_15	bio_18	bio_19	bio_2	bio_3	bio_4	bio_5	bio_7	bio_8	bio_9
mpi_ssp585_2071-2100	494.82	91.73	10.12	61.55	69.07	125.58	10.47	74.38	114.04	31.05	14.02	30.45	30.54
mri_ssp585_2071-2100	387.66	78.55	10.63	59.25	136.75	87.88	9.36	76.35	84.86	31.17	12.19	30.63	30.56
ukesm1_ssp585_2071-2100	676.16	130.46	19.45	60.17	161.22	168.92	7.41	70.33	89.00	31.26	10.44	30.75	30.73

Appendix 19: Standard deviation values of environmental predictor variables used for modeling the potential suitable habitats of wild edible plants in Turkana County, Kenya. In the title row, gcm_ssp_time represents global circulation model, shared socioeconomic pathway, and time. The abbreviated bio_x refers to bioclimatic variables used in the modeling workflow. Their full definitions and units of measurements are indicated in Table 6.2

gcm_ssp_time	bio_12	bio_13	bio_14	bio_15	bio_18	bio_19	bio_2	bio_3	bio_4	bio_5	bio_7	bio_8	bio_9
present	113.50	15.58	3.26	10.02	20.90	49.88	1.41	3.89	11.16	1.72	1.43	2.07	1.76
gfdl_ssp126_2041-2070	108.68	15.57	3.35	9.97	19.58	44.36	1.55	4.68	10.78	1.76	1.50	1.98	1.72
ipsl_ssp126_2041-2070	116.38	17.05	4.18	11.38	22.84	50.57	1.43	5.46	10.72	0.17	1.42	0.19	0.17
mpi_ssp126_2041-2070	121.01	19.51	3.39	10.13	20.60	51.73	1.38	4.43	10.62	0.17	1.40	0.19	0.18
mri_ssp126_2041-2070	119.48	17.83	4.01	9.21	29.98	52.06	1.37	3.52	8.86	0.17	1.43	0.20	0.17
ukesm1_ssp126_2041-2070	154.32	25.11	5.83	11.29	35.22	60.67	1.36	4.68	9.45	0.18	1.37	0.20	0.17
gfdl_ssp370_2041-2070	111.90	15.46	3.95	9.78	21.65	50.06	1.50	5.36	12.48	1.76	1.33	2.21	1.87
ipsl_ssp370_2041-2070	121.96	17.93	3.97	12.16	21.98	51.19	1.42	5.70	10.13	0.17	1.41	0.19	0.17
mpi_ssp370_2041-2070	126.90	16.87	3.50	9.94	26.39	53.85	1.36	4.74	11.19	0.17	1.38	0.20	0.18
mri_ssp370_2041-2070	121.81	15.91	3.12	9.21	26.34	52.02	1.38	4.73	8.01	0.17	1.35	0.21	0.17
ukesm1_ssp370_2041-2070	170.47	28.14	6.64	11.68	40.13	70.52	1.35	5.45	10.53	0.19	1.36	0.21	0.18
gfdl_ssp585_2041-2070	107.97	13.19	3.13	9.41	20.08	45.22	1.53	5.03	10.88	1.80	1.44	2.18	1.78
ipsl_ssp585_2041-2070	116.77	17.89	4.09	12.49	24.79	50.14	1.42	5.79	9.59	0.17	1.42	0.18	0.17
mpi_ssp585_2041-2070	140.60	19.26	3.24	9.79	26.42	58.85	1.31	4.55	9.65	0.17	1.36	0.20	0.17
mri_ssp585_2041-2070	116.23	15.43	3.74	9.88	27.24	50.71	1.37	3.67	8.72	0.17	1.41	0.20	0.17
ukesm1_ssp585_2041-2070	182.66	29.11	6.21	12.23	40.85	74.22	1.32	4.73	9.89	0.20	1.41	0.21	0.18
gfdl_ssp126_2071-2100	107.27	14.75	3.11	10.33	20.41	48.02	1.55	4.46	11.98	0.17	1.54	0.21	0.18
ipsl_ssp126_2071-2100	124.55	19.34	4.06	12.56	25.05	55.89	1.41	5.51	10.99	0.17	1.41	0.19	0.17
mpi_ssp126_2071-2100	134.10	17.51	3.63	9.85	23.29	55.70	1.35	4.00	10.13	0.17	1.44	0.19	0.18
mri_ssp126_2071-2100	106.71	14.69	4.12	9.46	30.29	42.43	1.37	3.52	8.02	0.16	1.39	0.19	0.17
ukesm1_ssp126_2071-2100	168.33	24.83	8.19	11.69	46.67	59.87	1.34	4.72	9.98	0.18	1.35	0.19	0.17
gfdl_ssp370_2071-2100	112.06	13.91	3.69	8.79	22.71	47.30	1.35	5.79	14.26	0.18	1.26	0.22	0.20
ipsl_ssp370_2071-2100	129.82	23.56	4.55	13.92	25.61	54.75	1.42	7.06	9.00	0.17	1.44	0.18	0.17
mpi_ssp370_2071-2100	135.51	18.04	3.55	10.60	27.20	56.43	1.33	5.40	11.27	0.17	1.36	0.21	0.18
mri_ssp370_2071-2100	119.84	14.74	3.75	8.96	29.18	45.95	1.39	4.38	7.80	0.17	1.38	0.19	0.17
ukesm1_ssp370_2071-2100	210.82	34.79	8.92	10.46	57.78	86.59	1.35	6.21	9.13	0.20	1.40	0.22	0.18
gfdl_ssp585_2071-2100	118.01	15.60	4.27	9.28	26.95	49.13	1.58	5.15	10.36	0.19	1.53	0.21	0.18

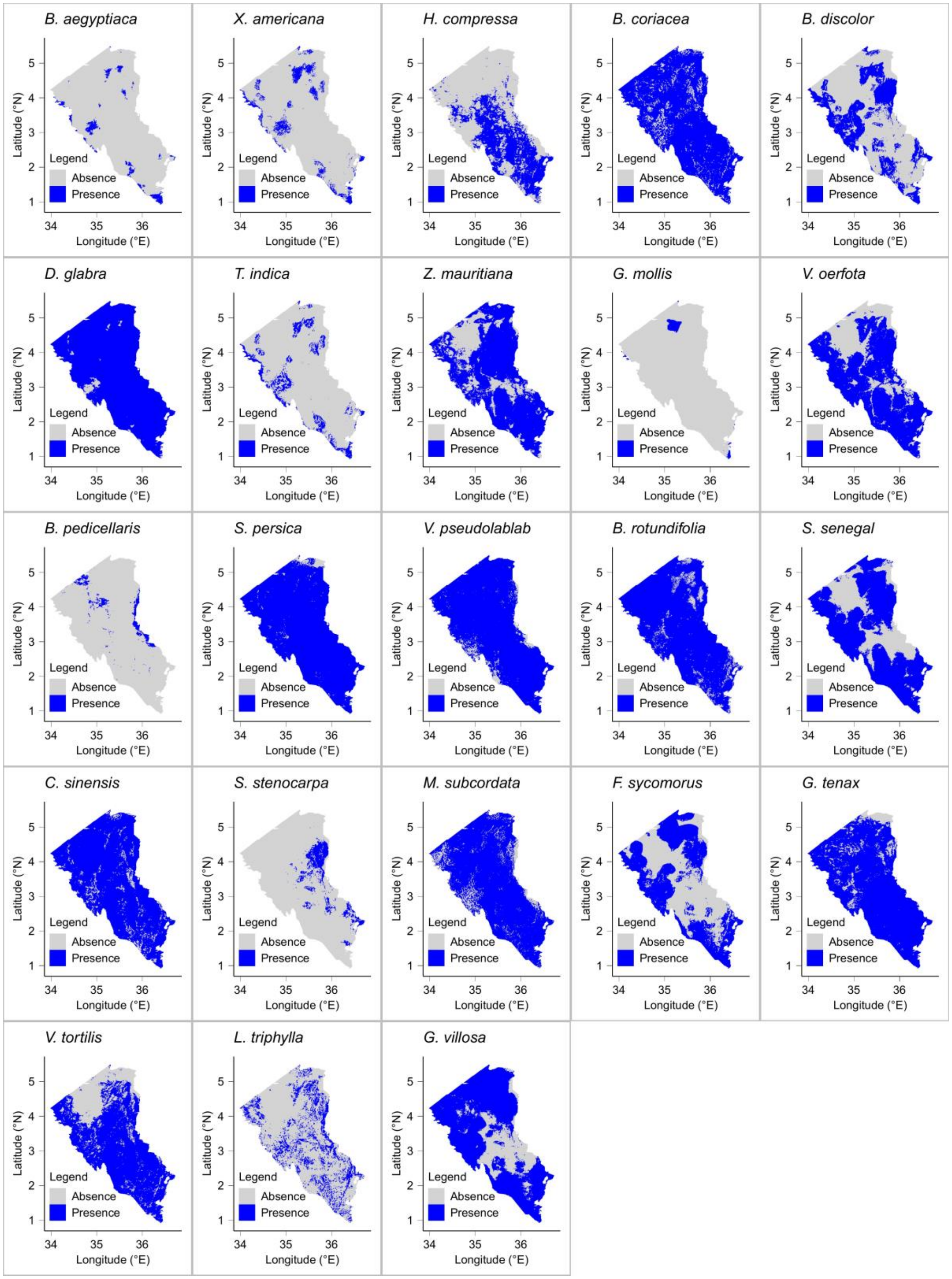
gcm_ssp_time	bio_12	bio_13	bio_14	bio_15	bio_18	bio_19	bio_2	bio_3	bio_4	bio_5	bio_7	bio_8	bio_9
ipsl_ssp585_2071-2100	138.43	21.09	5.61	13.17	31.90	55.74	1.43	7.83	8.00	0.18	1.43	0.17	0.17
mpi_ssp585_2071-2100	155.70	22.49	3.74	9.55	23.89	64.39	1.37	3.64	10.93	0.17	1.37	0.21	0.18
mri_ssp585_2071-2100	119.31	17.58	4.39	12.04	34.24	40.66	1.41	3.74	6.36	0.17	1.47	0.19	0.17
ukesm1_ssp585_2071-2100	227.52	36.23	10.20	11.16	60.17	81.99	1.33	6.17	10.22	0.20	1.38	0.21	0.18

