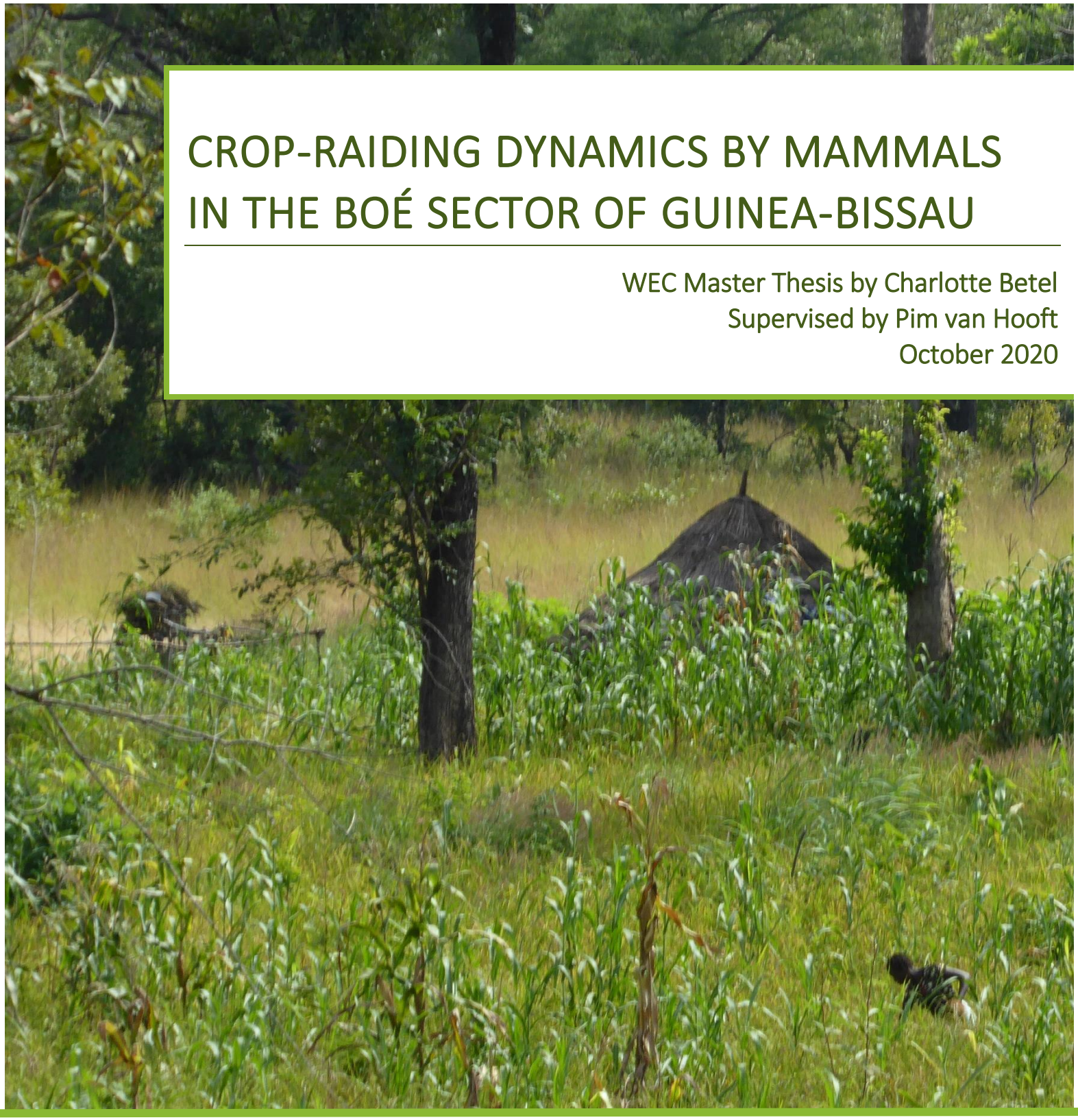
CROP-RAIDING DYNAMICS BY MAMMALS IN THE BOÉ SECTOR OF GUINEA-BISSAU

WEC Master Thesis by Charlotte Betel
Supervised by Pim van Hooft
October 2020



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Cover picture taken by author during fieldwork

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SUMMARY

Background
Research into crop-raiding by mammals in Guinea-Bissau is scarce. Crop-raiding is one of the major causes of human-wildlife conflicts. It can threaten the food security and economic situation of farmers and decrease tolerance for animals. Since Guinea-Bissau is home to the Western Chimpanzee and several other endangered animal species, it is of importance to understand crop-raiding and to adopt conservation strategies accordingly.

Aim
Assess which factors influence crop-raiding by mammals in the Boé Sector of Guinea-Bissau.

Organisms
Mammals

Methods
Fields (n = 60) were mapped with a GPS device. All fields contained either peanuts or rice, and most fields contained both. Other crops present in the field were also recorded. Crop-raiding damage was assessed by walking transects through the fields and recording all damage found, assessing per location which crop was damaged and which animal was responsible. Distances between fields and forest edge, savannah, and the nearest other field were analysed through ArcGIS. Finally, structured interviews were held with each farmer.

Principal findings
Primates were not the most frequent crop-raiding species but did relatively large amounts of damage per crop-raiding incident. Instead, the African striped ground squirrel was the most frequent crop-raiding mammal species. Of the studies crops, peanuts were damaged most and by the widest variety of mammal species. A negative association was found between field size and crop-raiding, where crop-raiding was more frequent in the smaller fields. No association was found between distance of field to the forest edge and crop-raiding. Percentage of area lost per field was low with an average loss of 2.75%.

Conclusion
The presence of crop-species can in some cases predict the occurrence of crop-raiding by mammals. Field size was shown to have significant effect on crop-raiding occurrence, but proximity to the forest did not. Crop-raiding by mammals in the Boé of Guinea-Bissau during the rainy season does not seem to cause major crop losses, but it is possible that crop damage is underestimated since only fields were only visited once.

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1. INTRODUCTION

Growing human populations and rapid conversion of natural habitats to human land use such as agriculture increasingly exposes wildlife populations to cultivated foods and causes wildlife to venture into anthropogenic habitats more frequently (Bessa, Sousa, & Hockings, 2015; Hockings & McLennan, 2012). As a result, mammals may start incorporating agricultural crops into their diet, a behaviour commonly called 'crop-raiding' (Sillero-Zubiri & Switzer, 2001). A large variety of species worldwide are known to raid agricultural crops including elephants (Ngene & Omondi, 2008; Pittiglio *et al*., 2014), wild boar (Linkie *et al.*, 2007; Schley & Roper, 2003), macaques (Yamada & Muroyama, 2010), bearded capuchin monkeys (Freitas et al., 2008), baboons (Hill, 2000; Y Warren, 2008), and chimpanzees (Bessa et al., 2015; Hockings & McLennan, 2012; Hockings & Sousa, 2012). Wildlife can severely damage crops and in extreme cases even destroy whole harvests. This has huge implications for the economic situation of farmers, especially in less developed areas (Sillero-Zubiri & Switzer, 2001). Furthermore, crop-raiding can generate negative perceptions of wildlife and decrease tolerability for species (Bessa et al., 2015) leading to human-wildlife conflicts. Because of this, it is important to study crop-raiding dynamics by endangered species and incorporate this in conservation strategies.

Both rodents and primates are often mentioned in regard to damaging crops. In rodents, the amount of crop-raiding is linked to the spatial and temporal fluctuation of population size (Massawe et al., 2011). An increase of rainfall is an important factor for the increase of rodent populations in tropical areas (Madsen & Shine, 1999; Massawe et al., 2011; Monadjem et al., 2011), as this boosts growth of vegetation cover and nutritious seeds (Massawe et al., 2011). Cropping cycles often coincide with these population peaks, which makes the crops prone to damage by rodents. In primates, crop-raiding behaviour is commonly associated with scarcity of natural forage, which happens periodically in many tropical habitats due to the environmental conditions in these areas (Lemessa, Hylander, & Hambäck, 2013; Yamada & Muroyama, 2010; Hockings, Anderson, & Matsuzawa, 2009; Naughton-Treves *et al.* , 1998). In these periods of scarcity, primates can occasionally use crops as fall-back foods to fill the gaps. However, as habitats become degenerated, the natural scarce periods can stretch for longer than normal. Strum (1994) found that reduced availability of natural forage was the most significant factor contributing to the development of crop raiding behaviour in olive baboons (*Papio anubis*). Siex and Struhsaker (1999) found a similar response to wild food scarcity in colobus monkeys (*Procolobus kirkii*). The coconut consumption of the monkeys was highest in areas with low alternative food availability. However, scarcity of resources is not the only reason for primates to raid crops. Naughton-Treves and colleagues (1998) found that raiding of maize by three primate species at Kibale National Park in Uganda was not influenced by the availability of forest food sources. Agricultural crops like maize tend to be easily digestible and highly palatable, often more so than non-cultivated food sources (Biru & Bekele, 2012; Gross et al., 2018; McLennan & Hockings, 2014; Yamada & Muroyama, 2010). Because of this, crop-raiding can become a year-round feeding strategy rather than filling up the gaps in times of scarcity (Riley, 2007).

There are several factors that influence the likelihood of crops being raided by wildlife. Firstly, the location of the field can have a significant effect on the occurrence and frequency of crop-raiding. Saj and colleagues (2001) found that distance from the field to the forest edge influenced the occurrence of crop-raiding by vervet monkeys (*Chlorocebus pygerythrus*) in Uganda. Crop-raiding by vervet monkeys occurred significantly more on fields located at 100 meters or less from the forest edge than on fields located farther from the forest edge. They further found that proximity to human settlement was negatively associated with the occurrence of crop-raiding. The size of the fields and the number of crops per field were also of importance. Little research so far has focussed on the relationship between field size and the occurrence of crop-raiding. A study by Naughton-Treves (1998) did find a positive correlation between the amount of

crop damage by elephants and field size. It is highly likely that other location factors such as distance to water and the size of the nearest forest are also important for the likelihood of the occurrence of crop-raiding. Furthermore, the species of crops grown on the fields can also influence the occurrence and amount of crop raiding. Some crops are more preferable than others. High carb crops like maize, sugar cane, fruits, and nuts are very attractive to most animal species (Fungo, 2011; Sillero-Zubiri & Switzer, 2001) and thus fields containing these crop types may get raided more frequently. Finally, the kinds of animals living near the fields are a factor too. Some animals are more likely to develop crop raiding than others. Primates are especially susceptible to developing crop-raiding as their diet is very similar to that of humans and because they are highly intelligent (Hill, 2017). Thus, proximity to primate habitats could increase the likelihood of raiding.

Crop-raiding dynamics have been studied worldwide in a multitude of ways, but data on crop-raiding in Guinea-Bissau is scarce. Guinea-Bissau is one of the few countries that still contains a healthy population of the Western chimpanzee (*Pan troglodytes verus*) (Hockings & Sousa, 2013; Kormos et al., 2003; Serra et al., 2007). The Western chimpanzee is listed as 'critically endangered' on the IUCN Red List (Humle et al., 2016). Because of this, it is important to study any threat to wildlife in these areas to understand how it could affect conservation of threatened species like the Western chimpanzee. Chimbo Foundation, an NGO focussed on the conservation of the Western chimpanzee in the Boé sector of Guinea-Bissau, has received reports from local farmers about animals damaging their crops. There are several mammal species that could be looked at as potential crop-raiders in Guinea-Bissau. It is home to several rodent species that are known to damage crops, such as the cane rat (*Thryonomys swinderianus*), African striped ground squirrel (*Xerus erythropus*), and crested porcupine (*Hystrix cristata*). Potential crop-raiding primate species include the green monkey (*Chlorocebus sabaeus*), the patas monkey (*Erythrocebus patas*), the Guinea baboon (*Papio papio*), and the Western chimpanzee (*Pan troglodytes verus*) (Gippoliti & Dell'Omo, 2003). Finally, both the common warthog (*Phacochoerus africanus*) and the red river hog (*Potamochoerus porcus*) are also known to damage crops. While elephants are a very common crop-raiding species in most of Africa (Ngene & Omondi, 2008; Pittiglio et al., 2014), the population in Guinea-Bissau is so small (Brugie et al., 2006; Leblan, 2014) that it is highly unlikely that they form a consistent problem here. The Boé sector is a historically underdeveloped area due to poor soil quality, but this area has started developing in the last couple of decades. As the human population in the area grows, more strain is being put on the natural environment as more forest is being cleared for agricultural fields. It is likely that crop-raiding will increase because of this, and therefore it is good to understand the dynamics of this human-animal interaction on a deeper level to prevent conflicts getting out of hand.

The aim of this thesis is to explore the dynamics of crop-raiding by mammals in the Boé sector of Guinee-Bissau, so that potential human-wildlife conflicts concerning crops can be better managed. To do this, several questions have to be answered:

1. What environmental factors influence the occurrence of crop-raiding by mammals in the Boé of Guinea-Bissau?
2. Which mammal species cause most crop damage and does this align with farmers' perspectives?

In addressing these questions, several hypotheses have been formulated.

1. Crop-raiding by primates is significantly more frequent than crop-raiding by other mammal species.
2. The presence of preferable crop species in a field positively correlates with a more frequent occurrence of crop-raiding.

3. Crop-raiding is positively correlated with field size, where occurrence of crop-raiding increases with an increase of field size.
4. Crop-raiding is positively correlated with proximity to the forest edge, where crop-raiding increases with increased proximity of a field to the edge of a forest.

