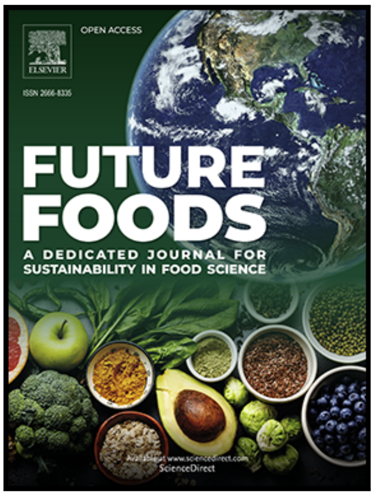
Journal Pre-proof



Agro-Ecological Distribution and Consumption of Wild Harvested Edible Insects, Fruits, and Vegetables in Rural Zimbabwe

Lesley Macheka , Faith A. Manditsera , Ruth T. Ngadze ,
Juliet Mubaiwa , Shingai Nyarugwe , Courage Bangira ,
Godfrey Pachavo , George Kembo

PII: S2666-8335(22)00074-0
DOI: https://doi.org/10.1016/j.fufo.2022.100187
Reference: FUFO 100187

To appear in: *Future Foods*

Received date: 10 June 2022
Revised date: 13 August 2022
Accepted date: 16 September 2022

Please cite this article as: Lesley Macheka , Faith A. Manditsera , Ruth T. Ngadze , Juliet Mubaiwa , Shingai Nyarugwe , Courage Bangira , Godfrey Pachavo , George Kembo , Agro-Ecological Distribution and Consumption of Wild Harvested Edible Insects, Fruits, and Vegetables in Rural Zimbabwe, *Future Foods* (2022), doi: https://doi.org/10.1016/j.fufo.2022.100187

Agro-Ecological Distribution and Consumption of Wild Harvested Edible Insects, Fruits, and Vegetables in Rural Zimbabwe

*Lesley Macheka[1], Faith A. Manditsera[2], Ruth T. Ngadze[3], Juliet Mubaiwa[2], Shingai Nyarugwe[4], Courage Bangira[5], Godfrey Pachavo[6], George Kembo[7]

[1]Centre for Innovation and Industrialisation, Marondera University of Agricultural Sciences and Technology, P. O Box 35 Marondera, Zimbabwe
[2]Department of Food Science and Technology, Chinhoyi University of Technology, P. Bag 7244, Chinhoyi, Zimbabwe
[3]Food and Quality Design Group, Wageningen University and Research, Borne Weilanden 9, 6708 WG, Wageningen, the Netherlands
[4]School of Sport and Health Sciences, Faculty of Allied Health and Well-being, University of Central Lancashire, Preston, PR1 2HE, United Kingdom
[5]Department of Natural Resources Management, Marondera University of Agricultural Sciences and Technology, P. O Box 35 Marondera, Zimbabwe
[6]Faculty of Earth and Environmental Sciences, Marondera University of Agricultural Sciences and Technology, P. O Box 35 Marondera, Zimbabwe
[7]Food and Nutrition Council of Zimbabwe, 1574 Alpes Road, Hatcliffe, Harare, Zimbabwe

*Corresponding Author: Lesley Macheka – lesleymacheka@gmail.com

Abstract

Natural resources are a valuable component of traditional food systems that contributes to food and nutrition. The distribution and consumption patterns of these natural resources still needs exploration for follow-up research and optimum utilisation. The aim of this study was to investigate the agro-ecological distribution and the consumption of wild harvested edible insects, indigenous fruits and vegetables in rural Zimbabwe. Secondary data generated from a cross-sectional survey targeting 11,973 randomly selected households rural districts was used. The results revealed that at least 14 wild harvested edible insect species, 26 indigenous fruits and 10 indigenous vegetables are commonly consumed. The results showed that the highly consumed indigenous fruits, vegetables and insects were widely distributed in all provinces irrespective of the agro-ecological region and varied due to rainfall pattern and also due to soil type. However, their distribution was in some cases restricted to specific administrative boundaries or provinces. Consumption pattern and preference for some insects, fruits and vegetables varied with province. The distribution and consumption data presented in this study offers an opportunity to advocate for the conservation, production, processing and promotion of specific species in districts by relevant stakeholders and can be used as an advocacy tool for policymakers.

Keywords: *Edible Insects; Non-Timber Forest Food Products; Food and Nutrition Security; Indigenous Foods; Traditional Food Systems; Livelihoods*

1. Introduction

Malnutrition in all its forms remains a global challenge. In 2020 it was estimated that 22% (149.2 million) of children under 5 years of age were stunted, 45.4 million were wasted and 38.9 million were overweight (FAO, 2021). This shows food insecurity is growing steadily and although several food insecurity mitigation strategies have been proposed, these have proven to be inadequate (Lugo-Morin, 2020). Perpetual hunger, that has been exacerbated by climate change and high population growth, and unsustainable management of natural resources, has become a global threat to food security (UNICEF, 2018). A study by Siegel et al. (2014) showed that the global fruit and vegetable supply is insufficient to meet the nutritional needs of the world's growing populations. Consequently, it is important to increase crop production and yield to meet the increasing food demands. However, according to Borelli et al. (2020), growing food crops in sufficient quantities to meet rising demands for food is also threatening the natural resource base for agriculture production.

One innovative way to meet the rising demands for food is to take advantage of local dietary and agricultural biodiversity, such as forest food products, which are often nutritionally superior to exotic crops (Kobori & Amaya, 2008) and usually more resistant to biotic and abiotic stresses (Bharucha & Pretty, 2010). In the past decade, there has been an increasing number of rural and urban households relying on indigenous foods, as these are widely available in the surrounding environment (Chadare et al., 2018). The potential role of indigenous foods in improving food and nutrition and security and livelihoods has been widely acknowledged (Ahenkan & Boon, 2011; Sardeshpande & Shackleton, 2019). In Southern Africa, these indigenous food products are part of traditional food systems that contribute to food and nutrition security as local communities incorporate a wide range of locally available foods into their daily meals (Smith, 2013).

The indigenous foods which we refer to as Non-Timber Forest Food Products (NTFFPs) in this paper can be defined as biological products, other than high-value timber, harvested by humans from wild biodiversity in natural or human-modified environments (Shackleton et al., 2011). In this study, NTFFPs include indigenous fruits, vegetables, and wild-harvested edible insects. Consumption of wild- harvested edible insects, indigenous vegetables and indigenous fruits forms an integral part of the livelihood strategy of rural communities in most African communities. These foods are an important component of household subsistence (Arnold & Pérez, 2001) and contribute immensely to household food and nutrition security (Shackleton & Shackleton, 2004). According to Talukdar et al. (2021), more than three-quarters of the rural populations in most developing countries are dependent on NTFFPs for their nutrition and primary health. More so, NTFFPs provide safety nets against adverse effects of climate change, which often results in insecurity and thus accelerates the vulnerability in the agricultural system (Talukdar et al., 2021).

In recent years, research focus has been on NTFFPs and their role in poverty reduction, contribution to nutrition and health, and sustainable management of forest resources in Zimbabwe (Gonçalves et al., 2021; Manditsera et al., 2019; Matiza Ruzengwe et al., 2022; Mipun et al., 2019; Ngadze et al., 2017b). Moreover, the contribution of NTFPs to healthy diets has been exploited complemented people's diets and their contribution to healthy diets has been exploited (Durazzo et al., 2020; Rowland et al., 2017). Although the contribution of NTFFPs to food security, nutrition, and sustainable livelihoods has been widely researched, including in Zimbabwe (Gonçalves et al., 2021; Mipun et al., 2019; Pandey et al., 2016) and acknowledged, there are still limited policies to sustainably manage these. One way to further encourage and buttress the importance of NTFFPs would be closing the knowledge gap by conducting studies on mapping the distribution and consumption patterns of NTFFPs in Zimbabwe. Therefore, tfocus of this paper was to examine the distribution and consumption patterns of wild harvested edible insects, indigenous fruits and vegetables. The link between the distribution of these NTFFPs and agro-ecological regions in Zimbabwe was explored. In addition, this study presents for the first-time maps showing the distribution of NTFFPs (wild harvested edible insects, indigenous fruits and vegetables) in Zimbabwe. In particular, the study was aimed at answering the following research questions; (i) which are the most consumed wild harvested edible insects, fruits and vegetables by rural households in Zimbabwe? (ii) how are these most consumed wild harvested edible insects, fruits and vegetables spatially distributed across the country?

2. Material and Methods

2.1 Sampling strategy and data collection tool

Secondary data drawn from the Zimbabwe Vulnerability Assessment Committee (ZimVAC) rural and livelihood assessment survey conducted in 2019 was used for this study (ZimVac, 2019). The 2019 ZimVAC rural and livelihoods assessment survey was a cross-sectional study targeting randomly selected households in 60 rural districts of Zimbabwe (Figure 1). A total of 11,973 rural households were sampled.

2.2 NTFFPs distribution maps

NTFFPs distribution maps were done in Quantum GIS (QGIS), which is an open-source geographic information system (GIS) environment. Data on NTFFPs was categorised based on occurrence and consumption across the 60 administrative districts in Zimbabwe. Other important spatial data such as the agro-ecological zones and Zimbabwe soil classification map were overlaid to indicate the distribution patterns of these NTFFPs.

