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Wilson Filipe da Silva Vieira; Chimpanzee use of space in a forest-agricultural mosaic at Madina in Cantanhez National Park,
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Dissertação apresentada para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Antropologia, especialização em Natureza e Conservação, realizada sob a orientação científica de Kimberley Jane Hockings (Universidade Nova de Lisboa e Oxford Brookes University) e Amélia Frazão-Moreira (Universidade Nova de Lisboa)

Setembro, 2017

To the voiceless

Aos que não têm voz

Chimpanzee use of space in a forest-agricultural mosaic at Madina in Cantanhez National Park, Guinea-Bissau

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Abstract

Continuous human population growth and increased fragmentation of natural habitats are leading to numerous non-human primate species living in proximity to human settlements. Like other non-human primates, chimpanzees (*Pan troglodytes verus*) are frequently reported to inhabit human-influenced habitats. However, our understanding about chimpanzee behavioural adaptations to these habitats is still limited. This dissertation presents a cross-disciplinary approach to understand chimpanzee and human sympatry in a forest-agricultural mosaic habitat at Madina in Cantanhez National Park, Guinea-Bissau. The aim of this research is to examine the home range and habitat preference on this unhabituated and unstudied community of chimpanzees to better inform their long-term survival alongside local people. A set of interviews were done in order to understand local people's perceptions toward chimpanzees, their agricultural activities, and use of forest resources. These data help to create a framework to understand the extent of human activities in the area. During the study period, there were high levels of human-influenced changes on the landscape due to slash-and-burn activities. Cashew seems to have an increasing value to human communities. However, human-chimpanzee interactions are considered 'low-conflict' due to local cultural beliefs towards chimpanzees and differential utilization of this cash crop by both species. A map of the study area was created showing a highly fragmented habitat, and a set of indirect (faeces, feeding traces, nest) and direct (opportunistic observations) chimpanzee signs were collected to understand this communities distribution. For the first time, two commonly used methods to calculate animal home range size (Minimum Convex Polygon and Kernel analysis) were used in an unhabituated chimpanzee community living in a human-influenced habitat. The data demonstrate that Kernel analysis gives more realistic results suggesting that Madina chimpanzee community has an estimated home range size of 8.93 Km^2. The correlation of home range size and community size of different chimpanzee communities suggests that Madina chimpanzees may have a community size of about 48 individuals. These results show a relatively small home range and large community size, which suggests that Madina chimpanzees may currently be successfully exploiting this anthropogenic habitat. Analysis of the distribution of chimpanzee signs show higher levels of utilization of 'natural' habitats by the species. However, feeding trace distribution showed that orchards and young forest areas have similar levels of utilization by chimpanzees for foraging. Analysis of the feeding traces during the study period suggests that chimpanzees are feeding on similar proportions of cultivated and forest resources suggesting that chimpanzees are integrating cultivars into their feeding strategies. This may be caused by the relative tolerance shown by neighbouring human communities

, despite chimpanzees likely perceiving elevated levels of the foraging risk in human environments. Oil palm (*Elaeis guineensis*) groves show high levels of utilization by chimpanzees, particularly for nesting, and this research confirms that the oil-palm an important resource for humans and chimpanzees. Despite the ‘low conflict’ interactions at Madina, the increasing monetary value of cashew may create more severe and permanent changes of the landscape and human perceptions toward chimpanzees are likely to change in the future.

Keywords: *Pan troglodytes*; home range, habitat preference, human-dominated habitat

Resumo

O aumento da população humana e a consequente fragmentação dos habitats naturais tem levado a que primatas não-humanos tenham de viver junto de populações humanas. Como outras espécies de primatas, os chimpanzés (*Pan troglodytes*) são altamente adaptáveis e já foram observados a viver em habitats antropogénicos. No entanto, o entendimento sobre as adaptações e alterações no seu comportamento ainda é limitado. Esta dissertação faz uma abordagem inter-disciplinar para compreender a coexistência entre chimpanzés e humanos no mosaico agro-florestal de Madina, no Parque Nacional de Cantanhez, Guiné-Bissau. Esta investigação teve como objetivo compreender a distribuição e a preferência de habitat de uma comunidade de chimpanzés não habituada e que ainda não tinha sido estudada. Foram conduzidas entrevistas para se poder compreender quais as atividades e perceções que a população local tem dos chimpanzés. O período desta investigação foi o que apresentou maiores níveis de mudanças na paisagem devido a atividades agrícolas de derrube-e-queima. O caju aparenta ter uma crescente importância para as populações locais, no entanto, as interações humanos-chimpanzés são de 'baixo-conflito' devido às crenças locais e ao uso diferencial do caju pelas duas espécies. Um mapa da área de estudo foi criado mostrando um habitat altamente fragmentado, e um conjunto de dados indiretos (fezes, rastos, ninhos) e diretos (observações) da presença de chimpanzés foi recolhido para compreender a sua distribuição. Pela primeira vez, dois métodos usados para estimar o tamanho de territórios (MCP e análise Kernel) foram utilizados numa comunidade de chimpanzés não habituada vivendo em habitat antropogénico. Os resultados da análise Kernel foram mais realistas sugerindo que a comunidade de chimpanzés de Madina terá um território de 8.93 km^2. A correlação entre o território e o tamanho da comunidade em outros estudos com chimpanzés sugere que a comunidade de Madina possa ser composta por 48 indivíduos, mostrando que, apesar do território relativamente pequeno, os chimpanzés de Madina possam estar a prosperar neste habitat. Análises feitas à distribuição dos vestígios deixados por chimpanzés mostraram que existem maiores níveis de utilização de habitats 'naturais'. No entanto, a distribuição dos rastos alimentares mostram que certas plantações e floresta jovem têm níveis similares de utilização para busca de alimento. Analisando o conteúdo destes vestígios, é sugerido que os chimpanzés podem estar a alimentar-se em proporções semelhantes destes recursos, incluindo os campos agrícolas nas suas estratégias alimentares. Os bosques de palmeiras apresentaram os mais altos níveis de utilização, principalmente para a construção de ninhos. As palmeiras são um importante recurso para humanos e chimpanzés, mas a disponibilidade de alimento ao longo do ano e os altos níveis de tolerância por parte da população leve a que os chimpanzés usem este território. É provável que esta coexistência aconteça devido aos baixos níveis de conflito com comunidades humanas, ainda que os chimpanzés compreendam os riscos associados a habitats antropogénicos. Apesar do 'baixo conflito" destas interações em Madina, o aumento do valor monetário do caju pode vir a criar alterações severas e permanentes neste habitat, e nas perceções das populações humanas em relação aos chimpanzés poderão mudar.

Palavras-Chave: *Pan troglodytes*; território, preferência de habitat, habitat antropogénico

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1. Introduction

1.1. Theme and main goals

This dissertation falls within the scope of a Master's degree programme in Anthropology: Nature and Conservation, at Department of Anthropology, Faculty of Social and Human Sciences, New University of Lisbon. All data and results presented in this dissertation are based on four months of field work conducted by Wilson Vieira in Cantanhez National Park, Guinea-Bissau. The main goal of this research was to better understand the home range and habitat use of an unstudied community of wild chimpanzees (*Pan troglodytes verus*) living on a forest-agricultural matrix landscape around Madina de Cantanhez village, Central Cantanhez National Park.

More specifically, this research employs a cross-disciplinary approach to understand human-chimpanzee coexistence and chimpanzee behavioural adaptations to a human-influenced habitat. In this thesis, I analyse human activities and perceptions on chimpanzees collected during interviews to create a framework of the landscape in which both human and chimpanzees coexist. I also compare the effectiveness of two frequently used methods to calculate chimpanzees' home range sizes. This is the first time this has been done on an unhabituated chimpanzee community living in a human-influenced habitat. I also examine the habitat preference and diet of chimpanzees at Madina. The results of this research will deepen our knowledge about chimpanzee behavioural adaptations to anthropogenic habitats.

1.2. Primates on human-influenced environments

Modern humans and wildlife have coexisted since the emergence of our species (*Homo sapiens*). Across South America, Africa and Asia, there are several examples of human-primate sympatry in which primates play an important role in human survival and perception of the natural world. For example, the Tikuna people in Columbia consider some primate species as an important food source [e.g. *Alouatta seniculus*; *Lagothrix lagotricha*, *Pithecia monachus* (Paratian & Maldonado, 2010)]. Monkey skins and infants are also integrated into human livelihoods and traditional activities such as ceremonies and pet-keeping (Paratian & Maldonado, 2010). However, in some areas, primates can be offered some protection due to humans. In Bali, long-tailed monkeys (*Macaca fascicularis*) thrive in human-influenced environments such as forested temples due to local religious beliefs to not disturb the forests (Fuentes, *et al*., 2005). In Sulawesi, Indonesia, the Tonkean macaque (*Macaca tonkeana*) is seen as belonging to humans and as protectors of the traditional law to the Kaili Tado people (Riley, 2010). Likewise, some primate species are protected by local taboos and are considered human ancestors [e.g. *Lemur catta* and *Propithecus verreauxi* (London *et al*., 2006a)]. Primates can also play a mythological and religious role in human cultures. In some Chinese folklore, the monkey is considered a mythological entity called 'the Monkey King', an immortal being with supernatural powers that protects a monk on his journey (Burton, 2002), and in Japan, the Japanese macaque (*Macaca fuscata*) is believed to be one of the reincarnations of Buddha (Knight, 1999).

In some situations, local people may also hold negative perspectives towards primates. Due to their ecological flexibility, almost all families of primates include cultivars on their feeding strategies (Hill, 2005; McLennan *et al*., 2017). In particular, baboons (*Papio anubis*) are reported to cause severe damages to crops at Budongo forest Reserve in Uganda (Hill, 1997). Despite the role that Japanese macaques play on the local folklore, they are persecuted due to damage they cause to crops (Sprague, 2002; Sprague & Iwasaki, 2006). In Costa Rica, Capuchin monkeys (*Cebus capucinus*) are regarded as a problematic species that can cause severe crop damage (Baker & Schutt, 2005), whereas at sites in Brazil, capuchin monkeys (*Sapajus libidinosus*) crop foraging is tolerated (Spagnoletti *et al*., 2017). Like other nonhuman primates, great apes have been reported to forage on crops, but due to their larger body size, they can threaten people's personal safety [e.g. *Gorilla beringei* (Madden, 2006); *Pan troglodytes* (Webber, 2006; McLennan, 2008; Hockings *et al*. 2010a; Hockings & McLennan, 2016); and *Pongo abelli* (Campbell-Smith *et al*., 2010)].

Despite frequent reports of negative human-primate interactions, their presence can provide important monetary income to local human communities which may create positive perceptions toward them, increase tolerance in local communities, and assist primate conservation efforts. In Dzanga-Sangha at Central African Republic, which has one of highest densities of Western Lowland gorillas (*Gorilla gorilla gorilla*), local community acceptance of conservation projects is related to the monetary income from park entrance fees that helps build infrastructure (e.g. schools) and create new jobs for local people (Blom, 2000). Other examples include the Barbary monkeys (*Macaca* *sylvanus*) in the Upper Rock Nature Reserve in Gibraltar and the long-tailed monkeys in Padangtegal at Bali, that are maintained and protected due to tourism that brings which helps support local businesses (Fuentes *et al*., 2007). Tourism activities and associated monetary income can have positive effects on certain primate species living close to humans. For example, between 1979 and 1989, the population of Mountain Gorillas (*Gorilla beringei*) at the Volcanoes National Park in Rwanda increased from 260 to 320 individuals, due to tourist fees that helped to fund the Park security and education programs (Weber, 1993). Primate related tourism can be an alternative to activities such poaching, mining and other environmental destructive activities, especially when related with formal employment and monetary income, and can also raising funds to environmental conservation projects (Hvenegaard, 2014). In summary, the relationship between humans and primates can be different according to cultural and economic contexts and vary due ecological and political reasons.

Chimpanzees (*Pan troglodytes*) are humans' evolutionary closest relatives (Ruvolo, 1997). Many different communities have cultural beliefs toward chimpanzees. Local people from Bossou at Guinea believe that chimpanzees are their ancestors' reincarnation and the species is seen as a sacred totem (Kortlandt, 1986; Yamakoshi, 2005). Others, such as local communities of Cantanhez National Park at Guinea-Bissau, believe that chimpanzee were humans that were forced to return to the forest as a punishment for not complying with the religious laws (Sousa & Frazão-Moreira, 2010; Sousa *et al*., 2014a). These beliefs are associated with positive perceptions toward chimpanzees and have allowed these two species to share the same habitat for several generations. Human-chimpanzee sympatry means that humans explore wild resources and chimpanzees also explore human sources of food such as cultivated fields (Hockings *et al*., 2009; Bessa *et al*., 2015). Despite the low 'conflict' levels in these situations, the proximity between these species can create problematic situations that can cause retaliatory killings toward chimpanzees (Hockings & Sousa, 2013). Continuous human population growth within the National Park is placing increasing demand on space and natural resources which is causing a decrease in forested habitats and likely increasing interactions between humans and chimpanzees, which might eventually lead people to change their tolerant views toward chimpanzees. Elsewhere in Africa there have been recent changes in peoples' attitudes and perceptions towards chimpanzee crop-foraging. At Bulindi in Uganda, people tolerate chimpanzee crop-foraging on fruit-crops that they own although showing less tolerance towards crop-foraging on cash-crops (e.g. sugar cane) (McLennan & Hill, 2012). People of the same region also consider chimpanzees as dangerous due to their increasing proximity to the villages (McLennan & Hill, 2012). At Bossou oranges went from having low monetary value to being an expensive crop, which change peoples' tolerance towards chimpanzee crop-foraging.