Appendix 20: Predicted areal values (km2) for presence and absence for the studied wild edible plants in Turkana County, Kenya under current and projected future (2041-2070 and 2070-2100) climate scenarios and shared socioeconomic pathways (SSP126, SSP370, and SSP585). Current represents the extent of potentially suitable habitat under the current climate conditions (1970 - 2000) period

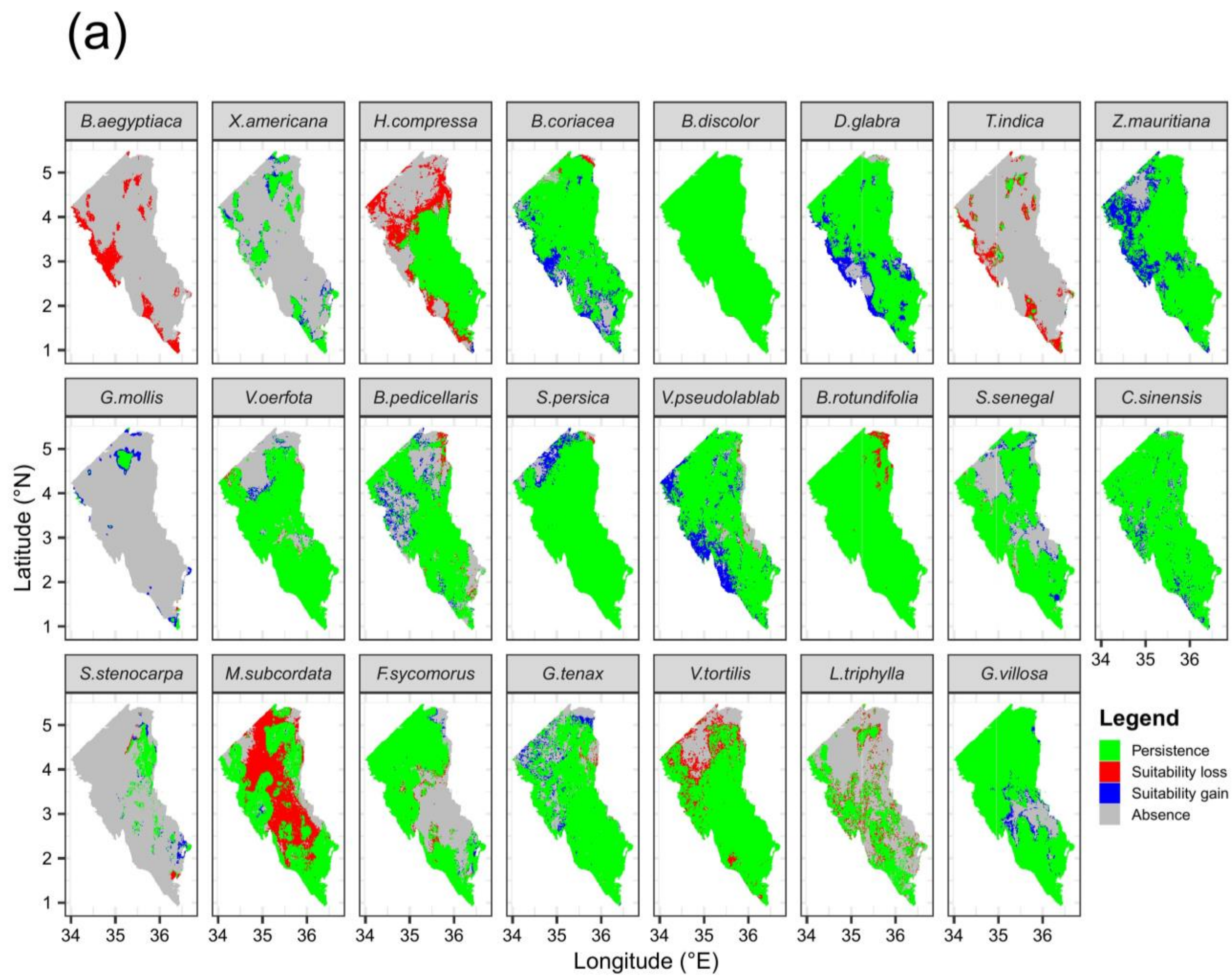
			2041-2070			2071-2100		
Wild edible plant	**Suitability**	**Current**	**SSP126**	**SSP370**	**SSP585**	**SSP126**	**SSP370**	**SSP585**
Balanites aegyptiaca	Presence	9405	0	0	0	0	0	0
Balanites aegyptiaca	Absence	58848	68253	68253	68253	68253	68253	68253
Balanites pedicellaris	Presence	44981	48088	55921	53095	49630	59360	59899
Balanites pedicellaris	Absence	23272	20165	12332	15158	18623	8893	8354
Balanites rotundifolia	Presence	68211	66376	68189	67767	67777	68112	67423
Balanites rotundifolia	Absence	42	1877	64	486	476	141	830
Berchemia discolor	Presence	68207	68195	68214	68239	68072	68183	68195
Berchemia discolor	Absence	46	58	39	14	181	70	58
Boscia coriacea	Presence	54662	61206	62029	60485	62358	62557	62392
Boscia coriacea	Absence	13591	7046	6224	7768	5895	5696	5860
Cordia sinensis	Presence	62703	65850	65678	65723	66149	65899	65536
Cordia sinensis	Absence	5550	2403	2575	2530	2104	2354	2716
Dobera glabra	Presence	54574	63616	65332	66094	65116	66323	66753
Dobera glabra	Absence	13679	4637	2920	2159	3137	1930	1499
Ficus sycomorus	Presence	45597	45076	49093	50140	48778	52632	53921
Ficus sycomorus	Absence	22656	23177	19160	18113	19475	15621	14332
Grewia mollis	Presence	1907	4026	5174	8391	7796	10308	17212
Grewia mollis	Absence	66346	64227	63079	59862	60957	57944	51041
Grewia tenax	Presence	52722	56029	48806	52178	54658	48455	52023
Grewia tenax	Absence	15530	12224	19447	16075	13595	19798	16230
Grewia villosa	Presence	59073	62007	59503	63661	62875	64772	64102
Grewia villosa	Absence	9180	6246	8750	4592	5377	3480	4150
Hyphaene compressa	Presence	44225	31742	30756	30802	31682	30197	30872
Hyphaene compressa	Absence	24028	36511	37497	37451	36571	38074	37381
Lannea triphylla	Presence	28988	23413	28304	24529	25213	24168	21994
Lannea triphylla	Absence	39265	44840	39949	43724	43040	44085	46258