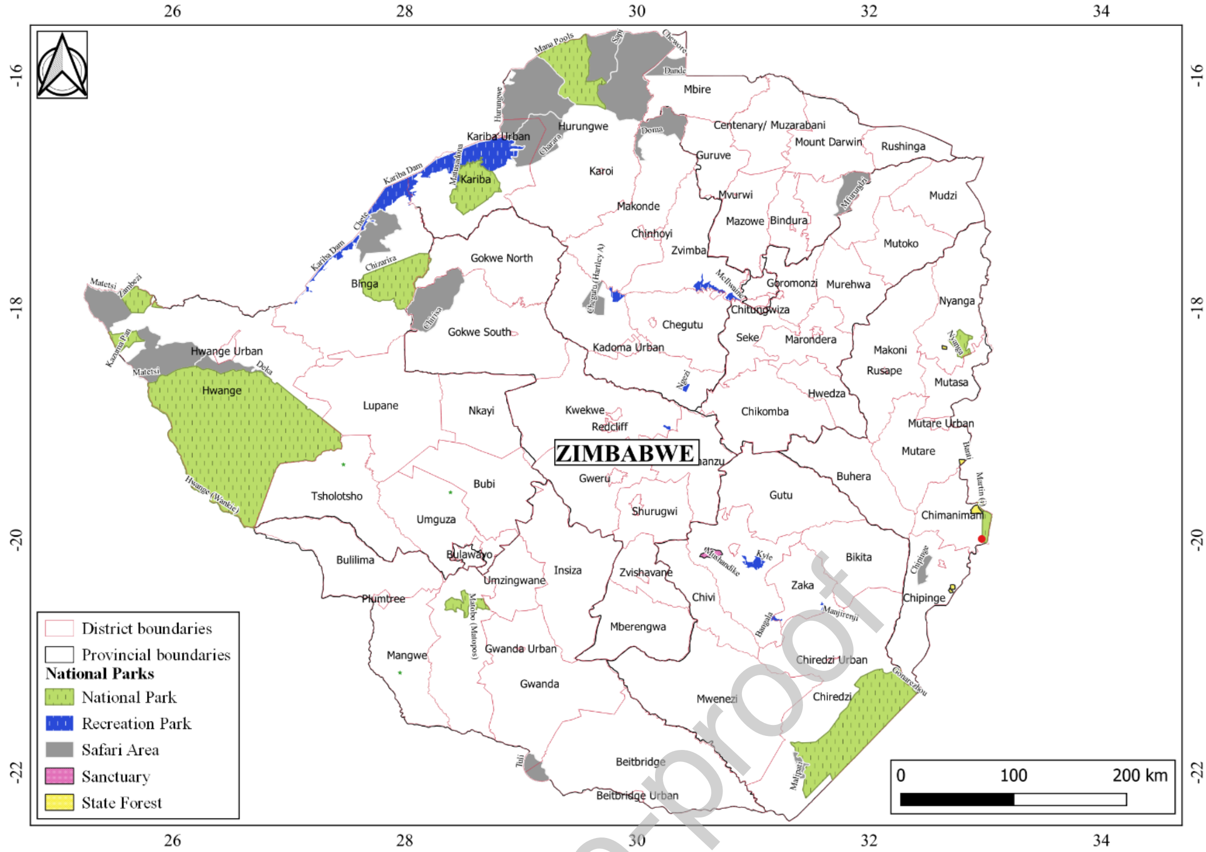


Figure 1: Presentation of the Zimbabwean Districts.

2.3 Data analysis

Data analysis was done using the statistical software package IBM SPSS Statistics version 22. Normality of distributions was tested by comparing the sample distribution with a standard normal distribution using quantile–quantile (Q–Q) plots. Descriptive statistics, percentage and frequency for categorical variables were computed. A paired sample t-test, Chi-square, and Pearson's correlation coefficient were calculated to determine the mean distribution differences and correlations between food security indicators and consumption of wild harvested edible insects.

2.4 Measurement of key variables and indicators

2.4.1 Food Consumption Score

Food consumption data was used to calculate food consumption scores (FCS) consistent with World Food Program methodology (WFP, 2008). The FCS was measured by collecting both consumption and frequency of different food groups by a household during the past 7 days before the survey. To calculate the FCS, standard weights were attached for each of the food groups. The food consumption groups include starches, pulses, vegetables, fruit, meat, dairy, fats, and sugar. The consumption frequencies of the different foods in the groups are summed, with the maximum value for the groups capped at 7. The formula, based on these groups, with the standard weights, is FCS = (starches*2) + (pulses*3) + vegetables + fruit + (meat*4) + (dairy*4) + (fats*.5) + (sugar*.5) (Oils*.5). The food consumption score therefore ranges from 0 to 112.

2.4.2 Coping Strategy Index (CSI)

Consumption-based coping strategies are short-term adjustments to food consumption patterns when confronted by food insecurity (Coates *et al.*, 2006; Maxwell *et al.*, 2008; Maxwell *et al.*, 2014; Vaitla *et al.*, 2017). The CSI of a household is calculated by multiplying the frequency of consumption coping strategies used in the last thirty days by their respective severity weights. The weights are as follows (Relied on less preferred, less expensive food * 1) + (Borrowed food or relied on help from friends or relatives * 1) + (Reduced the number of meals eaten per day * 1) + (Reduced portion size of meals *2) + (Reduction in the quantities consumed by adults/mothers for young children *3). Consequently, the CSI ranges from 0 to 56.

2.4.3 Minimum dietary diversity score for women (MDD-W)

The minimum dietary diversity score for women was measured according to the FAO guidelines for measuring the minimum dietary diversity score for women. It measures micronutrient adequacy in the diets of women at the population level. All the foods consumed by women of reproductive age (15 - 49 years) at or outside the home during the previous day or night (last 24 hours) were recorded. To compute the score, the foods were assigned to the following 10 food groups: (1) Grains, roots, and tubers, (2) Pulses, (3) Nuts and seeds, (4) Dairy, (5) Meat, poultry, and fish, (6) Eggs, (7) Dark leafy greens and vegetables, (8) Other Vitamin A-rich fruits and Vegetables, (9) Other vegetables, (10) Other fruits. The threshold for adequacy is 5 or more food groups.

3 Results and Discussion

3.1 Wild harvested edible insects

3.1.1 Background characteristics of households consuming edible insects

Table 1 shows that 74.3 % of the sampled households consumed wild harvested edible insects. The households that consumed wild-harvested edible insects were headed by older persons as compared to those that did not consume, where the difference between consumption based on older household heads and younger household heads was statistically significant at the 1% level of significance. Furthermore, the results revealed that more of the consuming households were headed by divorced (5.9 %) and widowed (22.5 %) persons as compared to those who did not consume, 5 % and 20.4 % respectively. Also, consumption of wild-harvested edible insects was higher in households headed by lowly educated persons, who attained primary education only, as compared to those headed by highly educated persons where the difference was statistically significant at the 1 % level of significance. In addition, the results revealed that consumption was high in large size households as compared to those with few household members and again the difference was statistically significant at the 1 % level of significance.

Table 1. Characteristics of households consuming edible insects

Variable	Yes [Y]	No [N]	Difference [Y – N]
Observations # (%)	8,893 (74.3%)	3,078 (25.7%)	
Household head age (years)	51.7	50.5	1.221***
Married living together	63	64	-0.005
Divorced/separated	5.9	5.0	0.008*
Widow/widower	22.5	20.4	0.021**
Never married	2.0	2.1	-0.001
Household head is female	34.0	33.1	0.009
None	14.3	14.5	-0.003
Primary level	41.0	37.9	0.031***
ZJC level	14.1	13.7	0.004
O' level	28.0	31.1	-0.032***
A' level	1.0	1.1	-0.001
Diploma/Certificate after primary	0.4	0.4	0.000
Diploma/Certificate after secondary	0.9	0.8	0.001
Graduate/Post-Graduate	0.4	0.5	-0.002
Household size	4.962	4.827	0.135***
Household has mentally ill member	11.1	10.1	0.010
Household has chronically ill member	14.3	13.2	0.011
Household is HIV/AIDS affected	5.9	4.8	0.012*
Household income (ZWL)	2717	3388	-671

Total sample size is 14,965. The final column shows the results of two-tailed t-test for the difference in the means. ***, **, and * indicate the 1, 5, and 10 percent levels of significance.

Interestingly, the results show no statistically significant difference in household income between consuming and non-consuming households. These results corroborate findings from other studies (Dobermann et al., 2017; Dürr & Ratompoarison, 2021; Lange & Nakamura, 2021) that consumption of wild harvested edible insects is not only driven by poverty but is also by the contribution of the insects to food and nutrition security.

3.1.2 Consumption of edible insects by provinces in rural Zimbabwe

Figure 2. shows the proportion of the sampled households consuming edible insects in rural provinces in Zimbabwe. The results show that at least 14 wild harvested edible insect species are consumed in rural Zimbabwe. The number of consumed species is less than the 32 previously reported by DeFoliart in 1997 for Zimbabwe (van Huis, 2003) and greater than 14 reported in other African

countries (Ishara et al., 2022; Raheem et al., 2019). All the reported species are consumed at their adult stages except three species *madora* (*Gonimbrasia belina*), *harati* (*Cerina forda*) and *magandari* (*Gonanisa maia*) which are consumed at larval stage. Worldwide, edible insects can be consumed at any stage of development depending on the species.

