**Crop diversity and susceptibility of crop fields to elephant raids in eastern Okavango Panhandle, northern Botswana**

**Abstract**

1. Elephants frequently raid farmers’ crops within their ranges in Africa and Asia. This can have a large impact on agricultural productivity and food security for farmers.
2. Previous studies have examined susceptibility of crop fields to elephant raids using field characteristics such as field size and proximity to water sources. However, there are limited studies investigating how different crop types, individually and in their combinations influence crop susceptibility to elephant raiding. Also, spatio-temporal patterns in elephant crop raids in agro-ecological landscapes have not been extensively examined.
3. This study utilised data collected from crop fields raided by elephants between 2008 and 2018. Data on crops grown, number of crop-raiding incidences for each crop, and elephant raiding incidences were recorded for each field assessed. Incidence risks (IR) and field risk value (RV) were computed using an adaptive epidemiological approach.
4. The results showed that elephant crop raiding incidents varied significantly amongst crop types, and over space and time (P<0.0001). Cereal crops (millet: *Eleusine conaracana,* maize: *Zea mays*) incurred a higher number of crop raiding incidents compared with leguminous crops (cowpea: *Vigna unguiculata*; groundnut: *Arachis hypogea)*. Field RVs significantly varied depending on which crop was present in the field. There was a significant negative correlation between the number of crop types and the susceptibility of the field to raiding (R2 = -0.680, P<0.0001).
5. Our results suggest that the susceptibility of the fields to elephant raids could be minimised by selecting crop types and combinations less susceptible to elephant damage, thus enhancing food security for local subsistence farmers.

**Keywords:** crop raiding, crop species, incidence risks, field risk value, food security, human-elephant conflict

**Introduction**

Human-elephant conflict (HEC) is a major concern in areas where elephant and human-inhabited ranges overlap. Competition for space and resources is the main underlying driver of HEC (Songhurst & Coulson, 2014), with an array of social, ecological, economic and political factors also contributing (Songhurst, 2017). The negative interactions arising from such conflicts include direct and indirect impacts, such as crop losses (Bond, 2015) and consequent potential income from the lost crop (Gontse et al., 2018). When the cost of coexisting with elephants far outweighs the benefits (Mayberry et al., 2017), the crop loss can lead to resentment towards elephant by local communities (Kansky & Knight, 2014).

Botswana has the largest population of elephants (*Loxodonta africana*) in the world, with current estimates between 130 and 150 thousand individuals (Chase et al., 2016; Thouless et al., 2016) ranging throughout protected and unprotected areas. In much of the elephant range outside of protected areas, people are living and farming, with the main livelihood being subsistence farming (Gontse et al., 2018). In the eastern Okavango Panhandle in Botswana, the location of this study, HEC incidents are frequent, with crop raiding being the most common form of HEC (Songhurst et al., 2016).

Many studies have identified and elaborated on factors influencing the susceptibility of crops and agricultural fields to crop raiding by wildlife (Naughton et al., 1998; Sitati et al*.,* 2005; Jackson et al*.,* 2008; Songhurst & Coulson, 2014). Different methods have been used to assess and characterise such susceptibility to elephant crop raiding. These methods included comparative assessments of raided and non-raided fields, determination of the influence of spatiotemporal characteristics, and the effect of field size, location and mitigation measures on field and crop susceptibility (Jackson et al, 2008; Sitati et al., 2005; Songhurst & Coulson, 2014). Large fields with fences were observed to be more susceptible to crop raiding, and consistent guarding, and use of fire and noise were found to be more effective than fences in protecting crops against elephant raids ( Sitati et al*.,* 2005). In the eastern Okavango Panhandle, the distance of a field to a main elephant movement path and the age of the field was the most robust significant factor influencing crop raiding (Songhurst & Coulson, 2014). In Hwange region in Zimbabwe the distance from the refuge or protected area was found to be a driver of crop raiding by elephant (Guerbois et al*.,* 2012). Fewer studies, however, have determined the influence of crop types and cropping strategies on patterns of elephant crop raiding. In Uganda and Kenya it was found that crop types can be good predictors of frequency of elephant raids on crop fields (Naughton et al., 1998, Sitati et al., 2005). In addition to crop types, the size of the farm and proximity to protected areas were also found to be good predictors of elephant crop raiding in Ghana (Monney et al., 2010). More recently, Monney et al. (2010) showed that season and crop characteristics influenced patterns of elephant crop raids.