Wild edible plant	Suitability	Current	2041-2070			2071-2100		
			SSP126	SSP370	SSP585	SSP126	SSP370	SSP585
Maerua subcordata	Presence	59950	35961	33770	34612	35995	33157	34489
Maerua subcordata	Absence	8303	32292	34483	33641	32258	35096	33764
Salvadora persica	Presence	62738	65570	61392	61299	63081	60597	62420
Salvadora persica	Absence	5515	2682	6861	6953	5172	7656	5833
Senegalia senegal	Presence	49397	51767	47198	51402	51774	52069	53758
Senegalia senegal	Absence	18856	16486	21055	16851	16479	16184	14495
Sterculia stenocarpa	Presence	6736	7542	7866	6850	7822	7419	6094
Sterculia stenocarpa	Absence	61517	60711	60386	61403	60431	60834	62159
Tamarindus indica	Presence	9159	2550	2623	3225	2771	3632	2681
Tamarindus indica	Absence	59094	65703	65630	65028	65482	64621	65572
Vachellia oerfota	Presence	54250	54998	54387	53338	52451	55045	56668
Vachellia oerfota	Absence	14003	13255	13865	14915	15802	13208	11585
Vachellia tortilis	Presence	59019	51596	53014	50072	51413	51413	50139
Vachellia tortilis	Absence	9234	16657	15239	18181	16840	16840	18114
Vatovaea pseudolablab	Presence	52148	61576	55697	60197	63924	52016	61661
Vatovaea pseudolablab	Absence	16105	6677	12556	8056	4329	16237	6592
Ximenia americana	Presence	12045	14425	15018	15896	15958	17215	20253
Ximenia americana	Absence	56208	53828	53234	52357	52294	51037	48000
Ziziphus mauritiana	Presence	52093	63687	61838	62416	61211	62153	61802
Ziziphus mauritiana	Absence	16160	4566	6415	5837	7042	6100	6450

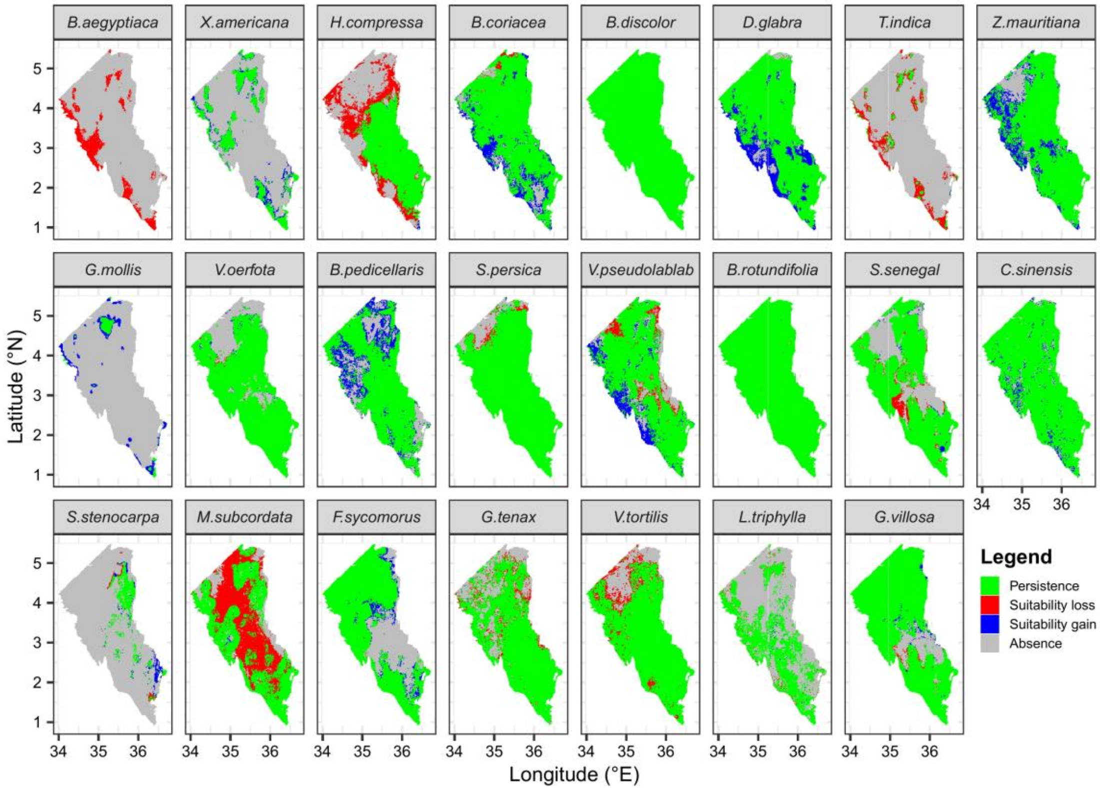
Appendix 21: Spatial extent of predicted current potential suitable habitats of the 23 wild edible plants of Turkana County, Kenya. Full genera names of the abbreviated scientific names can be accessed in the Table 6.1. Blue regions represent predicted presence while gray are predicted absences. Numeric values of the areas (km^2) can be found in **Appendix 20**.



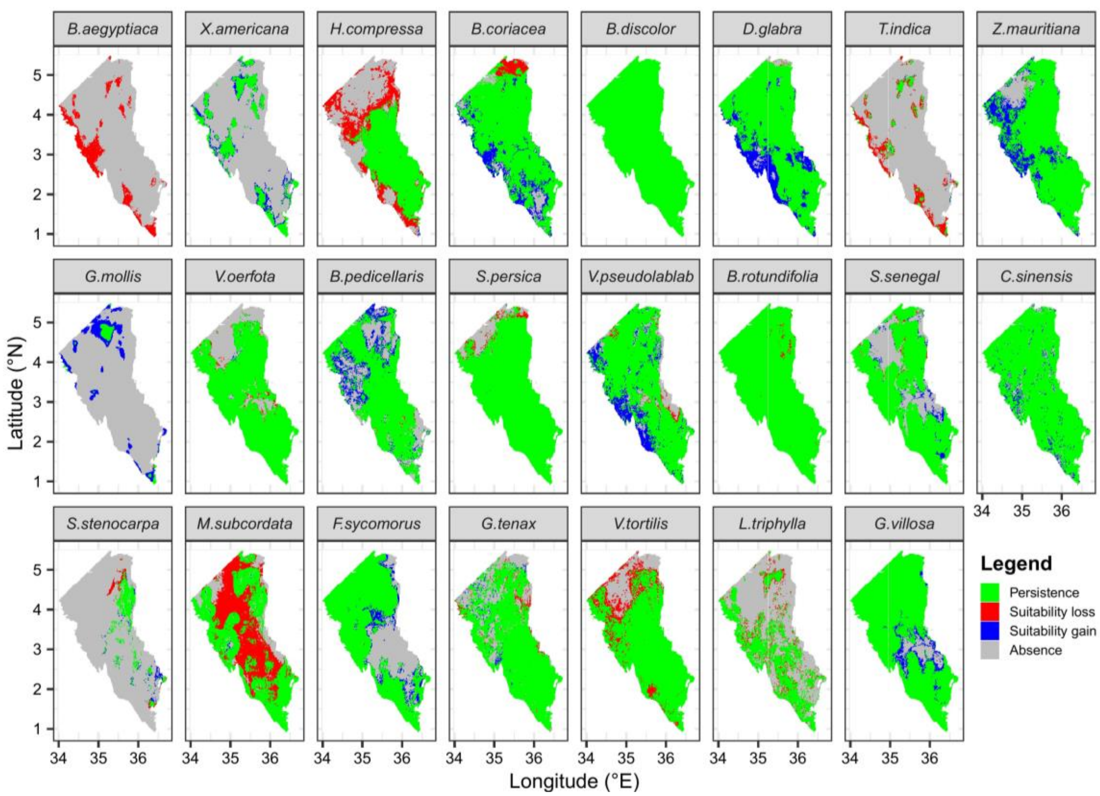
Appendix 22: Spatial extents of habitat suitability changes, relative to current potential suitable habitat extents, of 23 wild edible plants in Turkana County, Kenya, under two future time intervals (2041-2070 and 2071-2100) and three shared socioeconomic scenarios (SSP126, SSP370, and SSP585). Blue shade represents pixels where species are absent in present but present in future (suitability gain). Green shade represents pixels where the species are predicted to be present in both present and future scenarios (persistence). Gray shade represents pixels where the species is predicted to be absent in both present and future scenarios (absence). Lastly, red shade represents pixels where the species are predicted to be present under current climatic conditions but absent in future (suitability loss). See the bottom right panel for the legend, time period, and SSP scenario information. Genus names of each WEP is abbreviated, for full scientific names see the Table 1 in the main article



