Human Ecology
https://doi.org/10.1007/s10745-022-00370-0

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

Wyclife Agumba Oluoch[1,4] · Cory W. Whitney[1,2] · Céline Termote[3] · Christian Borgemeister[1] · Christine B. Schmitt[1,4]

Accepted: 26 October 2022

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

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; Ouma, 2017).

Northwestern Kenya is characterized by arid and semi-arid 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., 2017a). The Turkanas have depended on WEPs throughout their history (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

✉ Wyclife Agumba Oluoch
wyclifeoluoch@gmail.com

1 Center for Development Research (ZEF), University of Bonn, Genscherallee 3, 53113 Bonn, Germany

2 Department of Horticultural Sciences, University of Bonn, Auf Dem Hügel 6, 53121 Bonn, Germany

3 Alliance of Bioversity International and International Center for Tropical Agriculture (CIAT), Nairobi, Kenya

4 Geography Section, University of Passau, Innstrasse 40, 94032 Passau, Germany

Published online: 01 December 2022

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 semi-arid 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 (Supplementary Table S1). 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.

Materials and Methods

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 Supplementary Table S1) of the study region (Fig. 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 (Supplementary Table S1). 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, 2016b). 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) (Fig. 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).

Data Collection

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.,

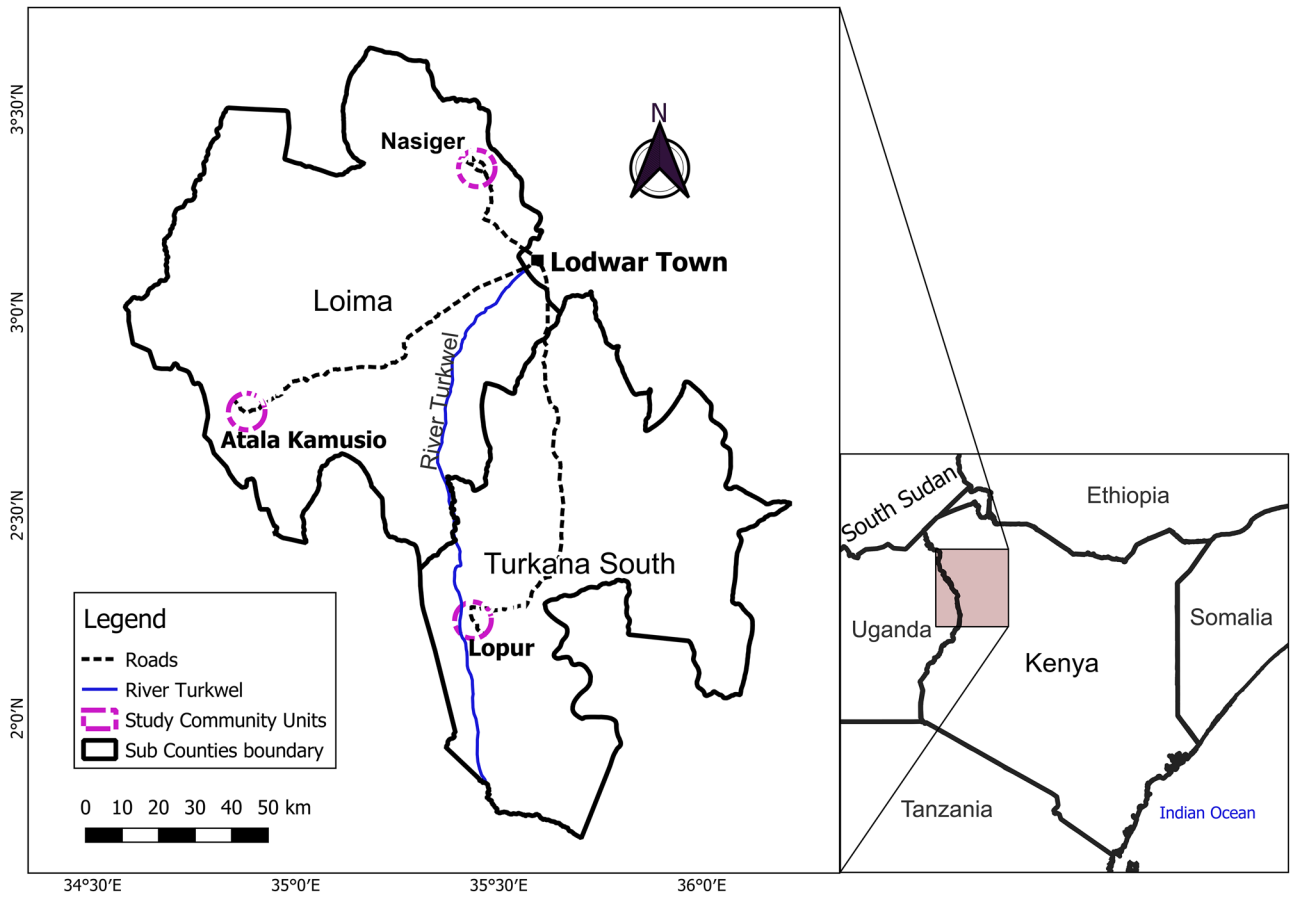

Fig. 1 Study area map showing the three study community units (Nasiger, Atala Kamusio, and Lopur), River Turkwel and connecting roads to the three community units. We obtained administrative boundary data from the database of Global Administrative Areas (GADM, version 4.0.4, accessed on 9th June 2022) (https://gadm.org/maps/KEN.html) using version 3.5.15 of raster package (Hijmans, 2022), 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 64 s. We composed the map in QGIS software (QGIS Development Team, 2022) version 3.24.3

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 (Supplementary Table S2) 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 (Supplementary Table S2). 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, Supplementary Table S2), which was then included as response parameter in our model.

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 "Overview of Wild Edible Plants" regardless

of socio-economic and environmental differences (Supplementary Table S1). 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 (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 Supplementary Fig. S1.

Data Analysis

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 2.21.3 in (R Core Team, 2022) version 4.2.1. 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, 2022) version 4.2.1. 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 Supplementary Tables S3, S4, S5, and S6.

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 (Supplementary Table S2). We dropped two highly correlated ($r >= 0.7$) parameters, notably abundance and market, and retained the non-collinear ones ($r < 0.7$) (Supplementary Figs. S2 and S3). To check multi-collinearity among predictor parameters we used the vifcor function in the usdm (Naimi, 2015) package version 1.1.18 in R (R Core Team, 2022) version 4.2.1. 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 (Supplementary Tables S3, S4, S5, and S6).

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.

Results

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 "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 "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).

Overview of Wild Edible Plants

We observed similarities in woody WEPs listed across the three community units (Supplementary Table S2). 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 (Supplementary Table S2). 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 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 Supplementary Table S2.

Table 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 Supplementary Table S2

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 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.

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 (Supplementary Table S7). 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 (Fig. 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 (Fig. 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 (Fig. 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 (Fig. 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 (Fig. 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.

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 (Supplementary Table S8).

Bayesian Model Outputs and Focus Group Discussions 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 (Fig. 2A) as highlighted in the red bounding box (Fig. 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 (Supplementary Table S8). Culture and traditions strongly influenced the view of whether WEPs were available or not, with 126 statements supporting (Supplementary Table S8), 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 (Supplementary Table S8). 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