2. METHODOLOGY

2.1 Study area: Guinea-Bissau, Boé sector

This study took place from September to the end of December 2018 (end of wet - beginning of dry season) in the Boé sector of Guinea-Bissau. With its area of 36.120 km^2, the Republic of Guinea-Bissau is one of the smallest countries in coastal West Africa at 10°55'–12°40'N and 13°38'–16°43'W (Kormos et al., 2003). It borders Senegal to the north and Guinea to the south and the east. The continental part of Guinea-Bissau can be divided into three areas: coastal lowland, the interior plain, and the south-eastern highlands (Hockings & Sousa, 2013). This study took place in the Boé sector which is located in the most south-eastern corner of the province Gabu and is roughly situated between 11°30'–12°05'N and 13°45'–14°30'W. It has a total area of 3289 km^2. The Boé sector, like the rest of Guinea-Bissau, has a tropical climate with two sharply defined seasons. The rainy season lasts from half May to October and the dry season from November to half May, with an annual rainfall between 1600 – 2100 mm. The average temperature is 28°C, with minimum daily values of 12°C in January and maximum daily values of 39°C in April. The habitat in the Boé sector is characterized as a forest-savannah mosaic, with most of the area covered by a laterite cap which makes large parts of the sector unsuitable for agriculture (Wit & Reintjes, 1989). The sector is the most scarcely populated area of the country, but the population of the whole of Guinea-Bissau, including the Boé sector, has more than doubled over the last 30 years (Departamento Central de Recenseamento, 1981; INEC, 2009). Because of this growth, increasing amounts of forest are being cleared for agricultural purposes since these forested areas have a higher fertility than the surrounding savannahs. Traditional 'slash and burn' agriculture, where bushes and trees are slashed and the cleared area is burned, is still predominant in the Boé sector. In the wet season, the most important crops being grown include peanuts, rice, millet, corn, and several types of vegetables. Cashew nuts and various fruits are grown in the dry season (Willemsen, 2013; Temudo, Figueira, & Abrantes, 2015).

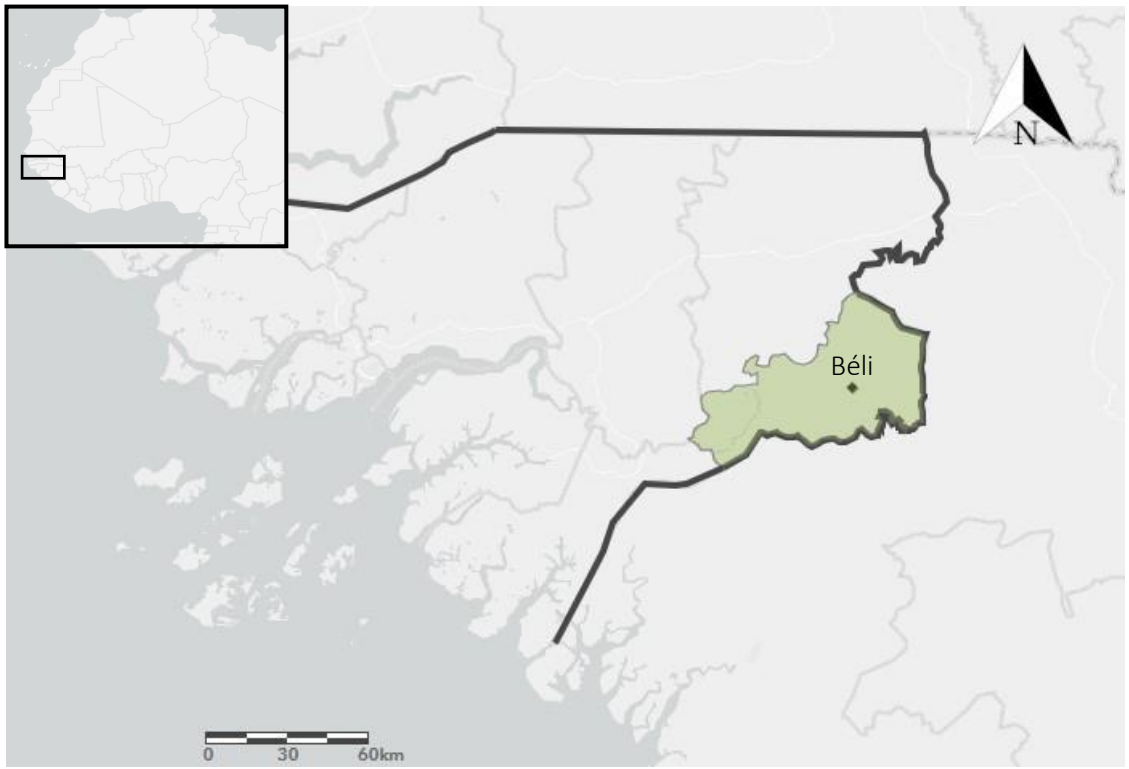

Figure 1. Map of Guinea-Bissau, with the Boé marked in green and the village of Béli marked with a dot.

2.2 Study species

2.2.1 Potential crop-raiding mammals in Guinea-Bissau

The Boé is home to many different animal species, of which several could act as potential crop-raiders. The first large group of animals that should be considered are the primates. The Boé sector has a variety of primate species, including the green monkey (*Chlorocebus sabaeus*), the patas monkey (*Erythrocebus patas*), the Guinea baboon (*Papio papio*), and the Western chimpanzee (*Pan troglodytes verus*) (Gippoliti & Dell'Omo, 2003). Each of these primate species has a different habitat and feeding strategy. The green monkey mainly resides in habitats that provide a dense tree cover such as closed woodland, forest and scrubs (Harrison, 1983b). Their diet consists mainly of fruits, but they also consume invertebrates, seeds, flowers, and other plant parts (Dunbar, 1974; Harrison, 1983a). Patas monkeys show a preference for woodland edges and open savannah woodlands (Henty & Mcgrew, 2014; Jong, Butynski, & Nekaris, 2008). Patas monkey diet mainly depends on buds and flowers of plants, and they also consume larvae and other insects (Henty & Mcgrew, 2014; Nakagawa, 1989). Patas monkeys are known crop-raiders in places with domesticated plant species, mostly consuming maize but will also eat sweet potato, cassava, and ground nuts (Jong et al., 2008). Guinea baboons have a widespread habitat range but spend the majority of their time in shrubby savanna (Swedell & Leigh, 2006). Guinea baboons are heavily hunted for bushmeat (Ferreira da Silva et al., 2014). The species is classified as 'near threatened' on the IUCN Red List and its overall habitat has contracted by 20-25% over the last 30 years (Oats et al., 2008). Baboons are omnivorous and eat a wide variety of plant materials and various classes of animals, however animal matter usually forms only a very small proportion of their overall diet (Johnson, Swedell, & Rothman, 2012; Sharman, 1982). Baboons are especially notorious for crop-raiding throughout the whole of Africa (Nigeria: Warren, 2008; Uganda: Hill, 2000; South Africa: Fehlmann, O'Riain, Kerr-Smith, & King, 2017; Zimbabwe: Schweitzer et al., 2017), so it is possible that they will also be one of the crop-raiding species in the Boé sector. Western chimpanzees prefer gallery forests and dry forests as their main habitat types (Kormos et al., 2003). Chimpanzees are omnivorous, but the majority of their diet consists of plant material (Bessa et al., 2015; Moscovice et al., 2007; Watts, Potts, Lwanga, & Mitani, 2012). Because fruit is typically their main diet component chimpanzees are labelled as ripe-fruit specialists (Moscovice et al., 2007; Watts et al., 2012). Chimpanzees raid crops in various places in Africa (McLennan & Hockings, 2014; Fungo, 2011; Hockings, Anderson, & Matsuzawa, 2009), and are also reported to raid crops in Guinea-Bissau, where they show a preference for corn and sugar cane according to interviews with farmers (Brugiere *et al.*, 2009; Kormos et al., 2003).

Apart from primates, rodents are a group notorious for damaging crops throughout the world. Rodents mainly damage cereal crops like wheat, maize, rice, sorghum, and millet, but also eat root crops like cassava, ground nut, and sweet potato (Prakash, 2018). Known crop-raiding rodents in Guinea-Bissau include the crested porcupine (*Hystrix cristata*), striped ground squirrel (*Xerus erythropus*) and the cane rat (*Thryonomys swinderianus*).

The final group to include are the hog species. The common warthog (*Phacochoerus africanus*) and red river hog (*Potamochoerus porcus*) are common in Guinea-Bissau (De Jong *et al.*, 2016; Reyna *et al.*, 2016). The common warthog is often identified as a notorious crop-raiding species throughout its range (Swanepoel, Leslie, & Hoffman, 2016; Tufa, Girma, & Mengesha, 2018; Warren, Buba, & Ross, 2007). The red river hog is also known to consume crops (Mccollum, Conway, Lee, & Carroll, 2016), but less is known about this species compared to the warthog with regard to crop-raiding behaviour.

2.2.2 Agriculture in Guinea-Bissau

Agriculture is the main driver of the economy in Guinea-Bissau (Temudo et al., 2015). Shifting cultivation, where a field is cultivated for several years and then abandoned until its fertility is naturally restored, is the most common agricultural strategy in Guinea-Bissau. This is done through slashing and burning, where the ashes of burned trees and shrubs increase the fertility of the soil. Fields are on average used for 3 years and then left for 6 years (Temudo & Abrantes, 2014). However, increasingly fields are not being abandoned but converted into cashew orchards (Temudo & Abrantes, 2014; Temudo et al., 2015), which does not allow the original vegetation to recover like it did before.

The most important crops in Guinea-Bissau at a national level are rice, peanuts, maize, and cashews (Havik *et al.,* 2018). Other important crops include sorghum, millet (Temudo et al., 2015), sweet potato, pumpkin, sugar cane, cassava, and yams (Havik *et al.,* 2018).

2.3 Data collection

Farmers were asked for their participation during a village meeting, after which 60 fields were selected based on their distance from Béli (bicycles were the only form of transportation available) and their proximity to forest (Figure 2). Each field was mapped by walking along the perimeter with a Garmin eTrex 10 handheld GPS device with the 'area calculator' application, which outputted the area in square meters. This was done separately for the rice plots and peanut plots at each field, since these were the main crop species and were most important for this study. This created the peanut field size (PFS) and the rice field size (RFS). All other crop species present in the field were also documented.

After determining area size, the fields were assessed for crop-raiding damage. This was done by walking in lines through the field with a 5-meter distance between each line. Deviations from these lines sometimes occurred because of obstructions or a change in the landscape. During this, all crop damage was recorded in square meters damaged by walking around the damaged area with the 'area calculator' application of the GPS device (Linkie et al., 2007). A trained guide then determined which animal species was responsible for the damage by looking at the type of damage, bite marks, droppings, and footprints in the vicinity of the damaged crops (Sukumar, 1990). To further determine which animals damaged the crops, five randomly selected fields were fitted with camera traps and placed in spots which the farmers pointed out to be frequently raided areas. The cameras were placed on trees or poles with a minimum diameter at breast height of 5 cm and the camera was places between 0.9 and 1.1m from the forest floor as measured from forest floor to the middle of the camera lens (Arandjelovic et al., 2014).

Structured interviews were held with the owners of the fields to gather data about the age of the field, sowing and harvesting times, perceptions of farmers about crop-raiding, and protection techniques for their field. In total 56 interviews were conducted. Some farmers owned multiple fields, hence the discrepancy between the total analysed fields and total interviews conducted. A complete list of questions can be found in Appendix I. Since hardly anyone in the region speaks English or Portuguese, an English-speaking local guide assisted with translating the interviews to the local language of Fula.

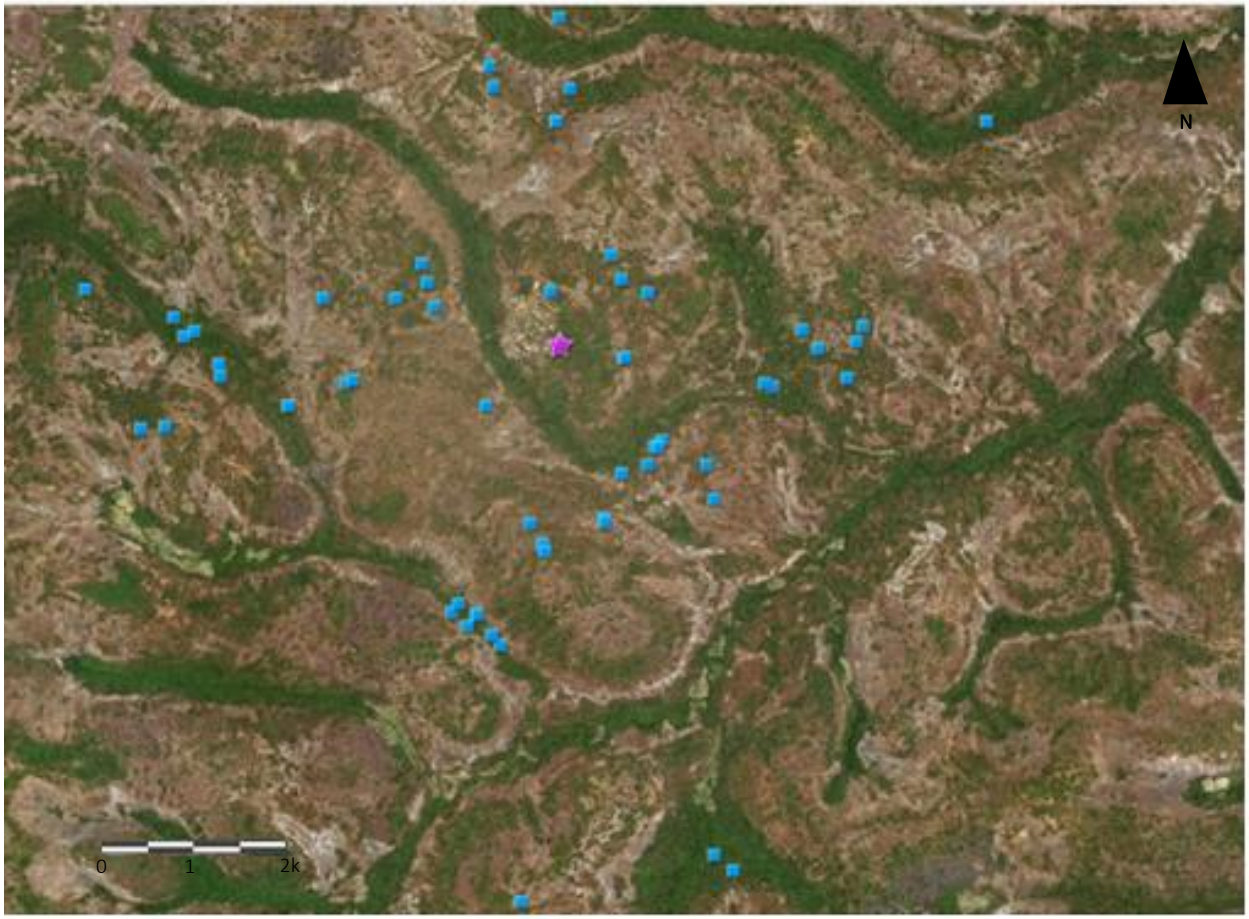

Figure 2. Locations of all (n = 60) mapped fields marked in blue squares, with Béli marked with a purple star.