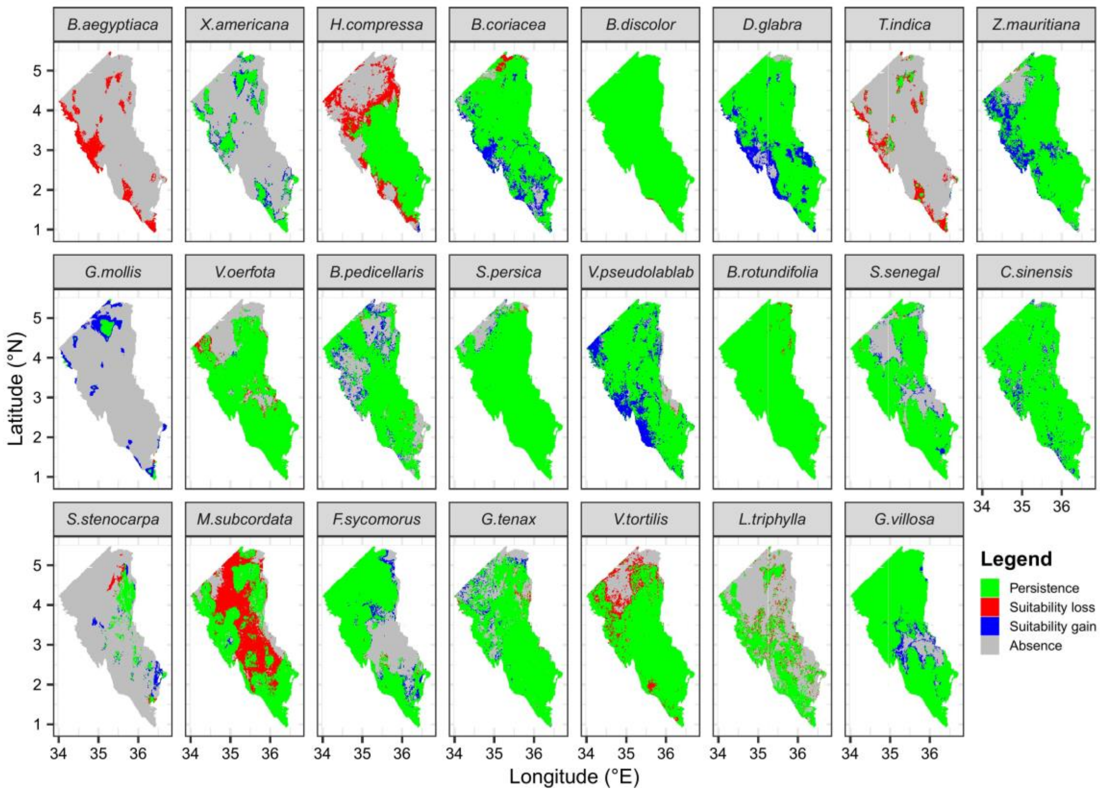
(b)


B.aegyptiaca
X.americana
H.compressa
B.coriacea
B.discolor
D.glabra
T.indica
Z.mauritiana
G.mollis
V.oerfota
B.pedicellaris
S.persica
V.pseudolablab
B.rotundifolia
S.senegal
C.sinensis
S.stenocarpa
M.subcordata
F.sycomorus
G.tenax
V.tortilis
L.triphylla
G.villosa
Latitude (°N)
Longitude (°E)
Legend
Persistence
Suitability loss
Suitability gain
Absence

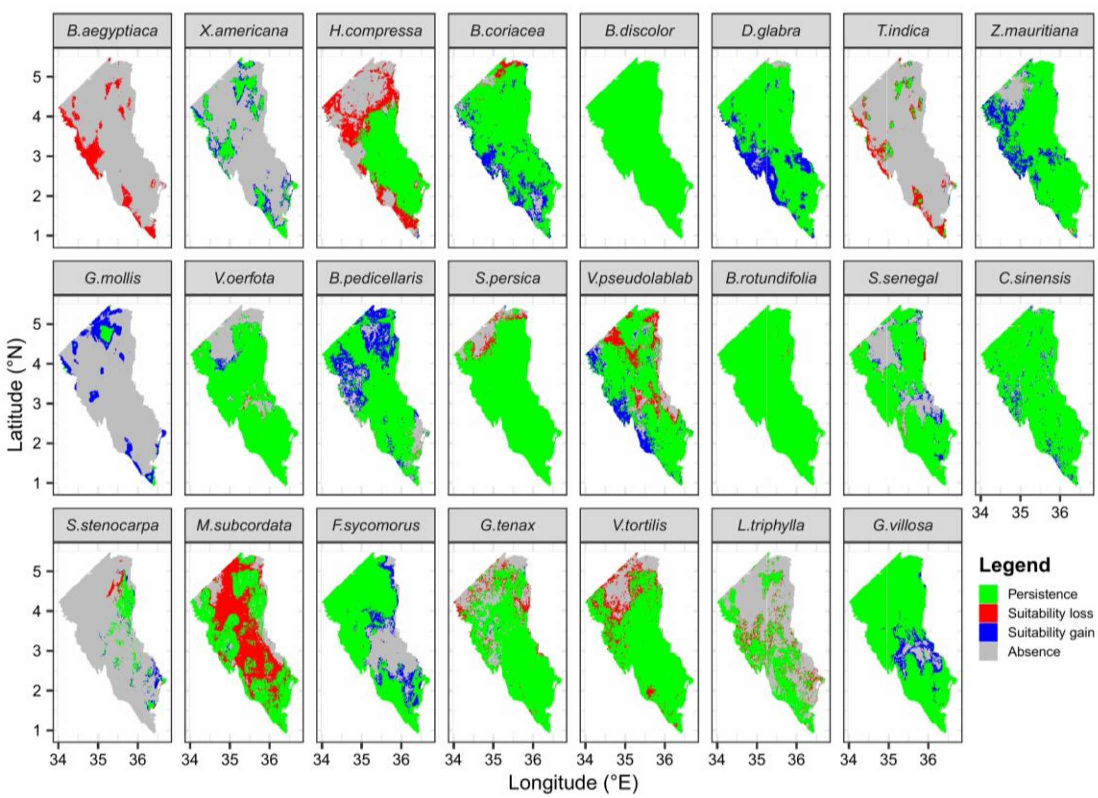
(c)


B.aegyptiaca
X.americana
H.compressa
B.coriacea
B.discolor
D.glabra
T.indica
Z.mauritiana
G.mollis
V.oerfota
B.pedicellaris
S.persica
V.pseudolablab
B.rotundifolia
S.senegal
C.sinensis
S.stenocarpa
M.subcordata
F.sycomorus
G.tenax
V.tortilis
L.triphylla
G.villosa
Latitude (°N)
Longitude (°E)
Legend
Persistence
Suitability loss
Suitability gain
Absence

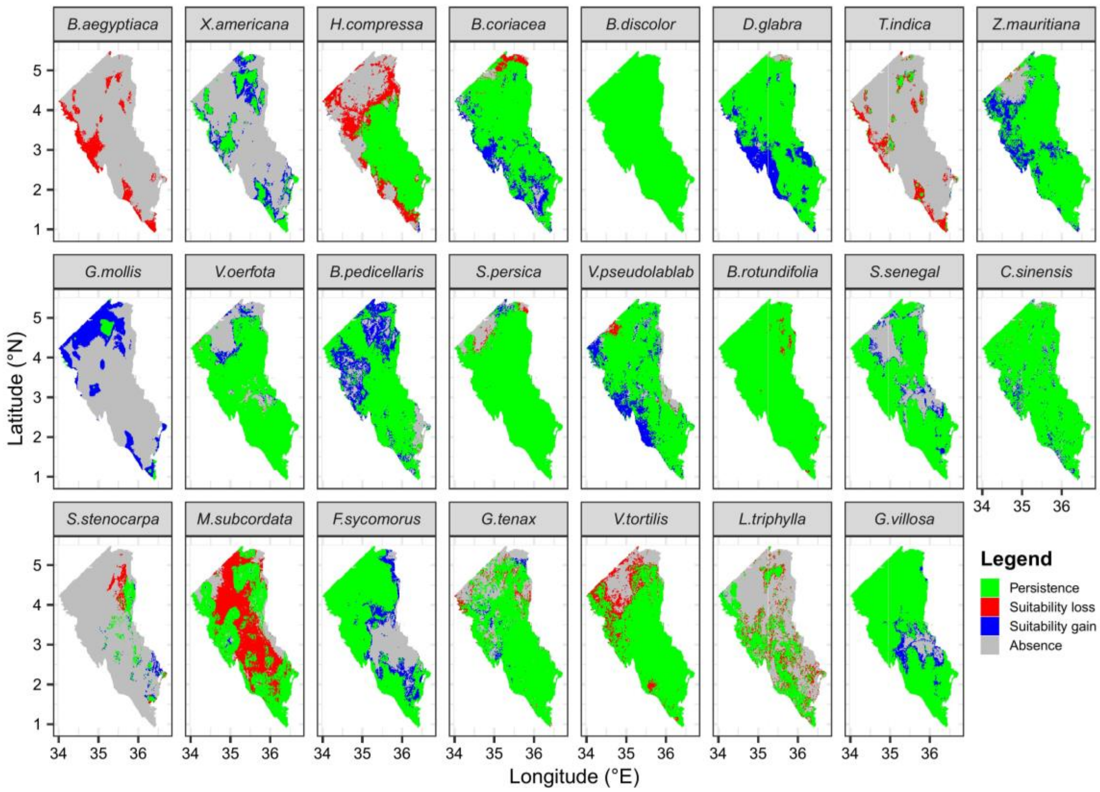
(d)