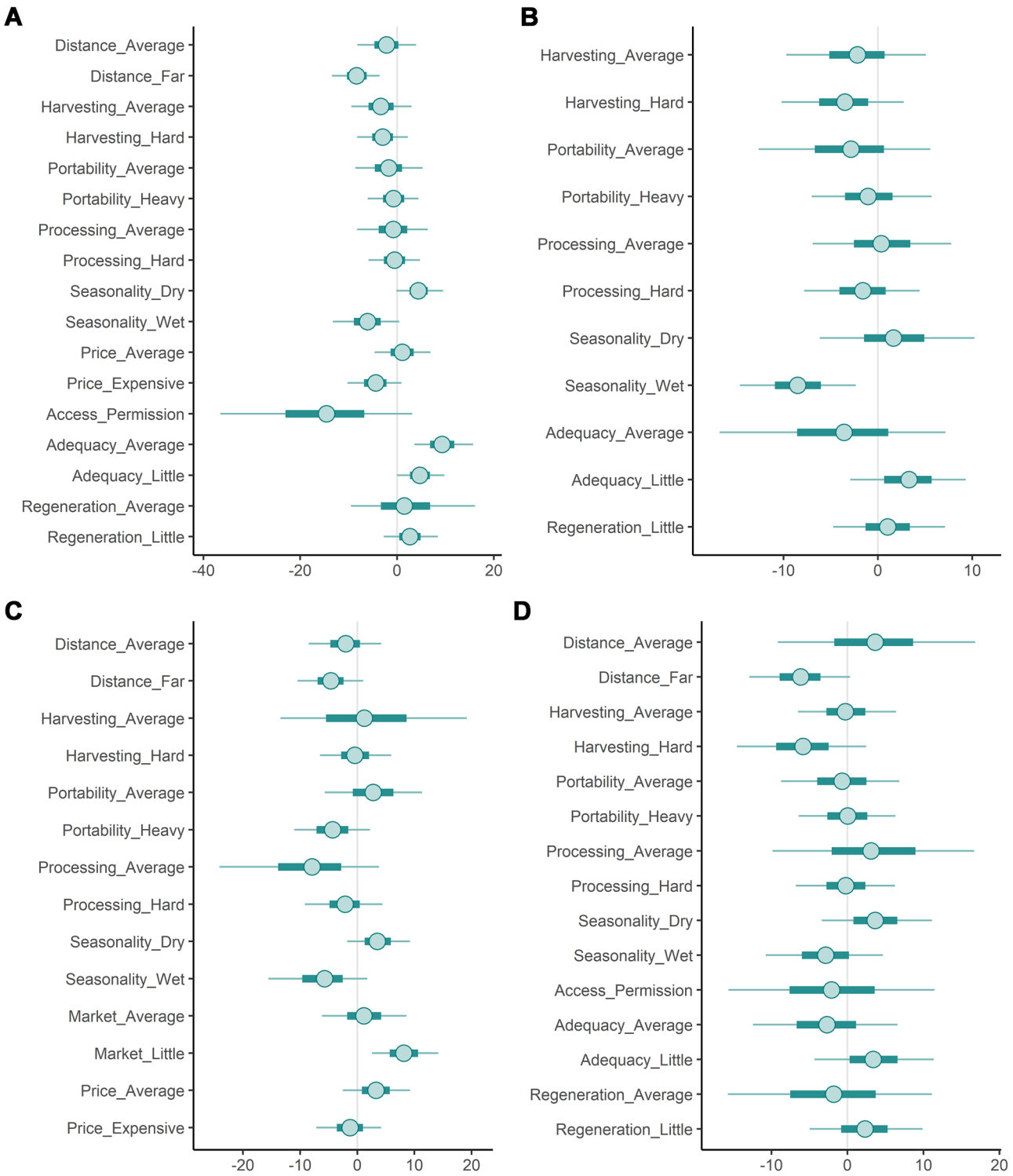

Fig. 2 Contributions of predictor parameter levels on availability of wild edible plants. A. overall model for the three community units (n = 49), B. Nasiger community unit (n = 13), C. Atala Kamusio community unit (n = 23), and D. Lopur community unit (n = 13). The central small circles represent median 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