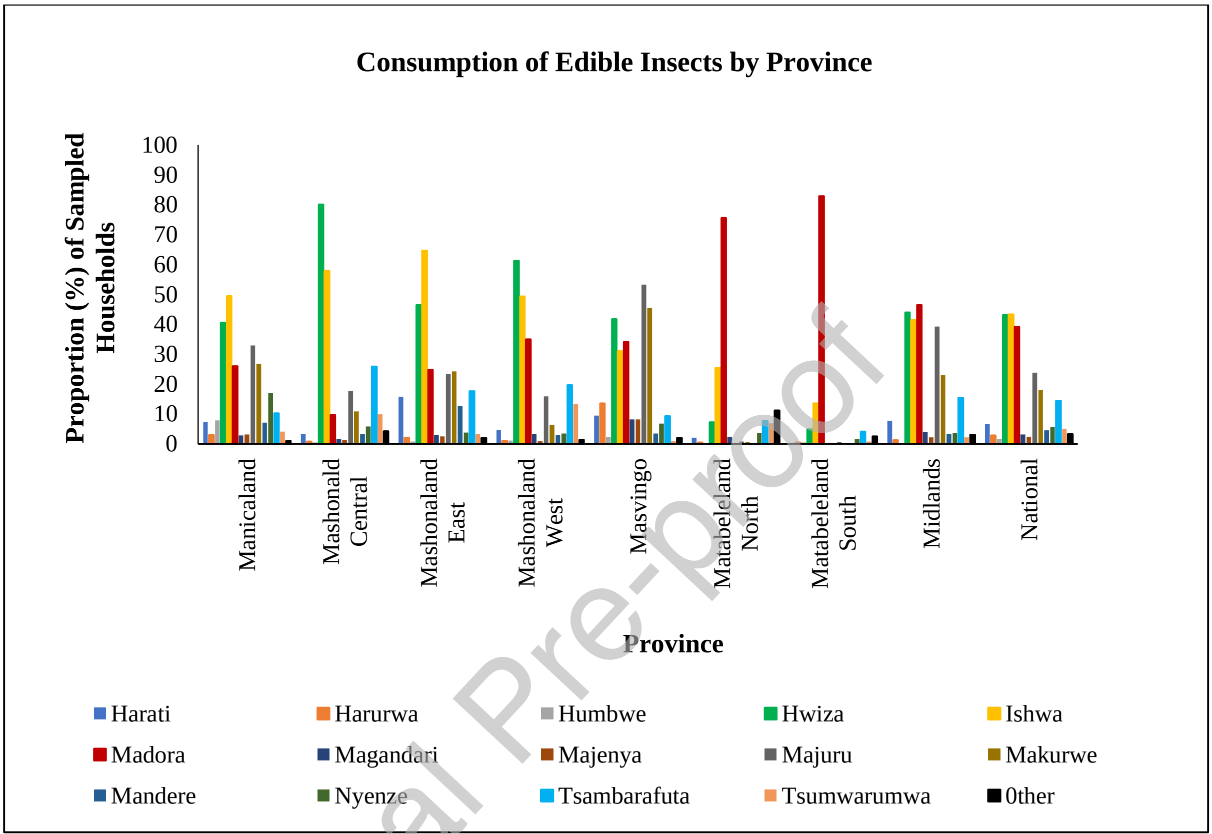


Figure 2. Consumption of edible insects by provinces in rural Zimbabwe

At the national level, the most consumed insects are *hwiza* (*Ornithacris turbida)* and *ishwa* (*Macrotermes natalensis*) (approx. 43 % of sampled households reported consumption) followed by *madora* (*Gonimbrasia belina*) (39.2 %). The results show that the popularity of consumed edible insects varied by province. *Hwiza* (*Ornithacris turbida*) were the most consumed insects in Mashonaland Central and Mashonaland West provinces reporting 80.1 % and 61.2 % consumption, respectively. In Manicaland and Mashonaland East, *ishwa* (*Macrotermes natalensis*) were the most popularly consumed edible insect with reported consumption of 49.3 % and 64.6 %, respectively. *Madora* were the most consumed edible insect in Matabeleland North (75.6 %), Matabeleland South (82.9 %) and Midlands (46.4 %). In Masvingo, the most consumed insect was *majuru* (*Macrotermes sp*) (53.3 %). The least consumed insect nationally was *humbwe* (*Acheta afer*) (1.6 %) and its consumption was only reported in Manicaland (7.6 %) and Masvingo 2.2 %. Manicaland and

Masvingo provinces showed the greatest diversity in edible insects consumed as all the 14 reported insects were consumed. Matabeleland South province has the least diversity in edible insects consumed (7 out of 14 insects are consumed). The high consumption of edible insects in rural Zimbabwe has been previously reported by Dube et al. (2013) and Manditsera et al. (2018).

The results on variation in the most preferred insect with the province is in line with what Ishara et al (2022) reported in Democratic Republic of Congo, that insects are appreciated differently in various territories. Agreeing with their findings, our results showed that one insect species can be preferred in more than one region (province). Availability, ethnicity/cultures, palatability, and seasonality have been reported to be linked to preference as some species are more prevalent and familiar in some areas than others (Ishara et al., 2022). Whilst it is widely reported that entomophagy habits differ by country and by culture (Raheem et al., 2019; Tang et al., 2019), the results presented in this paper indicate that within the country, the consumption patterns can differ by geographical location. All the 14 species identified in this study were harvested from the wild. As such, reported consumption can be influenced by availability and seasonality. Therefore, agroecological conditions can influence the availability of wild harvested edible insects and thus consumption. To ensure constant availability either in many regions or throughout the year, it is important to start insect rearing. According to Raheem et al. (2019), edible insects can also be obtained through semi-domestication (habitat manipulation to increase production) and farming/rearing. Changes in the weather patterns have influenced the numbers and patterns of emergence of insects (Selaledi et al., 2021) and insect rearing using sustainable production systems are key to mitigating the impact of climate change on the availability and sustainability of the edible insects' value chain. However, domestication of wild-harvested edible insects can result in changes in the nutritional composition of the insects (Meyer-Rochow, Gahukar et al. 2021).

3.1.3 Food and nutrition security outcomes by consumption of wild harvested edible insects

Table 2 displays the results for food and nutrition security outcomes by consumption of wild harvested edible insects. The results reveal that households consuming wild harvested insects had higher Women Dietary Diversity Scores (WDDS) (2.289 points) as compared to non-consuming households (2.188 points). The mean difference of 0.101 points was significant at the 1% level of significance. Pertaining to FCS, households consuming wild harvested edible insects had a 0.667-point higher FCS than non-consuming households and the difference was significant at the 10% level of significance. These results indicate that consumption of wild harvested edible insects was not a coping strategy as there was no significant difference in coping strategy index between consuming and non-consuming households. These findings contribute to the evidence on the contribution of edible insects to food and nutrition security. More so, these findings provide a different narrative that the consumption of wild harvested edible insects is not a sign of poverty as usually reported in literature (Bodenheimer, 1951; Hlongwane et al., 2021; Smith et al., 2021).

Table 2. Food and nutrition security outcomes by consumption of wild harvested edible insects

Food security indicator	Yes [Y]	No [N]	Difference [Y – N]
Minimum Dietary Diversity Score (MDD)	0.006	0.005	0.000
Minimum Acceptable Diet (MAD)	0.002	0.001	0.002
Minimum Meal Frequency (MMF)	0.065	0.066	-0.001
Women Dietary Diversity Scores (WDDS)	2.289	2.188	0.101***
Food consumption Score (FCS)	28.184	27.517	0.667*
Coping Strategy Index (CSI)	25.418	24.738	0.680

Notes: The "difference" column shows the results of two-tailed t-test for the difference in the means. ***, **, and * indicate the 1, 5, and 10 percent levels of significance

3.1.4 Distribution of edible insects by agro-ecological region

The distribution of the 14 commonly consumed edible insects in Zimbabwe is shown in Figure 3. The delineation of the agro-ecological regions of Zimbabwe was based mainly on long-term temperature and rainfall patterns (Vincent and Thomas, 1961). In general, rainfall decreases from more than 1000 mm to less than 450 mm per annum from Natural Region I to Natural Region V, respectively. Mean annual temperature increases from about 20 ºC in the Natural Region I to 30 ºC per annum in Natural Region V. Common in all agro-ecological regions were *ishwa (Macrotermes natalensis)*, *majuru (Macrotermes sp)* and *makurwe* (*Brachytypes membranaceus*). Agro-ecological region I had the least number of species of edible insects (28.6%), while Natural Region IV had the highest (100%). This trend could be attributed to the wide variation in rainfall (>400 mm per annum) and temperature (>10ºC per annum) between these agro-ecological regions. Unique to Natural Regions III and IV were the occurrences of *humbwe* (*Acheta domesticus*) and *harurwa* (*Encosternum delegorguei*) These insects only occurred in the southern and south-eastern parts of Natural Region III and IV. *Majenya* (*Henicus whellani*) only occurred in Natural Regions IV and V and were mostly located in the western regions of Zimbabwe. Although the occurrence of *madora* (*Gonimbrasia belina*) increased from natural region III to Natural Region IV, these edible insects were found only in the southern and western regions of Zimbabwe.

Agro-ecological region I is dominated by *ishwa*, *majuru*, *tsambarafuta* (*Carebara vidua*) and *makurwe*. *Tsumwarumwa*, *nyenze* (*Platypleura haglundi*), *mandere* (*Eulepida mashona*), *majenya*, *madora, hwiza, humbwe, harurwa* and *harati* (*Cirina forda*) were absent. This region is characterized by average annual rainfall and temperature greater than 1000 mm and 20 ºC, respectively. In agro-ecological region IIa the following insects are dominant: *hwiza~ishwa >> majuru>tsambarafuta>Tsumwarumwa>makurwe>mandere*.A similar trend of *hwiza* and *ishwa* dominance in natural region 1a was observed in agro-ecological region IIb. *Harati* and *magandari* (*Gonanisa maia*) were present. However, there was no record of the occurrence of *tsumwarumwa* and *majenya* in agro-ecological region IIb.