2.4 Data analysis

Out of the 60 fields sampled, three fields had to be excluded from analysis due to human error in the recording of the crop-raiding data. Crop-raiding data was quantified with three different variables. The first was the observed amount of damage done to a specific crop species by a specific animal species in m2, the Damage Area (DA). This continuous data was then transformed to binary data in order to get the second variable, namely occurrence of damage in a field per animal species to a specific crop species (0 = no damage occurred, 1 = damage occurred), the Damage Occurrence per Animal per Crop (DOAC). Finally, occurrence was simplified to only note if damage occurred by an animal species in a field or not, thus ignoring which crop species were damaged, creating the Damage Occurrence Per Animal Total (DOAT). DOAT was only analysed for animal species with an occurrence of 10 individuals or higher to minimize statistical outliers. These species were the cane rat (n=35), patas monkey (n=28), ground squirrel (n=40), and bushbuck (n=11). All statistical testing was done in IBM SPSS Statistics for Windows (version 26).

Crop type

To test if DOAT was influenced by the presence of specific crop species in a field, a Chi-square test was performed. The effect of the presence of a crop species in a field on DA was assessed with a Mann-Whitney U test, where the dependent variable was DA and the independent grouping variable was the presence of a crop species in the field.

Field size

The total size of each field (TFS) was computed by adding up the PFS and RFS. A Mann-Whitney U test was used to analyse the effect of TFS, PFS, and RFS on DOAT and DOAC (i.e. on crop-raiding). The relationship between DOAC and field size was only explored for the patas monkey and cane rat, since they were the only two species that damaged several different crops.

Distance

Distances between the fields and nearest forest, nearest savannah, and nearest other field were computed with a geographic information system (GIS; ArcMap 10.8). EarthExplorer.gov.us was used to download the appropriate Landsat 8 imagery. An image from November 2018 was selected. The bands of the satellite image were set to the correct colour to get a realistic colour scheme of the landscape, where red corresponded with band 4, green with band 3, and blue with band 2. Data measured with GPS device was transformed to polygon shapefiles, so that the fields could be displayed over the satellite image. Both the shapefiles and the satellite data were projected in UTM. Maximum Likelihood Classification was then used to classify the forest and savannah areas. Finally, distances were calculated in meters by creating a 'near' table using Euclidean distance. This generated the nearest forest, nearest savannah, and nearest other field for each field.

The data was first explored in Canoco5 (version 5.12). A canonical correspondence analysis (CCA) was performed between the distance types and DOAT to get an idea of the relationship between the distance types and occurrence of crop-raiding. Next, a Mann-Whitney U test was performed to analyse the relationship between DOAT and each of the distance types. Furthermore, to further analyse this relationship a binary logistic regression was done (0 = no damage occurred, 1 = damage occurred).

3. RESULTS

3.1 Crop-raiding animal species and total damage

A total of eight mammal species was found to raid crops in the fields around Béli. Most frequently recorded were the striped ground squirrel, cane rat, and patas monkey (see Figure 3). However, the most frequent crop-raiders were not necessarily the most damaging species (see Figure 4). The red river hog damaged on average a large area per crop-raiding incident, but damage occurred in only two fields. On average, the African striped ground squirrel damaged only a small amount of area per crop-raiding incident. The percentage of the total area that was damaged reflects the average amount of damage per field (see Figure 5). The patas monkey and green monkey damaged a relatively large percentage of the total area they occurred in, but overall, the percentage of area damaged by the individual mammal species was quite low. The percentage of the total area damaged in the fields varied strongly (see Figure 6). Some fields were not damaged at all, whereas one particular field had a total of 15.4% of damaged area due to crop-raiding. However, fields were on average found to not be damaged a huge amount with a mean of 2.75% damage (SE = 0.38).

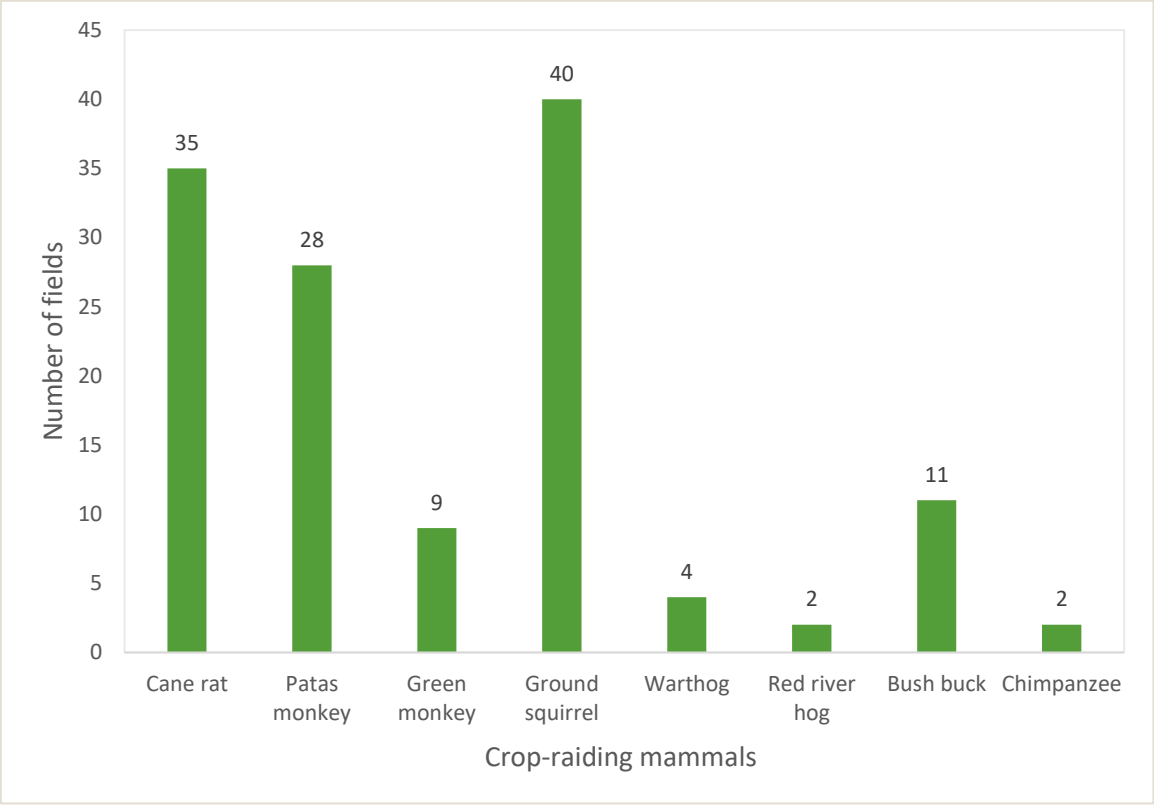

Figure 3. The number of fields damage occurred by each of these mammal species.

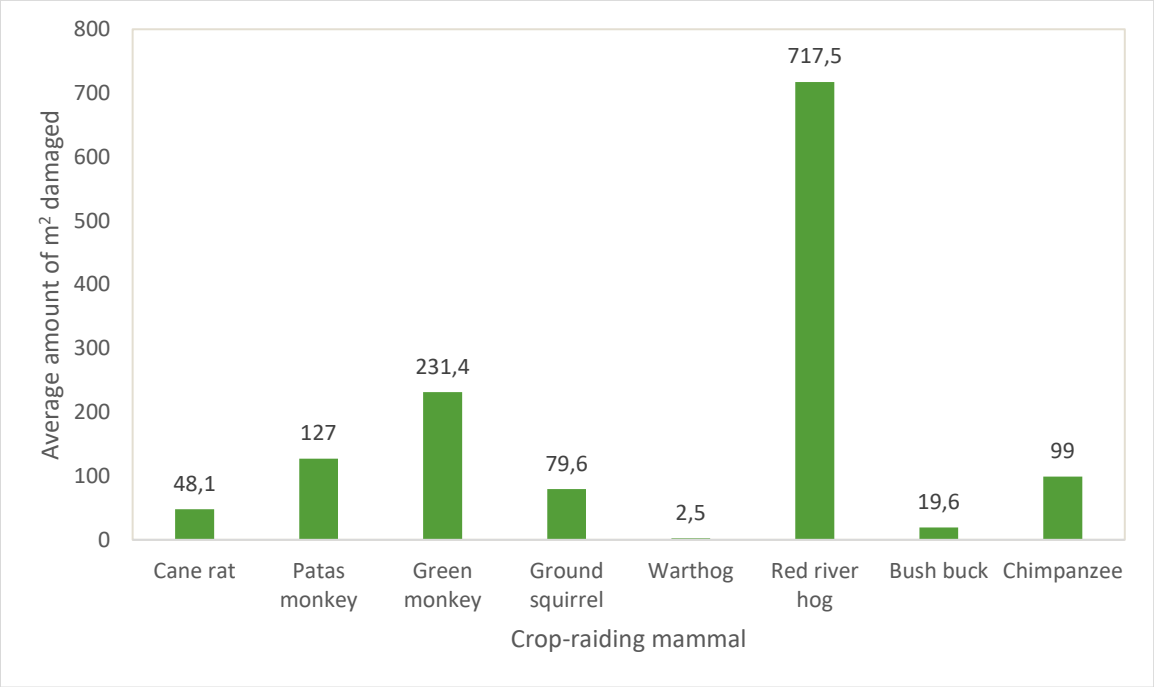

Figure 4. The average amount of area in m^2 damaged per animal species per crop-raiding incident.

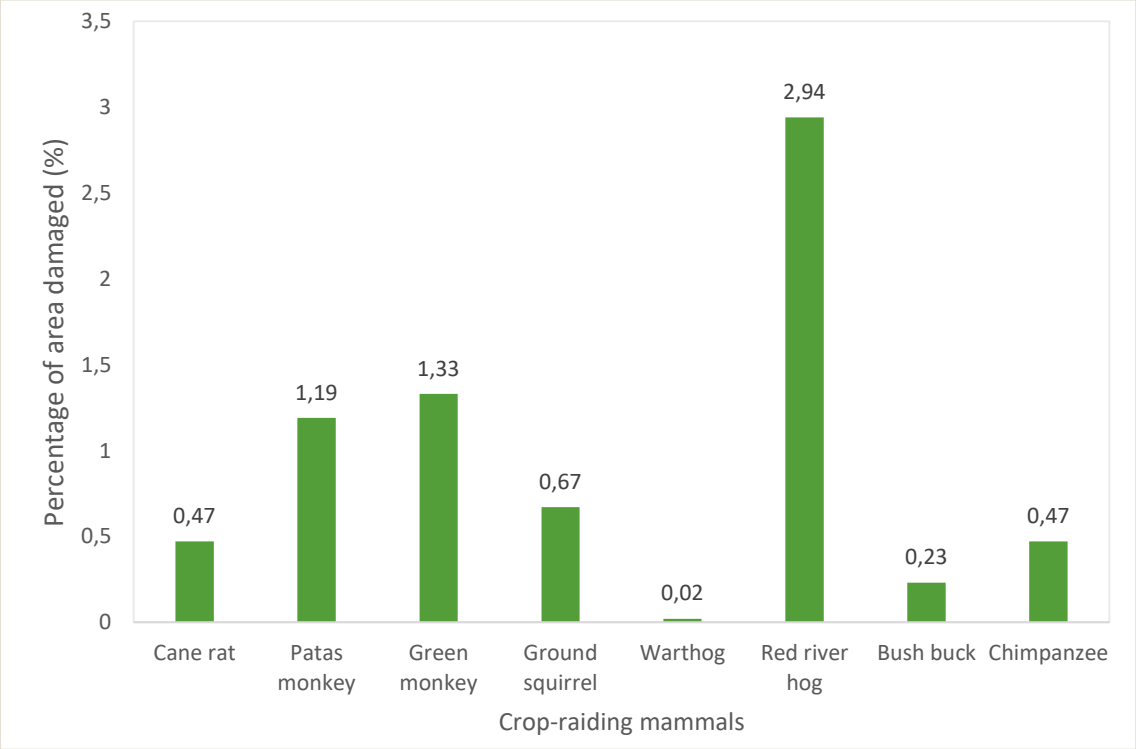

Figure 5. Percentage of area damaged out of the total area of the fields the mammals occurred in.

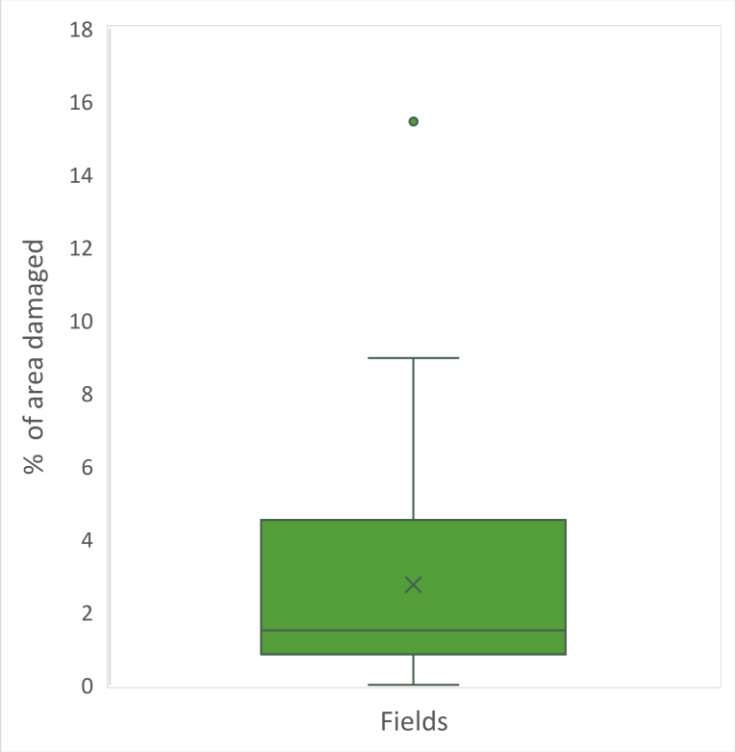

Figure 6. A boxplot of the total percentage of area damaged per field (mean=2.75, SE=0.38).