Habitat degradation has resulted in many primate populations having their natural habitats reduced and with individuals consequently having to adapt to living in forest-agricultural mosaics (Estrada, 2013). As outlined, these environments are complex and human-primate dynamic are constantly changing due to economic or political factors. Due to this, understanding the coexistence between humans and primates might be one of the most important areas in primatology (Fuentes & Hockings, 2010). Primate adaptations and people perceptions of primates must be understood to promote long-term coexistence between primate species and humans.

To understand human-chimpanzee coexistence in human-influenced environments, the present research will focus on their shared use of habitat. In Madina de Cantanhez, local people rely on agricultural products and interact with chimpanzees on a daily basis. In order to survive in this human-influenced habitat, chimpanzees have to make a set of behavioral and ecological adaptations. This chimpanzee community has never been systematically studied in the past and very little is known about them. To place chimpanzee behavioural adaptations in context it is necessary to understand the nature of human changes to the landscape and the factors that drive these changes.

1.3. Dissertation structure:

As outlined, the main goal of this research is to understand home range and habitat use of an unhabituated community of western chimpanzees inhabiting a forest-agricultural mosaic habitat in Madina de Cantanhez village. For that purpose, this dissertation has been divided into seven main chapters. Following this introduction, Chapter 2 describes the study species and the study site. Chapter 3 provides an overview of the methodology used during the study period, including mapping methods, interviews with the local human community, and direct and indirect analysis of chimpanzee behaviour. In Chapter 4, a framework of human agricultural activities and perceptions to chimpanzees is created based on interviews with the local human community. Chapter 5 examines the Madina chimpanzee community's home range and core area and compares this with other chimpanzee sites. Chapter 6 explores the habitat preferences of this community, including those that are preferred for nesting and foraging. To conclude, Chapter 7 compiles the main finding of this research and suggests future directions for research.

2. Study species and site

2.1. The chimpanzee (*Pan troglodytes*)

2.1.1. General information about the species

The common chimpanzee (*Pan troglodytes*) is the most widespread and abundant species of the Great Apes. They are found in 22 African countries, between 13º N to 17º S latitude, and from the sea level to 2600m altitude (Humle *et al*, 2016a). Estimates of their population size range from 172,700 to 299,700 individuals living in the wild, spread across a geographic range of about 2.6 million km^2 (Butynski, 2003; Humle *et al*., 2016a).

Four different subspecies are recognised: the Western chimpanzee (*Pan troglodytes verus*); the Nigerian-Cameroon chimpanzee (*Pan troglodytes ellioti*); the Central chimpanzee (*Pan troglodytes troglodytes*); and the Eastern chimpanzee (*Pan troglodytes schweinfurthii*) (Figure 1). The Eastern chimpanzee is the most abundant of all the subspecies with an estimated number of 181,000 to 256,700 individuals, followed by the Central chimpanzee with an estimated 140,000 individuals. The Western chimpanzee have an estimated number of 18,000 to 65,000 individuals, and the Nigerian-Cameroon subspecies has the smallest estimated population of about 6,000-9,000 individuals (Butynski, 2003; Plumptre, 2010; Morgan, *et al*., 2011; Humle *et al*., 2016a).

Chimpanzees can be found in a variety of environments, including low to high altitude forests, seasonal forests, woodland, and woodland mixed with savannah and forest galleries (Reynolds & Reynolds, 1965; Baldwin *et al*., 1982; Ghiglieri, 1984; Kawanaka, 1984; Goodall, 1986; Nishida, 1990). Their behavioural flexibility also allows them to occur in the farmland-forest matrix and other human-influenced habitats (McLennan & Hill, 2012; Sousa *et al*., 2014; Hockings *et al*., 2012, 2015).

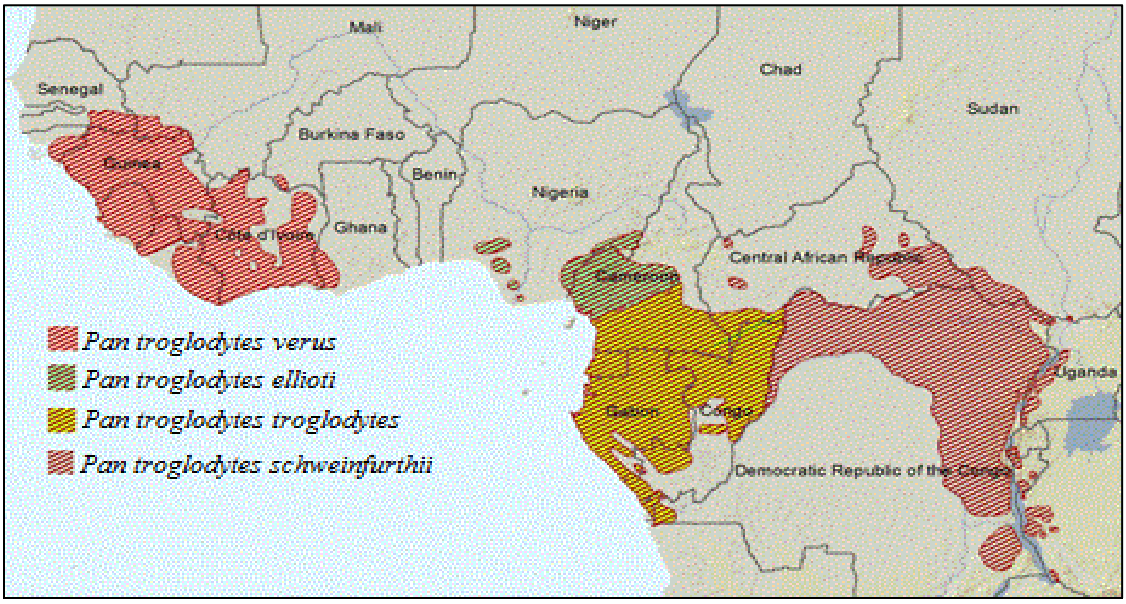


Figure 1. Distribution of the four chimpanzee subspecies on the African continent. Light red: Western chimpanzee; Green: Nigerian-Cameroon chimpanzee; Yellow: Central chimpanzee; Eastern chimpanzee. Map adapted from: http://www.greencorridor.info/en/chimp/.

Chimpanzees spend between 50 and 75 % of their feeding effort on ripe fruits (Goodall, 1986; Wrangham, 1977; Wrangham *et al*., 1991; Tutin *et al*., 1997; Morgan & Sanz, 2006; Pruetz, 2006). However, in times of fruit scarcity, they feed on other plant parts including leaves, pith, woody tissue, gum, tubers, as well as non-plant items, such animal meat, insects, and honey (Teleki, 1975; Basabose, 2002; Morgan & Sanz, 2006; Hockings *et al.*, 2010; Bessa *et al.*, 2015). In some communities, chimpanzees are known to prey on other primate species such as red colobus (*Procolobus spp.*) and lesser bush babies (*Galago senegalensis*) (Watts & Mitani, 2002; Pruetz & Bertolani, 2007).

Chimpanzees are very social and live in communities that can range from 20 to 150 individuals (Goodall, 1986; Nishida, 1990; Watts, 1998; Boesch & Boesch-Achermann, 2000). Chimpanzees exhibit high fission-fusion dynamics, forming temporary parties (or subgroups) of different age and sex composition (Nishida, 1968; Goodall, 1986). The size of these subgroups is dependent on various ecological variables, in particular the size and the food availability of the patches in which they forage. (Goodall, 1986; Anderson *et al*., 2002). Other factors such predation risk, the presence of maximally swollen females, and the size and sex ratio of the community may also have impact the formation of parties (Goodall, 1986; Boesch, 1991; Boesch, 1996; Newton-Fisher *et al*., 2000; Lehmann & Boesh, 2004; Lehmann *et al*., 2007).

Chimpanzees have slow life histories and can live for more than 40 years in the wild (Humle, 2003). To avoid inbreeding, adolescent female chimpanzees disperse from their natal community to another neighboring chimpanzee community (Nishida & Kawanaka, 1972; Pusey, 1979; Williams, 1999). The age at which female chimpanzees first give birth varies considerably [Bossou community: 10.9 years old (Sugiyama, 2004); Gombe community: 13.3 (Goodall, 1983; Wallis, 1997; Pusey *et al*., 1997) Tai community: 13.7 years old (Boesch & Boesch-Achermann, 2000); Mahale community: 14.6 (Nishida *et al*., 1990)]. After 225 days of gestation, usually one offspring is born and reaches puberty at 8-11 years old (Marson *et al*., 1991; Wallis, 1997). Females inter birth interval averages from 4.6-6 years old (Hiraiwa-Hasegawa *et al*., 1984; Nishida *et al*., 1990; Wallis, 1997; Sugiyama, 2004). Chimpanzees have large home ranges sizes, that are usually between $10km^2$ and $40km^2$ (Amsler, 2009), but vary according to ecological, demographic, and anthropogenic factors. As some other primate species, chimpanzees show high levels of behavioural flexibility which evolve in response to a changing or heterogeneous habitat (Jones, 2005; Boesch *et al*, 2002; Hockings *et al*., 2012).

Wild chimpanzees living in human-influenced landscapes often have overlapping territories and use the same resources as the local human population (Duvall, 2008; Hockings & McLennan, 2012; Hockings *et al*, 2012; Hockings & Sousa, 2013). Thus, human presence can also be a major factor in determining chimpanzee behaviour and ecology. In human-influenced habitats, chimpanzees' community size can be smaller than in habitats with less human influence (Hockings *et al*., 2009), possibly because their territories are more fragmented. For example, at Bossou in Guinea (Hockings *et al*., 2006), roads frequented by vehicles cut through the chimpanzees' home ranges. Even National Parks such as CNP, Guinea-Bissau (Hockings & Sousa, 2013) and Kibale National Park, Uganda (Cibot *et al*., 2015) can have roads dissecting the forest. In these situations, chimpanzees frequently cross roads and anthropogenic environments to access to patches of food resources, which may include crops (Reynolds *et al*., 2003; McLennan, 2008, 2013; Hockings *et al*., 2009; Kriefs *et al*., 2014).

2.1.2. The conservation status of chimpanzees

Although chimpanzees are capable of living in proximity to humans, human activities are threatening their survival. Since 1996, chimpanzees have been classified as *Endangered* (Humle *et al*, 2016a). The main threats to the species survival are due habitat loss and fragmentation, poaching and diseases. Slash-and-burn agriculture, commercial agriculture and extractive industries (e.g. mining, logging) reduced chimpanzee habitats (Humle *et al*., 2016a). Forest logging and mining increase accessibility to remote areas, and chimpanzees became more susceptible to negative interactions with humans. Due to the close phylogenetic relationship between humans and chimpanzees, these interactions can result in disease transmission, such as Ebola, that can be lethal to chimpanzee communities (Leroy *et al*., 2004; Walsh *et al*., 2007; Köndgen *et al*., 2008 Humle, 2011), or to live trade, bushmeat and traditional medicine (Sodeinde, 1999; Hicks *et al*., 2010; Sá, 2012). Also, accidental killings and injuries can be caused by snares set for other animals or by people defending its crops (Teleki, 1989; Waller &Reynolds, 2001; Brncic *et al*., 2010).

The Western Chimpanzee is classified as *Critically Endangered,* and its distribution ranges from southern Senegal to the Niger river in Nigeria (Humle *et al*., 2016b). It is also present in Guinea-Bissau, Côte D'Ivoire, Sierra Leon, Guinea, Liberia, Mali and Ghana. This subspecies is considered extinct in Benin, Togo and Burkina Faso (Brownell, 2003; Butynski, 2003; Humle *et al*, 2016b). High levels of poaching, habitat fragmentation and transformation due to human activities are responsible for the decline in the population sizes of this subspecies over the past 50 years (Humle *et al*, 2016b). Their suitable habitat decreased by 11% between 1990 and 2000 (Junker *et al*., 2012). It is expected that in 69 years, Western chimpanzees' population loss will be 80% (Humle, 2016b).

There have been various arguments for why it is important to conserve chimpanzees in the wild. These range from ethical reasons, to them being our closest living relatives, to their importance in seed dispersal and ecosystem health (Wrangham, *et al*., 1994). Chimpanzees are also charismatic megafauna that can act as flagship species for conservation, and an umbrella species for the conservation of other wildlife (Ducarme *et al*., 2013). The legal protection of chimpanzees and the establishment of protected areas are important conservation tools; however, it can be argued that chimpanzee conservation efforts might be more successful in areas where local people have pre-existing protective beliefs such as totems or taboos against harming chimpanzees (Kormos *et al*., 2003; Sousa *et al*., 2014a). However, much information is required to understand how local people's behaviours and attitudes influence the persistence of sympatric chimpanzees, and how chimpanzees modify their behaviours, including habitat use and ranging patterns, to exploit anthropogenic habitats. In Guinea-Bissau, chimpanzees are an important flagship species for conservation in terrestrial habitats (Sousa & Frazão-Moreira, 2010). Their study and protection will help to protect biodiversity and preserve ecosystems in this country.

2.2 Location of the study site

2.2.1. Guinea-Bissau

The Republic of Guinea-Bissau has an area of approximately 36,125 km^2 and is one of the smallest countries in West Africa. It lies on the Atlantic coast, and borders the Republic of Senegal in the North and the Republic of Guinea on the East and South (Figure 2). The country's continental area is divided in different regions: coastal lowlands, interior plains and north-eastern highlands (Hockings & Sousa, 2013).

The country's average elevation is 70m, with the lowest point at sea level and the highest point 300m above sea level (CIA, 2017). The climate is characterized as tropical humid with two different seasons: rainy season from June to November and dry season from December to May.