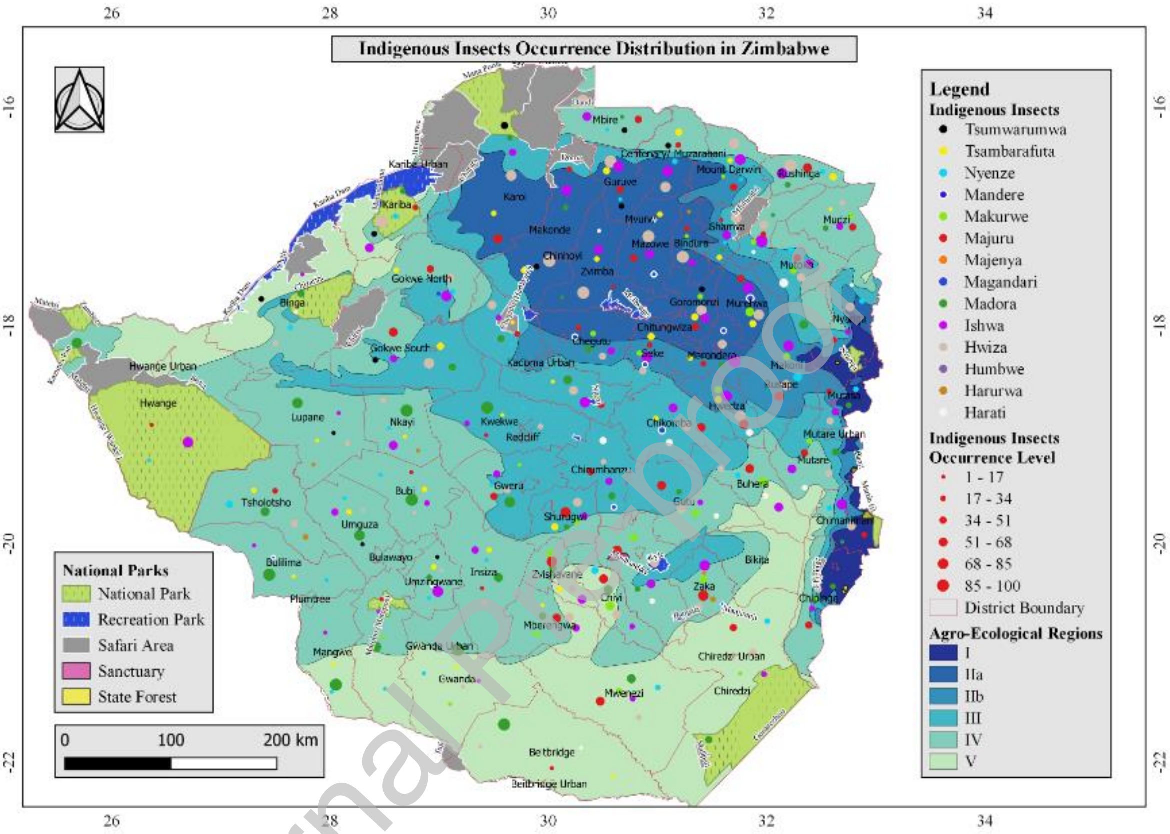


Figure 3. Distribution of edible insects in different agro-ecological regions in Zimbabwe

Agro-ecological region III has a mean annual rainfall of 650-750 mm and a temperature of 30 ºC. In this region, the prevalence of insect occurrence follows the order: *ishwa~majuru~makurwe~hwiza>> tsambarafuta>harati>harurwa>madora*. In agro-ecological region IV, *ishwa*, *majuru*, *hwiza*, *makurwe* and *madora* were much more prevalent than *tsumwarumwa*, *tsambarafuta and harurwa*. *Harurwa* only occurs in the south-east parts of this region while *tsumwarumwa* is most prevalent in the north and north-eastern region. *Ishwa* and *madora occur* predominantly in the south-west and western regions of agro-ecological region 4.

These results corroborate findings by Ishara et al. (2022) that the availability of some edible insects depends on the geographical distribution of their host plants and more so, their distribution is associated with the natural environment conditions (Twine et al., 2003). Some wild harvested edible insects are host specific whilst other host plants for various inventoried edible insects do not necessarily have host plants (Ishara et al., 2022). This could be the reason for some insects such as *ishwa* being found in all the agro-ecological regions, whilst some such as *harurwa* or *madora* being specific to only one or a few agro-ecological regions. For example, *madora* exclusively feed on the mopane tree (*Colophospermum mopane*) and their distribution is associated with the availability of the mopane tree. In Zimbabwe, the mopane trees are confined to the southern part of the country (Makhado et al., 2014; Bara et al., 2022), hence the high availability of the *madora* in that region.

3.2 Indigenous fruits

3.2.1 Consumption of indigenous fruits

Surveyed households reported consumption of at least 26 different indigenous fruits. The most popular and important species for consumption at the national level in descending order are: *matohwe* (*Azanza garckeana*) (52 %) > *matamba* (*Strychnos cocculoides*) (40 %), *tsubvu* (*Vitex mombassae*) (38 %) > *mazhanje* (*Uapaca kirkiana*) 28 % > and *masau* (*Ziziphus mauritania*) and nyii (*Berchemia discolor)* both at (24 %). The lowest consumption was with *nzambara* (*Carissa edulis*) (2 %) and *masekesa* (*Piliostigma thonningii*) (0.3 %) (Figure 4). The most consumed indigenous fruits are widely distributed in all provinces irrespective of the agro-ecological region. The findings of this study showed that the fruits consumed at the national level are similar to the proportion consumed at the household level. Differences in consumption patterns and distribution patterns are evident in Matabeleland North, South and Masvingo province where *mauyu* (*Adansonia digitata*) and *mapfura/marula* (*Sclerocarya birrea*) consumption ranged between (16-3 %). However, we cannot deduce extensively the provincial preferences, marketing and value addition potential of indigenous fruits from the data gathered.

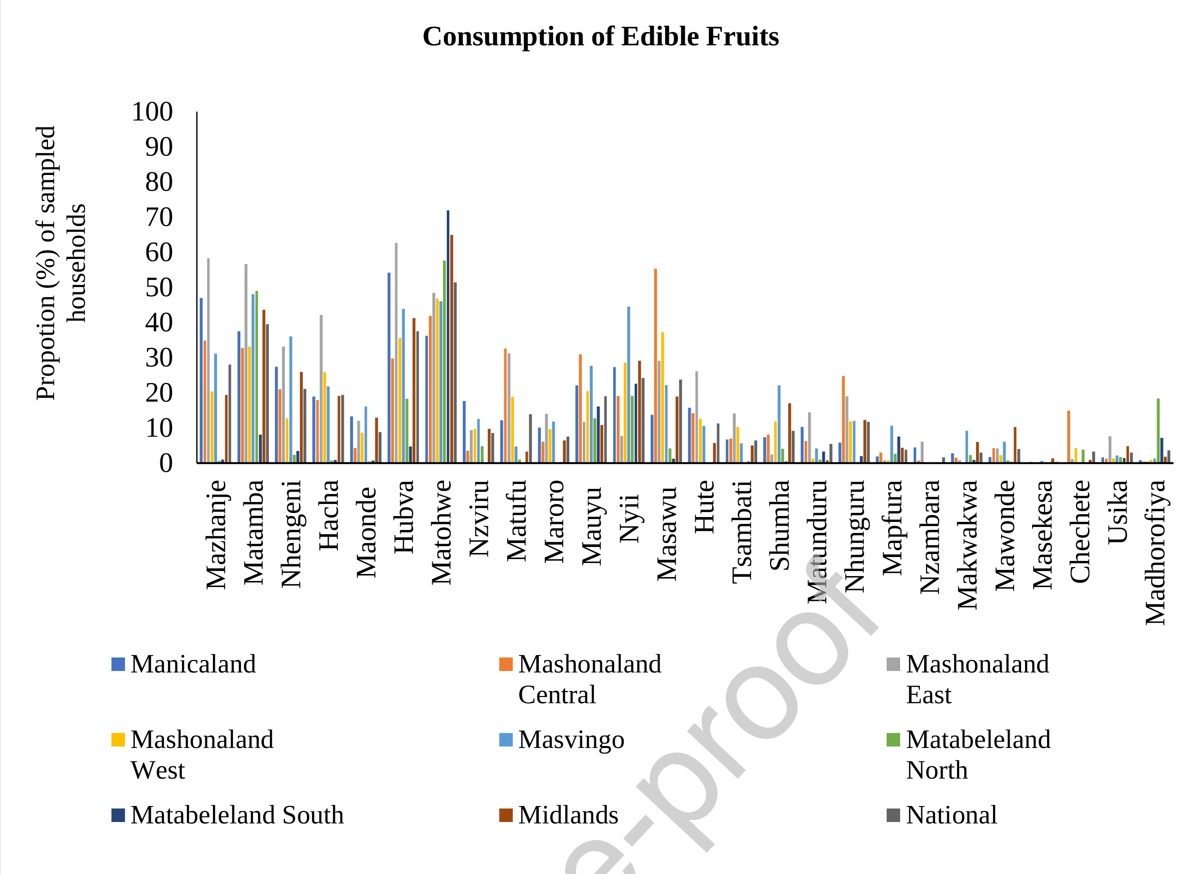


Figure 4. Consumption of indigenous fruits by province

Consumption distribution per province showed that the most popular fruits in Manicaland in the descending order *tsubvu* (54.2 %) > *mazhanje* (47 %) > *matamba* (37.5 %) > *matohwe* (36.2 %) and *nyii* (*27.3 %*). In Mashonaland Central the 5 highest consumed were *masau* (55.3 %) was the most consumed fruit followed by *matohwe* (41.9 %) > *matufu* (*Vangueria infausta*) (32.6 %) > *mazhanje* (34.9 %) > *matamba* 32.7%. In Mashonaland West province, *matohwe* (46.8 %) was mostly consumed followed by *tsubvu* (35.7 %), *masau* (37.2 %), *matamba* (33.2 %) and nyii 28.6 %. In Mashonaland East Province, *tsubvu* was highly consumed with 62.7 % of respondents, followed by *mazhanje* (58.3 %), *matamba* (56.7 %), *hacha* (*Parinari curatellifolia*) and *matohwe* had 42.2 and 48.5 % respectively.

In Masvingo province, *matamba* (48.1 %) was the most consumed followed by *nyii* (44.6%) > *matohwe* (46.1 %) > *tsubvu* (43.9%) and (nhengeni) *(Ximenia caffra)* (36.1). In Matebeleland North, *matohwe* (57.7%) > *matamba* (49 %) > *nyii* (19.1 %) > *madhorofiya (Opuntia).* Matebeland South, *matohwe* (72 %) > *nyii* (22.6 %) > *Mauyu* (16.1 %) > *matamba* (8.1 %) and *mapfura* (7.5 %). In Midlands, *matohwe* (65 %) > *matamba* (43.6 %) > *tsubvu* (41.2 %) > *nyii* (29.2 %) *and mazhanje* (19.4%).