3.2 Crop species as predictor for crop-raiding

All of the 57 fields contained multiple crop species. Peanut (53 fields) and rice (52 fields) were by far the most commonly grown crops. Other crops included maize, millet, pumpkin, cassava, potato, and beans. Only one of the fields had a sugar cane patch. Crops where not damaged equally and not all by the same animal species (see Table 1). Rice and peanut where damaged most frequently, and peanut crops were damaged by the highest number of animal species. Amount of damage varies greatly between the different animal species.

Table 1. Number of fields a specific crop type was damaged by a species and the amount of damage done in m^2.

	Number of fields containing crop type damaged (total m^2 damaged)				
Animal species	**Rice**	**Peanut**	**Maize**	**Millet**	**Sugarcane**
Cane rat	35 (896.5)	11 (886)	1 (1)	13 (112)	0
Patas monkey	0	26 (3329)	5 (115)	1 (113)	0
Green monkey	2 (28.5)	3 (1364)	3 (102)	3 (588)	0
Ground squirrel	0	40 (3183)	0	0	0
Bush buck	0	11 (216)	0	0	0
Warthog	4 (10)	0	0	0	0
Red river hog	0	2 (1435)	0	0	0
Chimpanzee	0	0	0	1 (21)	2 (177)

Damage by cane (DAOT) rats occurred most frequently when rice was present in a field (X^2=8.719, N=57, p=0.003). Crop damage (DAOT) by striped ground squirrel, bush buck and red river hog happened only

when peanut plants were present in a field (X^2=4.195, N=47, p=0.041). Chimpanzee damage was only found in fields which contained sugar cane and were found to only damage sugarcane and millet crops. Damage by patas monkeys (DAOT) was predominantly found in fields which contained peanuts, but the presence of peanut plants was not found to be an accurate predictor for the occurrence of crop damage by patas monkeys (p=0.32). The occurrence of damage (DAOT) by the other animal species could also not be predicted based on the presence or absence of a specific crop species (p=0.15). Furthermore, the presence or absence of any specific crop type could not reliably predict the actual amount of damage done (DA) by any of the observed animal species (p=0.93).

3.3 Field size

Field size was split up into three categories: Total Field Size (TFS), Rice Field Size (RFS), and Peanut Field Size (PFS). Some fields did not contain any rice or peanut plots. The average size and range of size per field type can be found in Table 2, and the distribution of the different field sizes are shown in Figure 7.

Table 2. Average size and range of size per field size type

Type of field	Average size (m^2)	Range (m^2)
Total Field Size	14609.1	800 – 87507.1
Rice Field Size	9389.9	0 – 48531.0
Peanut Field Size	5219.1	0 – 53947.0

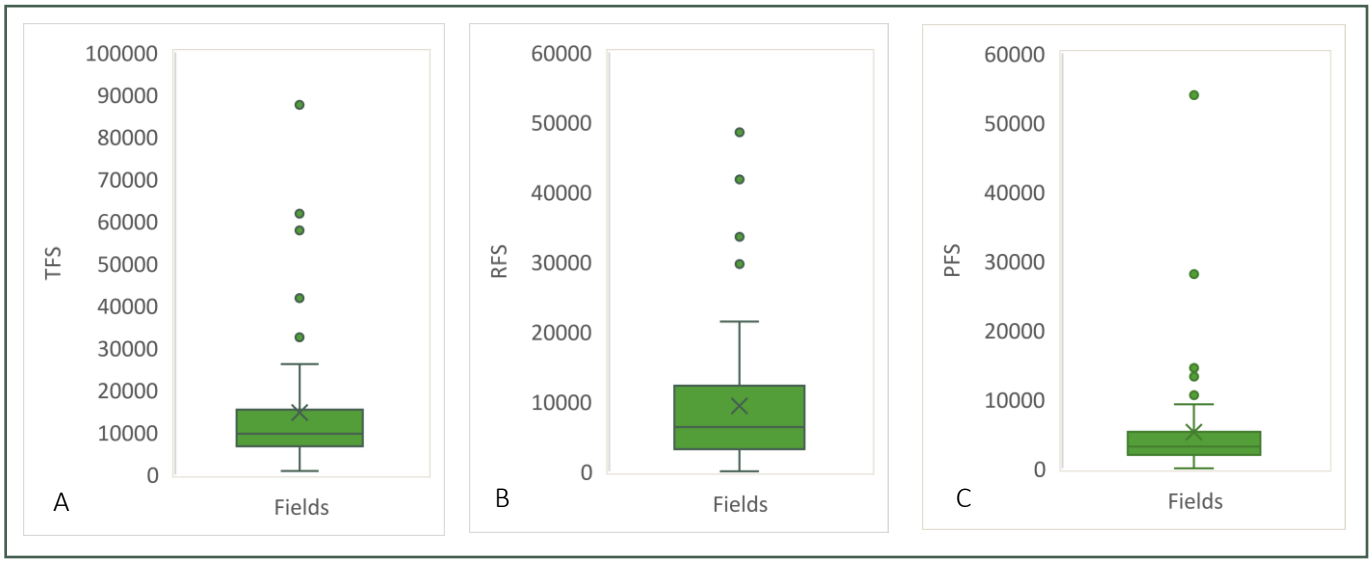

Figure 7. Boxplots showing the distribution of each of the different field size types, where A is the distribution of TFS (median=9626.6 m^2), B is the distribution of RFS (median=6333.7 m^2), and finally C is the distribution of PFS (median=3159.4 m^2).

A trend was found between TFS and DOAT by bush buck in a field (U=165, p=0.075), where damaged fields had a smaller TFS (Figure 8). There was no significant relationship between TFS and DOAT by cane rat (p=0.51), patas (p=0.12), and striped ground squirrel (p=0.121). RFS was smaller for fields with crop damage from patas monkeys (U=290.5, p=0.065) (Figure 9) and striped ground squirrels (U=221.5, p=0.039) than for fields without damage (Figure 10).

Out of the analysed mammal species, only the patas monkey and cane rat damaged multiple crop species, and therefore their DOAC was analysed. Fields with peanut damage by patas monkeys had a smaller TFS (U=296, p=0.086) and a smaller RFS (U=279.5, p=0.048) compared to fields without peanut damage by the

patas monkey (Figure 11). No relationship was found between peanut damage by patas monkeys and PFS (p=0.67). Furthermore, no relationship was found between TFS, PFS, or RFS and damage of maize (p=0.86) or millet (p=0.24) by the patas monkey. Fields with peanut damage by cane rats had a smaller TFS (U=97 p=0.003) and a smaller RFS (U=107 p=0.002) compared to fields without peanut damage by cane rats (Figure 12). Damage of rice and millet by cane rats was not found to be related to TFS, PFS, or RFS (p=0.95). Thus overall, peanut damage by both patas monkeys and cane rat occurred more frequently when the RFS and TFS were relatively small.

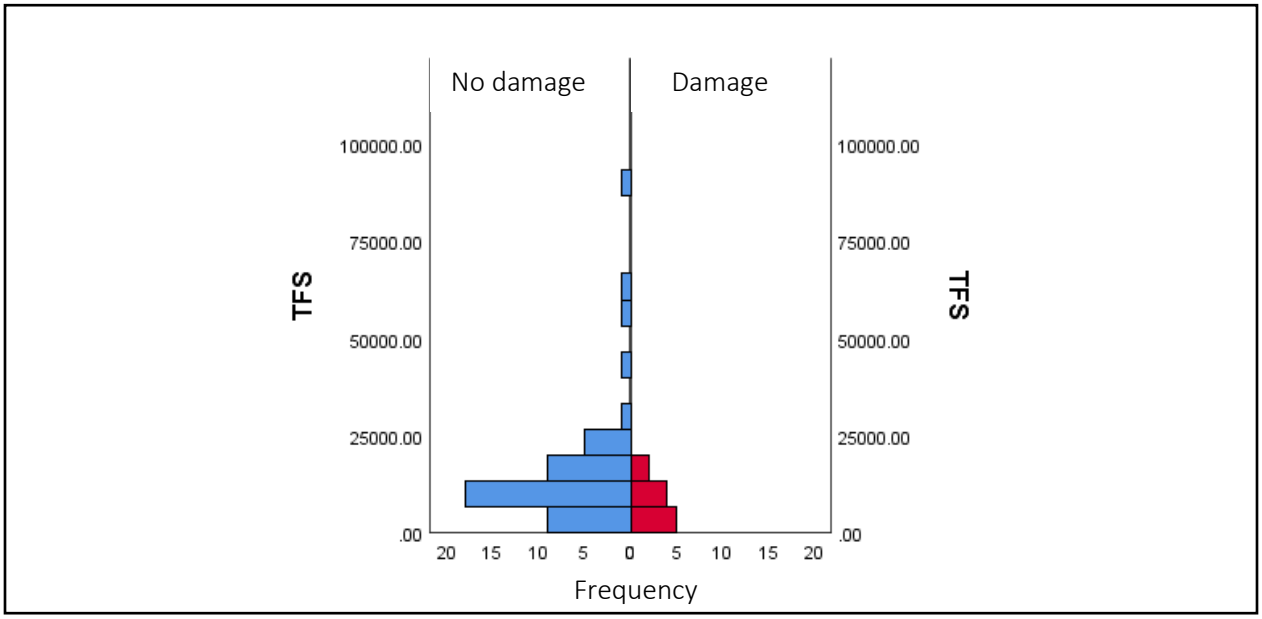

Figure 8. Frequency distribution of crop damage by bush bucks in relation to TFS, where TFS for fields with damage < TFS for fields with no damage (MWU test: p = 0.075)

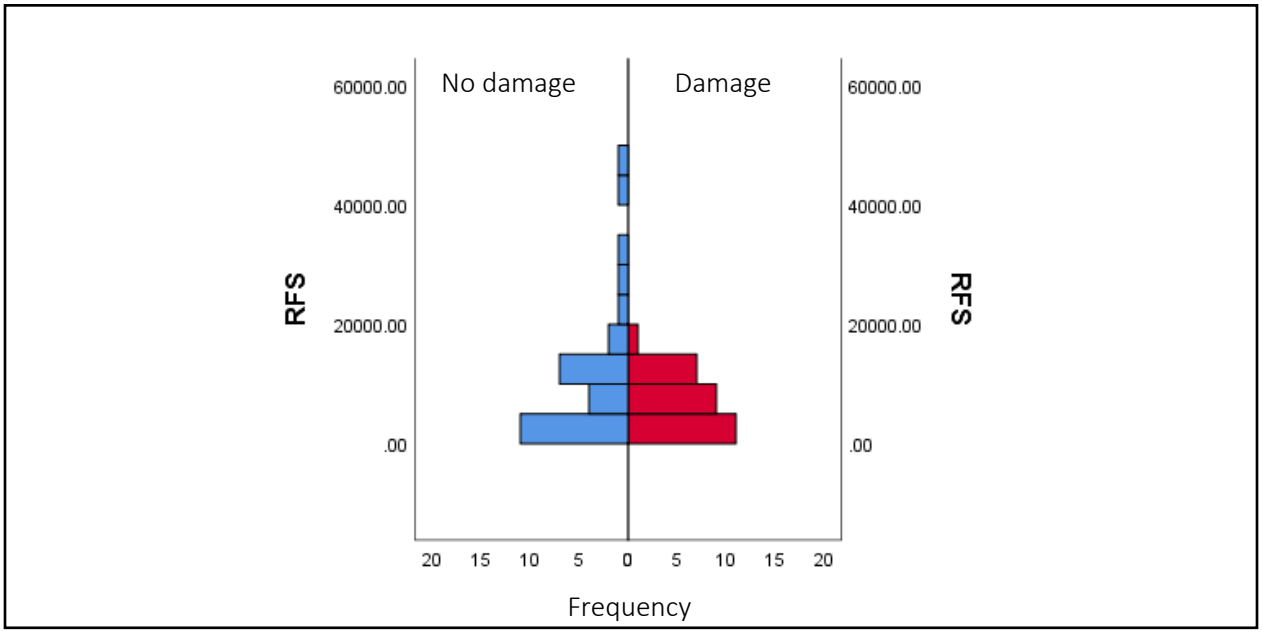

Figure 9. Frequency distribution of crop damage by patas monkeys in relation to RFS, where RFS for fields with damage < RFS for fields with no damage (MWU test: p = 0.065)