Priston and Underdown (2009) and Nijman and Nekaris (2010) tried a predictive model based on individual crops and the impact of those crops when planted together in a farm. These two pieces of research were initially formulated and based on an epidemiological approach, which is often used to predict the pattern and probabilities of disease outbreaks. Priston and Underdown (2009) disputed the fact that crop raiding was species-dependent, and that it had differential rates of occurrences. Nijman and Nekaris (2010) improved on the accuracy of the Priston and Underdown (2009) method. This improvement presents an opportunity to use the method and investigate the susceptibility of crop fields to elephant raiding. The epidemiological approach method uses the data derived from the actual elephant raiding events to identify which crop is more vulnerable (incidence risk) and how a combination of crop types collectively influences the vulnerability of the whole field or farm (RV). The accuracy of the determination is improved by computing incidence risks (IRs) from a larger sample size or number of farms rather than relying on fewer sample sizes or secondary experience from the farmer (Regmi et al., 2013). Even though the epidemiological approach has been used largely on larger primates as crop-raiding wildlife the method has also proved to be very precise for other crop raiding animals (Nijman & Nekaris, 2010).

Currently, many farmers depend on active guarding of crops to deter elephants, using a variety of mitigation measures, but these can be labour intensive and resource consuming (Bond, 2015). Such mitigation measures include the use of bees (King et al*.,* 2016) and processed chilli (Osborn, 2002; Park & Osborn, 2006; Chang et al., 2016; Pozo et al., 2017). Elephants are also averse to mature chilli crop, which can add to the deterrent toolbox, and be planted as a buffer to other plants that it is intercropped with (Matsika et al., 2020). The role of different crop combinations and crop choice by the farmer in relation to reducing the susceptibility of a field to elephant raiding is currently poorly understood.

The aim of this study was to investigate (a) the susceptibility of individual crops to elephant crop raiding; (b) the influence of crop diversity on field’s susceptibility to elephant raiding; and (c) spatio-temporal patterns of elephant crop raiding in the eastern Okavango Panhandle. Through this investigation, we intended to answer the questions (i) how susceptible are individual crops to crop raiding? (ii) how crop diversification influences the vulnerability of a farmer’s field to crop raiding and (iii) how elephant crop raiding incidents are distributed over time and space in the eastern Okavango Panhandle? The study tested three null hypotheses: (1) the level of susceptibility of individual crops to elephant crop raiding does not differ significantly between the crop types; (2) crop diversity does not significantly influence the field susceptibility to elephant raiding.

**Materials and Methods**

*Study Area*

The study took place in the eastern Okavango Panhandle, in northern Botswana. It comprises three wildlife management areas (WMAs), namely NG11, NG12 and NG13, and covers an area of around 8500km2. There are 14 villages spread over a distance of 162 km from Mohembo-East in the far north of the Panhandle to Gudigwa in the south-east, including Mohembo -East, Xakao, Kauxwi, Kaputura, Sekondomboro, Ngarange, Tobera, Mogotho, Mokgacha, Seronga, Gunotsoga, Eretsha, Beetsha and Gudigwa. The villages and settlements form a linear pattern along the Okavango River and its tributaries (Fig. 1). The fenced international boundary borders these villages between Namibia and Botswana in the north, Northern Buffalo veterinary cordon fence in the east and the Okavango River in the west and south. These physical boundaries enclose the villages and restrict the movement and dispersal of elephants as they come and leave the Okavango River, which provides them with permanent surface water to drink. The Okavango Delta receives an annual rainfall of about 450mm. The cumulative mean minimum and maximum temperatures are 25oC and 35oC, respectively (Botswana Department of Meteorological Surveys, 2016).