It is important to note that though *hacha*, *nhengeni* and *madhorofiya* are distributed in all provinces, their consumption was mainly confined to Mashonaland East, Manicaland and Masvingo provinces. *Mapfura* was highly consumed only in Matabeleland South as expected since the fruit is distributed in these regions. The low consumption observed in some provinces could be attributed to the food culture and identity of the localities, where the fruits are further processed into secondary products or ingredients in main staples during times of droughts and famine from information that was passed from generation to generation. A study by Fentahun and Hager (2009) in Ethiopia revealed that cereal-based dietary habits, cultural perceptions and attitudes were some of the reasons for the low consumption of some indigenous fruits although they might be in abundance. Similarly, ethnic and cultural dietary patterns were reported by Hawea et al. (2021) to be a major reason for the non-consumption of indigenous fruits for Fijians of iTaukei origin and their diet was often supplemented with fish or meat, some vegetables, and root crops. However, the nutritional benefits of NTFFPs seem to be undervalued by modern food systems (Gruenwald, 2009; Jäckering et al., 2019). It is therefore important to promote the consumption and value addition of NTFFPs.

3.2.2 Distribution of indigenous fruits by agro-ecological region

Figure 5 shows the distribution pattern of indigenous fruits by agro-ecological area. Mazhanje (*Uapaca kirkiana*) is one of the most abundant and dominant wild fruit tree in Zimbabwe and occurs in mixed communities of *Brachystegia-Julbernardia* woodland vegetation as a co-dominant or dominant species (Chawafambira et al., 2020; Ngulube et al., 1995). Its distribution is mainly in dry and semi-dry areas especially well-drained escarpments, with low fertility soil or gravelly with good drainage although it can grow in some relatively wet areas (Ngulube et al., 1995) The main wild fruit trees associated with *mazhanje* are *hacha* (*Parinari curatellifolia*) (Chirwa & Akinnifesi, 2008). *Hacha* and Maonde (*Ficus sp*) trees occur in soils that are sandy (Maharaj & Glen, 2008) and derived from granitic rocks. These soils have a relatively shallow perched water table. Therefore, a large proportion of these trees are in agro-ecological region II.

Strychnos species (*Matamba*, *Mazhumu*, *Hakwa*) *Tsambatsi*, *Nhunguru* and *Matohwe* are widely distributed across the agro–ecological regions of the country in a range of soil types ranging from deep, well- drained sandy or gravelly to clay soils. *S. spinosa* common in the north, east, central south and west, S. *innocua* in the north, central, and south *and S. madagascariensis* in the north, west, central, east, and south, and *S. pungens* in the north, central and west (Ngadze et al., 2017a). *S. cocculoides* occurs in the north, central, south and western areas especially in the *Brachystegia* woodlands, deciduous woodlands, mixed forests, and lowlands (Ngadze et al., 2017a). The species grows in areas with a prolonged dry season and in a range of soil types from rocky slopes, less fertile, deep sandy soil, and acidic clays to red or yellow-red loams and is commonly found in the miombo woodlands as one of the dominant or codominant species and in the *Terminalis-Combretum* woodlands together with *S. Spinosa*, *S. Birrea* and *Terminalia sericea* (Chirwa & Akinnifesi, 2008). *Marula/ mapfura* (*Sclerocarya birrea*), occurs in mixed deciduous woodlands, wooded grasslands and dry savannahs, is mainly distributed, but not restricted to the miombo woodlands and is associated with seasonal rainfall patterns.

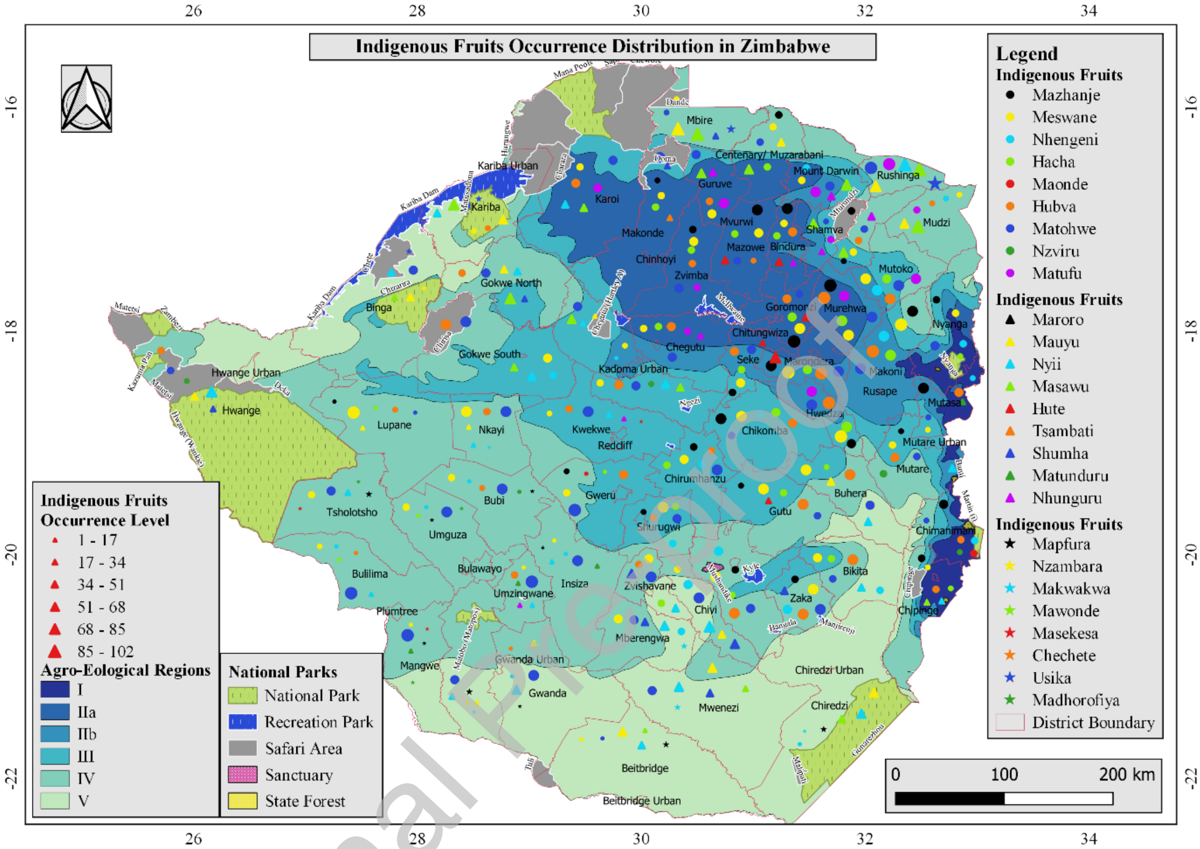


Figure 5: Distribution pattern of indigenous fruits by agro-ecological area

The *caffra* subspecies, common in Southern Africa, proliferates in more humid areas (National Research Council, 2008). *Ximenia caffra* (sourplum fruit) occurs in various types of woodland and wooded grassland, mostly on termite mounds and rocky kopjes, and is drought resistant when mature (Chivandi et al., 2008). *Parinari curatellifolia* (mobola plum**)**, grows on well-drained, sandy and fairly sour soils and primarily occurs singly but it is not uncommon to find others occurring nearby (Maharaj & Glen, 2008).

Tsubvu (*Vitex L*) occur within the flora Zambesiaca area in a variety of soils, near termite mounds, deserted areas and rocky places including semi-arid areas (Maroyi, 2017). *Mauyu* (*Adansonia digitata*) occur in semiarid low- altitude areas and hot dry woodlands (Mashapa et al., 2013) and the tree is widespread along the Zambezi valley in Manicaland, Mashonaland West, Matabeleland North, Mashonaland Central and the dry woodlands of Mashonaland East and some parts in Matabeleland

South and Masvingo provinces. *Madhorofiya* (*Opuntia megacantha Salm Dyck*) can survive in a wide range of climates including adverse conditions hence it is widely distributed in all regions and has become naturalized on rangelands in Zimbabwe. It is therefore established in the south-western parts of the country in some parts of Gwanda and Beitbridge districts (Masocha & Dube, 2017). *Chechete* (*Mimusops zeyheri*) is found in dry, open, and bushveld woodland and can withstand various soil and climate conditions and can easily be cultivated in low to medium-altitude areas (Omotayo & Aremu, 2020). *Masekesa* (*Piliostigma thonningii*) is common in open woodland and wooded grasslands rapidly colonises abandoned areas, and grows on any soil type, especially medium loamy or heavy clayey soils.

3.3 Indigenous vegetables

3.3.1 Consumption of indigenous vegetables

The results presented in Figure 6 show that *nyevhe* (*Cleome gynandra*) was the most consumed vegetable with 80 % of the sampled households consuming it followed by *mowa* (*Amaranthus thunbergii Moq*) and *munyemba* (*Vigna unguiculata*) which were equal with 61.7 % consumers. This trend is similar to the findings of Maroyi (2013) who rated the importance of the indigenous vegetables in Zimbabwe. The most important edible vegetables (weeds as presented in the study by Maroyi (2013) were *Cleome gynandra*, cited by 93.9 % of the participants, *horned melon (Cucumis metuliferus)* (90.5 %), *maroon cucumber (Cucumis anguria)* (87.8 %), *gusha* (*Corchorus tridens)* (50.3 %) and mowa (*Amaranthus hybridus)* (39.5 %). According to Maroyi, (2011), the top five most important traditional vegetables were sweet potatoes (*Ipomoea Batatas)*, *muboora* (*C. maxima*), *mapudzi* (*Lagenaria siceraria)*, munyemba (*C. gynandra*) and *munyemba* (*Vigna. unguiculata*), respectively. In our study, *munyemba* was the most preferred traditional leafy vegetable. Ndoro et al. (2005) reported that pumpkin leaves are usually consumed three to four times per week during the rainy season.