Guinea-Bissau has a population of around 1,991,000 people (African Statistical Yearbook, 2016) that are made up of more than 20 ethnic groups, the most represented being the Fula (28.5%); the Balanta (22.5%), the Mandinga (14.7%); the Papel (9.1%); and the Manjaco (8.3%). Some ethnic groups, such the Nalu, inhabit specific regions of the country. Of all religions, Islam is practiced by the majority (45.5% of the population) followed by Christianity (22.1%), while 14.9% practice traditional African religions (CIA, 2017). However, it is important to note that, as in other West African contexts, Muslim religion is combined with pre-Islamic beliefs and practices, making it an Islam with syncretic characteristics (Lewis, 1966; Trimingham, 1980).

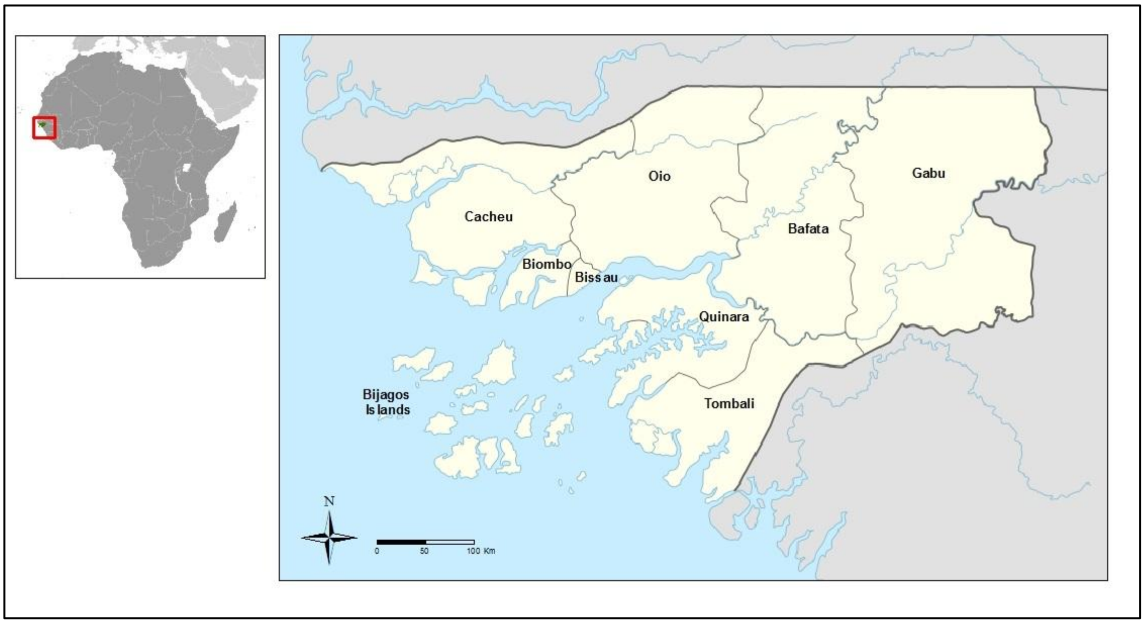


Figure 2. Location of Guinea-Bissau in West Africa and different regions within Guinea-Bissau

Guinea-Bissau is listed as the 13th poorest countries in the world (Global Finance, 2017) with 67% of the population living under the poverty line of US$1.90 per day (African Statistical Yearbook, 2016). The country's economy relies on exportations of fish and agricultural products, such as cashew nuts (*Anacardium occidentale*), palm kernels (*Elaeis guineensis*) and peanuts (*Arachis hypogaea*). People traditionally practise slash-and-burn agriculture and in some coastal areas farm rice fields in mangrove areas (Sousa & Frazão-Moreira, 2010; Sousa *et al.*, 2014b). Nowadays, cashew plantations are an important income for rural communities and cashew nuts represent 80% of the country's exports (CIA, 2017). It is estimated that cashew plantations cover 4.8% of the national territory and that the rate of conversion of land to this cash crop it about 4% per year (The World Bank, 2009). Landsat satellite analyses by Oom *et al*. (2009) showed that between 1990 and 2007 Guinea-Bissau lost forest habitat areas (closed forest and open forest together) at a rate of 1.17% every year. The main cause of this change seems to be slash-and-burn agriculture and land conversion to cashew plantations. In contrast, savannah woodland habitats increased by 0.76% in the same period, possibly due to the cleaning of open forest habitats to slash-and-burn agriculture (Oom *et* al., 2009). Between 1990 and 2014 forest cover in Guinea-Bissau was reduced by 26% to 30% (FAO, 2014).

Fragments of well-preserved, closed broadleaved forests still occur in Tombali and Quinara regions (south-western part of the country) and the Cacheu region (north-western part of the country) (Figure 1) (Gippoliti & Dell'Omo, 2003). West African forests are one of the 25 global biodiversity hotspots with 1,320 vertebrate species, of which 270 are endemic (Mittermier *et al*., 1999; Myers *et al*., 2000). In Guinea-Bissau, 12 orders of mammals are found, including 11 species from the Primate order (Casanova & Sousa, 2007). The Western chimpanzee (*Pan troglodytes verus*) is the only species of nonhuman great ape found in Guinea-Bissau. Although in 1988 chimpanzees were thought to be nationally extinct (Lee *et al.*, 1988; Scott, 1992), Gippoliti & Dell'Omo (1996) confirmed the presence of chimpanzees in Cantanhez forests, supporting the previous distribution proposed by Kortlandt (1983). Current data estimates suggest that there are between 600 and 1000 chimpanzees in Guinea-Bissau, distributed from the Gabu region (in the north) which includes the Dulombi National Park and the Boé National Park, to the Tombali and Quinara regions (in the south-east), which includes Cantanhez National Park and Lagoas de Cufada National Park (Gippoliti *et al.*, 2003; Casanova & Sousa, 2007; Kühl *et al*, 2016; Carvalho *et al*., 2013) (Figure 3).

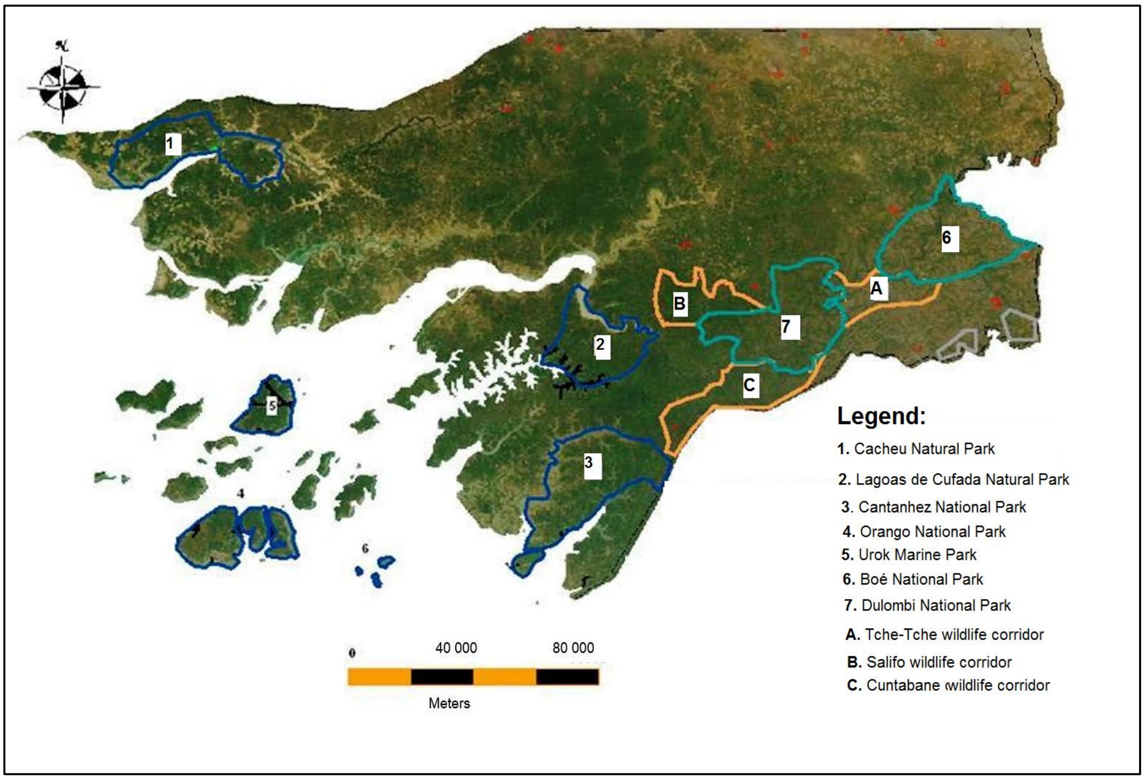


Figure 3. Location of the protected areas in Guinea-Bissau. (Adapted from Carvalho *et al*., 2014).

The conversion of natural habitat to other land uses (such as agriculture), coupled with poaching and the live trade of infants, are some of main threats to the western chimpanzee's survival (Humle *et* al., 2016a). Nevertheless, in Guinea-Bissau, local people's beliefs about chimpanzees make it taboo to hunt them for food (Gippoliti *et al.*, 2003; Sousa *et al.*, 2005; Casanova & Sousa, 2007; Sousa & Frazão-Moreira, 2010; Costa *et al.*, 2013). However, there are reports of body parts being used for medicinal purposes (Minhós *et al.*, 2013a), and the accidental killing of chimpanzees through crop protection, e.g. gun shots or snares (Gippoliti *et al.*, 2003; Sousa & Frazão-Moreira, 2010).

2.2.2. Cantanhez National Park:

Considered a hunting reserve in the 1980's, Cantanhez National Park (hereafter CNP) was formally created in 2008 (Hockings & Sousa, 2013; European Commission, 2017). It is situated in the Cubucaré region, on the south-western part of the Tombali administrative sector region (Northeast limit 11º22'58''N, 14º46'12''W and 18 Southwest limit 11º02'18''N, 15º15'58''W) (Cantanhez Management Plan, 2017). Covering an area of 1,057,67 km², CNP borders the Cacine river and the Atlantic Ocean to the south, the Balana river to the north, the Cumbinjã river to the west, and the Republic of Guinea and the Cacine river to the east (Cantanhez Management Plan, 2017) (Figure 4).

People and wildlife in Cubucaré region (part of the Bedanda sector which includes CNP) have coexisted there since humans first inhabited the area. The first reports date back to the XVI century. Portuguese writings from that period note the presence of Nalu populations in the region that would become territory of Guinea-Bissau (Pereira, (1954[1506-1508]); D'Almada, 1841 [1594]). The Nalu are the traditional owners of the land and might have been in that territory long before these dates (Frazão-Moreira, 2009).

Nowadays, CNP human density is about 21 people/km^2 with a population of approximately 23,992 people, distributed across an estimated 110 villages (Hockings & Sousa, 2013; Cantanhez Management Plan, 2017). Over time, several ethnic groups have entered this region. (Carvalho, 1949). The Fula and the Sosso, both brought the Islam religion, and later the Balanta arrived (Frazão-Moreira, 2009). Today, CNP is home to several different ethnic groups: Nalus (32.4%); Balanta (26.1%); Mandinga (15.3%); Fula (9 %); Tanda (5.4%); Sosso (3.6%), among others, which mainly rely on slash-and-burn agriculture (Cantanhez Management Plan, 2017).

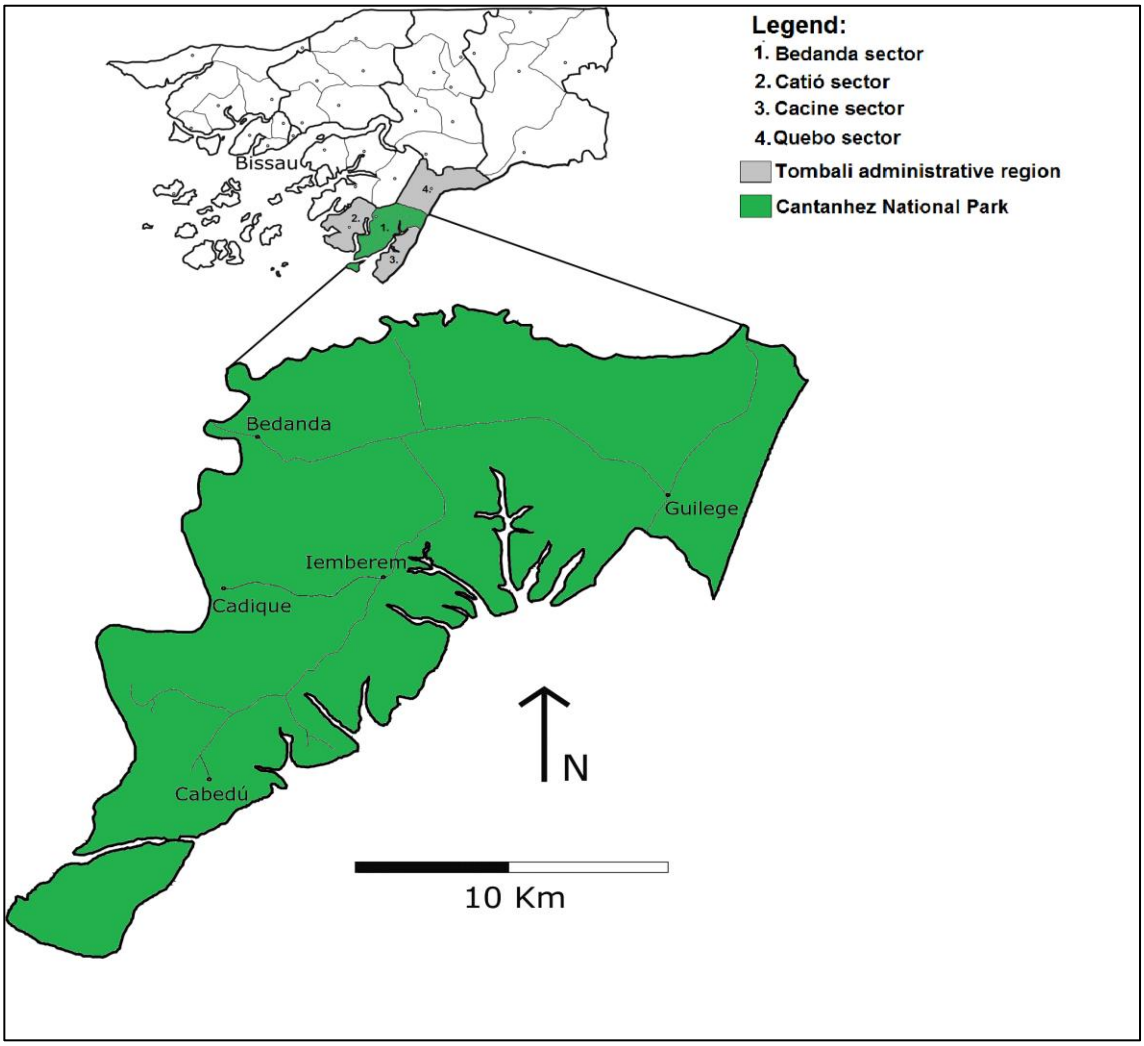


Figure 4. Location of Cantanhez National Park (Adapted from Temudo, 2009)

Despite severe habitat fragmentation, it still contains some of the most well-preserved patches of primary sub-humid forests of the country (Oom *et al.,* 2009, Temudo, 2009), along with savannah, mangroves, evergreen and semi-deciduous forests, and cultivated fields (Gippoliti & Dell'Omo, 2003; Catarino, 2004). Along with several other animal species, Cantanhez NP shelters six species of primates: western chimpanzee (*Pan troglodytes verus*), red colobus (*Procolobus badius temminckii*), black and white colobus (*Colobus polykomos*), Guinea baboon (*Papio papio*), green monkey (*Chlorocebus aethiops sabaeus*), Campbell's monkey (*Cercopithecus campbelli*); and the Senegalese bushbaby (*Galago senegalensis*) (Gippoliti & Dell'Omo, 1996; Minhós *et al.,* 2013b; Da Silva *et al*., 2014).