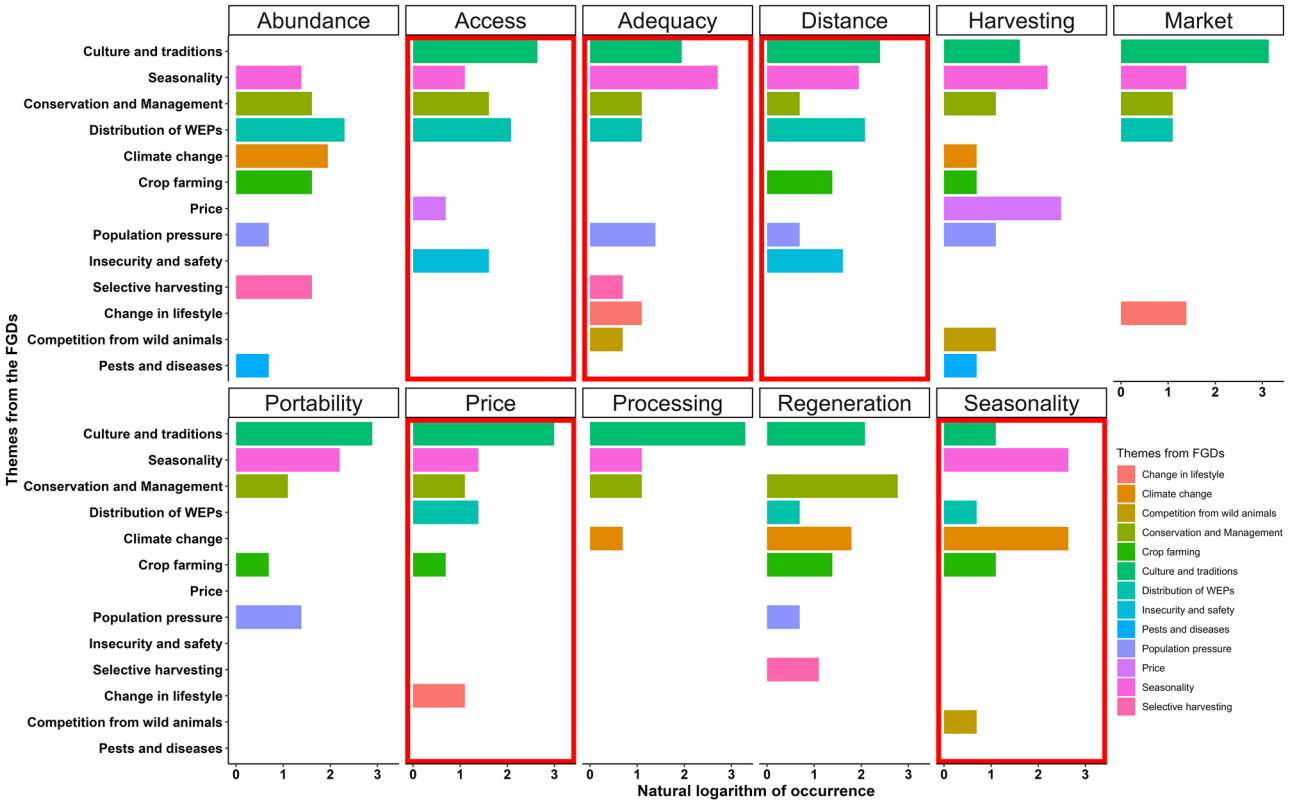

Fig. 3 Distribution of themes (n = 13) derived from statements (n = 348) obtained during Focus Group Discussions (FGDs) conducted in Nasiger, Atala Kamusio, and Lopur community units of Turkana County, Kenya. The distributions are faceted by parameters used in model building and those within the red boxes were important in explaining availability

and traditions, distribution of WEPs, and seasonality (Fig. 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 (Fig. 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 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.

Culture 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

Table 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
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

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.

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 "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.

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.

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.

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.

Discussion

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 (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.

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, 2016a, 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 et al., 2017b). 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, counter-intuitively. 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 2 on adequacy).

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.

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 potential 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 1).

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.

References

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

Addis, G., Asfaw, Z., & Woldu, Z. (2013). The role of wild and semi-wild edible plants to household food sovereignty in Hamar and Konso Communities, South Ethiopia. *Ethnobotany Research and Applications, 11*, 251–271.

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

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

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., Nascimento, A. L. B., Soldati, G. T., Feitosa, I. S., Campos, J. L. A., Hurrell, J. A., Hanazaki, N., de Medeiros, P. M., da Silva, R. R. V., Ludwinsky, R. H., et al. (2019). Ten important questions/issues for ethnobotanical research. *Acta Botanica Brasilica, 33*(2), 376–385. https://doi.org/10.1590/0102-33062018abb0331

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

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.

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.

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

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

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 Mexico. *Sustainability, 11*(14), 3779. https://doi.org/10.3390/su11143779

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

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

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

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

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*.

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

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

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

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

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

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

Gaur, A., & Kumar, M. (2018). A systematic approach to conducting review studies: An assessment of content analysis in 25 years of IB research. *Journal of World Business, 53*(2), 280–289. https://doi.org/10.1016/j.jwb.2017.11.003

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

Gonçalves, P. H. S., Albuquerque, U. P., & de Medeiros, P. M. (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

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