The estimated population of elephants in the area is 18,000 (Songhurst, 2018), and the estimated population of people is 16,000 (CSO, 2011). The area comprises diverse ethnic groups, mainly Hambukushu, Wayei and Basarwa. These people primarily depend on subsistence agriculture and fishing for sustaining their livelihoods (Motsholapheko et al., 2012). The main livelihood in the area is subsistence agriculture. Farmers plant a variety of crops, mainly maize *(Zea mays*), sorghum (*Sorghum bicolor*), millet (*Eleusine conaracana*), watermelon (*Citrullus lanatus*), pumpkin (*Cucurbita spp*), groundnut (*Arachis hypogea L*) and cowpea (*Vigna unguiculata*), with maize, millet and sorghum being the primary crops planted (Marumo et al., 2014). The study area is a hotspot of human-elephant conflict because of the intense competition for space and food resources; these incidents include crop raiding by elephants, property damage and injury or death of people, and injury or death of elephants (Songhurst et al., 2016; Buchholtz et al., 2019).

*Data collection*

Data on elephant crop raiding was collected by A. Songhurst and the Ecoexist team between 2008 to 2018, following the IUCN data collection protocol (Hoare, 1999). According to Hoare (1999)’s ‘Method 2’, an actual assessment of crops raiding by elephants is measured and quantified by an enumerator instead of total reliance on a verbal report from the farmer. This method quantifies actual losses and reduces bias. Data on crops grown, number of crop-raiding incidents for each crop, and damage details were recorded for each field assessed. Crops were categorised in three groups for analysis, which were cereals (sorghum, maize, and millet), melons (watermelon, pumpkin) and legumes (groundnut and cowpea).

*Data analysis techniques*

Adaptive epidemiological models (Priston & Underdown, 2009; Nijman & Nekaris, 2010) were used to determine each crop’s susceptibility to elephant raiding and the susceptibility of the farmers’ fields to elephant raiding. These models are reliable in predicting the likelihood of crop raiding and vulnerability of fields to crop raiding dependent on different types of crops grown within the fields (Nijman & Nekaris, 2010). R version 3.5.1 + R studio statistical package (R Core Team, 2013) was used to map yearly raiding incidents for villages.

All data used were from the fields that were all raided. Crops were coded as planted and available (1) or not planted or absent (0). The incidence risk (IR) of crop raiding is defined as the ratio of new occurrences over time to the crops at risk over that period (Nijman & Nekaris, 2010). The IR was thus calculated using the following formula:



where

a = number of fields in which elephants damaged the crop

b = number of fields where the crop was present and available for potential crop raiding

The highest IR that a crop could have was 1, which indicates that a crop is highly susceptible to crop raiding, whereas the lowest IR was 0, indicating low susceptibility to crop raiding. Risk value (RV) for each field was then calculated by summing up of IRs for all the crops present in the field (Nijman & Nekaris, 2010). A higher RV indicated higher susceptibility of a field to elephant raiding. Pearson’s correlation was used to establish the strengths of association between independent variables (presence of a particular crop) and dependent variables (crop raiding) at P<0.05 (Hauke & Kossowski 2011).

*RV= Σ IR* (all crops present in the field)

The correlation coefficient was computed as:



where:

*d*=the difference between the two ranks of each observation

*n*=the number of observations (Hauke & Kossowski, 2011)

The outcome of correlation analysis ranges from -1 to +1. A coefficient closer to +1 means a stronger relationship and indicates the high influence of the number of crops on RV. On the other hand, a coefficient closer to -1 meant a weaker relationship (Hauke & Kossowski, 2011). The data on the incidence of elephant raiding were analysed using the Generalised Linear Models (GLM) procedure in SPSS (Version 23.0.0) to test for the following effects: crop; year and crop x year interactions. Differences in the incidence of raiding between crops (averaged across the year) and between years (averaged across crops) were significant if their respective 95% confidence intervals (CI) did not overlap. Mann-Whitney U test was used to compare risk of raiding (IR) for the crops.