Heavily fragmented coastal forests of CNP have been identified as one of the seven priority areas in West Africa for chimpanzee conservation (Kormos *et al*., 2003). Nowadays, an estimated 400 individuals are living in the National Park (Casanova & Sousa, 2007; Hockings and Sousa, 2011). However, other research based on the analysis of suitable habitat for chimpanzee populations and using three population scenarios, argue that, in 2003, the species population in Tombali (Cantanhez, Catio and Cacine regions included) ranged between 376-2632 individuals (Torres *et al.,*2010). Using marked-nest analysis, chimpanzee densities across four forests in central-southern CNP - Lautchande, Cadique, Caiquene and Madina suggested that between 17 and 106 individuals are present (Sousa *et al*., 2011). However, more recent observational data collected during road-crossings suggests that in Cadique-Caiquene forest chimpanzee community have a minimum of 39 individuals (Bessa, 2014).

2.2.3. Madina de Cantanhez:

The study area of Madina de Cantanhez, Farim and Catomboi (Figure 5) was selected based on preliminary research that estimated the location of potential chimpanzee communities in central-southern Cantanhez NP (Hockings & Sousa, 2013) (Figure 6). Madina de Cantanhez (hereafter Madina) is a small village located in Cantanhez National Park (Latitude: 11° 13' N Longitude: 15° 3' W), originally a Mandinga and Fula village. Its population is now mostly Fula, Mandinga, Susso and Balanta (Sousa *et al*., 2014a) with some individuals from other ethnic groups, such as Nalu and Saraculé. The main religion is Islam, with exception of the Balanta that either practice traditional African religions or are converting to Christianity.

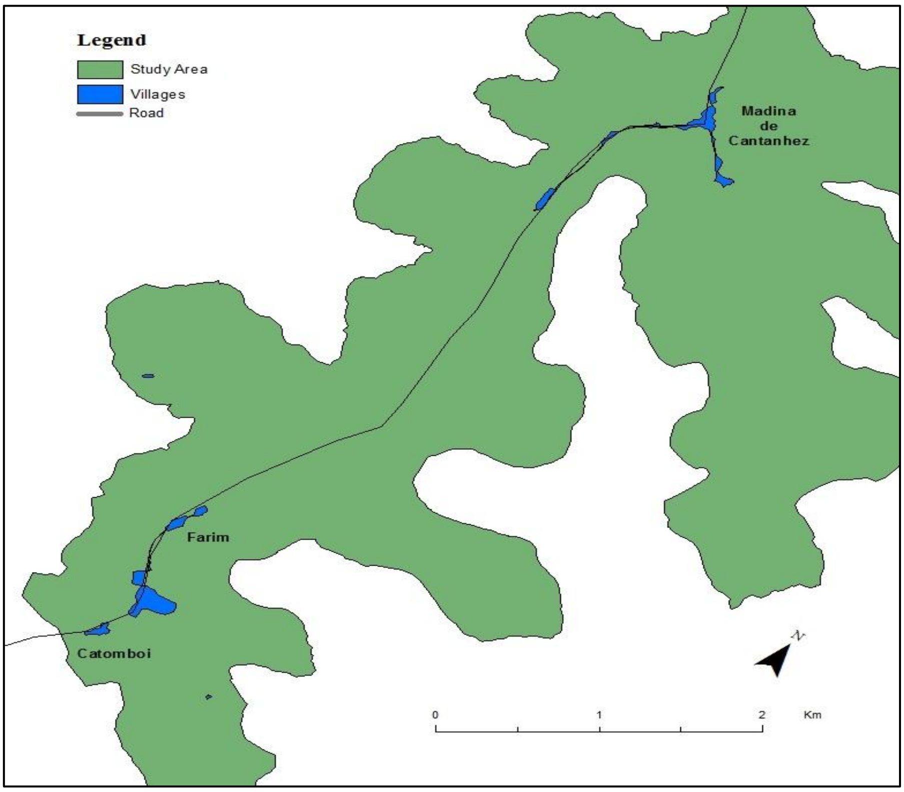


Figure 5. Location of Madina, Farim and Catomboi villages within the study area.

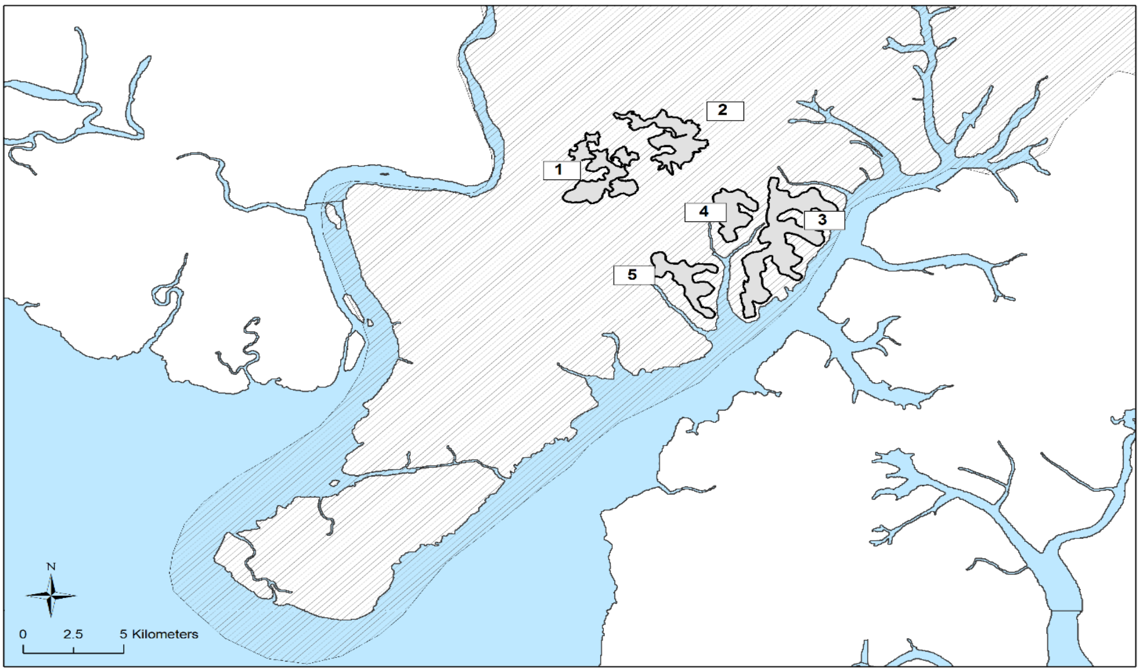


Figure 6. The forests of central-southern Cantanhez National Park in which chimpanzees inhabit; (1) Cadique and Caiquene, (2) Lautchande, (3) Camecote and Cambeque, (4) Madina, and (5) Catomboi (Hockings & Sousa 2013).

Madina has a population of about 286 inhabitants and 36 *moranças* (hereafter households). The number of people in each household is highly variable, ranging from 1 to 19 individuals. The average number of people per household is about eight individuals. In Madina there are households of different ethnic groups. Based on interviews with local people, about nine house households reported to be Fula; nine to be Mandinga; five to be Sussu; seven to be Balanta; and one to be Bágá. Within the same household, individuals of different ethnic groups can be present for several reasons including marriage. Its inhabitants depend mostly on agriculture for their livelihoods. Cashew nuts are taken to the neighbouring village of Iemberem to be sold. Likewise, other vegetables (e.g. *Abelmoschus esculentus, Capsicum frutecens*, *Cucumis sativus, Lycopersicum esculentum*, *Musa. sp*, *Solanum anguivi*) are sold to other *moranças* in Madina or in Iemberem. Other cultivated products (e.g. *Mangifera indica*) are used mainly for personal consumption but are sporadically sold.

2.2.4. Chimpanzees of Madina:

From opportunistic observations of chimpanzees, local reports, and the location of chimpanzee signs (including nests and faeces), Hockings and Sousa (2013) suggested that several chimpanzee communities live in the central-southern part of CNP, including in the Madina forest. During my stay in Madina I also observed the presence of chimpanzees near the village (Figure 7). Despite previous research on local people's perceptions about chimpanzees (see Sousa *et al.*, 2014a) and chimpanzee nesting behaviour and oil-palm use at Madina and other neighbouring areas (see Sousa *et al.*, 2011), to-date there has been no systematic research to understand the behaviour and ecology of chimpanzees at Madina.

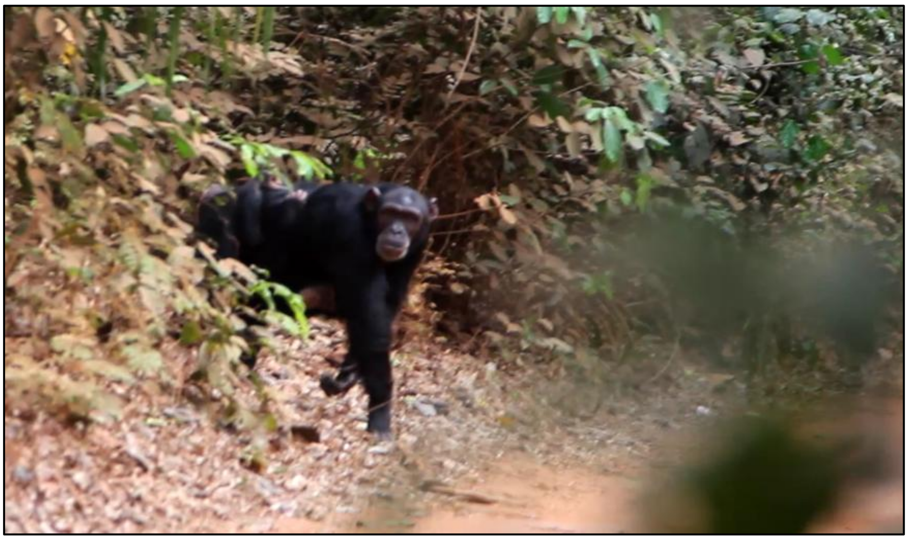


Figure 7. A female chimpanzee carrying an infant ventrally crossing the main road close to Madina village.

3. Study Methods

3.1. Overview of the methods:

To understand chimpanzee distribution and use of space in this anthropogenic habitat, I employed cross-disciplinary data collection methods. Firstly, I collected indirect data on chimpanzee feeding traces, faeces, and nests, as well as opportunistic observations of individuals within the study area at Madina and the neighbouring areas of Farim and Catomboi villages. I also mapped anthropogenic areas (i.e. agricultural areas, villages, and roads) in order to assess human modifications to the landscape, as well as the forest-agricultural matrix that the chimpanzees use as its habitat and evaluate how chimpanzees respond to those changes. Whilst mapping the landscape, I conducted interviews with the inhabitants of each *morança* (household) in Madina village to understand local peoples' use of wild and cultivated resources.

3.2. Study period

I collected data on the distribution and use of habitat by chimpanzees at Madina from the 18th February 2017 to the 26th May 2017, which coincided with the dry season. Data were collected 6 days a week, except in the cases of illness or religious holidays for the guides. I mapped the cultivated areas at the end of the slash-and-burn period in May as the perimeter of fields and orchards were more easily accessed. I also conducted the interviews in May when I had established relationships with local people and had a better understanding of Creole and local culture.

3.3. Chimpanzee habituation and visibility

The community of chimpanzees at Madina is unhabituated to researchers. Encounters between chimpanzees and local people occur on a daily basis, especially when chimpanzee's cross roads, and enter agricultural areas or the village to feed on crops. Although I occasionally encountered chimpanzees, I collected few data due to poor visibility or the difficulty of observing unhabituated animals that tend to flee or hide. Certain questions can only be answered through following habituated individuals; however, the objective of this study was not to habituate the community. The habituation process is time-consuming and raises ethical issues. It must be considered carefully, especially in human-influenced landscapes, where habituated chimpanzee communities might become more vulnerable to hunting and human diseases or lose their fear of people potentially increasing the likelihood of attacks on children (Hockings *et al*., 2010a).