Consumption patterns per province (Figure 6) showed that the most popular vegetables in Manicaland were *Mowa* (73.1 %), followed by *nyevhe* (66.3 %) and *nhungunira* (*Bidens pilosa*) (65.2 %). *Gusha* (*Corchorus olitorius)*, *munyemba* and *mutsine* (blackjack, *Bidens pilosa*) had consumption between 30-37 %. In Mashonaland Central, *mowa* (79 %) was the most consumed vegetable followed by *nyevhe* (75 %), *munyemba* (63.5 %) and *mutsine* (47.2 %) respectively. In Mashonaland West province, consumption was generally lower than other provinces but *nyevhe* (72%) was mostly consumed followed by *mowa* (60 %), *munyemba* (54 %) and *mutsine* (46.1 %). In Mashonaland East Province, *nyevhe* was highly consumed with 83 % of respondents, followed by *mowa* (73.2 %), *munyemba* (72.5 %), *gusha* and *mutsine* had 40 and 42 % respectively.

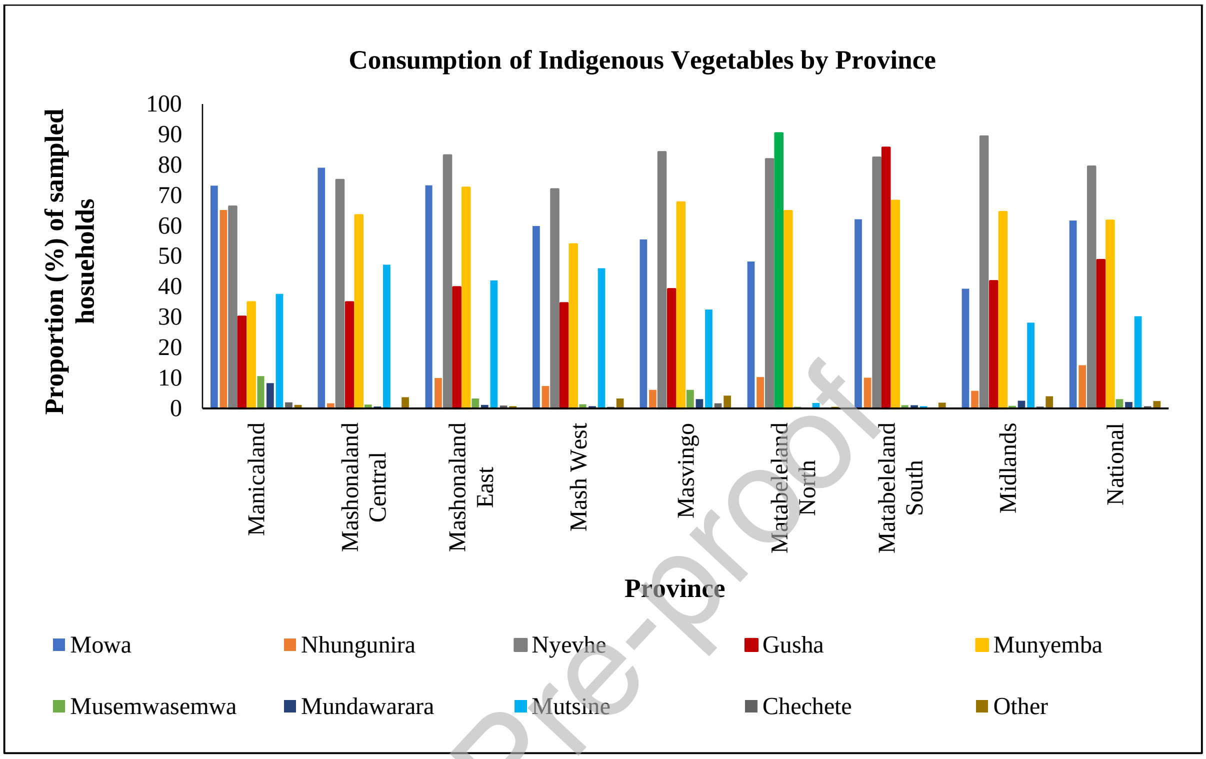


Figure 6. Most consumed indigenous vegetables

In Masvingo province, *nyevhe* (84.2 %) was the most consumed followed by *munyemba* (67.6%) and *mowa* (55.5 %). *Gusha* and *mutsine* had 39.1 % and 32.4 % respectively. In Matebeleland North, *Musemwasemwa* was the most consumed vegetable followed by *nyevhe* (81.8 %) and *munyemba* (64.9 %) and *mowa* (48.2 %) respectively. Matabeleland South had a different trend, *Gusha* (85.7 %) was the most consumed vegetable followed by *nyevhe* (82.4 %), *munyemba* (68.2 %) and *mowa* (62.1 %). In Midland, *Nyevhe* was the most common vegetable followed by *munyemba, mowa* and *mutsine* respectively.

The use of NTFFPs to complement cultivated crops in times of food shortages was observed by Harris and Muhammed (2003), Shava (2005) and Shava et al. (2009). Previous research in Zimbabwe has shown that rural farmers mostly depend on indigenous vegetables in either fresh or processed forms, especially during the rainy season (Mazike et al., 2022). According to Maroyi,(2013), vegetable species domesticated or tolerated in home gardens include *Cleome gynandra (nyevhe), Cucumis anguria* and *Cucumis metuliferus* which are deliberately spared during digging, weeding and land clearing activities for the benefits or usefulness they provide to households as traditional vegetables. This could be the reason why *nyevhe* is the most popularly consumed vegetable as shown in Figure 6.

3.3.2 Distribution of indigenous vegetables

The distribution of dominant indigenous vegetables in agro-ecological regions of Zimbabwe is shown in Figure 7. *Mowa*, *Nyevhe* and *Munyemba* occurred in all agroecological regions, though their abundance varied from one region to another. *Mutsine* was absent in agro-ecological region V. In natural environments, plant growth and occurrence are largely controlled by climatic and edaphic (soil fertility, drainage, and soil depth) factors. Although several types of soils occur in each agro-ecological region, generally soil fertility increases from agro-ecological region 1 to V owing to reduced rainfall that reduces plant nutrient leaching (Thomson and Purves, 1978). Our findings suggest that *Mowa*, *Nyevhe* and *Munyemba* occur in all soil types, though *Nyevhe* tends to be associated with sandy soils.

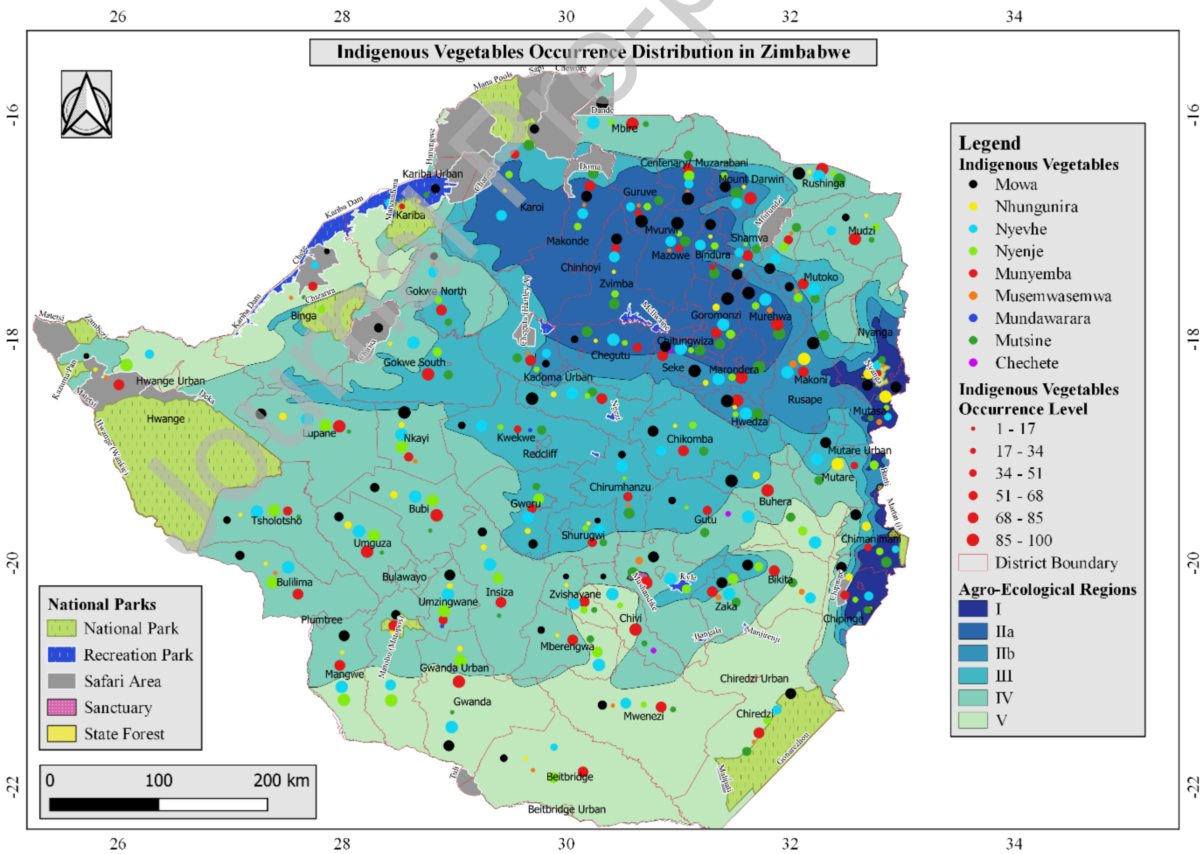


Figure 7: Distribution of indigenous vegetables in different agro-ecological regions in Zimbabwe

The predominant vegetables in agroecological regions I-III are *Mowa*, *Munyemba*, *Nyevhe and Mutsine*. In agro-ecological region 1, the order of vegetable dominance is *Mowa* ~ *Nhungunira* > *Mutsine* > *Nyevhe* ~ *Nyenje*. Agro-ecological regions IV and V are dominated by *Munyemba*, *Nyevhe*, *Mowa* and *Nyenje*. In agroecological regions IIa and IIb, *Mowa*, *Nyevhe* and *Munyemba* are much more dominant than *Musemwasemwa* and *Nhungunira*. *Munyemba*, *Nyevhe*, *Nyenje and Mowa* occur much more abundantly than *Nhungunira* and *Mutsine* in region IV. The latter vegetable occurs predominantly east of longitude 30 degrees. A similar trend of vegetable distribution was observed in agro-ecological V but with *Nhungunira* and *Musemwasemwa* as additional vegetables.