**Results**

*Farmer cropping choice*

Cereals [millet (*Eleusine conaracana L. Gaertn)* (94.51%), maize (*Zea mays L.)* (81.29%), grain sorghum (*Sorghum bicolor L*.) (67.78%) and sweet sorghum (*Sorghum bicolor*) (53.08%) combined] were the crop types most preferred by elephant, followed by cucurbits [watermelon (*Citrullus lanatus sp)* (78.10%) and pumpkin (*Cucurbita spp*.) (53.16%) combined], and then legumes [groundnut (*Arachis hypogea* L*.*) (38.68%) and cowpea *Vigna unguiculata* (L.) Walp.) (63.85%) combined] (Fig. 2). There has been a dramatic decline in the number of farmers that planted different crop types between 2008 and 2018. The number of farmers who planted cereals also declined from over 1000 farmers in 2008 to less than 300 in 2018. The number of farmers that planted melons also declined from over 500 to less than 200 as well as for legumes, which declined from 400 to less than 100 farmers within the study period.

*Incidence of elephant raiding over time*

There was a significant difference in the number of crop raiding incidents between crop types (F = 9.16, *df* = 7, P < 0.0001) and year (F = 19.23, *df* = 9, P < 0.0001, Supporting Information). A significantly higher number of crop raiding incidents by elephants occurred on millet followed by maize, watermelon and sorghum when compared with cowpea and groundnut as indicated by non-overlapping confidence intervals (Fig. 3). The lower numbers of incidents were observed on groundnut and cowpea, respectively. The availability of a crop in the field or the frequency of cultivation did not correlate with the field's susceptibility to elephant raiding (r = 0.017, *n* = 792, P = 0.63; Supporting Information).

A higher number of incidences of crop-raiding by elephant occurred in 2008, and then in 2009 and 2010, and 2015 (Fig. 4). A significantly lower number of incidents occurred in 2013 and 2016.

Cereals (millet, maize, sorghum and sweet sorghum) were consistently the most raided crop types followed by melons (watermelon and pumpkin) then legumes (groundnut and cowpea) (Fig. 5). There was a consistent decline in the number of farmers whose crops were destroyed by elephants between 2008 and 2018, indicating also a decline in the number of crop-raiding incidents. The number of farmers whose cereal crops were destroyed decreased from 700 to 200; for melons the numbers decreased from 300 to 100, and legumes the numbers decreased 200 to less than 10 between 200 and 2018.

*Assessing susceptibility of crops to elephant raiding*

The Incident Risk (IR) was calculated for the eight crop types or species (Table 1)**.** Millet was the most susceptible crop to elephant raiding because of higher IR, and was followed by maize, sorghum, watermelon, sweet sorghum, and pumpkin, respectively. Cowpea and groundnut were the least susceptible crops to elephant raiding. The risk of raiding for a crop significantly and positively correlated with the actual raid incidents for that particular crop (r = 0.39, *n* = 792, P < 0.0001; Supporting Information). As above, the availability of a crop in the field did not influence the field's susceptibility to elephant raiding.

The above scores for risk of raiding for crops were compared against millet, which is the most susceptible using Mann Whitney U test (Table 2). There was a significant difference in the risk of raiding for all crops in relation to millet.

There was a significant decrease in the number of crop raiding incidents from 2008 to 2013, with the number of raids dropping from157.75 in 2008 to 6.87 in 2013, a slight increase between 2015 and 2018, and a decline between 2008 and 2018 (Supporting information).

Field RV’s significantly varied depending on which crop was present on the farm (F = 16.8, *df* = 84, P < 0.0001) (Table 3). Pearson correlation showed that an increase in the number of crop types grown in a field significantly reduced the vulnerability of that particular field from elephant raiding (r = -0.680, *df* =1346, P = 0.00) (Supporting Information). The location (villages) also influenced elephant raiding (F = 5.58, *df* = 12, P < 0.0001), with fields in Xakao, Beetsha, Mogotho, Ngarange and Seronga having a higher risk of being raided (mean RV ≥ 3.50) compared with those in Eretsha, Tobera, Kauxwi and Mohembo (mean RV = ≤2.96) (Table 3). There were significant differences in crop types damaged between villages (Supporting Information).