3.4. Data collection

3.4.1 Mapping:

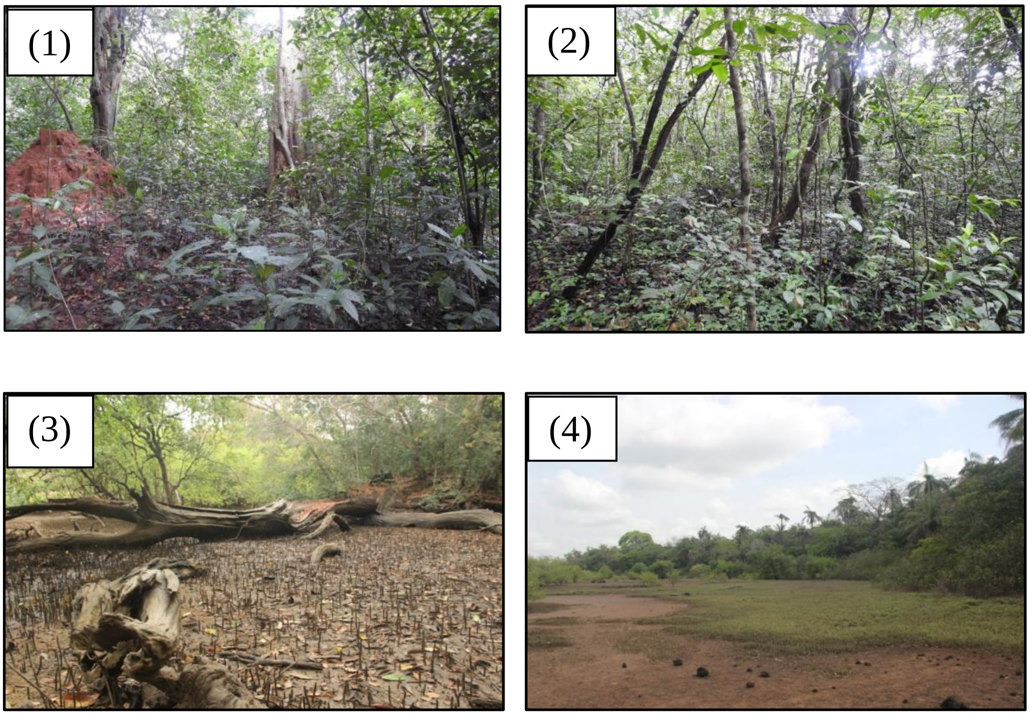
To understand habitat use by chimpanzees I created a GIS map of the study area (Madina, Farim and Catomboi villages), focusing on anthropogenic habitats including villages, roads and crop fields. I used a Garmin GPSMap 64s GPS device which can record automatic points by time or by distance. In order to generate the area of an anthropogenic habitat, I set the GPS device recoding geographic points each 30seconds. I then walked along the edges of the chosen area and the GPS generated a track. By finishing the track in the same place that I started, it is possible to create a polygon that represents the mapped area. I chose this setting because, due to relatively large cultivated areas and the difficulty of walking on the edges of fields, time recording are more accurate.

3.4.2. Interviews:

To understand people's use of the land, including their agricultural calendar, type of crops used by the different households and what resources people collect from the forest, I conducted interviews with 31 of the 36 households in the village of Madina (Albuquerque *et al*., 2014; Alexiades *et al*., 1996; Bernard, 2002). There were fewer interviews than households because some inhabitants, despite having their own house, belong to a different household. I conducted the interviews in Creoule; Guinea-Bissau Creole is the language used by the different ethnic groups to communicate with each other. I worked with a local translator, who was fluent in local languages for when it was necessary to use expressions in languages of the different ethnic groups. I wrote down and taped with the recorder all the interviews in order to guarantee the quality of the data collected. I also collected other information, such as the number of people from each household, as well as their ethnic group, and monetary income related with owning cattle. I also asked to people about where and time they usually encounter chimpanzees during the year. This information was not analysed in this thesis, although it was used to create a basic framework of Madina village in Chapter 2 (See interview questionnaire on Appendix I). Finally, I interviewed a local man with deep knowledge of the Madina history to understand the story of how the village was founded and the human occupation of the territory. This information was collected to better understand the arrival of people to the forest of Madina.

3.4.3. Distribution and presence

To understand chimpanzee use of space and habitat preference at Madina, I marked the location of every direct encounter or indirect sign (faeces, nests, feeding traces, foot and knuckle prints, and tool use) with a GPS (Nicolas *et al*, 2007). When evidence of chimpanzee presence was found, I categorised the immediate area into one of eight categories (Figure 8; Table 1). The definition of these categories was based in literature review, field observation, and ethno-ecozones (ecosystems locally identified) collected in this study.



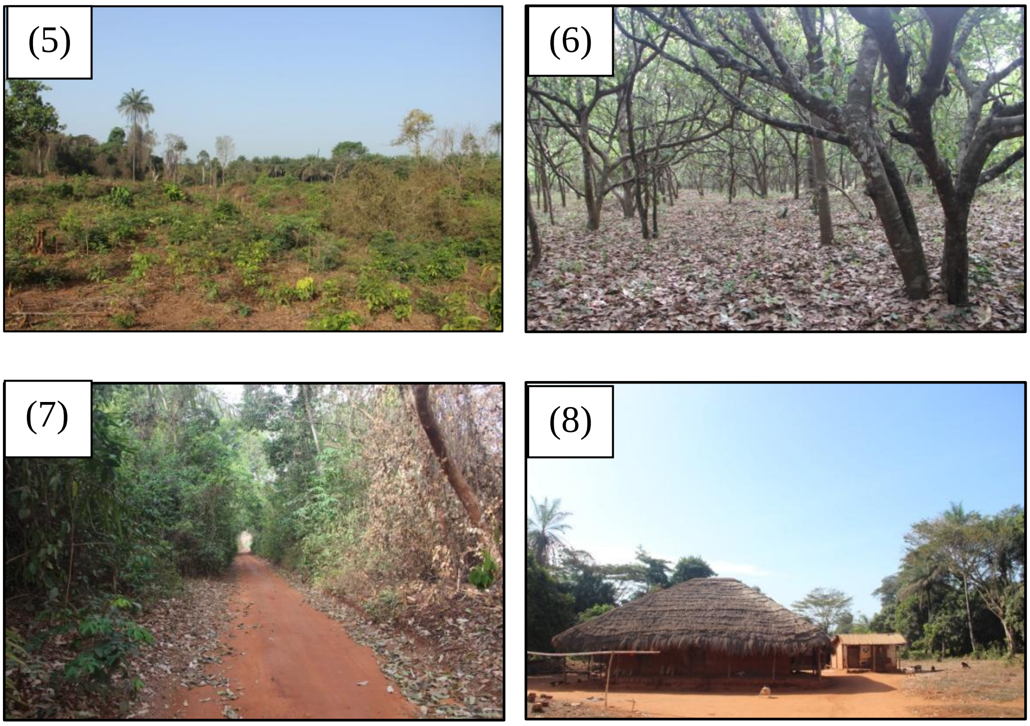


Figure 8. The eight habitat categories recorded at the study area: (1) mature forest, (2) secondary forest, (3) mangrove, (4) palm grove, (5) slash-and-burn field, (6) orchard, (7) road, or (8) village

Table 1. Characterization of the different habitat types

Habitat type	Characterization
1) mature forest	Closed forest, characterized by the high densities of large trees and native species such as *Pentaclethra macrophyla, Anisophyllae laurina, Ceiba pentandra; Alstonia congolensi; Dialium guineensis; Parinari excelsa; Strombosia postulate* (Catarino *et al*., 2012).
2) young forest	Open forest, characterized by the presence of small trees, bushes and small lianas. It is forest that might be recovering from human intervention. It is often close to roads, crops and forest edges (Catarino *et al*., 2012).
3) mangrove	Tidal areas characterized by the presence of mangrove tree species, including *Rhizophora racemosa and Avicennia germinans* (Frazão-Moreira, 2009).
4) palm grove	Usually present on the forest edge or the interface of the forest and mangrove or cultivated area within addition to the presence of young tree species and bushes, it is characterized by a

	predominance of oil-palm trees (*Elaeis guineensis*) (Catarino *et al*., 2012).
5) Field (created using slash-and-burn)	Cultivated area characterized by the presence of plant species that humans consume: e.g. rice (*Oryza spp*.); African eggplant (*Solanum anguivi*); tomato (*Lycopersicon esculentum*); peanut (*Arachis hypogaea*); Okra (*Abelmoschus esculentus*) and *Hibiscus sp.* Few or no tree species are present
6) orchard	Cultivated area characterized by the presence of tree species planted and used by humans including mango (*Mangifera indica*); Cashew (*Anacardium occidentale*); Lemon (*Citrus lemon*); Orange (*Citrus sinensis*); and Kola (*Cola nitida*).
7) road	A main road regularly used by pedestrians and vehicles.
8) village	A human settlement, with some species of cultivated species [including: Papaya (*Carica papaya*); Mango (*Mangifera indica*); Guava (*Psidium guajava*)] and wild plants that human consume including baobab (*Adansonia digitata*) and fig (*Ficus spp*.).

3.4.4. Faecal Sampling

I collected and analysed faecal samples following the methodology suggested by McGrew *et al*. (2009) and McLennan (2010) (see also Bessa *et al*., 2015). Chimpanzee faeces are distinguishable from those of other primate species by size, colour, form and odour (McLennan, 2013). Whenever several dung piles were found in the same area (usually along trails) and considered to be from the same individuals (e.g. same colour and age), I would collect only one sample to guarantee independence of the data (McLennan, 2010). Faeces are usually found on chimpanzee trails, under fresh nests or in recently used areas (McGrew *et al*., 1988). I collected only fresh samples (i.e. fresh (≤ 1 day) or recent (≤2 days)) and when decomposition activity by insects was not present. Then I placed all faecal samples individually in plastic cases (Figure 9a). I used these cases for transportation of the samples and to preserve it for later analysis. I was careful to remove any other external matter (e.g. twigs and leaves) from the faeces that was not part of the faecal matter (McGrew *et al*. 2009).

At camp, I transferred the faecal samples to a shelter, and washed the faeces every 2 days. Due to the inexistence of running water or streams, I used buckets of water to wash the faeces and the material. I used a 1mm mesh sieve to filter food matter from the faeces and a watering can, for a continuous flow of water. After washing away the soft matrix of the faeces and removing dung insects that might be present, I placed the faeces on a newspaper and analysed it while wet (Figure 9b).

I identified and separated different components: fruit (seeds and pulp); foliage (leaves, pith and bark); flowers (flower parts) and other (insects, honey, etc.). Each component of the faecal matter was rated at intervals of 5%. Whenever possible, I identified seeds species. Within the percentage of fruit in the faeces, I rated the different seed species at intervals of 5%. When the seed species were unidentified, I preserved a sample in 70% alcohol and/or dried them for further analysis. Due to size constrains, the analysis of this data will not be done in this thesis (See list of plant species found on feaces on Appendix II).

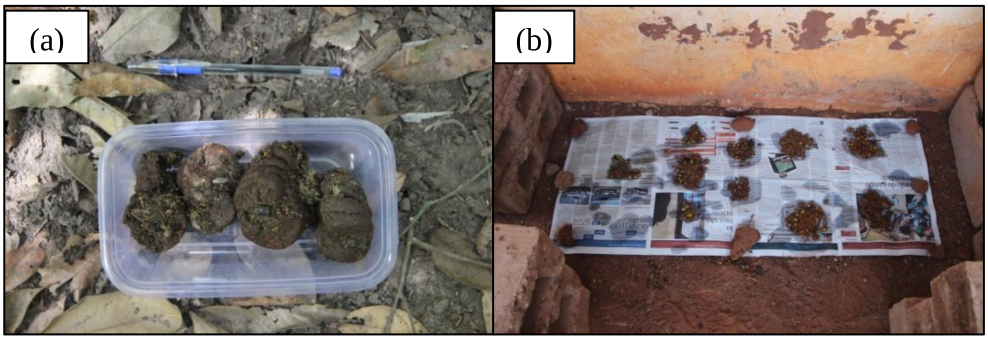


Figure 9. (a) Faeces collected in plastic cases for transportation; (b) faeces washed and placed on newspaper for analysis.

3.4.5. Feeding traces

I collected data on feeding traces when it was certain that the trace belonged to chimpanzees. The signs were identified with the help of the local guide who could distinguish them from those of other sympatric non-human primates. A sign was confirmed to belong to chimpanzees whenever they were associated with other evidence of chimpanzee presence (e.g. faeces; knuckle prints), or when it was associated to species-specific signs (e.g. fruit wadge, tool use) (see Figure 10 for a range of chimpanzee traces), or whenever it was known that an individual or a feeding party had been in the area recently (Pruetz, 2006; McLennan, 2010; Morgan & Sanz, 2006).

I only recorded feeding traces that were less than three days old, except when I found traces in new areas. For each feeding trace item, I recorded and marked the location with a GPS point. When I found several feeding traces of same age in the same location, that could be associated with larger feeding parties, I only recorded one GPS point, to assure independence of data points (McLennan, 2010). I took photographs of feeding remains of new plant species.