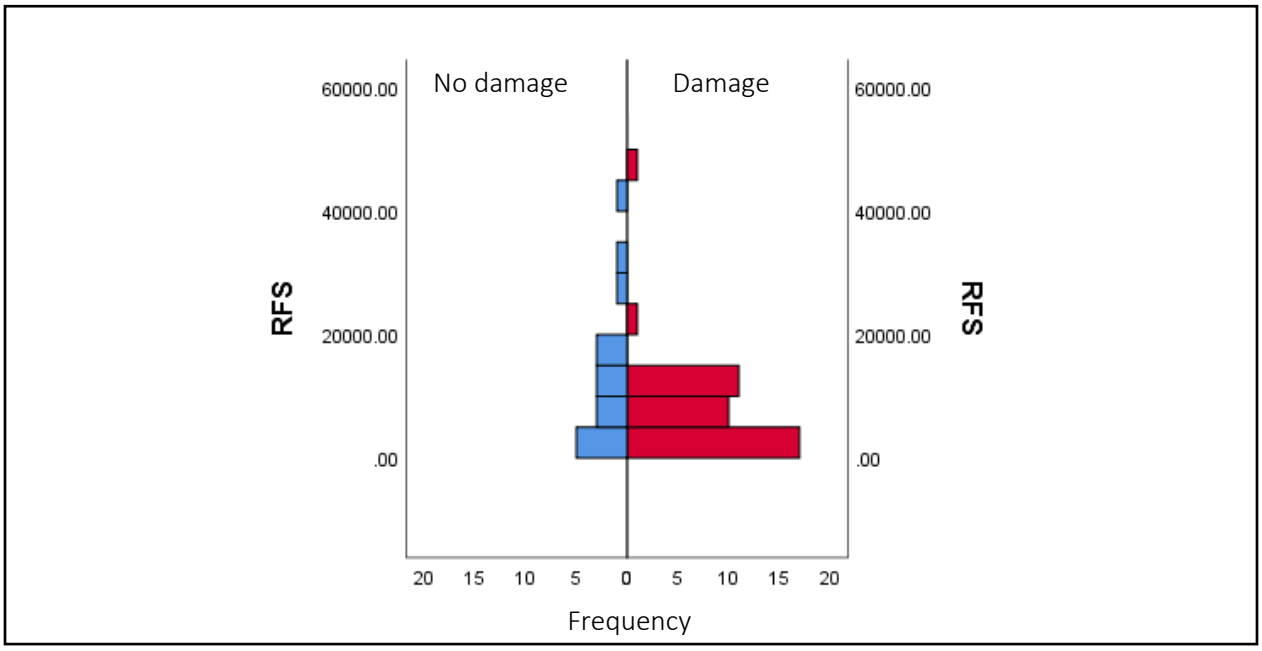

Figure 10. Frequency distribution of crop damage by striped ground squirrels in relation to RFS, where RFS for fields with damage < RFS for fields with no damage (MWU test: p = 0.039)

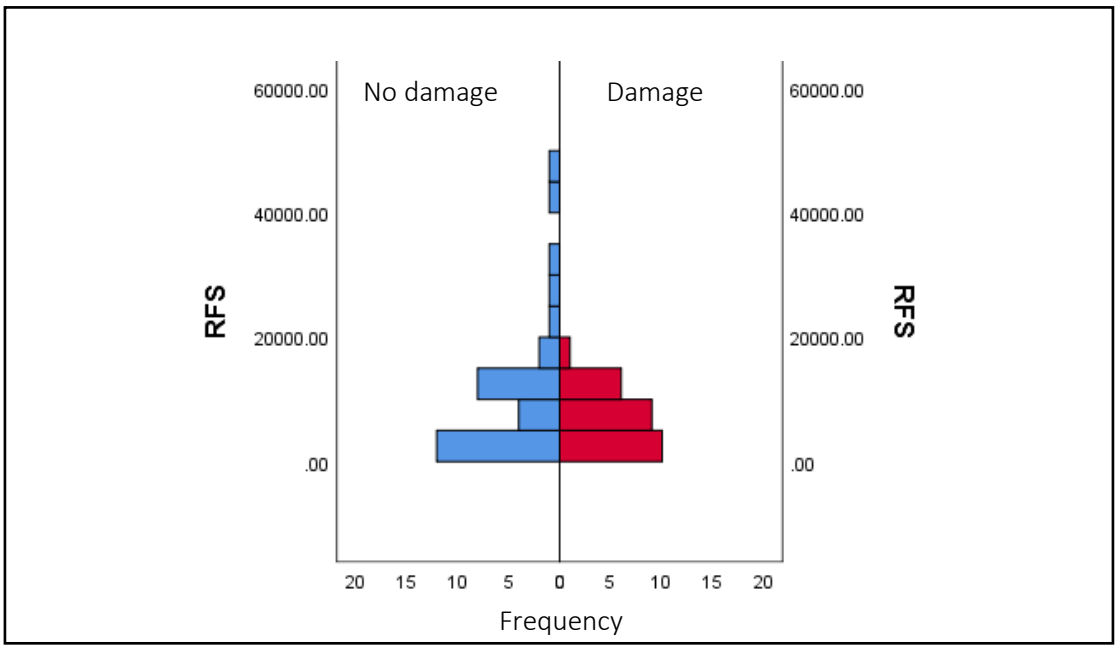

Figure 11A. Frequency distribution of damage to peanut plants by patas monkeys in relation to RFS, where RFS for fields with damage < RFS for fields with no damage (MWU test: p = 0.048)

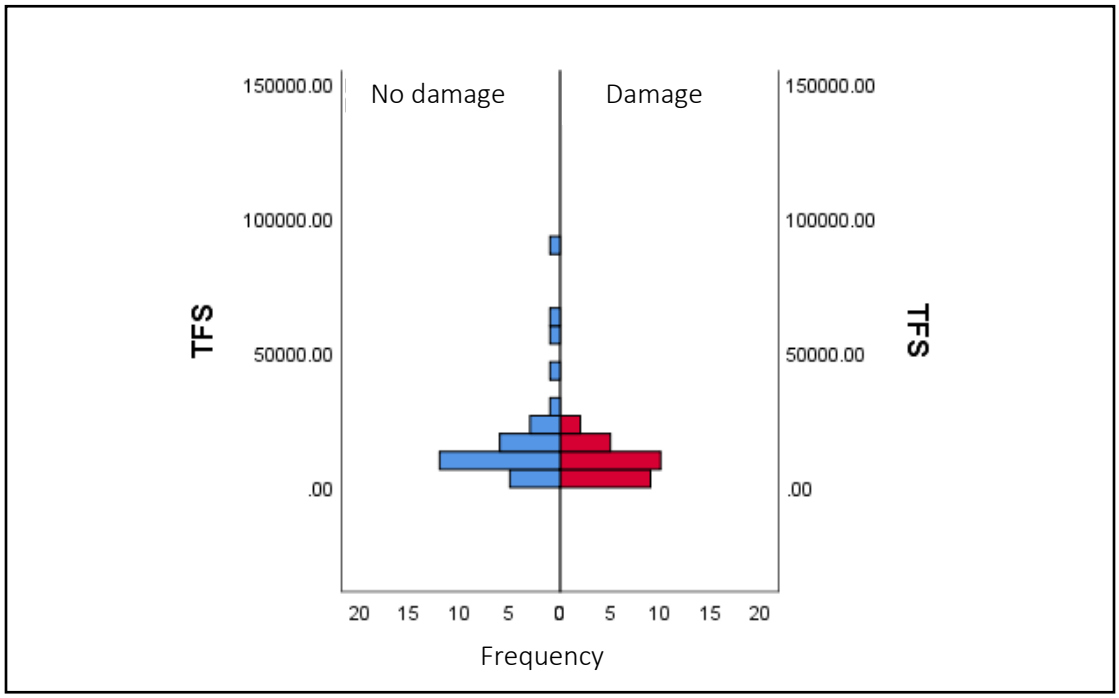

Figure 11B. Frequency distribution of damage to peanut plants by patas monkeys in relation to TFS, where TFS for fields with damage < TFS for fields with no damage (MWU test: p = 0.086)

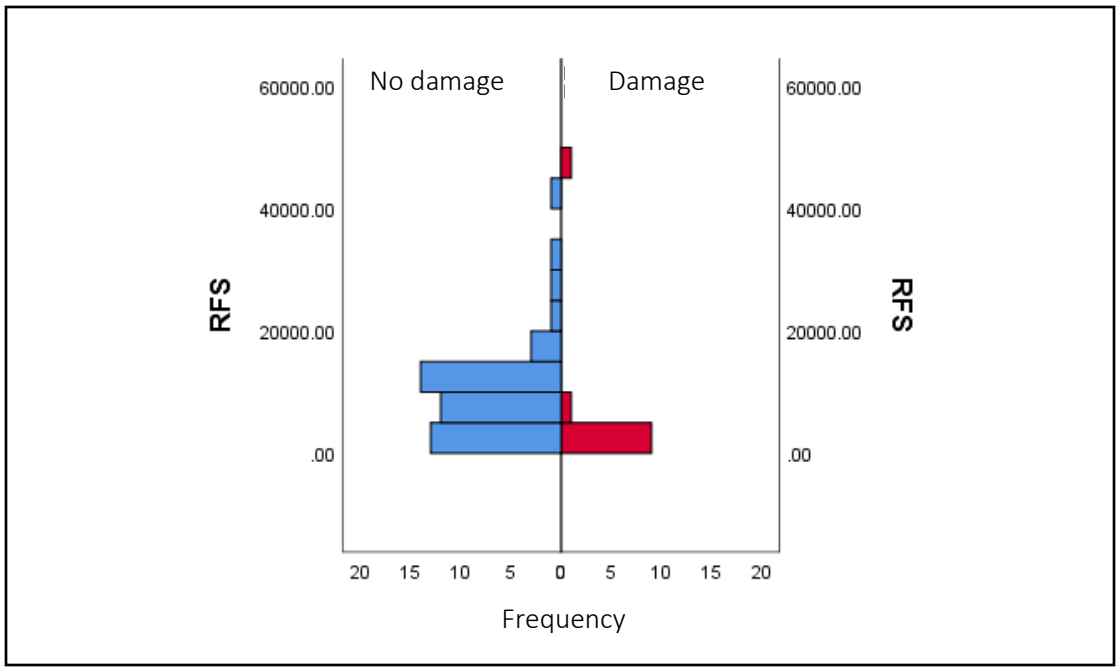

Figure 12A. Frequency distribution of damage to peanut plants by cane rats in relation to RFS, where RFS for fields with damage < RFS for fields with no damage (MWU test: p = 0.002)

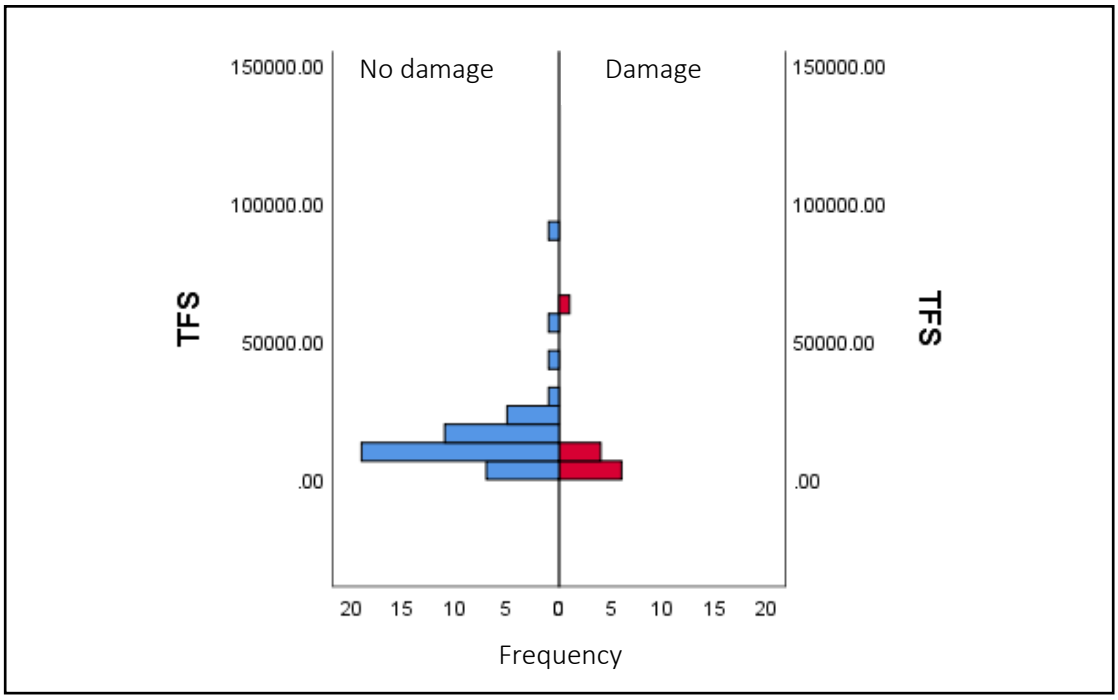

Figure 12B. Frequency distribution of damage to peanut plants by cane rats in relation to TFS, where TFS for fields with damage < TFS for fields with no damage (MWU test: p = 0.003)

3.4 Distance to forest, savannah, and other fields

The mean and range of each distance type is displayed in table 3. Occurrence of crop-raiding (DAOT) was not found to be associated with any of the distance types (p=0.141). The amount of damage done to a field (DA) was also not related to any of the distance types (p=0.219). However, when looking at the canonical correspondence analysis (CCA) between occurrence of crop-raiding and distance (see Figure 13), it suggests that occurrence (DAOT) of bush buck damage is more frequent in fields closer to the forest than fields further away from the forest.