**Discussion**

Human-elephant conflict is complex and there are many factors which influence crop raiding patterns by elephants (Hoare, 2012; Songhurst, 2017). Our study shows that crop type and crop diversity within a field are key factors for farmers to consider when making an effort to reduce the risk of elephant crop raiding. Cereal crops (millet, maize, sorghum) posed a higher risk of crop raiding than leguminous plants (cowpea, and groundnut). Likewise, our results showed a significant negative correlation between the number of crop types planted and the raiding vulnerability (RV) for the farm. The more crop types the field had, the lower the RV. Due to this variation in crop raiding risk, putting a high-risk crop into the farm increased the potential of the farm getting raided and more risks of crop loss. This association presents an opportunity for farmers to diversify their cropping strategy by planting lower risk crops and a wider variety of crops to assist in reducing the vulnerability to raiding and ultimately increase crop yields and food security in a human-elephant landscape.

Many of the farmers in the study area rarely grow a single crop, and there is always a likelihood that less susceptible crops are included in the field. This may explain the low RV found for all the fields. Although the increased diversity in the form of species richness is important in reducing RV, the characteristics of a crop species are more critical. For instance, in this study a field with four crops (maize, millet, sorghum and watermelon) had an RV of 2.73 and another field with four different crop groups (groundnut, cowpea, pumpkin and sweet sorghum) had an RV of 1.80. These two crop diversities were significantly different in their susceptibility to elephant crop raiding despite both combinations having four crop types. The latter diversity had a lower chance of being raided, possibly because of the presence of groundnut and cowpea. When making crop combinations for planting it is advised to include crops with a lower IR to reduce the fields' risk value to elephant crop raiding (Nijman & Nekaris, 2010). The above findings further indicate that a functional group of a food crop is also a critical factor to consider when trying to reduce incidents of crop raiding by elephants. In this study, we found that elephants were averse to certain crops, and the aversion increased when more crops with repulsive characteristics from other functional groups were added to the mixture of crops in the field. As a result, a combination of the crops from different functional groups showed varying susceptibility to elephant crop raiding.

Determining crop susceptibility to elephant crop raiding adds another promising dimension to mitigation efforts against human-elephant conflict. These crop diversification measures would need to compliment other mitigation measures such as fences, flashlights, drums, chilli, in order to reinforce the guarding (Sitati et al., 2005). Farmers invest more resources such as time and mechanical equipment to guard against elephant crop raiding (Bond, 2015) and the supply of modern mitigation tools is often a limiting factor to subsistence farmers in the eastern Okavango Panhandle (Noga et al., 2015). However, the use of crops with low susceptibility to elephant damage together with other non-invasive and locally available mitigation measures can be a sustainable solution to the high human-elephant conflict in the eastern Okavango Panhandle and other regions with similar issues.

A significant decrease in the number of elephant crop raiding incidents in the eastern Okavango Panhandle was observed over the past decade. Certain crops, individually or in combination, deterred crop raiding, and susceptibility of crops to raiding varied between crop types and functional groups. The findings support Hoare (2012) and Nyirenda et al. (2018) 's observations that some crop types are more susceptible to elephant damage than others. Most of the crops, which elephants raided in this study, are also preferred human food crops (Marumo et al., 2014), which farmers depend on for food and financial income. In earlier studies in the eastern Okavango Panhandle, elephants were found to strongly favour millet which is a principal food in the area (Songhurst, 2017). Our findings similarly demonstrated the preference and risk brought about by growing millet. In Ghana, elephants were observed to raid cereal crops such as maize and sorghum more frequently than other crops (Monney et al., 2010). Similar findings were reported elsewhere (Barua et al., 2013; Das et al., 2014; Goswami et al., 2015). Preference by elephants for cereal crops that farmers are dependent on for food and economic progress presents a difficult situation for reducing human-elephant conflict in Africa. Competition for food aggravates the conflict and leads to a reduced food supply from the farms (Sitati et al., 2005), loss of surplus harvest and potential income (Gontse et al., 2018).