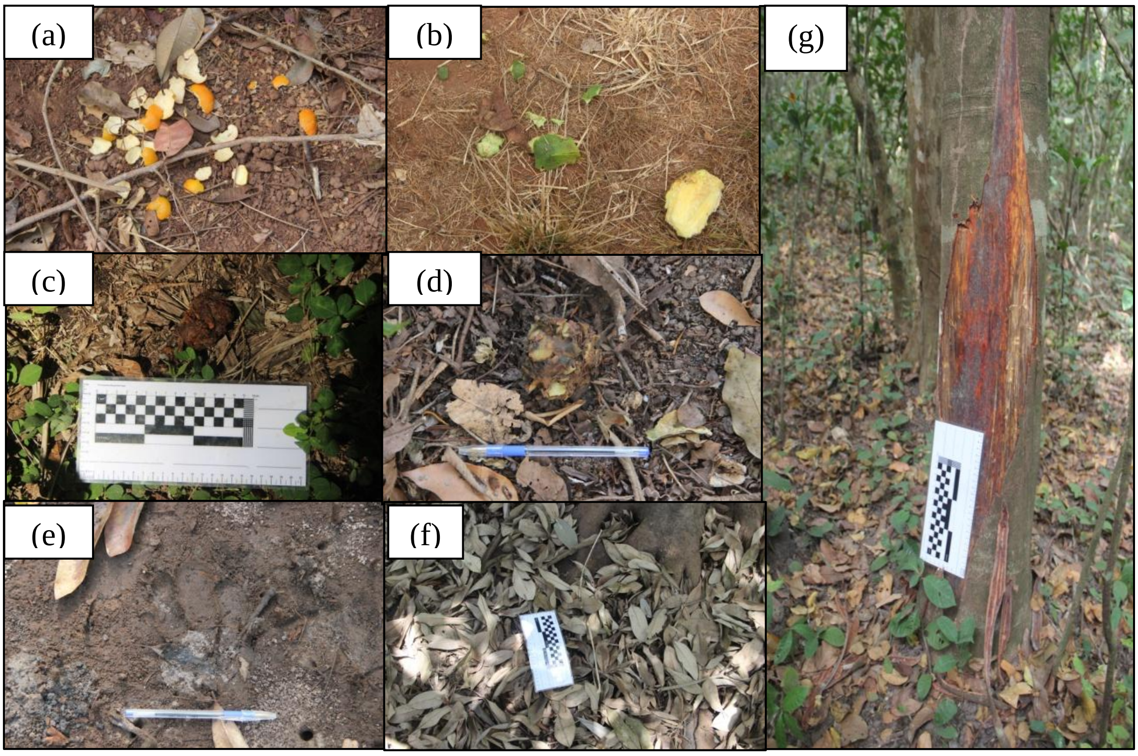


Figure 10. Different types of chimpanzee feeding remains and signs**.** (a) Orange feeding remains (*Citrus sinensis*); (b) Mango feeding remains (*Mangifera indica*); (c) Chimpanzee wadge (*Treculia africana*); (d) Chimpanzee wadge (*Parinari excelsa*); (e) Chimpanzee knuckle print; (f) Chimpanzee stick tool use sign (*Avicennia germinans*);(g) Bark feeding trace (*Dialium guineense*)

3.4.6. Nesting

Recording the geographical position of nests is a viable method to examine chimpanzee presence and distribution (Baldwin, 1982). I encountered nests opportunistically when walking across the chimpanzees' habitat. When I found a new nest, I would try to identify nest clusters. A nest cluster is a group of nests of the same age that lie within as radius of 30 meters (Furuichi *et al*., 2001). These clusters are likely to have been built by the chimpanzees on the same night. I marked one GPS point for each individual nest or for each identified cluster (Figure 11a, c). Along with nest age and locality, I also recorded the tree species in which the nest was present (Figure 11b). I was careful not to sample the same nest repeatedly by using previous GPS points to identify previously recorded trees.

Figure 11. Chimpanzee nests and nest sites. (a) an oil-palm nest (*Elaeis guinnensis*); (b) a chimpanzee nest in *Strombosia postulate*; (c) A cluster of oil-palm nests.

3.4.7. Opportunistic encounters:

Encounters with chimpanzees were mainly opportunistic. When a chimpanzee group was heard or whenever the group's location was known (e.g. local people’s reports), the research team would try to locate and follow signs left by the chimpanzees. Only when I was certain that I could get close to the chimpanzees without causing any stress to the individuals, did I try to approach the group. When a chimpanzee was found, I maintained an appropriate distance and reduce noise to a minimum (e.g. whispering conversation) to ensure minimal disturbance.

I mostly found chimpanzees in the forest, on human trails, in agricultural areas, while crossing roads, and close to the village. During each encounter, I took a GPS point and collected additional data such as the habitat type. When a chimpanzee was feeding and there was good visibility of the individual, I recorded the food type including plant species and which part of the plant was being eaten. I also recorded videos and took photos of the encounter, when possible.

4. Human activities by the habitants of Madina

4.1. Introduction

As in many places in Cubucaré, people from CNP rely mainly on agriculture to subsistence and as economic income (Cantanhez Management Plan, 2017). Rice cultures, oil-palm plantations and other cultivars such as cashew, pineapple, banana, potato, and maize, amongst others, are the main types of cultivars in the region (Verjans *et al*., 2000). The agriculture system was characterized as a 'mixed system' due the fact that both paddy-rice production and slash-and-burn agriculture are present (Anginot, 1988). In slash-and-burn agriculture, a given area is 'open' by a slash and burn process and agriculture is practiced in that area until the soil runs out of nutrients and a new area is open, leaving the previous area to fallow. (Verjans *et al*., 2000; Frazão-Moreira, 2009). Palm-oil and peanuts are important agricultural products that are commercialized by people (Frazão-Moreira, 2009). Along with these products, cashew nuts are an important cash-crop, being cultivated in several areas of CNP (Cantanhez Management Plan, 2007).

Madina inhabitants also practice all these types of agriculture. During the period of this study it was possible to observe the transformation of the landscape due to slash-and-burn agriculture, as well as the preparation of certain products for sale (e.g. production of palm-oil). Madina people economy also relies in other activities including cattle; and several species of plants found in the forest are used in human diet and are collected. The main objective of this chapter is to understand humans' use of space in Madina village and try to understand the nature of human-influenced changes on the landscape (the methods are explained in Chapter 3). Understanding the main cultivated plants and the main agriculture activities; the forest plant species that are collected; and peoples' perceptions of chimpanzees in Madina will help to create a framework of the landscape in which people and chimpanzees interact. I predict that cash-crops such as cashew orchards and peanut will prevail over other cultivar species due the fact that they are more valuable and a direct monetary income to each household.

4.2. Results

4.2.1. Agricultural activities

The data provided by the interviews was analysed mainly using descriptive methods. Due to qualitative nature of the data, this set of information is used mainly to describe peoples' use of the space, particularly related with cultivars.

From the 36 households present in Madina, 31 were interviewed. Overall, 55 orchards and 34 fields belong to people inhabiting in Madina. The number of orchards and fields per household were variable, ranging from none to four cultivated areas in both cases. However the majority of the households have two orchards and one field.

The number and type of cultivated plants was variable. In orchards, cashew is the most represented cultivar (n=27), followed by kola and lemon. Orange, mango and jackfruit are present in the same number of cultivars (Figure 12a). Some orchards were composed by different tree species. In these cases, 'mixed' orchards were treated in this research as a different type of cultivated orchards. The same pattern is observable on the fields. Fields have a high variety of different plant species that people use in their diet [e.g. beans; cassava; chilli pepper (*Capsidum frutecens*); cucumber (*Cucumis sativus*); okra (*Abelmoschus esculentus*); sweet potato; tomato (*Lycopertion esculentum*)]. However, this variety of cultivated species are present on the field of a main cultivated species, such has peanuts and maize. Thus, fields were categorized based the main species present. Fields composed by peanuts (n=6) are the most represented, followed by 'mixed' fields of rice and peanuts (Figure 12b). Although, during the time of the interviews, the majority of the fields wasn't open or burned. Despite this situation, some interviewed people stated that after burn the field they would plant peanuts and cashew trees (n=2); maize, beans and peanuts (n=1) or maize and cashew (n=1). An agricultural calendar of the main cultivated plants found in Madina was created (Table 2). This calendar is based on an interview with a key-informant. It was asked to this informant to state the months of cut and burn of the fields, and the sow and fructification of the main cultivated species. Despite other cultivars species may be present in orchards and fields; the calendar only covers the most represented species referred by the chosen informant during the interview

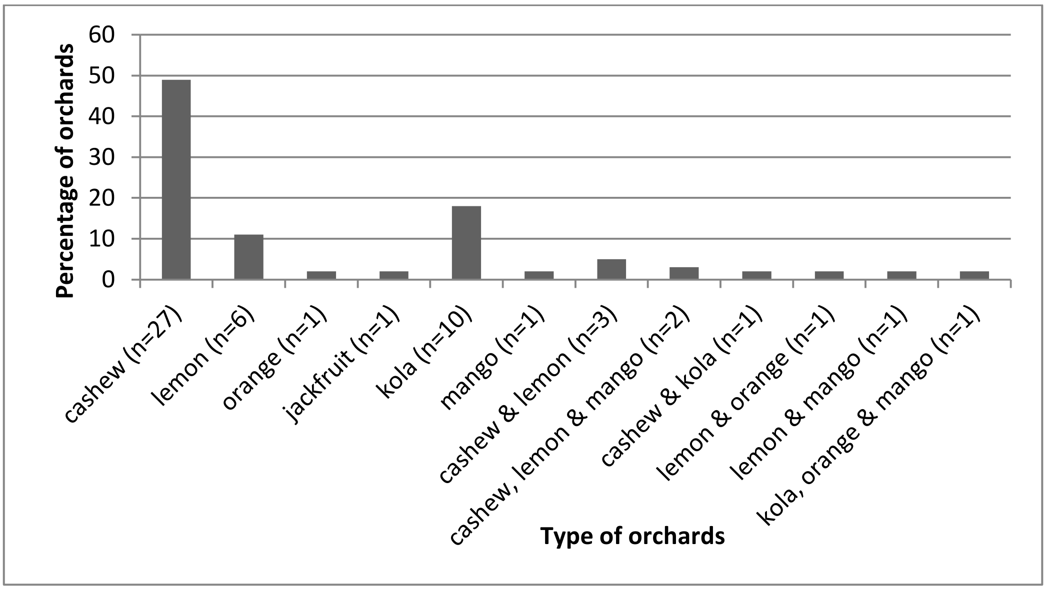


Figure 12a. Percentage of orchards owned by the people of Madina based on the interviews.

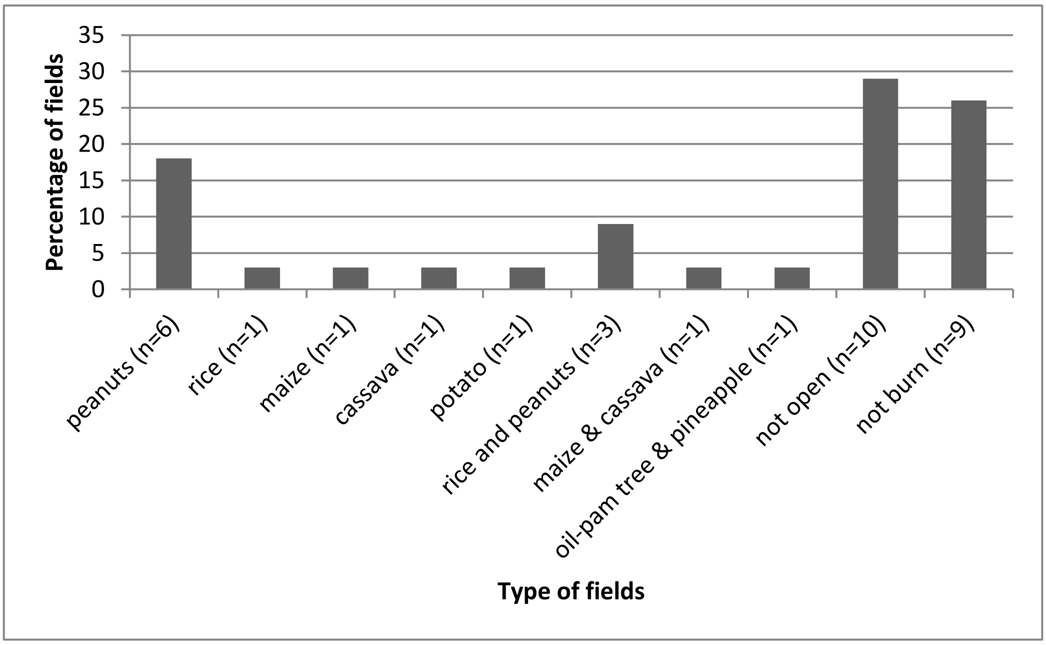


Figure 12b. Percentage of fields owned by the people of Madina based on the interviews.

Table 2. Agricultural calendar of the main cultivar plant species used by Madina people (n=18). Table was created based on formal interviews with a key- informant of Madina with great knowledge of the agricultural activities. Creole was used as lingua franca during the interviews, instead of languages of other ethnic groups. Creole names of the plants are shown in this calendar. ■= clear field; ▲= burn field; ●= sow; ▭ = fruiting period. Scientific names were based on information from Frazão-Moreira, 2009 and Bessa *el al*., 2015.