3.4 Determinants of consumption of wild harvested edible insects, fruits and vegetables

The results presented in sections 3.1 - 3.3 show that consumption of the three indigenous foods is mainly due to availability. The most popularly consumed indigenous food could be due to wide use as part of traditional diet and culture, especially as ingredients in alcoholic- *kachasu* and non-alcoholic beverages – *mahewu*, as food products substitutes for sugar, flavour and general enhancement food such as maize porridge, traditional cakes (Nyanga et al., 2008; Ngadze et al., 2019). This assumption is corroborated by Talukdar et al. (2021) who indicated that indigenous foods are usually associated with traditional beliefs and cultures, and this could be the reason for their popularity in the rural areas in Zimbabwe. For indigenous fruits, though, availability may be high and regardless that indigenous foods have been verified to be of superior nutritional quality compared to exotic fruit due to high contents of micronutrients and bioactive compounds consumption was on the low side. For example, the percentage of most consumed fruits shows that not all households consume indigenous fruits irrespective of distribution levels. The consumption at the household level was observed to be low (Figure 4) due to the probable association of indigenous fruits with hunger, socioeconomic status and primitive nature due to the practice of gathering from the forest which has greatly influenced consumption at the household level (Gari, 2004). Taxonomic details, diversity of species and local names for each indigenous fruit are likely to cause confusion and misidentification such as *matamba* and *makwakwa* in which interspecies differences when one name can be given are noted. The level of knowledge of differentiation does influence use and consumption levels, especially among the younger informants.

NTFPs are gathered principally during the rainy season when food is scarce and when women and children fend the field. As such, the lower use seen during the data collection period (beginning of the dry season) could be attributed to the availability of cultivated crops. Most studies on seasonal variation and indigenous food consumption are consistent with our findings. Powel et al., (2013) found that informants in East Africa use wild foods when food is scarce and during the drought period. Additionally, those NTFPs that are closer to homesteads and on boundary fences and roads are more readily identified, harvested and consumed as gathering deeper in the forest is something that is done in times of extreme droughts.

4 Conclusion and Recommendations

The main findings from this study are that consumption patterns for wild harvested edible insects, fruits and vegetables vary by geographical location and could be linked to agro-ecological region. This was mainly pronounced with wild harvested edible insects as availability of some species depends on the geographical distribution of their host plants and more so, is associated with environmental conditions. For example, the abundance of the top three consumed indigenous vegetables (*Mowa, Nyevhe* and *Munyemba*) were highly associated with sandy soils. More so, the distribution of the indigenous fruits and vegetables varied with rainfall patterns and soil type. As such, the study revealed that agro-ecological conditions influence availability of wild harvested edible insects, fruits and vegetables and ultimately their consumption. The results also revealed that the most consumed indigenous fruits and vegetables were widely distributed in all administrative provinces irrespective of the agro-ecological region. However, their relative abundance varied from one region to another. Some indigenous fruits and vegetables were unique to specific places within a province.

The findings on wild-harvested edible insects revealed that consumption of the insects is not a coping strategy and in fact, households consuming wild harvested edible insects were associated with improved food and nutrition security outcomes as compared to non-consuming households. Ultimately, we can conclude that consuming wild harvested edible insects is not associated with poverty as indicated in most previous studies. Further to this, it will be vital to assess the differences in nutritional composition of these indigenous food and how this relates to nutritional outcomes.

The first distribution maps for wild harvested edible insects, indigenous vegetables and fruits based on a large number of households shown in this study is significant to various stakeholders along the value chains of these indigenous foods. However, one limitation of the study is lack of data on seasonal occurrence of the three NTFFPs presented in this paper. Follow-up studies are needed to map the seasonal occurrence of these indigenous food. Moreover, research on how traditional food systems contribute to food and nutrition security and resilience building, especially with the increased climate change events, is needed. In view of this, it will be interesting to understand how indigenous knowledge systems influence food product preferences in various districts and how this relates to food sovereignty. More so, it is important to have multi-sectoral policy advocacy to enhance the successful production and processing of indigenous food. Currently, the regulatory framework for the sustainable management and utilisation of wild harvested edible insects, indigenous vegetables and fruits is not clearly defined nor does it provide adequate restrictive measures to protect these indigenous foods from over-harvesting and the destruction of the environment and ecosystem.

5 Acknowledgments

The authors would like to thank the Food and Nutrition Council of Zimbabwe for providing the Data set used in this paper.

6 Declarations

6.1 Ethics approval and consent to participate

Ethics approval is not required because we used secondary data. However, we understand that all interviews conducted during the actual survey were conducted after participants gave consent, expressed by signing the consent form.

6.2 Funding

The study was not funded. Authors used their own resources.

6.3 Conflict of Interests

The authors declare that they have no conflict of interests.

6.4 Availability of data and materials

The datasets analysed in the current study are available from the Food and Nutrition Council of Zimbabwe (FNC), but restrictions apply to the availability of these data, which were used under a Memorandum of Understanding for the current study, and so are not publicly available. Data is however available from the authors upon reasonable request and with permission of FNC.

7 References

Ahenkan, A., & Boon, E. (2011). Improving nutrition and health through non-timber forest products in Ghana. *Journal of health, population, and nutrition*, *29*(2), 141-148. https://doi.org/10.3329/jhpn.v29i2.7856

Arnold, J. M., & Pérez, M. R. (2001). Can non-timber forest products match tropical forest conservation and development objectives? *Ecological economics*, *39*(3), 437-447.

Bara, G. T., Sithole, R., & Macheka, L. (2022). The mopane worm (Gonimbrasia belina Westwood): a review of its biology, ecology and utilisation in Zimbabwe. *Journal of Insects as Food and Feed*, *0*(0), 1-14. doi: 10.3920/jiff2021.0177

Bharucha, Z., & Pretty, J. (2010). The roles and values of wild foods in agricultural systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *365*(1554), 2913-2926.

Bodenheimer, F. S. (1951). Insects as Human Food. In *Insects as Human Food: A Chapter of the Ecology of Man* (pp. 7-38). Springer Netherlands. https://doi.org/10.1007/978-94-017-6159-8_1

Borelli, T., Hunter, D., Padulosi, S., Amaya, N., Meldrum, G., de Oliveira Beltrame, D. M., Samarasinghe, G., Wasike, V. W., Güner, B., Tan, A., Koreissi Dembélé, Y., Lochetti, G., Sidibé, A., & Tartanac, F. (2020). Local Solutions for Sustainable Food Systems: The Contribution of Orphan Crops and Wild Edible Species. *Agronomy*, *10*(2), 231. https://www.mdpi.com/2073-4395/10/2/231

Chadare, F. J., Fanou Fogny, N., Madode, Y. E., Ayosso, J. O. G., Honfo, S. H., Kayodé, F. P. P., Linnemann, A. R., & Hounhouigan, D. J. (2018). Local agro-ecological condition-based food resources to promote infant food security: a case study from Benin. *Food Security*, *10*(4), 1013-1031.

Chawafambira, A., Sedibe, M. M., Mpofu, A., & Achilonu, M. (2020). Uapaca kirkiana, an indigenous fruit tree in sub-Saharan Africa: A comprehensive review. *Cogent Food & Agriculture*, *6*(1), 1766735. https://doi.org/10.1080/23311932.2020.1766735

Chirwa, P., & Akinnifesi, F. (2008). Ecology and biology of Uapaca kirkiana, Strychnos cocculoides and Sclerocarya birrea in Southern Africa. *Indigenous fruit trees in the tropics: Domestication, Utilisation and Commercialisation*, 322-340.

Chivandi, E., Davidson, B. C., & Erlwanger, K. H. (2008). A comparison of the lipid and fatty acid profiles from the kernels of the fruit (nuts) of Ximenia caffra and Ricinodendron rautanenii from Zimbabwe. *Industrial Crops and Products*, *27*(1), 29-32.

Dobermann, D., Swift, J. A., & Field, L. M. (2017). Opportunities and hurdles of edible insects for food and feed. *Nutrition Bulletin*, *42*(4), 293-308. https://doi.org/https://doi.org/10.1111/nbu.12291

Dube, S. C., Dlamini, N., Mafunga, A., Mukai, M., & Dhlamini, Z. (2013). A survey on entomophagy prevalence in Zimbabwe. *African Journal of Food, Agriculture, Nutrition and Development*, *13*, 7242-7253.

Durazzo, A., Lucarini, M., Zaccardelli, M., & Santini, A. (2020). Forest, Foods, and Nutrition. *Forests*, *11*(11), 1182. https://www.mdpi.com/1999-4907/11/11/1182

Dürr, J., & Ratompoarison, C. (2021). Nature's "Free Lunch": The Contribution of Edible Insects to Food and Nutrition Security in the Central Highlands of Madagascar. *Foods*, *10*(12). https://doi.org/10.3390/foods10122978

Fentahun, M. T., & Hager, H. (2009). Exploiting locally available resources for food and nutritional security enhancement: wild fruits diversity, potential and state of exploitation in the Amhara region of Ethiopia. *Food Security, 1*(2), 207. doi: 10.1007/s12571-009-0017-z

FAO, I., UNICEF, WFP and WHO. (2021). *The State of Food Security and Nutrition in the World 2021. Transforming food systems for food security, improved nutrition and affordable healthy diets for all* (240, Issue. [Record #1563 is using a reference type undefined in this output style.]