The melon category comprising pumpkin and watermelons was the second most preferred and raided group. The high-water content of the melon crops renders them an excellent alternative source of water, especially during the dry season (Warner, 2008). On the contrary, legumes consisting of groundnut and cowpea were the least preferred and the least susceptible to elephant raiding. These findings are consistent with Mingyong (2008), who found that beans were more resilient to elephant crop raiding than maize. Similarly, elephants in Cambodia were not interested in groundnut (Webber et al., 2011). As already discussed in previous studies, the differential preference of a particular crop over the other by elephants possibly emanates from the ease of access to the crop, caloric or nutritional content and palatability (Monney et al., 2010; Songhurst et al., 2015; Vogel et al., 2020). The decline in elephant raiding incidents observed in this study between 2008 and 2013 coincided with the period when many farmers had planted cowpea (Statistics Botswana, 2019), which is a crop that elephants are averse to. During this period, there was an increase from 939 to 2021 individual farmers who planted cowpea instead of cereal crops (Statistics Botswana, 2019). Similarly, in 2015, fewer farmers (172) planted cowpea than the 2021 farmers in 2013 (Statistics Botswana, 2019), potentially resulting in an increase in crop raiding incidents. Adopting less vulnerable crops to elephant raiding, such as groundnut and cowpea, can be an effective and sustainable strategy in mitigating human-elephant conflict in agro-ecological systems.

However, farmers still prefer some crops despite these crops being also preferred by elephants. The melons are second in terms of preference by farmers and elephants. The preference of these crops by farmers increases opportunity costs for farmers since the government of the Republic of Botswana does not compensate for melons when damaged by wildlife, including elephants (Department of Wildlife and National Parks, 2013). For the crops assessed in this study, the Botswana government only compensates for wildlife damages on maize, sorghum, millet, cowpea, and groundnut (Department of Wildlife and National Parks, 2013). Farmers, therefore, see the exclusion of some crops from the compensation scheme as unjustifiable. Moreover, it often leads many farmers failing to report crop-raiding incidents and crop losses as reporting does not make any financial difference to them (DeMotts & Hoon, 2012). Issues underlying attachment to certain crops such as cultural attachment, popularity, economic reasons, ease of getting seeds (Guei et al., 2011) often make farmers to continue planting highly susceptible crops despite being aware of the unrecoverable losses in case of elephant raids.

Our results suggest that the susceptibility of the fields to elephant raids could be minimised by carefully selecting crop types and combinations not susceptible to elephant damage, and this will enhance food security for the local farmers. We recommend that human-elephant coexistence strategies have a strong focus on educating farmers to select and grow combinations of low risk crops. An effective crop diversification strategy will include; different types of crops from different functional groups; less susceptible crops to elephant raiding such as legumes; and less palatable crops to elephants. Further research is needed to monitor the role of using combinations of food crops and diversifying crop types grown as a strategy to minimize the risk of crop-raiding by elephants.

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**Authors contribution:** TAM, ACS, GM, AS and JAA conceived the ideas (CI), designed methodology (DM), collected the data (CD), analysed and interpreted the data (AI), and led the writing of the manuscript (WM). GSM was involved in AI and MW; and AM was involved in AI. All authors contributed critically to the drafts and gave final approval for publication.

**Data availability:** Data are stored at Botswana University of Agriculture and Natural Resources, Gaborone, Botswana and Ecoexist Trust offices in Maun.

**Supporting Information**

Supplementary tables on the analysis of variance for crop raiding incidents over years (Appendix S1); influence of crop diversity on fields’ vulnerability to crop raiding (Appendix S2); correlation procedure between crop available, crop damaged, and IR (Appendix S3); the Generalised Linear Model (GLM) procedure, dependent variable: crop damaged (Appendix S4); and the GLM procedure, t Test (LSD) for crop damaged in different villages (Appendix S5) are available online in the Supporting Information section at the end of the online article. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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**Table 1.** Susceptibility of individual crops to elephant raiding measured by incidence risk (IR) between 2008 and 2018 (*n*=1347).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Crop | Number of farms with crop available (b) | Percentage of farms with crop | Number of farms where crop was raided (a) | Risk of raiding for crop (*IR*) |
| Millet | 1273 | 94.51 | 1015 | 0.80 |
| Maize | 1095 | 81.29 | 757 | 0.69 |
| Sorghum | 913 | 67.78 | 562 | 0.62 |
| Watermelon | 1052 | 78.10 | 649 | 0.62 |
| Pumpkin | 716 | 53.16 | 362 | 0.51 |
| Sweet sorghum | 715 | 53.08 | 431 | 0.60 |
| Cowpeas | 860 | 63.85 | 311 | 0.36 |
| Groundnut | 521 | 38.68 | 174 | 0.33 |