Table 3. Average distance and range of distance per distance type

Distance type	Average distance	Median	Range
Distance to forest	14.6 m	0	0 – 157.1 m
Distance to savannah	150.3 m	67.9	0 – 1007.8 m
Distance to nearest other field	264.0 m	120.7	0 – 2560.6 m

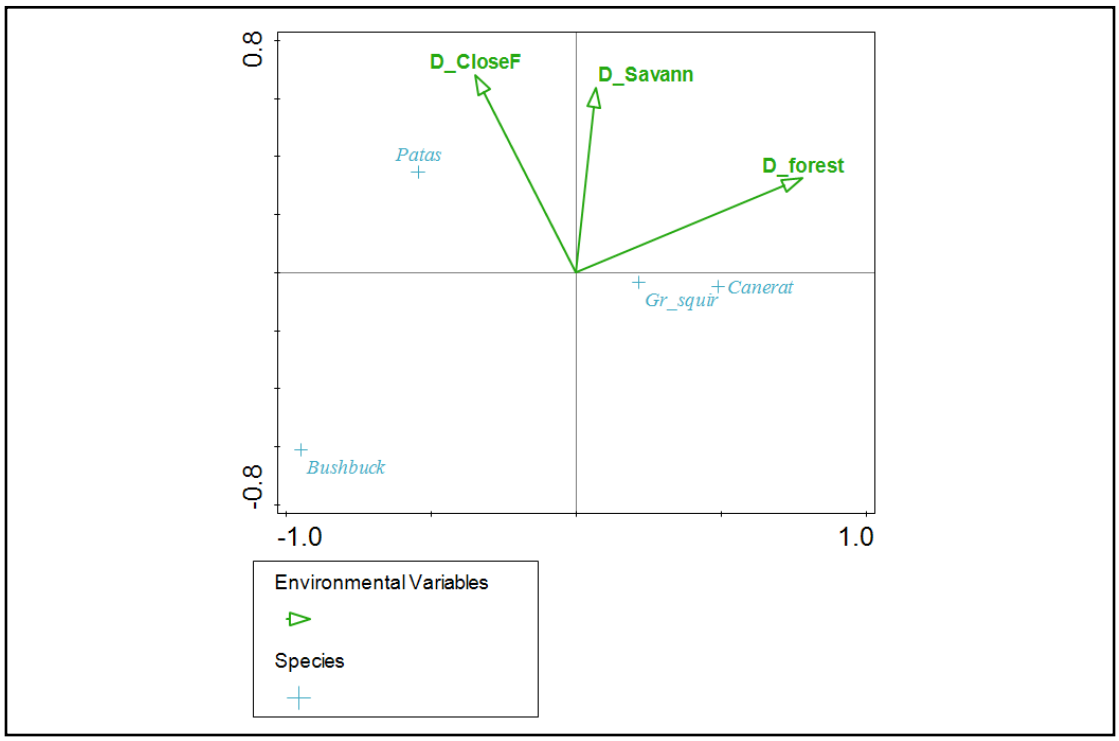

Figure 13. CCA between the different distances and the occurrence of crop-raiding damage by a specific animal species in a field, where D_forest is the distance to the nearest forest, D_Savann is the distance to the nearest Savannah, and D_CloseF is the distance to the closest other field. DOAT of bush buck is suggested to be more frequent in fields closer to the forest.

3.5 Interviews

From the collected surveys, the average age of the recorded fields was 1.8 years with a range of 1 – 5 years (SD±1.096). The majority of farmers (93 percent) planned to continue to grow crops on the same field for on average another 3.2 years. When asked about their future plans for the fields, 82.5 percent of the farmers reported that they wanted to start cashew plantations in the fields and 12.3 percent would leave the field to fallow. The final 5.2 percent weren't sure yet about their future plans for the field.

Most (77.2 percent) of the farmers sowed their crops in June (range from May – July) and started to harvest in October (63.2 percent, range from September – December). The most commonly grown crop was rice, closely followed by peanuts. Other popular crops include maize, pumpkin, beans, millet, okra, and cassava. Just over half (50.9 percent) of the farmers reported to sometimes sell a part of their peanut harvest, but the remaining crops are for subsistence.

Farmers were asked what they perceive as the most destructive crop-raiding species (see Figure 14). Multiple answers were allowed. The species most mentioned were the cane rat and patas monkey, closely followed by the green monkey. This somewhat corresponds with what was observed in the field, as the cane rat and patas monkey were among the most frequent crop-raiding species. However, green monkey crop-raiding was observed far less than expected when compared to the farmers' experiences, and bushbuck was not reported once by the farmers but was a relatively frequent crop-raiding mammal species.

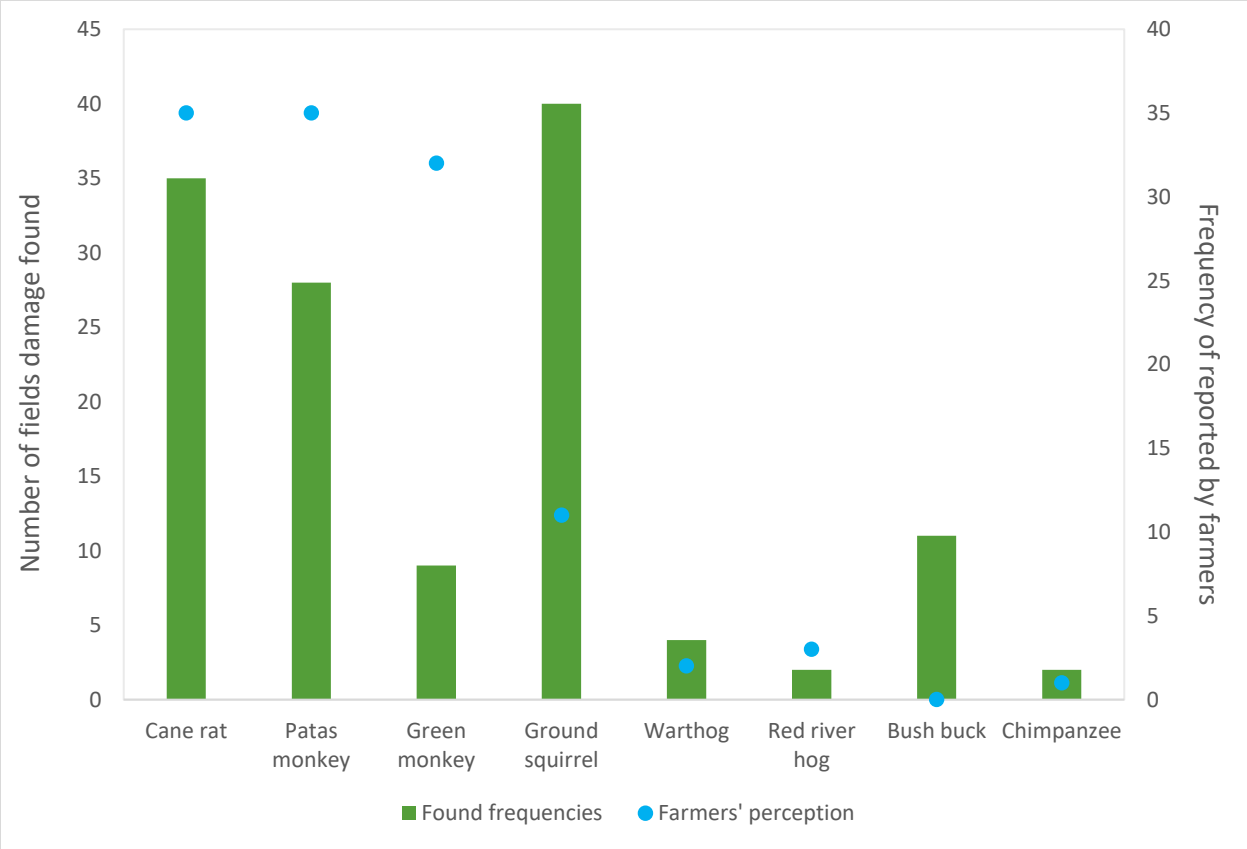

Figure 14. Difference between found crop-raiding frequencies found in the fields and farmers' perception of most frequently raiding mammal species.

Farmers protected their crop in several different ways. Many farmers sleep in their fields so they can chase away animals in the night. It is also common to build a higher platform in the field, sometimes multiple ones scattered throughout the field, to get a better view on the field and to spot animals coming from further away. To actively chase away animals, a slingshot (Figure 15) is often used. Some farmers also owned a gun or a whip, used to generate loud noises. Dogs are sometimes kept at the field, but this was less frequently seen during this survey.

Figure 15. Farmer holding slingshot in his field

4. DISCUSSION

4.1 Discussion of weaknesses in the research

There are several weaknesses in this study which could decrease the credibility of the results. Fields were only visited once during this study. Because of this, the amount of damage done to the fields is likely underestimated since animals return to a field throughout the growing season. This is extremely important to take into account when drawing conclusions about the severity of crop-raiding in the Boé sector of Guinea-Bissau. To correct for this weakness in further studies, it would be better to study a fewer number of fields but to visit these fields on a regular basis. Some studies also ask the farmers to report when crop-raiding has occurred or to keep track of it themselves (Linkie et al., 2007; Ymke Warren, Buba, & Ross, 2007b). Another weakness was that only one trained guide assessed crop-raiding damage to determine the animal species responsible for that damage. It is possible that this guide had a bias towards animal species more familiar to him, which can shift the frequencies of crop damage by certain animal species. For future research it would be better to assess crop-raiding damage with several different people to be able to correct for these biases. Furthermore, fieldwork started post-sowing of the crops. As a result, damage to seedlings could not be assessed, even though this is a very vulnerable period for plants. This too may have caused crop damage to be underestimated. A final factor that could have influenced the result on occurrence and amount of crop-raiding damage is seasonality. This study primarily looked at crop-raiding during the rainy season, thus disregarding potential temporal crop-raiding patterns due to seasonality. As a result, conclusions can only be drawn about crop-raiding in the rainy season. This factor together with the fact that fields were visited only once likely influenced the conclusion more heavily than the other describe factors.

A lack of experience with working with the program ArcGIS can also be described as a weakness of this study. These distances were vital for one of the major hypotheses, and mistakes made during the measurements can have a large influence on the conclusion. It is better to have some training in complicated programs such as ArcGIS before deciding to use them as a method. More important however is that when measuring the distance between fields and forest, forest size was not taken into account. Some forests may not have been big enough to provide good refuge or habitat for the mammal species and thus should not have been included as 'forest edge'. For future studies, it is important to take this forest size into account when measuring these distances.

4.2 Discussion of the results

Crop-raiding had not yet been studied in the Boé before, so this study gives a first insight into crop-raiding dynamics by mammals in the area. It shows that a variety of mammal species raid crops in the Boé, albeit in different frequencies and amounts. Damage by the African striped ground squirrel, cane rat, and patas monkey was observed most frequently, but damage by the bush buck, common warthog, red river hog, green monkey, and chimpanzee was also observed.

Primates did not raid crops as frequently as expected. Baboons, one of the more notorious primate crop-raiding species throughout Africa (Fehlmann, O'Riain, Kerr-Smith, & King, 2017; Schweitzer et al., 2017; Warren, 2008; Hill, 2000), did not damage crops in any of the fields. This is most probably related to the hunting pressure on this species. Guinea baboons are heavily hunted for bushmeat production (Ferreira da Silva et al., 2014). The species is classified as 'near threatened' on the IUCN Red List and its overall habitat has contracted by 20-25% over the last 30 years (Oats et al., 2008). When asked, farmers said that they rarely saw a troop of baboons anymore. The other primate species also did not damage crops as frequently as expected. This could be because many primate species have a strong crop preference (Hill, 2000; Naughton-Treves *et al.*, 1998; Priston & Underdown, 2009). Rice and peanut crops were by far the most

frequently grown crops and in the largest quantities. Maize is a favoured crop by many primate species, but it was not raided frequently by primates in the Boé. The majority of the fields in this study contained maize plants, but not in large quantities. It is likely that maize was grown in too little quantity to be able to predict crop-raiding occurrence by primates. The presence of peanut damage by patas monkeys was not associated with the presence of peanut crops in a field, but they did damage peanuts more than any other crop. So, while it might not be an explanatory factor for patas crop damage, it does seem like they have a preference for peanuts. No significant preference was found for either the green monkey or the chimpanzee. Occurrence of damage by either of these primate species was recorded infrequently. Green monkey damage was just as frequently observed in fields containing maize or millet as fields containing peanuts. In terms of quantity, green monkeys damaged peanuts most out of the different crop species, which might suggest it is a preferable crop species to them, but further research is needed to confirm this. Chimpanzees were only recorded in fields with sugarcane, which they are known to damage in other African countries as well (Hill, 2017; McLennan & Ganzhorn, 2017; McLennan & Hockings, 2014), but also damaged millet crops. Both chimpanzees and green monkeys have a strong preference for (ripe) fruit as their main diet component (Dunbar, 1974; Harrison, 1983a; Moscovice et al., 2007; Watts et al., 2012), whereas the patas monkey has a more general diet (Henty & Mcgrew, 2014; Nakagawa, 1989). Therefore, it might not be the accessibility of crops that influences crop-raiding by chimpanzees and green monkeys, but the specific crop species available. The main crops available in the rainy season of Guinea-Bissau are simply not that preferable to some primate species.

Other crop-raiding species did show a crop preference. African striped ground squirrels and bush bucks only damaged peanuts, whereas the cane rat primarily damaged rice. Occurrence of damage by these animals was associated with the presence of their most frequently damaged crop species. Peanuts were raided most out of all crop species and were raided by the widest variety of mammal species, which suggests that it is a highly preferable crop species for many crop-raiding mammals.

The amount of damage done differed among the mammal species and did not always coincide with the frequency of raiding. This is likely related to the group size of the crop-raiding animals. The majority of species that cause relatively high amounts of damage per field have a large group size in comparison to the species with lower amounts of damage per field (red river hog: Mccollum *et al.*, 2016; Morgan, 2007; green monkey: Dunbar, 1974; Harrison, 1983b; patas monkey: Henty & Mcgrew, 2014; Jong, Butynski, & Nekaris, 2008; African striped ground squirrel: van der Marel, Waterman, & López-Darias, 2020). Large groups have the capacity to damage a larger area of the field in one crop-raiding event. The patas monkey and green monkey damaged in relatively large amounts compared to the African striped ground squirrel and cane rat.