Hijmans, R. J. (2022). *raster: Geographic Data Analysis and Modeling*. https://cran.r-project.org/package=raster

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

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

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

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.

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. Accessed 13 Jan 2021.

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

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

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., et al. (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.

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

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

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

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

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

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. (2015). usdm: Uncertainty analysis for species distribution models. *R Package Version, 1*, 1–12.

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, 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.

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.

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

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

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

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

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). Food Insecurity in Turkana District, Kenya: A Focus on the Impact of Colonial Rule. *Imperial Journal of Interdisciplinary Research (IJIR)*, *2*(11), 1812–1818. https://www.onlinejournal.in/IJIRV2I11/287.pdf

Otieno, J. R. (2016b). 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. (2020). Drought impact evaluation and perception model: a systems approach in Turkana County, Kenya. *IOSR Journal Of Humanities And Social Science (IOSR-JHSS)*, *25*(1), 8. www.iosrjournals.org

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

Peng, W., Ma, N. L., Zhang, D., Zhou, Q., Yue, X., Khoo, S. C., Yang, H., Guan, R., Chen, H., Zhang, X., et al. (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

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

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

QGIS Development Team. (2022). QGIS Geographic Information System. Open Source Geospatial Foundation Project. http://qgis.osgeo.org. In *Qgisorg* (3.26.0).

R Core Team. (2022). *R: A Language and Environment for Statistical Computing* (4.2.1). https://www.r-project.org/. Accessed 27 June 2022.

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*.

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

Renz, S. M., Carrington, J. M., & Badger, T. A. (2018). Two strategies for qualitative content analysis: An intramethod approach to triangulation. *Qualitative Health Research, 28*(5), 824–831. https://doi.org/10.1177/1049732317753586

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

Sarfo, J., Termote, C., Keding, G., Boedecker, J. and, & Pawelzik, E. (2017b). 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. *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*, 1.

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., Johns, T., Pelletier, B., & Galaty, J. (2014). Institutional factors affecting wild edible plant (WEP) harvest and consumption in semi-arid Kenya. *Land Use Policy, 38*, 48–69. https://doi.org/10.1016/j.landusepol.2013.10.014

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.

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

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

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

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

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.

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

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

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