Plant species (Creole name; English name)	**Month**											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Plant species found in orchards												
***Anacardium occidentale* (Caju; Cashew)**		■			▲●	●	●					
				▭	▭							
***Artocarpus heterophylla* (Jaca; Jackfruit**		■			▲		●	●				
			▭	▭	▭	▭	▭					
***Carica papaya* (Papaia; Papaya)**							●	●				
	▭	▭	▭	▭	▭	▭						
***Citrus cinensis* (Laranja; Orange)**		■			▲		●	●				
					▭	▭	▭	▭	▭			
***Citrus lemon* (Limon; Lemon)**		■			▲		●	●				
	▭	▭	▭									
***Cocos nucifera* (Coconete; Coconut)**	●	■●	●	●	▲●	●	●	●	●	●	●	●
	▭	▭	▭	▭	▭	▭	▭	▭	▭	▭	▭	▭
***Cola nitida* (Cola; Kola)**							●	■●				
	▭	▭	▭	▭	▭							
***Elaeis guineensis* (Chebem de granja; Oil-palm tree)**		■			▲		●	●				
	▭	▭	▭	▭	▭	▭	▭	▭	▭	▭	▭	▭
***Mangifera indica* (Mango; Mango)**		■			▲		●	●				
	▭	▭	▭	▭	▭							
***Persea americana* (Abacate; Avocado)**	■	■			▲		●	●				
								▭	▭	▭		
***Psidium guajava* (Goiaba; Guava)**		■			▲		●	●				
	▭	▭	▭									
Species found in fields												
***Ananas comosus* (Ananás; Pineapple**		■			▲		●	●				
				▭	▭	▭						
***Arachis hypogaea* (Mancarra; Peanuts)**			■	■	▲		●	●				
										▭	▭	
***Ipomoea batatas* (Batata; Sweet potato)**	■	▲●	●	●								
							▭					

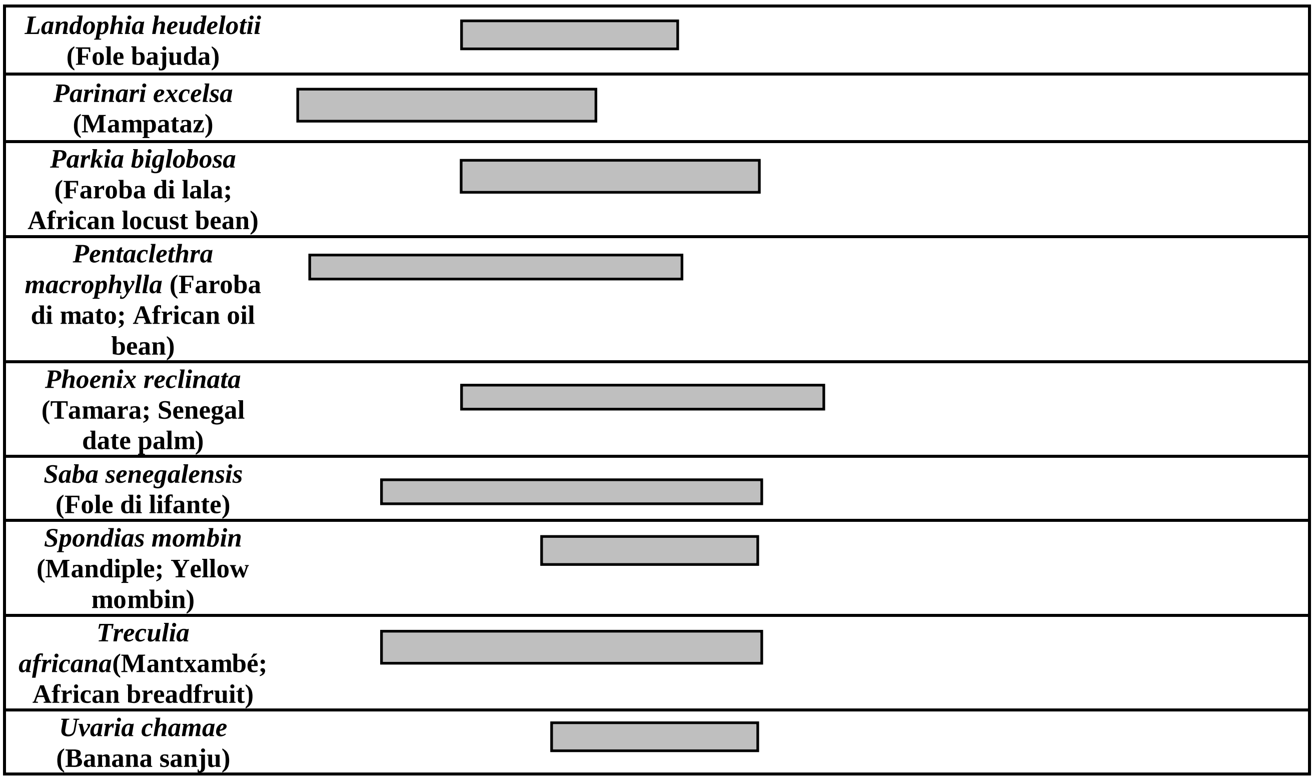
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
***Manhiot esculenta* (Mandioca; Cassava)**		■			▲●					█	█	█
***Oryza sativa*(Arroz; Rice)**		■			▲	●				█	█	
***Phaseoulus cylindricus* (Feijão mancanhe; Beans)**					■▲			●			█	█
***Zea mays* (Milho bacilo; Maize)**		■			▲●	●				█	█	█

4.2.2. Other economic activities and use of forest resources

Fishing is also part of the monetary income of some families (per. obs). Fishermen sell fish to other *moranças* in Madina or to people in other villages. Most of the people have cattle, mainly goats (*Capra aegagrus hircus*) or own chickens (*Gallus gallus domesticus*). The Balanta people of the village also have pigs (*Sus scrofa domesticus*). Goats and pigs are primarily used for monetary income, but can be consumed on specific occasions (e.g. religious festivals). During the interviews, people also stated that they use some of the forest plant resources to consume forest resources (e.g. velvet tamarind; monkey apple) (Table 3) and use certain tree species as construction material (e.g. oil-palm tree). A fructification calendar was created using the plant species consumed by people that are also present on chimpanzees' diet. An interview with a key-informant helped to create this calendar.

Table 3. Fruiting period of forest plant species consumed by people at Madina (n=14), based on formal interviews. All the plants are known as being part of the chimpanzee diet at Caiquene-Cadique (Bessa *et al.*, 2015).

Plant species (Creole name; English name)	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
***Anisophyllea laurina* (Miséria; Monkey apple)**		█	█	█	█							
***Borassus aethiopum* (Cibe; Borassus palm)**	█	█	█	█	█	█						
***Dialium guineense* (Veludo; Velvet tamarind)**		█	█	█	█	█						
***Elaeis guineensis* (Chebem; Oil-palm, tree)**	█	█	█	█	█	█	█	█	█	█	█	█
***Ficus sp.*(Fogueira; Fig tree)**		█	█	█	█							



4.2.3 Human perceptions of chimpanzees

Several formal and informal conversations with local people confirmed that they see chimpanzee on a daily basis. During interviews with the local community of Madina, several statements help to understand aspects of peoples' perceptions toward chimpanzees. Some sentences were transcribed from the interviews in order to create a framework about what people in Madina think about chimpanzees.

Some interviewees pointed out physical characteristics of chimpanzees and referred to a common past between humans and chimpanzees:

- *Chimpanzees walk on two feet. God gave the house to humans, but left chimpanzee in the forest* (Buassa Nagnhaba, May 2017).
- *Monkeys have a tail, but chimpanzees don't. Chimpanzees are like humans. Those were ancient people that denied God* (Foda Nanthchamba, May 2017).

Local people also talked about the time and the place that they saw chimpanzees, showing knowledge about chimpanzee ecology and behaviour:

- *I see chimpanzees crossing when I am cutting my field. In March, April and May we can see them more often. I see them in groups* (Ibraima Cantê, May 2017)
- *I saw chimpanzees close to my crop feeding on mampataz* (Yaguba Camará, May 2017).

- *Chimpanzees come to Madina in May to feed on mango* (Yaguba Silá, May 2017);
- *I see them cross the road. They come to the* tabanka *(village) to feed on papaya* (Mariama Turê, May 2017);
- *I see chimpanzees on the paths, but if they see humans they runaway* (Safietu Bangurá, May 2017).

People also stated chimpanzee behaviour in some of the fruit-crops and cash-crops:

- *In March chimpanzees come to the crops. They break cashew tree branches and lime tree branches* (Yaguba Camará, May 2017).
- *Chimpanzees come to the cashew crops. They eat cashew and break the branches. When they finish eating, they leave the cashew nuts on the ground* (Foda Nantchamba, May 2017).

One important aspect was stated by some of the older people in Madina that reflects the changes that these human environments go through:

- *In the past there were chimpanzees, but nowadays it's easier to see them because there are more, but there are more people as well* (Ussumani Silá, May 2017).

4.3. Discussion

The results of the interviews confirm the first prediction. The main plants cultivated by Madina people are cashew and peanuts, both cash-crops. Cashew nuts are sold by the Madina people in the village of Iemberem and then the nuts are transported to Bissau (per. obs). According the interviews, several 'mixed' orchards are composed by cashew trees along with other tree species. Some of the interviewed people also showed interest in planting cashew trees on their fields, or already have them planted. The majority of the fields were yet to be open and burn by the time of the interviews and people stated different cultivars that they intend to plant after clear the field. Most of them stated that they would plant peanuts, maize and cassava. Although, it was also stated that they will plant cashew in that fields as well. This means that in one or two years, the present fields will turn into orchards of cashew. The agricultural calendar also showed that this study occurred during the period of higher agricultural activity. In the end of the rainy season, most of the crops are opened and in May it is the period of burning the fields that were open.

After the analysis of the results, it is important to understand the role of cashew trees on the human-induced changes that are occurring on this landscape. As previously stated on Chapter 2, Guinea-Bissau economy relies heavily in the exportation of cashew nuts. The demand of this product it is leading people on these communities, particularly in CNP, to change the cultivar species that they use to plant and increase the plantation of cashew trees due to its relatively easy and fast monetary income. The monetary importance of cashew nuts leads to the expansion of this cultivar throughout CNP (Cantanhez Management Plan, 2017). The process of 'transition' from some cultivar species to the plantation of cashew may cause some changes in the present agricultural system. With time, local people may start to abandon the slash-and-burn system that allows the rotation of the cultivated area and the recovery of the forest during the time of fallow, to a perpetual occupation space by the cashew orchards.

It is known that chimpanzees feed on the cashew pseudo-fruit (Bessa *et al.*, 2015). Despite that, previous research and formal and informal conversations with local people in Madina stated that during crop-foraging chimpanzees use to leave the valuable cashew nut on the ground after finish eating (Hockings & Sousa, 2012). The tolerance of humans toward chimpanzees feeding on this cashew remains not only because the cultural beliefs (Sousa & Frazão-Moreira, 2010) but also due the differential utilization of this tree. However, Madina people also reported that chimpanzees use to break the cashew tree branches while trying to feed, which may represent a loss of production during that year. By now this is a low-conflict interaction, but the future is uncertain. During the study period, the price of cashew nuts increased, making it more valuable to people. Also, the increasing demand of this product may cause that new forested areas will be open to cashew plantation and that the process of soil recovery on slash-and-burn agriculture may stop, with new areas being open when the soil runs out of nutrients.

The interviews with Madina inhabitants also help to better understand interactions between humans and chimpanzees. Every day, chimpanzees and people use the same habitats and interact with each other, in the cultivated fields and in the forest. More than that, both species exploit similar forest resources. The fructification calendar of forest plant species showed that this study occurred in a time of higher fruit availability. That may cause that during these time of the years, chimpanzees and people interact more often with each other. However, human environments are dynamic and are likely to change in the future. To understand the potential for chimpanzees to persist at this site in the long-term, we need to better understand how they are using the mosaic of habitats and the nature of their interactions with local people. Peoples' perception of chimpanzees and the habitat in which they live may change due the dynamic changes caused by social and political factors in human-influenced environments. In the future, increasingly valuable cashew nuts and the shrinking of forested habitats may change peoples' interactions with wildlife, particularly with chimpanzees. Although, this changes are difficult to predict by now.

That was a brief analysis of the agricultural activities in Madina that helps to create a spatial and temporal framework of the landscape in which chimpanzees and humans coexist. Although, the interviews were focused on the population of only one village and it is possible that the chimpanzees that inhabit in Madina also move close to other villages to forage. More research in other parts of chimpanzee home range is needed to fully understand people activities and the changes that occur on the habitat in which chimpanzees and humans inhabit.

5. Distribution and home range size of the Madina chimpanzee community

5.1 Introduction:

Home range is defined as the area that an animal uses over a period of time for its daily activities, such as foraging and resting (Burt, 1943). Home range size can change daily, seasonally or yearly (Newton-Fisher, 2003). In mammals, home range sizes are typically influenced by animals' energetic expenses and food intake, which are impacted by environmental conditions (e.g. climate) and habitat type (McNab, 1963; Wingfield, 2005; Börger *et al*., 2006). In tropical forests, food availability is highly seasonal and is influenced by temperature, rainfall and sun radiation (Chapman *et al.*, 1999; Chapman *et al.,* 2005). Thus, the seasonal and temporal availability of food may impact a species use of space and their population densities within a habitat (Chapman & Chapman, 1999).

In addition to ecological factors, the ranging and habitat use of primates can change according to anthropogenic factors. Deforestation, habitat degradation and human population growth, have resulted in many primate populations being forced to adapt to forest-agricultural mosaics (Estrada, 2013; McLennan *et al*., 2017). In less disturbed habitat, ecological constraints theory predicts that food availability determines animals' group size, in which the low availability of food leads to the creation of smaller groups in order to avoid within-group feeding competition (Chapman *et al*., 1995; Gillespie & Chapman, 2001). Therefore, when habitat quality and food resources diminish, primates tend to have larger home range sizes, and spend more time moving [e.g., *Cebus capucinus* (McKinney, 2011); *Macaca fascicularis* (Sha and Hanya, 2013)]. On the other hand, primate species living in mosaic agricultural-forest landscapes often show smaller home range sizes, moving across smaller areas to satisfy their nutritional needs [e.g., *Cercopithecus albogularis labiatus* (Nowak *et al*., 2017); *Chlorocebus pygerythrus* (Saj *et al*., 1999); *Lemur catta* (Gabriel, 2013); *Papio cynocephalus* (Altmann & Muruthi, 1988); *Papio ursinus* (Hoffman & O'Riain, 2011); *Pongo abelli* (Campbell *et al*., 2011a, 2011b)].