Farmers' perceptions of the most damaging crop-raiding species more or less aligned with the damage found in the fields. The patas monkey and cane rat were perceived by most farmers as the most damaging species. The green monkey also damaged crops frequently according to farmers, but this was not confirmed in this study. It might be that crop damage by green monkeys was missed since fields were only visited once. The times that green monkeys were recorded, they did do a relatively large amount of damage, which can explain why farmers reported them as one of the more damaging species. The African striped ground squirrel was not often reported by farmers as a major crop-raiding species. Nonetheless, it raided crops quite frequently, and damaged on average more area than the cane rat. Ground squirrels are relatively small animals, which makes them harder to spot than larger mammal species. This can be a reason why farmers do not perceive them as a major crop-raiding species. Research about the crop-raiding behaviour of the African striped ground squirrel is lacking. One study by Key (1990) found that ground squirrels in Kenya were responsible for over fifty percent of total damage to maize, primarily by damaging the seedlings. Since current study started post-sowing of crops, damage to seedlings was not assessed, but it

would be interesting to assess if maize damage by ground squirrels is a major factor in Guinea-Bissau as well. Bush bucks were not perceived as significant crop damaging species. As mentioned previously, bush buck damage was only observed on peanut crops, and they damaged only small areas per crop-raiding event. Kagoro-Rugunda (2004) observed crop-raiding by bush bucks in Uganda. Here, bush bucks caused the largest monetary loss out of all the crop-raiding species by feeding extensively on beans, which are an expensive crop. Peanuts were also damaged heavily by bush bucks. Beans were grown in the fields during this study, but farmers did not report frequent damage to these plants during the interviews. Furthermore, beans are not considered a major cash crop in Guinea-Bissau (Havik *et al*., 2018), which may influence the perceived crop losses. Both bush bucks and ground squirrels damage relatively small areas per crop-raiding incident, whereas patas monkeys and green monkeys damage larger areas. These larger amounts of damage at once likely feel more catastrophic to the farmers, which explains why they might overlook damage by bush bucks and ground squirrels.

Both field size and distance of the fields to the forest edge, savannah, and each other were examined to see if these factors could predict crop-raiding occurrence or amount. The range of field sizes was quite large. The expectation was that crop-raiding would increase with an increase of field size. Contrastingly, occurrence of crop-raiding was found to be more frequent in small fields. Wallace & Hill (2012) found that primates raided primarily close to the edge of the fields. They further found a link between distance travelled on the fields and relative body size of the primates. Larger primate species were willing to travel further onto the field compared to smaller primate species. Raiding close to the field edge is presumably linked with the perceived risks of raiding. An open field is perceived by most animals as a high-risk habitat because of the lack of refuges (Altendorf, Laundré, López González, & Brown, 2001; Cowlishaw, 1997; Orrock, Danielson, & Brinkerhoff, 2004; Ylönen, Jacob, Davies, & Singleton, 2002), but this may be less so for larger animals. This could explain why Naughton-Treves (1998) did find a positive correlation between the amount of crop damage by elephants and field size, since the predation risk for elephants in a field is significantly lower than that of a smaller animal. The type of mammal species found to raid crops most frequently around Béli were smaller animals. Refuge was extremely scarce in the field, since all large vegetation is slashed down prior to tilling and sowing. Therefore, it is not unreasonable to assume that smaller fields have a lower perceived predation risk in comparison to larger fields because of their proximity to refuge on the edge of the field and are thus more prone to for crop-raiding.

Several studies have found a positive association between proximity of the field to the forest edge and the occurrence of crop-raiding, especially for primates (Linkie *et al.*, 2007; Naughton-Treves, 1998; Saj, Sicotte, & Paterson, 2001; Warren, Buba, & Ross, 2007). In the current study, this association was only suggested for the bush buck through a CCA. Kagoro-Rugunda (2004) found a similar result for bush buck crop-raiding, where bush buck damage increased in gardens closer to bushy conditions. Why this connection was not found for other crop-raiding species can have several reasons. It could be due to a difference in methods used for measuring said distance. Distances were not measured during fieldwork, but afterwards through a spatial analysis software. It is possible that due to a lack of experience working with ArcGIS mistakes were made during the measuring of distances. Furthermore, the size of the nearest forest was not accounted for in the analysis. The clearing of forest is increasing in the whole of West-Africa, causing fragmentation of forests (Goetze, Hörsch, & Porembski, 2006; Torres *et al*., 2010). Small forest fragments close to the fields may provide some refuge but are not a suitable habitat for any of the mammal species found to crop-raid in the Boé. Consequently, these patches might not be suitable when analysing a variable such as ‘distance to the forest edge’.

Overall, the percentage of damaged area per field was quite low. This suggests that farmers do not suffer major losses due to crop-raiding. However, since sustenance farming is the main driver for agriculture in

the Boé, any loss of potential food should be investigated critically. It is possible that crop protection was effective in deterring animals from the fields. Guarding the field was one of the most common methods of crop protection. Hill and Wallace (2012) tested several protection methods and guarding the field full-time or part-time proved to be effective in reducing crop-raiding frequencies. However, it is likely that the amount of crop-raiding damage was underestimated. As said previously, fields were only assessed once for crop-raiding damage, but animals may return many times to one field, resulting in higher crop-losses throughout the growing and harvesting season. Furthermore, only a small area of the Boé has been sampled in this study, and it might not be appropriate to extrapolate these results over the whole area.

Furthermore, this study only looked at crop damage from mammals, but certain bird species are also known to damage crops. A number of weaver species inhabit the Boé (Guilherme, 2014), several of which are known to damage rice crops (Bright, Tologbonse, & Ogunyemi, 2009; Ruelle, 1983; Subramanya, 1994). Finally, this study looked only at crop-raiding during the end of the rainy season, spanning only marginally over into the dry season. There is a deviation between crops grown in the rainy and dry season. Cultivated fruits such as bananas and mangos are mostly ripe in the dry season (Willemsen, 2013). It is not unreasonable to presume that crop-raiding by frugivorous animals like chimpanzees will increase during this season. Also, cashews (*Anacardium occidentalis*) ripen in the dry season. Cashews are a major cash crop in Guinea-Bissau (Havik et al., 2018; Temudo & Abrantes, 2014). Chimpanzees and humans use cashews differently in Guinea-Bissau, where the chimpanzees consume the fruit and humans collect the nuts. The fruit is considered unprofitable, and local farmers apparently benefit from the chimpanzees as the primates sometimes pile the nuts. (Hockings & Sousa, 2012). While chimpanzees do not seem to cause conflicts over the cashews, other animals might. Cashew plantations are spreading rapidly throughout the Boé (Temudo & Abrantes, 2014). Nearly all of the interviewed farmers planned to transform their field into a cashew plantation when shifting the other crops to a new field. This means that an increasing area will become anthropogenic habitat, because previously the fields would be left to fallow and natural vegetation was allowed to return. Consequently, less natural forage will be available for wildlife which will likely increase crop-raiding occurrence in the coming years.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, this study showed that several mammal species raid crops during the rainy season in the Boé sector of Guinea-Bissau. Primates are not the most frequent crop-raiders. Instead, rodents damaged fields most frequently. Primates are however one of the more damaging crop-raiding species, since they damage large areas per crop-raiding incident. Crop-raiding dynamics of primates may have seasonal differences. Perceptions of farmers did overlap mostly with crop-raiding found in the fields, but they tended to underestimate crop-raiding by animals which did not raid in large groups such as the African striped ground squirrel. Peanuts seem to be a highly preferred crop species to a wide variety of mammal species. The presence of peanuts in a field could explain the occurrence of crop-raiding by the African striped ground squirrels and the bush bucks, and the presence of rice in a field could predict the occurrence of crop-raiding by cane rats. Crop preference for other species could not be determined. This study did not find an association between distance to the forest edge and crop-raiding occurrence. This is likely due to errors made in the data collection and analysis of the distance. Field size had an effect on the occurrence of crop-raiding, and smaller fields were more at risk. Overall, the percentage of damage per field was not high, but any damage can threaten the food security of the farmers. And as mentioned before, it is highly likely that crop damage was underestimated. However, since this is the first study into crop-raiding in the Boé, it is impossible to compare damage to other years. Overall, this study provided a first insight into crop-raiding dynamics by mammals in the Boé of Guinea-Bissau and can serve as a good starting point for further research.

5.2 Recommendations

Further research into the crop-raiding dynamics in the Boé sector of Guinea-Bissau could focus on the seasonal differences in crop-raiding by studying this in both the dry and rainy season. When these seasonal differences are known, crop protection strategies may be adapted to be more effective in each specific season. Furthermore, it will give insight into when human-wildlife conflicts are more likely to develop which can aid in strengthening conservation efforts. It is probable that this seasonal difference is strongest for primate species, so it could be of interest to focus a study only on these species. A study into crop preference can also be interesting. Peanuts were found to be a preferable crop for many mammal species, but it is possible that preferences shift seasonally and also throughout the cropping season, as some animals might prefer young plant parts over older plant parts.

REFERENCES

Altendorf, K. B., Laundré, J. W., López González, C. A., & Brown, J. S. (2001). Assessing effects of predation risk on foraging behavior of mule deer. *Journal of Mammalogy*, *82*(2), 430–439. https://doi.org/10.1644/1545-1542(2001)082<0430:AEOPRO>2.0.CO;2

Arandjelovic, M., Boesch, C., Campbell, G., Hohmann, G., Junker, J., Célestin, K., … Jojo, H. (2014). Pan African Programme The cultured chimpanzee: Guidelines for research and data collection, 1–105.

Bessa, J., Sousa, C., & Hockings, K. J. (2015). Feeding ecology of chimpanzees (Pan troglodytes verus) inhabiting a forest-mangrove-savanna-agricultural matrix at Caiquene-Cadique, Cantanhez National Park, Guinea-Bissau. *American Journal of Primatology*, *77*, 651–665. https://doi.org/10.1002/ajp.22388

Biru, Y., & Bekele, A. (2012). Food habits of African elephant (Loxodonta Africana) in Babile Elephant Sanctuary, Ethiopia. *Tropical Ecology*, *53*(1), 43–52.

Bright, E. O., Tologbonse, E. B., & Ogunyemi, S. (2009). Farmers' Perceptions and Management Practices of Weaver Bird Pests in Niger State, Nigeria. *PAT*, *5*(1), 1–13.

Brugie, D., Badjinca, I., Silva, C., Serra, A., & Barry, M. (2006). On the road to extinction? The status of elephant Loxodonta africana in Guinea Bissau and western Guinea, West Africa. *Oryx*, *40*(4), 442–446. https://doi.org/10.1017/S0030605306001177

Brugiere, D., Badjinca, I., Silva, C., & Serra, A. (2009). Distribution of chimpanzees and interactions with humans in Guinea-Bissau and Western Guinea, West Africa. *Folia Primatologica*, *80*(5), 353–358. https://doi.org/10.1159/000259335

Cowlishaw, G. (1997). Refuge use and predation risk in a desert baboon population. *Animal Behaviour*, *54*(2), 241–253. https://doi.org/10.1006/anbe.1996.0466

Dunbar, R. I. M. (1974). Observations on the Ecology and Social Organization of the Green Monkey, Cercopithecus sabaeus, in Senegal. *Primates*, *15*, 341–350.

Fehlmann, G., O'Riain, M. J., Kerr-Smith, C., & King, A. J. (2017). Adaptive space use by baboons (Papio ursinus) in response to management interventions in a human-changed landscape. *Animal Conservation*, *20*(1), 101–109. https://doi.org/10.1111/acv.12293

Ferreira da Silva, M. J., Godinho, R., Casanova, C., Minhós, T., Sá, R., & Bruford, M. W. (2014). Assessing the impact of hunting pressure on population structure of Guinea baboons (Papio papio) in Guinea-Bissau. *Conservation Genetics*, *15*(6), 1339–1355. https://doi.org/10.1007/s10592-014-0621-0

Freitas, C. H. De, Setz, eleonore Z. F., Araujo, A. R. B., & Gobbi, N. (2008). Agricultural crops in the diet of bearded capuchin monkeys, Cebus libidinosus Spix (Primates: Cebidae), in forest fragments in southeast Brazil. *Revista Brasileira de Zoologia*, *25*(1), 32–39.

Fungo, B. (2011). A Review Crop Raiding Around Protected Areas: Nature, Control and Research Gaps. *Environmental Research Journal*, *5*(2), 87–92.

Gippoliti, S., & Dell'Omo, G. (2003). Primates of Guinea-Bissau, West Africa: distribution and conservation status. *Primate Conservation*, *19*, 73–77.

Goetze, D., Hörsch, B., & Porembski, S. (2006). Dynamics of forest-savanna mosaics in north-eastern Ivory Coast from 1954 to 2002. *Journal of Biogeography*, *33*(4), 653–664. https://doi.org/10.1111/j.1365-2699.2005.01312.x

Gross, E. M., Lahkar, B. P., Subedi, N., Nyirenda, V. R., Lichtenfeld, L. L., & Jakoby, O. (2018). Seasonality, crop type and crop phenology influence crop damage by wildlife herbivores in Africa and Asia. *Biodiversity and Conservation*, *27*(8), 1–22. https://doi.org/10.1007/s10531-018-1523-0

Guilherme, J. L. (2014). Birds of the Boé region, south-east Guinea-Bissau, including the first country records of Chestnut-backed Sparrow Lark. *Bull ABC*, *21*(2), 155–168.

Harrison, M. J. S. (1983a). Age and sex differences in the diet and feeding strategies of the green monkey, cercopithecus sabaeus. *Animal Behaviour*, (31), 969–977.