B.aegyptiaca
X.americana
H.compressa
B.coriacea
B.discolor
D.glabra
T.indica
Z.mauritiana
G.mollis
V.oerfota
B.pedicellaris
S.persica
V.pseudolablab
B.rotundifolia
S.senegal
C.sinensis
S.stenocarpa
M.subcordata
F.sycomorus
G.tenax
V.tortilis
L.triphylla
G.villosa
Latitude (°N)
Longitude (°E)
Legend
Persistence
Suitability loss
Suitability gain
Absence

(e)

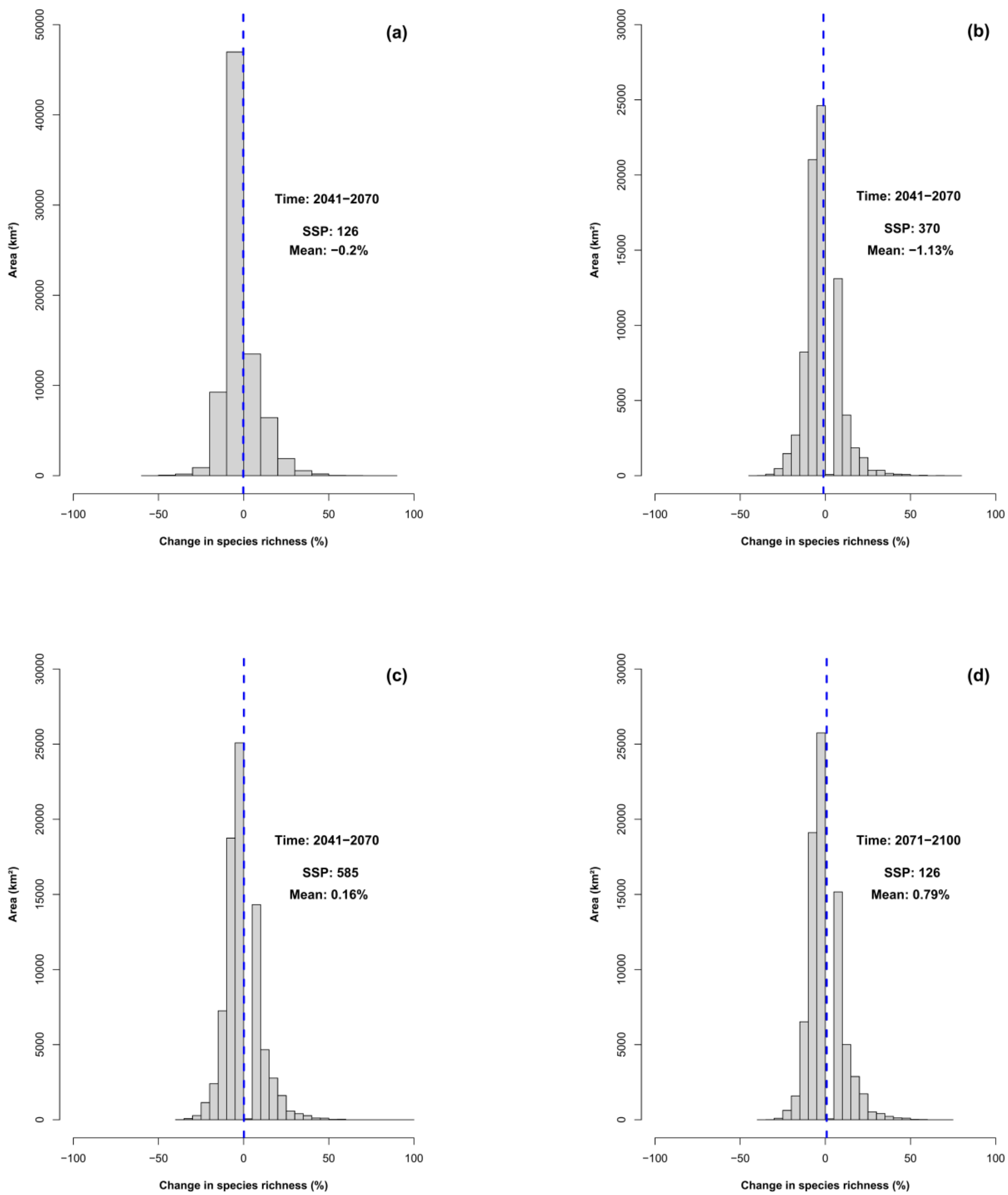

B.aegyptiaca
X.americana
H.compressa
B.coriacea
B.discolor
D.glabra
T.indica
Z.mauritiana
G.mollis
V.oerfota
B.pedicellaris
S.persica
V.pseudolablab
B.rotundifolia
S.senegal
C.sinensis
S.stenocarpa
M.subcordata
F.sycomorus
G.tenax
V.tortilis
L.triphylla
G.villosa
Latitude (°N)
Longitude (°E)
Legend
Persistence
Suitability loss
Suitability gain
Absence

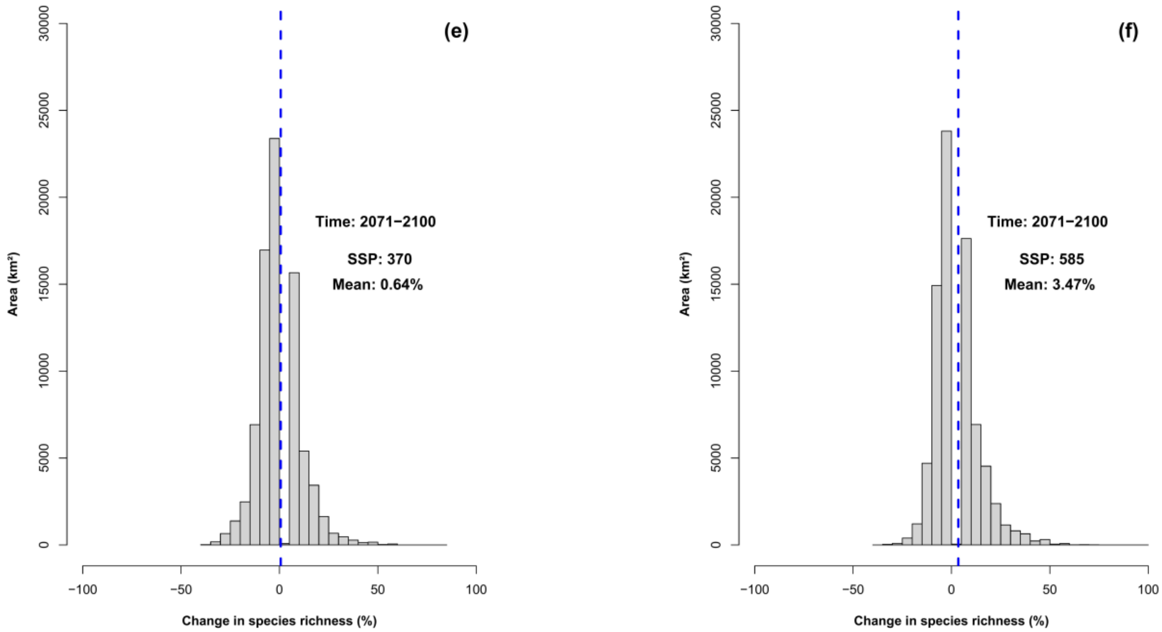
(f)