Gonçalves, C. d. B. Q., Schlindwein, M. M., & Martinelli, G. d. C. (2021). Agroforestry Systems: A Systematic Review Focusing on Traditional Indigenous Practices, Food and Nutrition Security, Economic Viability, and the Role of Women. *Sustainability*, *13*(20), 11397. https://www.mdpi.com/2071-1050/13/20/11397

Hawea, S. M. C., Singh, P., & Whiting, S. J. (2021). Cultural Determinants of Fruits and Vegetable Consumption in Indigenous (iTaukei) Fijian Children: A Qualitative Study of Caregivers. *Asia Pacific Journal of Public Health, 33*(6-7), 747-752. doi: 10.1177/10105395211038458

Hlongwane, Z. T., Slotow, R., & Munyai, T. C. (2021). Indigenous Knowledge about Consumption of Edible Insects in South Africa. *Insects*, *12*(1), 22. https://www.mdpi.com/2075-4450/12/1/22

Ishara, J., Ayagirwe, R., Karume, K., Mushagalusa, G. N., Bugeme, D., Niassy, S., Udomkun, P., & Kinyuru, J. (2022). Inventory reveals wide biodiversity of edible insects in the Eastern Democratic Republic of Congo. *Scientific Reports*, *12*(1), 1576. https://doi.org/10.1038/s41598-022-05607-y

Kennedy, G., Kanter, R., Chotiboriboon, S., Covic, N., Delormier, T., Longvah, T., Maundu, P., Omidvar, N., Vish, P., & Kuhnlein, H. (2021). Traditional and Indigenous Fruits and Vegetables for Food System Transformation. *Current Developments in Nutrition*, *5*(8). doi: 10.1093/cdn/nzab092

Kobori, C. N., & Amaya, D. B. R. (2008). Uncultivated Brazilian green leaves are richer sources of carotenoids than are commercially produced leafy vegetables. *Food Nutr Bull*, *29*(4), 320-328.

Korn, E. L., & Graubard, B. I. (1994). Variance Estimation for Superpopulation Parameters: Should One Use With-Replacement Estimators. Proceedings of the Section on Survey Research Methods, American Statistical Association,

Lange, K. W., & Nakamura, Y. (2021). Edible insects as future food: chances and challenges. *Journal of Future Foods*, *1*(1), 38-46. https://doi.org/https://doi.org/10.1016/j.jfutfo.2021.10.001

Lugo-Morin, D. R. (2020). Indigenous communities and their food systems: a contribution to the current debate. *Journal of Ethnic Foods*, *7*(1), 6. doi: 10.1186/s42779-019-0043-1

Maharaj, V., & Glen, H. (2008). Paranari curatellifolia Planch. ex Benth.(Chrysobalanceae).

Makhado, R., Potgieter, M., Timberlake, J., & Gumbo, D. (2014). A review of the significance of mopane products to rural people's livelihoods in southern Africa. *Transactions of the Royal Society of South Africa, 69*(2), 117-122. doi: doi:10.1080/0035919X.2014.922512

Manditsera, F. A., Lakemond, C. M. M., Fogliano, V., Zvidzai, C. J., & Luning, P. A. (2018). Consumption patterns of edible insects in rural and urban areas of Zimbabwe: taste, nutritional value and availability are key elements for keeping the insect eating habit. *Food Security*, *10*(3), 561-570. https://doi.org/10.1007/s12571-018-0801-8

Manditsera, F. A., Luning, P. A., Fogliano, V., & Lakemond, C. M. M. (2019). The contribution of wild harvested edible insects (Eulepida mashona and Henicus whellani) to nutrition security in Zimbabwe. *Journal of Food Composition and Analysis*, *75*, 17-25. https://doi.org/https://doi.org/10.1016/j.jfca.2018.09.013

Maroyi, A. (2013). Use of weeds as traditional vegetables in Shurugwi District, Zimbabwe. *Journal of Ethnobiology and Ethnomedicine*, *9*(1), 60. https://doi.org/10.1186/1746-4269-9-60

Maroyi, A. (2017). Azanza garckeana fruit tree: phytochemistry, pharmacology, nutritional and primary healthcare applications as herbal medicine: A Review. *Research Journal of Medicinal Plants*, *11*(4), 115-123.

Mashapa, C., Zisadza-Gandiwa, P., Gandiwa, E., & Kativu, S. (2013). Abundance and structure of African Baobab (Adansonia digitata) across different soil types in Gonarezhou National Park, Zimbabwe. *International Journal of Biodiversity*, *2013*, 1-7.

Masocha, M., & Dube, T. (2017). Modelling Opuntia fulgida invasion in Zimbabwe. *Transactions of the Royal Society of South Africa*, *72*(3), 217-224.

Matiza Ruzengwe, F., Nyarugwe, S. P., Manditsera, F. A., Mubaiwa, J., Cottin, S., Matsungo, T. M., Chopera, P., Ranawana, V., Fiore, A., & Macheka, L. (2022). Contribution of edible insects to improved food and nutrition security: A review. *International Journal of Food Science & Technology*, *n/a*(n/a). https://doi.org/https://doi.org/10.1111/ijfs.15570

Mazike, H. G., Chipurura, B., & Macheka, L. (2022). Value addition of African Indigenous Vegetables (AIVs) and their utilization as food to improve food and nutrition security: A review. *Food Reviews International*. https://doi.org/10.1080/87559129.2022.2062765

Meyer-Rochow, V. B., Gahukar, R. T., Ghosh, S., & Jung, C. (2021). Chemical Composition, Nutrient Quality and Acceptability of Edible Insects Are Affected by Species, Developmental Stage, Gender, Diet, and Processing Method. *Foods*, *10*(5). https://doi.org/10.3390/foods10051036

Mipun, P., Bhat, N. A., Borah, D., & Kumar, Y. (2019). Non-timber forest products and their contribution to healthcare and livelihood security among the Karbi tribe in Northeast India. *Ecological Processes*, *8*(1), 41. https://doi.org/10.1186/s13717-019-0194-4

Ngadze, R. T., Linnemann, A. R., Nyanga, L. K., Fogliano, V., & Verkerk, R. (2017a). Local processing and nutritional composition of indigenous fruits: The case of monkey orange (Strychnos spp.) from Southern Africa. *Food Reviews International*, *33*(2), 123-142.

Ngadze, R. T., Verkerk, R., Nyanga, L. K., Fogliano, V., & Linnemann, A. R. (2017b). Improvement of traditional processing of local monkey orange (Strychnos spp.) fruits to enhance nutrition security in Zimbabwe. *Food Security*, *9*(3), 621-633. https://doi.org/10.1007/s12571-017-0679-x

Ngulube, M. R., Hall, J. B., & Maghembe, J. A. (1995). Ecology of a miombo fruit tree: Uapaca kirkiana (Euphorbiaceae). *Forest Ecology and Management*, *77*(1), 107-117. https://doi.org/https://doi.org/10.1016/0378-1127(95)03572-R

Omotayo, A. O., & Aremu, A. O. (2020). Underutilized African indigenous fruit trees and food–nutrition security: Opportunities, challenges, and prospects. *Food and Energy Security*, *9*(3), e220.

Pandey, A., Tripathi, Y., & Kumar, A. (2016). Non timber forest products (NTFPs) for sustained livelihood: Challenges and strategies. *Research Journal of Forestry*, *10*(1), 1-7.

Raheem, D., Carrascosa, C., Oluwole, O. B., Nieuwland, M., Saraiva, A., Millán, R., & Raposo, A. (2019). Traditional consumption of and rearing edible insects in Africa, Asia and Europe.

Critical Reviews in Food Science and Nutrition, *59*(14), 2169-2188. https://doi.org/10.1080/10408398.2018.1440191

Rowland, D., Ickowitz, A. M. Y., Powell, B., Nasi, R., & Sunderland, T. (2017). Forest foods and healthy diets: quantifying the contributions. *Environmental Conservation*, *44*(2), 102-114. https://doi.org/10.1017/S0376892916000151

Sardeshpande, M., & Shackleton, C. (2019). Wild Edible Fruits: A Systematic Review of an Under-Researched Multifunctional NTFP (Non-Timber Forest Product). *Forests*, *10*(6), 467. https://www.mdpi.com/1999-4907/10/6/467

Selaledi, L., Hassan, Z., Manyelo, T. G., & Mabelebele, M. (2021). Insects' Production, Consumption, Policy, and Sustainability: What Have We Learned from the Indigenous Knowledge Systems? *Insects, 12*(5), 432.

Shackleton, C., Delang, C., Shackleton, S., & Shanley, P. (2011). Non-timber Forest Products: Concept and Definitions. Non-Timber For. Prod. Glob. *Context*, 3-21.

Shackleton, C., & Shackleton, S. (2004). The importance of non-timber forest products in rural livelihood security and as safety nets: a review of evidence from South Africa. *South African Journal of Science*, *100*(11), 658-664.

Siegel, K. R., Ali, M. K., Srinivasiah, A., Nugent, R. A., & Narayan, K. V. (2014). Do we produce enough fruits and vegetables to meet global health need? *PLoS One*, *9*(8), e104059.

Smith, I. F. (2013). Sustained and integrated promotion of local, traditional food systems for nutrition security. *Diversifying Food and Diets: Using Agricultural Biodiversity to Improve Nutrition and Health Issues in Agricultural Biodiversity*, 122-139.

Smith, M. R., Stull, V. J., Patz, J. A., & Myers, S. S. (2021). Nutritional and environmental benefits of increasing insect consumption in Africa and Asia. *Environmental Research Letters*, *16*(6), 065001. https://doi.org/10.1088/1748-9326/abf06c

Talukdar, N. R., Choudhury, P., Barbhuiya, R. A., & Singh, B. (2021). Importance of Non-Timber Forest Products (NTFPs) in rural livelihood: A study in Patharia Hills Reserve Forest, northeast India. *Trees, Forests and People, 3*, 100042. doi: https://doi.org/10.1016/j.tfp.2020.100042

Tang, C., Yang, D., Liao, H., Sun, H., Liu, C., Wei, L., & Li, F. (2019). Edible insects as a food source: a review. *Food Production, Processing and Nutrition, 1*(1), 8. doi: 10.1186/s43014-019-0008-1

Twine, W. C., Moshe, D., Netshiluvhi, T. R., & 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*, 467-473.

UNICEF. (2018). El estado de la seguridad alimentaria y la nutrición en el mundo: fomentando la resiliencia climática en aras de la seguridad alimentaria y la nutrición.

van Huis, A. (2003). Insects as Food in sub-Saharan Africa. *Insect Science and Its Application, 23*(3), 163-185. doi: 10.1017/S1742758400023572