Harrison, M. J. S. (1983b). Patterns of Range Use by the Green Monkey, Cercopithecus sabaeus, at Mt. Assirik, Senegal. *Folia Primatologica*, *41*, 157–179.
Havik, P. J., Monteiro, F., Catarino, S., Correia, A. M., & Romeiras, M. M. (2018). Agro-Economic Transitions in Guinea-Bissau (West Africa): Historical Trends and Current Insights. *Sustainability*, (10), 1–19. https://doi.org/10.3390/su10103408
Henty, C. J., & Mcgrew, W. C. (2014). Ethology and Ecology of the Patas Monkey (Erythrocebus patas) at Mt. Assirik, Senegal. *African Primates*, *44*, 35–44.
Hill, C. M. (2000). Conflict of interest between people and baboons: Crop raiding in Uganda. *International Journal of Primatology*, *21*(2), 299–315. https://doi.org/10.1023/A:1005481605637
Hill, C. M. (2017). Primate Crop Feeding Behavior, Crop Protection, and Conservation. *International Journal of Primatology*, *38*(2), 385–400. https://doi.org/10.1007/s10764-017-9951-3
Hill, C. M., & Wallace, G. E. (2012). Crop protection and conflict mitigation: Reducing the costs of living alongside non-human primates. *Biodiversity and Conservation*, *21*(10), 2569–2587. https://doi.org/10.1007/s10531-012-0318-y
Hockings, K. J., Anderson, J. R., & Matsuzawa, T. (2009). Use of wild and cultivated foods by Chimpanzees at Bossou, Republic of Guinea: Feeding dynamics in a human-influenced environment. *American Journal of Primatology*, *71*(8), 636–646. https://doi.org/10.1002/ajp.20698
Hockings, K. J., & McLennan, M. R. (2012). From forest to farm: Systematic Review of Cultivar Feeding by Chimpanzees - Management Implications for Wildlife in Anthropogenic Landscapes. *PLoS ONE*, *7*(4). https://doi.org/10.1371/journal.pone.0033391
Hockings, K. J., & Sousa, C. (2012). Differential utilization of cashew-a low-conflict crop-by sympatric humans and chimpanzees. *Oryx*, *46*(3), 375–381. https://doi.org/10.1017/S003060531100130X
Hockings, K. J., & Sousa, C. (2013). Human-Chimpanzee Sympatry and Interactions in Cantanhez National Park, Guinea-Bissau: Current Research and Future Directions. *Primate Conservation*, *26*(1), 57–65. https://doi.org/10.1896/052.026.0104
Johnson, C. A., Swedell, L., & Rothman, J. M. (2012). Feeding ecology of olive baboons (Papio anubis) in Kibale National Park, Uganda: Preliminary results on diet and food selection. *African Journal of Ecology*, *50*(3), 367–370. https://doi.org/10.1111/j.1365-2028.2011.01316.x
Jong, Y. A. De, Butynski, T. M., & Nekaris, K. A.-I. (2008). Distribution and conservation of the patas monkey Erythrocebus patas in Kenya. *Journal of East African Natural History*, *97*(1), 83–102.
Kagoro-Rugunda, G. (2004). Crop raiding around Lake Mburo National Park, Uganda. *African Journal of Ecology*, *42*(1), 32–41. https://doi.org/10.1111/j.0141-6707.2004.00444.x
Key, G. (1990). Pre-harvest crop losses to the African striped ground squirrel, Xerus erythropus in Kenya. *Tropical Pest Management*, *36*(3), 223–229. https://doi.org/10.1080/09670879009371477
Kormos, R., Boesch, C., Bakaee, M. I., & Butynki, T. M. (2003). *West African Chimpanzees: Status Survey and Conservation Action Plan*.
Leblan, V. (2014). The Impact of West African Trade on the Distribution of Chimpanzee and Elephant Populations (Guinea, Guinea-Bissau, Senegal, 19th-20th Century). *Human Ecology*, (42), 455–465. https://doi.org/10.1007/s10745-014-9654-8
Lemessa, D., Hylander, K., & Hambäck, P. (2013). Composition of crops and land-use types in relation to crop raiding pattern at different distances from forests. *Agriculture, Ecosystems and Environment*, *167*, 71–78. https://doi.org/10.1016/j.agee.2012.12.014
Linkie, M., Dinata, Y., Nofrianto, A., & Leader-Williams, N. (2007). Patterns and perceptions of wildlife crop raiding in and around Kerinci Seblat National Park, Sumatra. *Animal Conservation*, *10*(1), 127–135. https://doi.org/10.1111/j.1469-1795.2006.00083.x
Madsen, T., & Shine, R. (1999). Rainfall and rats: Climatically-driven dynamics of a tropical rodent population. *Austral Ecology*, *24*(1), 80–89. https://doi.org/10.1046/j.1442-9993.1999.00948.x
Massawe, A. W., Mulungu, L. S., Makundi, R. H., Dlamini, N., Eiseb, S. J., Kirsten, F., … Belmain, S. R.

(2011). Spatial and temporal population dynamics of rodents in three geographically different regions in Africa: Implication for ecologically-based rodent management. *African Zoology*, *46*(2), 393–404. https://doi.org/10.3377/004.046.0219

Mccollum, K. R., Conway, A. L., Lee, M., & Carroll, J. P. (2016). Occupancy and demographics of red river hog Potamochoerus porcus on Tiwai Island, Sierra Leone. *African Journal of Ecology*, (55), 47–55. https://doi.org/10.1111/aje.12314

McLennan, M. R., & Ganzhorn, J. U. (2017). Nutritional Characteristics of Wild and Cultivated Foods for Chimpanzees (Pan troglodytes) in Agricultural Landscapes. *International Journal of Primatology*, *38*(2), 122–150. https://doi.org/10.1007/s10764-016-9940-y

McLennan, M. R., & Hockings, K. J. (2014). Wild chimpanzees show group differences in selection of agricultural crops. *Scientific Reports*, *4*, 1–7. https://doi.org/10.1038/srep05956

Monadjem, A., Mahlaba, T. A., Dlamini, N., Eiseb, S. J., Belmain, S. R., Mulungu, L. S., … Taylor, P. J. (2011). Impact of crop cycle on movement patterns of pest rodent species between fields and houses in Africa. *Wildlife Research*, *38*(7), 603–609. https://doi.org/10.1071/WR10130

Moscovice, L. R., Issa, M. H., Petrzelkova, K. J., Keuler, N. S., Snowdon, C. T., & Huffman, M. A. (2007). Fruit Availability, Chimpanzee Diet, and Grouping Patterns on Rubondo Island, Tanzania. *American Journal of Primatology*, *69*, 487–502. https://doi.org/10.1002/ajp

Naughton-Treves, L. (1998). Predicting patterns of crop damage by wildlife around Kibale National Park, Uganda. *Conservation Biology*, *12*(1), 156–168. https://doi.org/10.1046/j.1523-1739.1998.96346.x

Naughton-Treves, L., Treves, A., Chapman, C., & Wrangham, R. (1998). Temporal patterns of crop-raiding by primates: linking food availability in croplands and adjacant forest. *Journal of Applied Ecology*.

Ngene, S. M., & Omondi, P. O. M. (2008). The costs of living with elephants in the areas adjacent to Marsabit National Park and Reserve. *Pachyderm*, *45*(1), 77–87.

Orrock, J. L., Danielson, B. J., & Brinkerhoff, R. J. (2004). Rodent foraging is affected by indirect, but not by direct, cues of predation risk. *Behavioral Ecology*, *15*(3), 433–437. https://doi.org/10.1093/beheco/arh031

Pittiglio, C., Skidmore, A. K., Van Gils, H. A. M. J., McCall, M. K., & Prins, H. H. T. (2014). Smallholder farms as stepping stone corridors for crop-raiding elephant in northern Tanzania: Integration of Bayesian expert system and network simulator. *Ambio*, *43*(2), 149–161. https://doi.org/10.1007/s13280-013-0437-z

Priston, N. E. C., & Underdown, S. J. (2009). A simple method for calculating the likelihood of crop damage by primates: An epidemiological approach. *International Journal of Pest Management*, *55*(1), 51–56. https://doi.org/10.1080/09670870802450268

Riley, E. p. (2007). The Human–Macaque Interface: Conservation Implications of Current and Future Overlap and Conflict in Lore Lindu National Park, Sulawesi, Indonesia. *American Anthropologist*, *109*(3), 473–484. https://doi.org/10.1525/AA.2007.109.3.473.474

Ruelle, P. J. (1983). Control of granivorous bird pests of rice using the partial crop treatment method in West Africa. *Tropical Pest Management*, *29*(1), 23–26. https://doi.org/10.1080/09670878309370764

Saj, T. L., Sicotte, P., & Paterson, J. D. (2001). The conflict between vervet monkeys and farmers at the forest edge in Entebbe, Uganda. *African Journal of Ecology*, *39*, 195–199.

Schley, L., & Roper, T. (2003). Diet of wild boar Sus scrofa in Western Europe, with particular reference to consumption of agricultural crops. *Mammal Review*, *33*(1), 43–56.

Schweitzer, C., Gaillard, T., Guerbois, C., Fritz, H., & Petit, O. (2017). Participant Profiling and Pattern of Crop-Foraging in Chacma Baboons (Papio hamadryas ursinus) in Zimbabwe: Why Does Investigating Age–Sex Classes Matter? *International Journal of Primatology*, *38*(2), 207–223. https://doi.org/10.1007/s10764-017-9958-9

Siex, K. S., & Struhsaker, T. T. (1999). Colobus monkeys and coconuts: a study of perceived human-

wildlife conflicts. *Journal of Applied Ecology*, *36*(6), 1009–1020. https://doi.org/10.1046/j.1365-2664.1999.00455.x

Sillero-Zubiri, C., & Switzer, D. (2001). Crop raiding primates: Searching for alternative , humane ways to resolve conflict with farmers in Africa. *People and Wildlife Initiative. Wildlife Conservation Research Unit, Oxford University*, (January 2001), 1–15.

Strum, S. C. (1994). Prospects for management of primate pests. *Revue d'Ecologie (La Terre et La Vie)*, *49*, 295–306.

Subramanya, S. (1994). Non-random foraging in certain bird pests of field crops. *Journal of Biosciences*, *19*(4), 369–380. https://doi.org/10.1007/BF02703174

Sukumar, R. (1990). Ecology of the Asian elephant in southern India. II. Feeding habits and crop raiding patterns. *Journal of Tropical Ecology*, *6*(1), 33–53. https://doi.org/10.1017/S0266467400004004

Swanepoel, M., Leslie, A. J., & Hoffman, L. C. (2016). Farmers' Perceptions of the Extra-limital Common Warthog in the Northern Cape and Free State Provinces, South Africa. *Wildlife Society Bulletin*, *40*(1), 112–121. https://doi.org/10.1002/wsb.617

Temudo, M. P., & Abrantes, M. (2014). The Cashew Frontier in Guinea-Bissau , West Africa: Changing Landscapes and Livelihoods. *Human Dimensions of Wildlife*, (42), 217–230. https://doi.org/10.1007/s10745-014-9641-0

Temudo, M. P., Figueira, R., & Abrantes, M. (2015). Landscapes of bio-cultural diversity: shifting cultivation in Guinea-Bissau, West Africa. *Agroforestry Systems*, *89*(1), 175–191. https://doi.org/10.1007/s10457-014-9752-z

Torres, J., Brito, J. C., Vasconcelos, M. J., Catarino, L., Gonçalves, J., & Honrado, J. (2010). Ensemble models of habitat suitability relate chimpanzee (Pan troglodytes) conservation to forest and landscape dynamics in Western Africa. *Biological Conservation*, *143*(2), 416–425. https://doi.org/10.1016/j.biocon.2009.11.007

Tufa, B., Girma, Z., & Mengesha, G. (2018). Human–large wild mammals conflict in Dhera-Dilfaqar Block of Arsi Mountains National Park, South Eastern Ethiopia. *Human Dimensions of Wildlife*, *23*(5), 474–481. https://doi.org/10.1080/10871209.2018.1464616

van der Marel, A., Waterman, J. M., & López-Darias, M. (2020). Social organization in a North African ground squirrel. *Journal of Mammalogy*, *101*(3), 670–683. https://doi.org/10.1093/jmammal/gyaa031

Wallace, G. E., & Hill, C. M. (2012). Crop Damage by Primates: Quantifying the Key Parameters of Crop-Raiding Events. *PLoS ONE*, *7*(10). https://doi.org/10.1371/journal.pone.0046636

Warren, Y. (2008). Crop-raiding Baboons (Papio anubis) and Defensie Farmers: A West African perspective. *West African Journal of Applied Ecology*, *14*, 1–11. https://doi.org/10.4314/wajae.v14i1.44705

Warren, Ymke, Buba, B., & Ross, C. (2007a). Patterns of crop-raiding by wild and domestic animals near Gashaka Gumti National Park, Nigeria. *International Journal of Pest Management*, *53*(3), 207–216. https://doi.org/10.1080/09670870701288124

Warren, Ymke, Buba, B., & Ross, C. (2007b). Patterns of crop-raiding by wild and domestic animals near Gashaka Gumti National Park, Nigeria. *International Journal of Pest Management*, *53*(3), 207–216. https://doi.org/10.1080/09670870701288124

Watts, D. P., Potts, K. B., Lwanga, J. S., & Mitani, J. C. (2012). Diet of chimpanzees (Pan troglodytes schweinfurthii) at Ngogo, Kibale National Park, Uganda, 1. diet composition and diversity. *American Journal of Primatology*, *74*(2), 114–129. https://doi.org/10.1002/ajp.21016

Wit, P., & Reintjes, H. C. (1989). An Agro-ecological Survey of the Boe Province, Guinea Bissau. *Agriculture, Ecosystems and Environment*, *27*(1), 609–620.

Yamada, A., & Muroyama, Y. (2010). Effects of vegetation type on habitat use by crop-raiding Japanese macaques during a food-scarce season. *Primates*, *51*(2), 159–166. https://doi.org/10.1007/s10329-

009-0183-9
Ylönen, H., Jacob, J., Davies, M. J., & Singleton, G. R. (2002). Predation risk and habitat selection of Australian house mice Mus domesticus during an incipient plague: Desperate behaviour due to food depletion. *Oikos*, *99*(2), 284–289. https://doi.org/10.1034/j.1600-0706.2002.990208.x

APPENDIX I. INTERVIEW QUESTIONS

1. How many years have you been growing crops on this field?
2. How many years will you continue to grow crops on this field?
3. What are your plans with the field after you're done growing crops here?
4. Which crops do you grow here?
5. When did you sow the crops?
6. When do you harvest the crops?
7. Do you sell any of your crops?
8. How many days of the week do you/family work in the field?
9. Do you ever see any animals in/near your field? If so, which ones?
10. Do animals ever steal or damage your crops?
11. How often do animals damage your crops?
12. Which crops are most often damaged?
13. Which animals have you seen damaging the crops?
14. Which animal do you think does the most damage to your crops?
15. In which way do you protect your crops against animals?