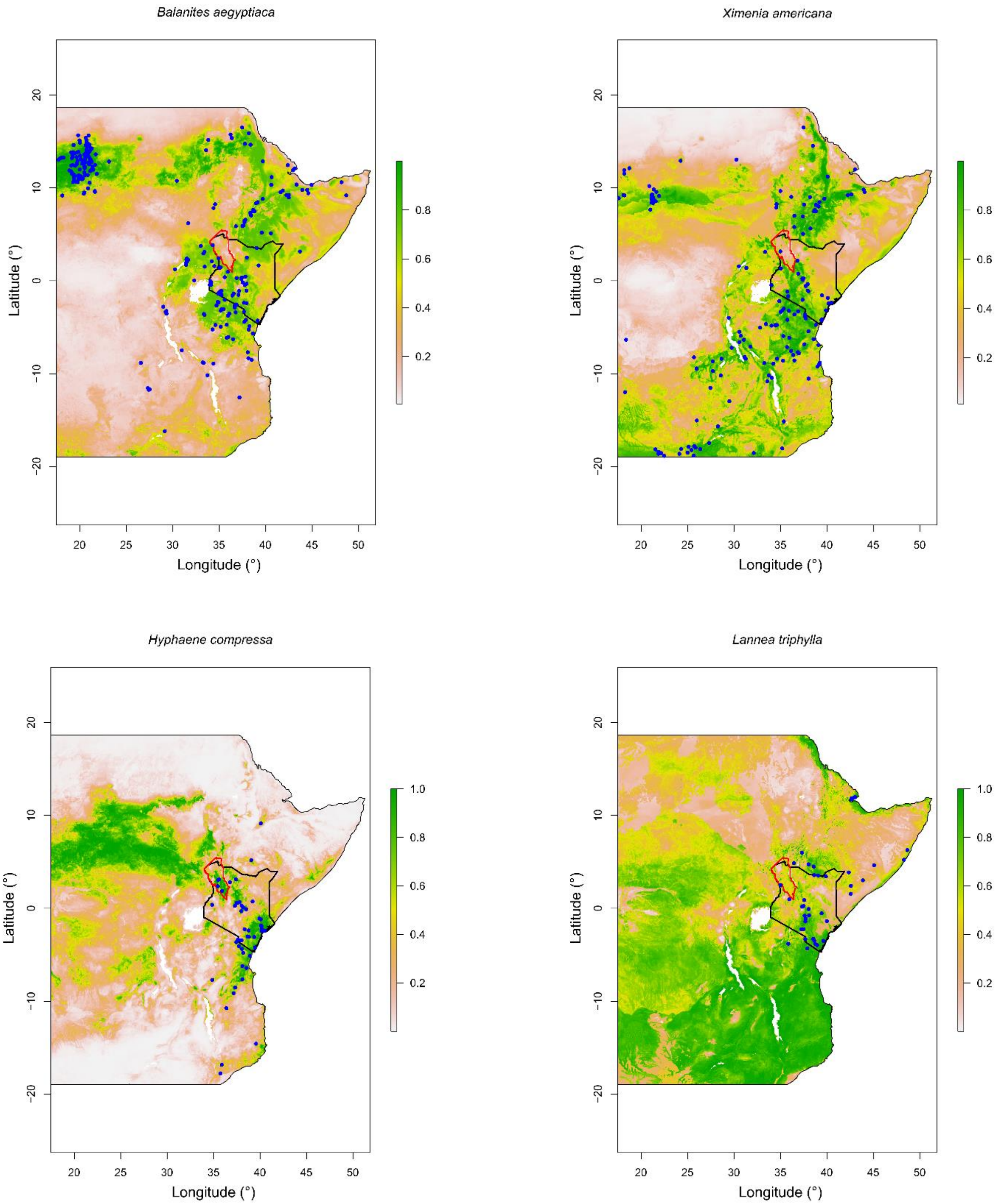
B.aegyptiaca
X.americana
H.compressa
B.coriacea
B.discolor
D.glabra
T.indica
Z.mauritiana
G.mollis
V.oerfota
B.pedicellaris
S.persica
V.pseudolablab
B.rotundifolia
S.senegal
C.sinensis
S.stenocarpa
M.subcordata
F.sycomorus
G.tenax
V.tortilis
L.triphylla
G.villosa
Latitude (°N)
Longitude (°E)
Legend
Persistence
Suitability loss
Suitability gain
Absence

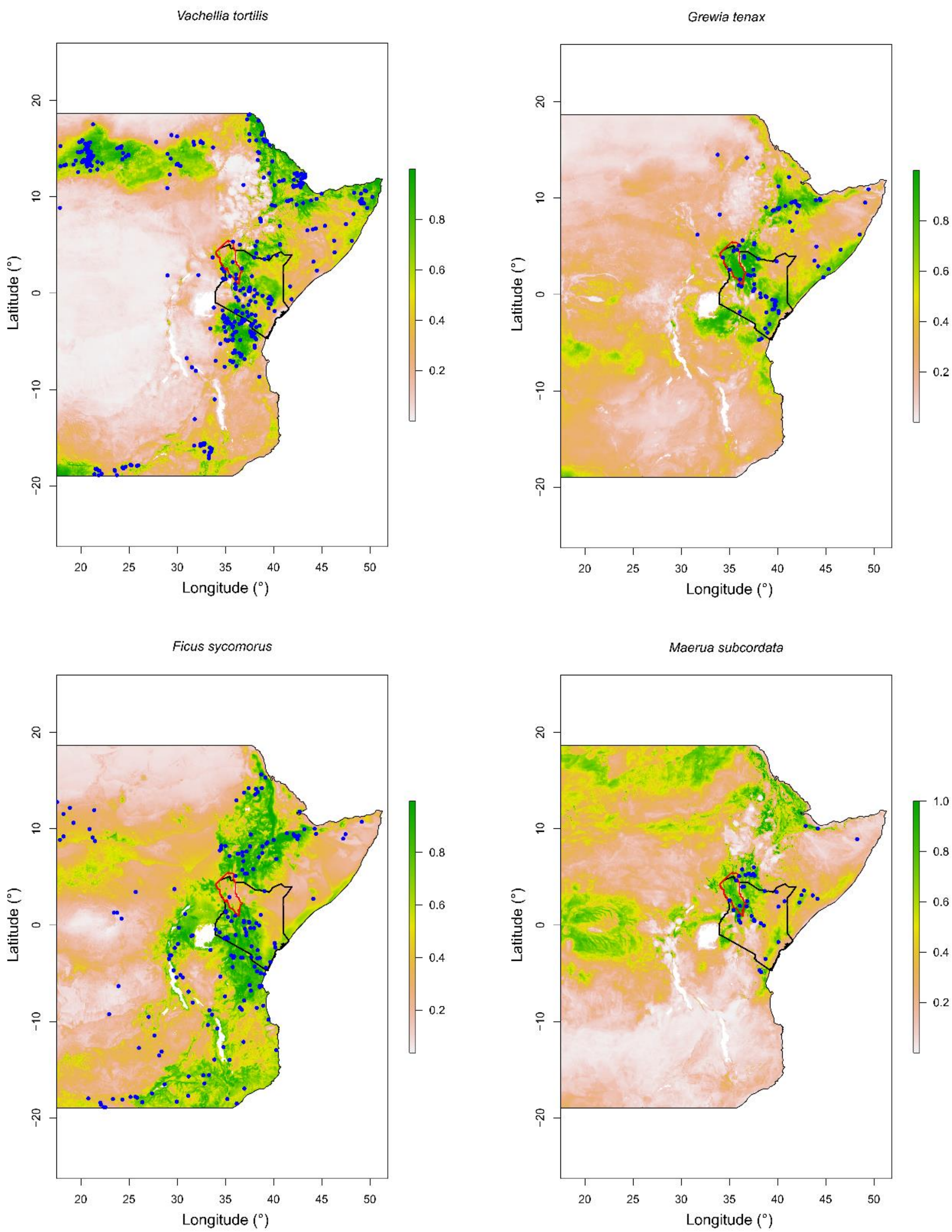
Appendix 23: Potential magnitude and direction of change in species richness and the size of land (km^2) undergoing such changes over time (2041-2070 and 2071-2100) and shared socioeconomic pathways (SSP126, SSP370, and SSP585). The blue dashed vertical line demarcates the mean magnitude of change whose value is indicated on each plot as well as time and SSP



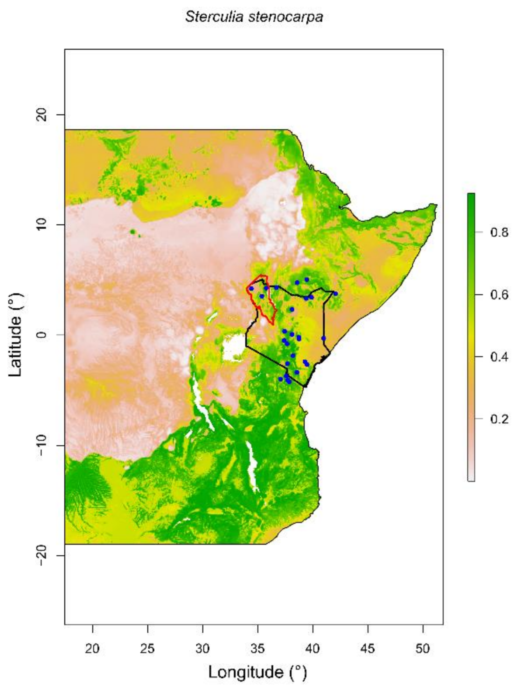

(e)
Time: 2071−2100
SSP: 370
Mean: 0.64%
Area (km²)
Change in species richness (%)
(f)
Time: 2071−2100
SSP: 585
Mean: 3.47%
Area (km²)
Change in species richness (%)