**Table 2.** Man-Whitney U test comparison on risk of raiding for millet against other crops.

|  |  |
| --- | --- |
|  |  |
| IR Comparisons | P-value |
| Maize vs. millet | 0.036 |
| Groundnuts vs. millet | <0.0001 |
| Watermelon vs. millet | 0.001 |
| Cowpea vs. millet | <0.0001 |
| Pumpkin vs. millet | <0.0001 |
| Sweet sorghum vs. millet | <0.0001 |
| Sorghum vs. millet | <0.0001 |

Crop comparisons computed at medians of Maize = 0.5, Groundnut = 0.05, Watermelon = 0.4, Cowpea = 0.11, Pumpkin = 0.03, Sweet sorghum = 0.16, Sorghum = 0.35, Millet = 0.66 and P = 0.05.

**Table 3.** Mean RVs of fields in villages in the eastern Okavango Panhandle during the period of 2008-2018.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Villages | Number of fields (*n*) | Crops planted in fields | Mean risk of raiding for fields (*RV*) | Std error |
| Beetsha | 155 | Mi (151), Ma (131), So (112), Wa (115), Gr (60), Pu (99), Sw (99), Co (96) | 3.65 | 0.08 |
| Eretsha | 117 | Mi (117), Ma (93), So (64), Wa (75), Gr (26), Pu (39), Sw (38), Co (43) | 2.96 | 0.09 |
| Gudigwa | 52 | Mi (52), Ma (49), So (39), Wa (43), Gr (18), Pu (32), Sw (18), Co (28) | 3.43 | 0.10 |
| Gunotsoga | 134 | Mi (131), Ma (113), So (84), Wa (100), Gr (47), Pu (69), Sw (62), Co (61) | 3.34 | 0.07 |
| Kauxwi | 81 | Mi (77), Ma (40), So (6), Wa (36), Gr (11), Pu (12), Sw (6), Co (25) | 2.22 | 0.08 |
| Mogotho | 118 | Mi (114), Ma (104), So (85), Wa (91), Gr (59), Pu (65), Sw (65), Co (68) | 3.62 | 0.07 |
| Mohembo | 101 | Mi (70), Ma (34), So (11), Wa (16), Gr (3), Pu (4), Sw (11), Co (12) | 2.03 | 0.08 |
| Mokgacha | 27 | Mi (27), Ma (23), So (22), Wa (17), Gr (7), Pu (5), Sw (14), Co (8) | 3.23 | 0.17 |
| Ngarange | 69 | Mi (65), Ma (65), So (61), Wa (58), Gr (29), Pu (44), Sw (40), Co (28) | 3.60 | 0.10 |
| Sekondomboro | 142 | Mi (139), Ma (132), So (75), Wa (118), Gr (43), Pu (47), Sw (102), Co (82) | 3.33 | 0.06 |
| Seronga | 156 | Mi (141), Ma (144), So (126), Wa (110), Gr (70), Pu (90), Sw (69), Co (77) | 3.50 | 0.06 |
| Tobera | 134 | Mi (130), Ma (109), So (61), Wa (43), Gr (14), Pu (28), Sw (17), Co (32) | 2.44 | 0.09 |
| Xakao | 61 | Mi (59), Ma (58), So (46), Wa (50), Gr (40), Pu (34), Sw (34), Co (44) | 3.69 | 0.12 |

Mi = millet, Ma = maize, So = sorghum, Wa = watermelon, Gr = groundnut, Pu = pumpkin, Sw = sweet sorghum, Co = Cowpea. The superscript numbers indicate the number of fields where the crop was available in the villages.

**FIGURE CAPTIONS**

1. Figure 1. The Eastern Okavango Panhandle, showing the 13 villages where field data was collected. (Source of basemaps: Esri, USGS, FAO; 2021).
2. Figure 2. Number of farmers who planted from different crop families between 2008 and 2018.
3. Figure 3. Mean of crop raiding incidences on different crops averaged across years of sampling (2008-2018).
4. Figure 4. Mean of elephant crop raiding incidences recorded on farmers’ fields between 2008 and 2018 in the eastern Okavango Panhandle.
5. Figure 5. Number of farmers whose crops were destroyed between 2008 and 2018