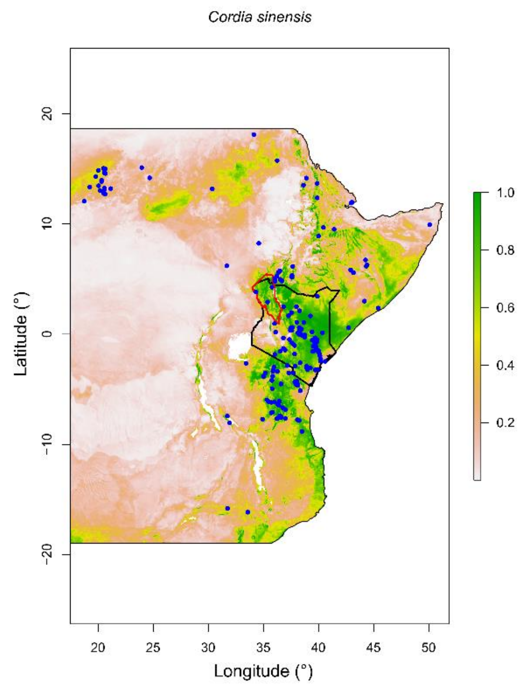
Appendix 24: Distribution of occurrence points (blue dots) used for calibrating potentially suitable habitats models throughout Eastern Africa for selected wild edible plants. The borders of Kenya (dark gray) and Turkana County (red) in northwestern Kenya are also shown for all the species studied. Background raster layer is the predicted habitat suitability (ranging from 0 (less suitable) to 1 (highly suitable)) for each wild edible plant

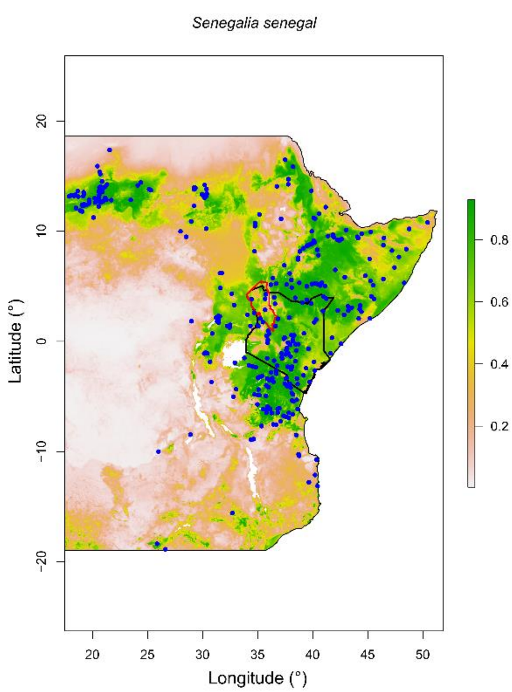


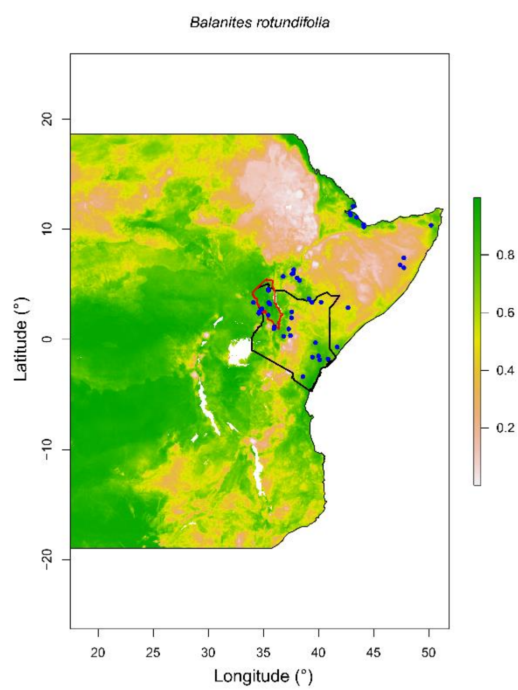


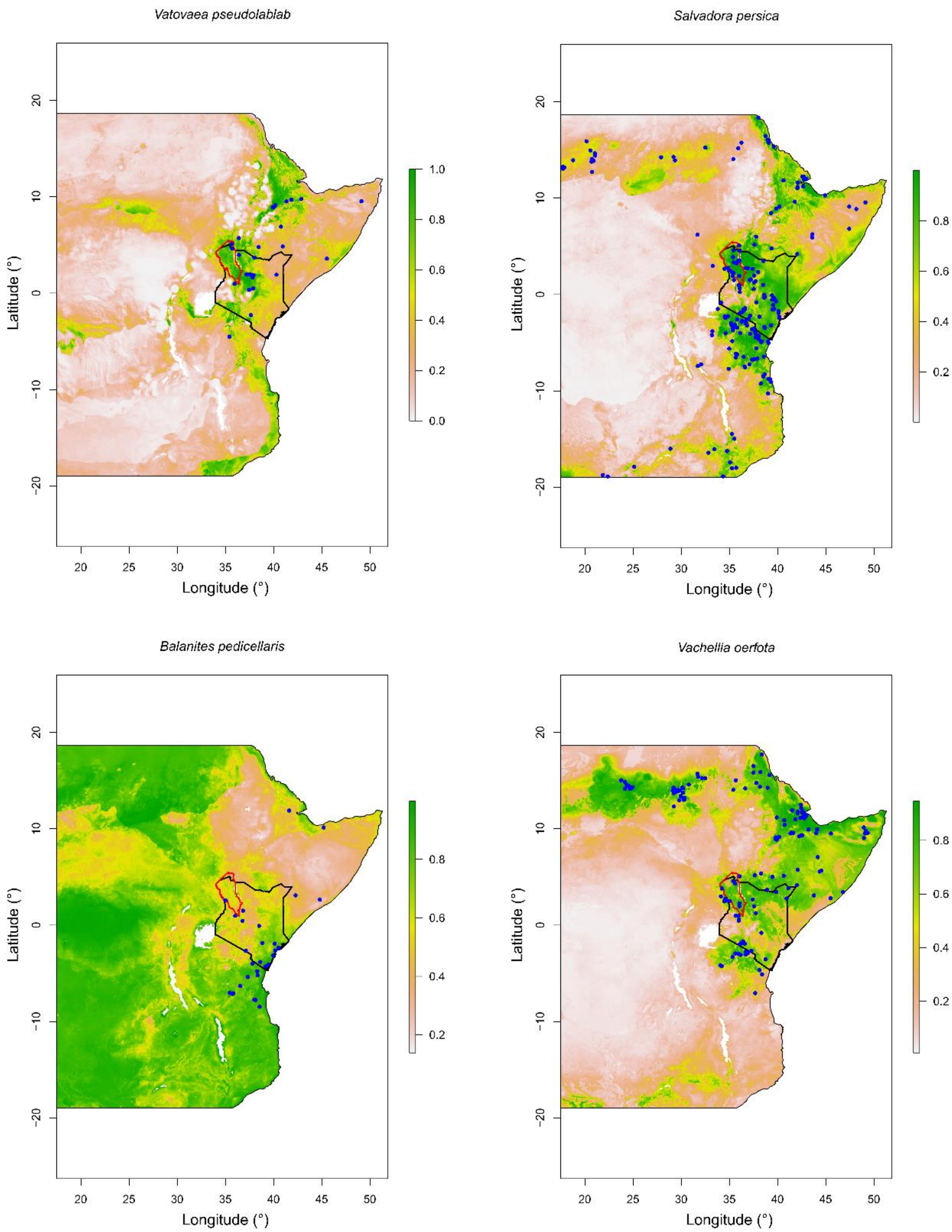
Vachellia tortilis
Grewia tenax
Ficus sycomorus
Maerua subcordata
Latitude (°)
Longitude (°)
20
10
0
−10
−20
20 25 30 35 40 45 50
0.2
0.4
0.6
0.8
1.0


Sterculia stenocarpa
Latitude (°)
Longitude (°)
20
10
0
−10
−20
20 25 30 35 40 45 50
0.8
0.6
0.4
0.2

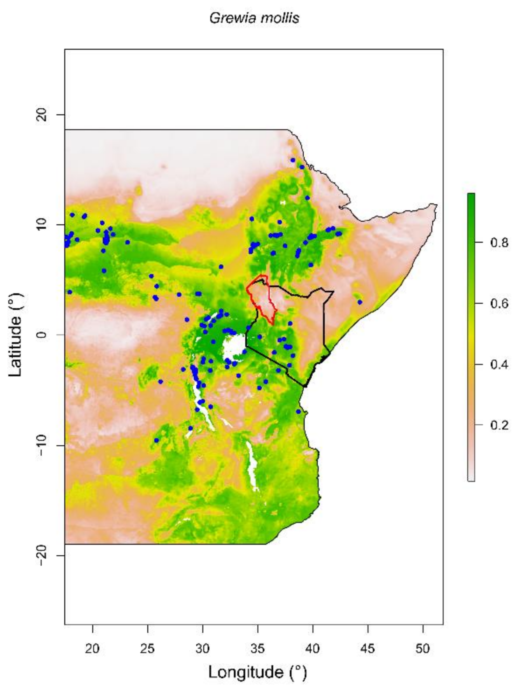

Cordia sinensis
Latitude (°)
Longitude (°)
20
10
0
−10
−20
20 25 30 35 40 45 50
1.0
0.8
0.6
0.4
0.2

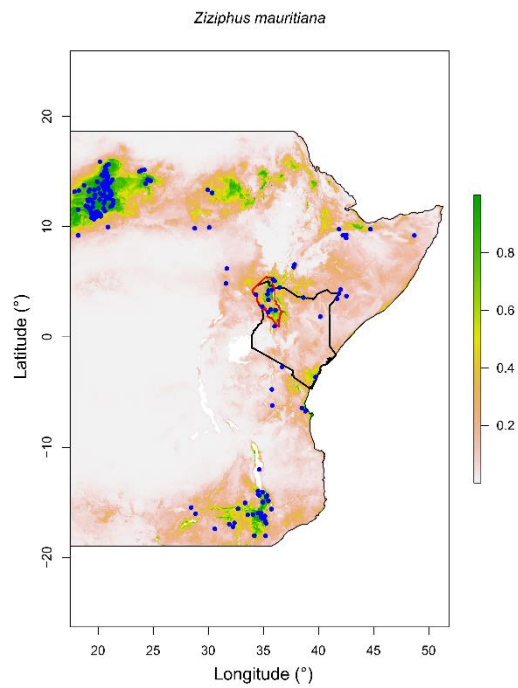

Senegalia senegal
Latitude (°)
Longitude (°)
20
10
0
−10
−20
20 25 30 35 40 45 50
0.8
0.6
0.4
0.2

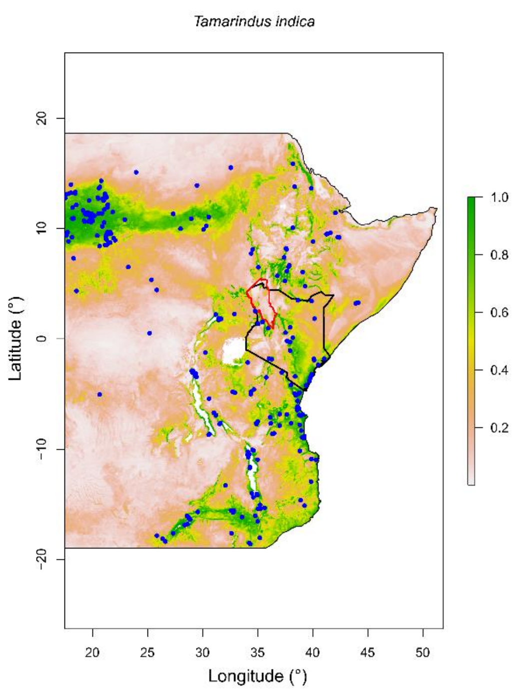

Balanites rotundifolia
Latitude (°)
Longitude (°)
20
10
0
−10
−20
20 25 30 35 40 45 50
0.8
0.6
0.4
0.2

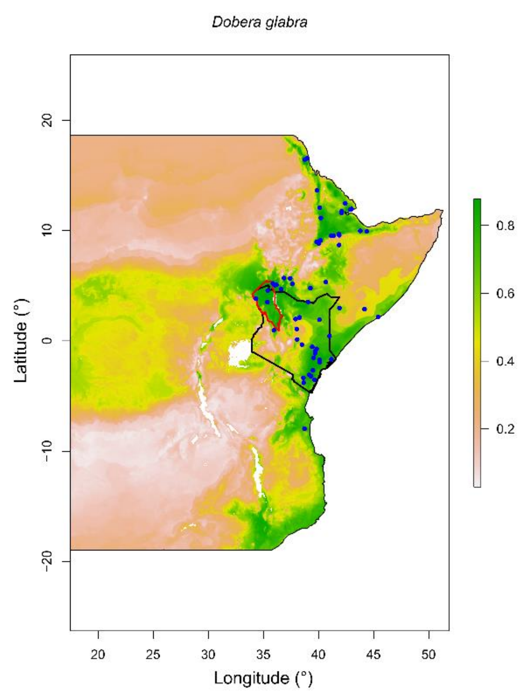


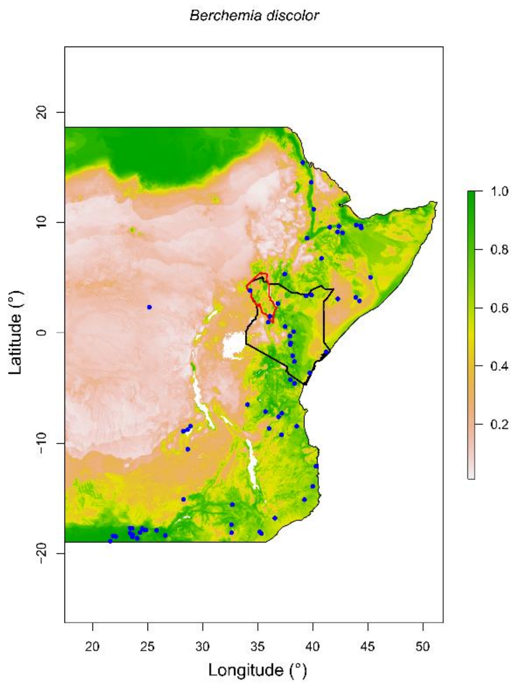
Vatovaea pseudolablab
Salvadora persica
Balanites pedicellaris
Vachellia oerfota
Latitude (°)
Longitude (°)
-20
-10
0
10
20
20
25
30
35
40
45
50
0.0
0.2
0.4
0.6
0.8
1.0

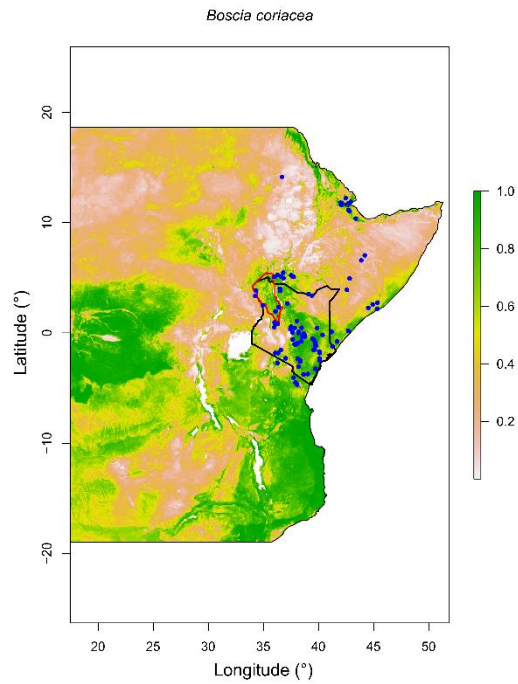

Grewia mollis
Latitude (°)
Longitude (°)
20
10
0
−10
−20
20 25 30 35 40 45 50
0.8
0.6
0.4
0.2

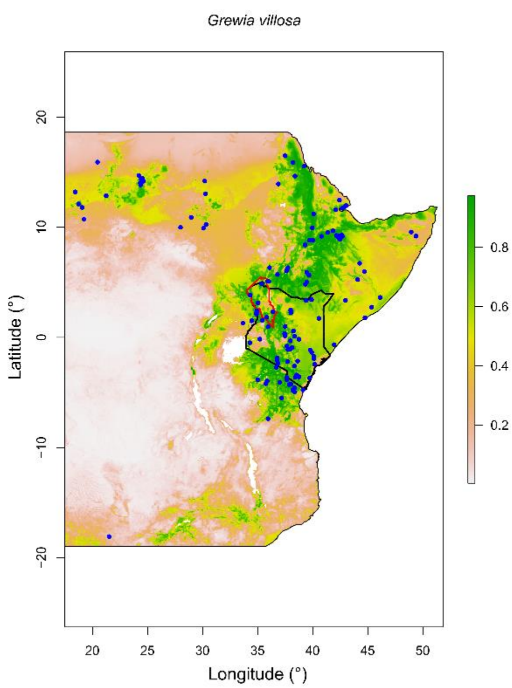

Ziziphus mauritiana
Latitude (°)
Longitude (°)
20
10
0
−10
−20
20 25 30 35 40 45 50
0.8
0.6
0.4
0.2


Tamarindus indica
Latitude (°)
Longitude (°)
20
10
0
−10
−20
20 25 30 35 40 45 50
1.0
0.8
0.6
0.4
0.2


Dobera glabra
Latitude (°)
Longitude (°)
20
10
0
−10
−20
20 25 30 35 40 45 50
0.8
0.6
0.4
0.2


Berchemia discolor
Latitude (°)
Longitude (°)
20
10
0
-10
-20
20 25 30 35 40 45 50
1.0
0.8
0.6
0.4
0.2


Boscia coriacea
Latitude (°)
Longitude (°)
20
10
0
-10
-20
20 25 30 35 40 45 50
1.0
0.8
0.6
0.4
0.2


Grewia villosa
Latitude (°)
Longitude (°)
20
10
0
-10
-20
20 25 30 35 40 45 50
0.8
0.6
0.4
0.2