Chimpanzees exhibit high fission-fusion social organization (Lehmann & Boesch, 2004). They spend most of the time in small parties that vary in composition, with all individuals of the same community sharing a common home range (Goodall, 1986; Wrangham, 1986; Lehmann *et al*., 2007). As large-bodied ripe fruit specialists (that also include other food parts in their diet such as leaves, piths, flowers, tubers, as well as animal meat, insects, and honey), their home ranges are usually large compared to other non-human primates. Estimates of chimpanzee home range size usually range between 10km^2 and 40km^2 (Amsler, 2009), but can be highly variable, from 3.1 km^2 in the Taï Middle community (lowland forest, Ivory Coast) (Herbinger *et al*., 2001) to 63 km^2 in the Fongoli community (savannah habitat, Senegal) (Pruetz & Bertolani, 2007).

Chimpanzees can live close to human settlements and use cultivated foods as part of their feeding strategy [e.g., Bossou in Guinea (Hockings *et al*., 2009); Bulindi in Uganda (McLennan, 2013); Cadique-Caiquene in Guinea-Bissau (Bessa *et al*., 2015)]. Cultivated foods are clumped in distribution, nutrient rich, and easy to digest (Loudon *et al*., 2006a). Cultivated fruits represent an important source of easily digestible carbohydrates (such as sugar) and are used to supplement natural diets (McLennan & Ganzhorn, 2017). Little is known about chimpanzee ranging in anthropogenic habitats. Although untested, it is possible that chimpanzees inhabiting forest-farm mosaics will have smaller home ranges than their counterparts living in less disturbed areas as they have access to high quality crops thereby increasing the foods available within an area, but their home ranges might be constrained due to roads, settlements and large agricultural areas.

To determine the extent that chimpanzees can survive in human-influenced environments we must understand all aspects of their behavioural flexibility. By testing the validity of different analytical techniques to examine the home range size of a chimpanzee community inhabiting an anthropogenically impacted habitat, and then comparing this with other communities inhabiting different habitat types with varying degrees of anthropogenic exposure, we can better understand how chimpanzees are responding to human-induced rapid environmental change.

Several methods are used to examine chimpanzee home range size and distribution, but results vary according the methodology used (Bertolani, 2013; Montanari, 2014). The Minimum Convex Polygon (MCP) method is the most frequently used to calculate home range size (Hayne, 1949; Powell, 2000). It is a simple non-statistical method that encloses a data set of GPS points to create a polygon with the internal angles lower than 180º, producing an empirical estimate of the home range size (Mohr, 1947). This method is 'assumption free', being considered the best alternative to comparisons between different studies (Harris *et al*., 1990). However, MCP presents several disadvantages. By only using the peripheral points, it may be severely biased, influencing the creation of the polygon and causing it to incorrectly represent the use of space by the animals. (Harris *et al*., 1990; Barg *et al*., 2005). Also, if the species home range is an irregular shape, as is the case in many human-impacted habitats, it may include areas that the animals are not using, thus overestimating their home range. This can be avoided by deleting a percentage of the most peripheral points and decreasing its influence on the resulting home range size (Bertolani, 2013). Importantly, this method does not provide information on the use of space inside the polygon (Harris *et al*., 1990).

The Kernel Point Density method (Kernel analysis) has been suggested as the most accurate to calculate home range size (Seaman and Powell, 1996; Worton, 1987, 1989, 1995). It is based on the concept of Utilization Distribution (UD) (Van Winkle, 1975), working with the probability of finding a certain animal in a certain place. Thus, the main function of Kernel analysis is not to give an area, but to create a probability of finding a positional point. The home range area is then calculated by high percentage isopleths (95%, 99%). This method indicates the intensity of the use of an area, uniting a finite set of location points into a continuous surface. To use this analysis, all data points must be independent.

In some cases, both methods can give similar home range estimates helping to better explain chimpanzee home range size (Newton-Fisher, 2003). However, the effectiveness of each method has not been examined for chimpanzee communities inhabiting anthropogenic habitats. Along with calculating the home range size, these methods can also calculate core range areas. Within an animal's home range, core areas are identified as places intensively used and defended by the territory owners (Herbinger *et al*., 2001). In studies with mammals a percentage of 50% is often used to calculate core areas size (Harris *et al*., 1990), although for chimpanzees, the percentage is higher (for example between 75% and 80%: Wrangham & Smuts, 1980; Herbinger *et al*., 2001; Newton-Fisher, 2003).

Most previous research on chimpanzee home ranges and habitat use has been conducted on habituated communities. As this study focused on an unhabituated chimpanzee community, some adaptations were made to suit the assumptions of the home range analysis methods, particularly for the independence of data points in Kernel analysis (Swihart & Slade, 1985; Worton, 1989). For habituated chimpanzee communities, the animals are followed and their locations are systematically sampled, ensuring the independence of data points (Newton-Fisher, 2003; Amsler, 2009; Bertolani, 2013). During travel one position can influence the next, meaning that data points are temporally and spatially correlated. However, during follows there are two ways to ensure independence of data points and calculate time-to-independence: a biological method (Lair, 1987) and a statistical method (Swihart & Slade, 1985). The biological method calculates the time necessary for the animal to go from one given location to any other location within the home range, based the speed of travelling of the chimpanzees. The statistical method estimates the time-to-independence based on the distribution of timed locations collected [e.g. 5 minutes (Bertolani, 2013)]. This method, based on empirical observations of chimpanzee movements and activities, calculates the minimum time delay by which two consecutive observations must be separated, creating a sub-sampling of data-points that reduces autocorrelations (Bertolani, 2013). In contrast, in research of unhabituated chimpanzee communities, follows of animals are not conducted and data-point collection relies mostly on indirect evidence of chimpanzee presence in a given area (McLennan, 2010). The independence of data points can be ensured by marking only one GPS location if a clump of traces of the same age are found in the same place (McLennan, 2010).

There are ongoing debates as to whether analysis of ranging patterns require independent data points (Herbinger *et al*., 2001, Netwon-Fisher, 2003) or if it is negligible (Solla *et al*., 1999; Barg *et al*., 2005; Blundell *et al*., 2001). Montanari (2014) showed that home range estimates for the Seringbara unhabituated chimpanzee community (at Nimba in Guinea) are influenced by sample size, in which MCP is highly influenced by sub-sampling but Kernel analysis is not. Thus, it is suggested that all data points should be used in order to get a better understanding of chimpanzee home ranges (Amsler, 2009; Montanari, 2014).

Along Kernel analysis, other statistical analysis can be used to calculate UD such as the Fourier's transformation (Anderson, 1982) and the harmonic mean (Dixon & Chapman, 1980). Some studies about chimpanzee home range sizes used Fourier's transformation instead of Kernel analysis (Herbinger *et al*., 2001). However these methods are analogous. Since both are used to calculate areas and UD based on high percentages of isopleths (e.g. 95%) their results can be used together to be compared with other methodologies of home range size estimate (Bertolani, 2013). Due to this they will be treated as Kernel analysis in this thesis.

The aim of this chapter is to compare two commonly employed methods for calculating home range size in primates (MCP and Kernel analysis), and determine their effectiveness in calculating the home range size and core areas of an unhabituated chimpanzee community inhabiting an anthropogenic landscape at Madina, Guinea-Bissau. In addition, the results of home range analysis were compared with other chimpanzee communities' home range sizes and community sizes. The methodology used has been described in Chapter 3.

5.2. Data analysis:

All spatial data were saved and analysed in Garmin BaseCamp. Maps were created using ArcGIS 10.3.1 software. Two techniques were employed to calculate the Madina chimpanzee community's home range size: MCP and Kernel analysis. MCP and Kernel analysis were calculated using HoRAE toolbox of OpenJUMP software. The areas of the polygons were calculated using ArcGIS 10.3.1 software. Home range calculations with MCP used 100% of data points and Kernel analysis used 95% of the data points (Powell, 2000). To calculate core areas, different percentages were used in both methods. For calculation of core areas, 50%, 75% and 80% of the data points collected were used. These percentages were chosen to aid comparisons with other home range studies on chimpanzees. A *Spearman's Rank correlation* was used to examine the relationship between community size and home range size of different chimpanzee study sites. Correlation analysis was done using Rx64 3.4.1 program and Microsoft Excel tool.

5.3. Results:

5.3.1. Chimpanzee home range size at Madina

The estimated study area of Madina, Farim and Catomboi is approximately 16.1 km^2, of which 3.3 km^2 (20.5% of total area) is classified as anthropogenic (including villages and cultivated areas) and 12.8 km^2 (79.5% of total area) are classified as ‘natural’ habitats (including mature forest, young forest, palm groves and mangrove). The use of the terms ’natural’ habitat and ’anthropogenic’ habitat results from the need to distinguish habitats that have been extensively transformed by human action from those where human presence and action changes over time. This does not mean that some of the habitats considered in this study as "natural" are not the result of human action, such as young forests, or that they are not periodically and temporarily occupied by humans, as in the case with palm groves. As most farmers use a slash-and-burn system for cultivation, cultivated areas are changing, and the landscape is reconfigured from year to year. Thus, the division between natural and anthropogenic habitats described in this study only concerns the situation observed in this year, and in reality, the degree of anthropogenic impact lies on a continuum. Chimpanzee traces were found across natural and anthropogenic parts of the study area (Figure 13). The map shows a highly fragmented forest habitat, with the study area divided by a main road which is frequently used by pedestrians and vehicle traffic and at least 174 cultivated fields.

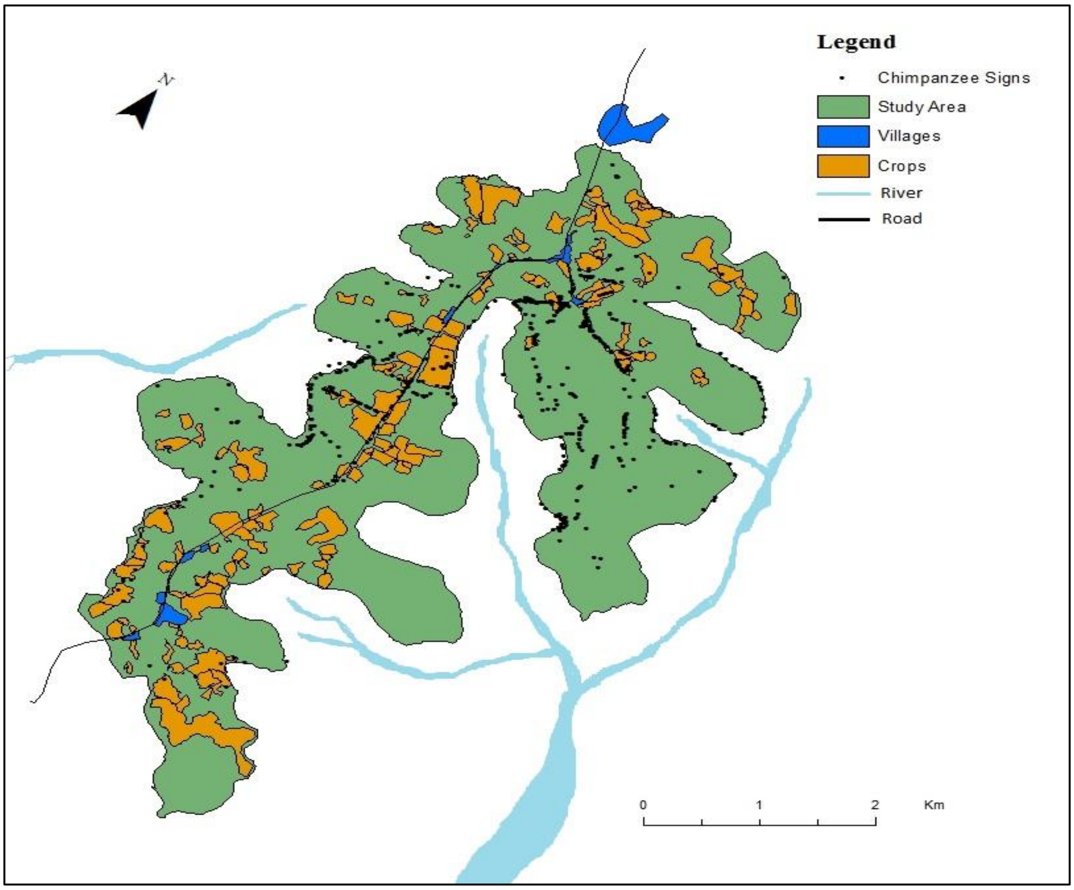


Figure 13. Map of the distribution of the chimpanzee signs (Nest sites, Feeding Traces, Faeces, Knuckle prints, Tool use and direct observations of individuals) across the study area. The map also shows the location of the villages and the cultivated areas.

MCP and Kernel analyses produced very different estimates of the Madina chimpanzees' home range and core areas. MCP estimated their home range size as 19.23 km^2, and kernel analysis calculated a value of less than half that size: 8.93 km^2. Core areas estimations ranged from 1.76 km^2 to 6.24 km^2, covering an area from 14.8% to 54.7% of the total home range (Table 4). Home range and core area results are shown in Figures 14a and 14b.

Table 4. Home ranges calculated using MCP (100% of the data) and Kernel analysis (95%). Core areas calculated with MCP and Kernel analysis, using 50%, 75% and 80 % of data.

	Home range	**50%**		**75%**		**80%**	
	Km^2	Km^2	%	Km^2	%	Km^2	%
MCP	19.23	2.85	14.8	5.57	28.9	6.24	32.4
Kernel	8.93	1.76	19.7	4.16	46.5	4.89	54.7

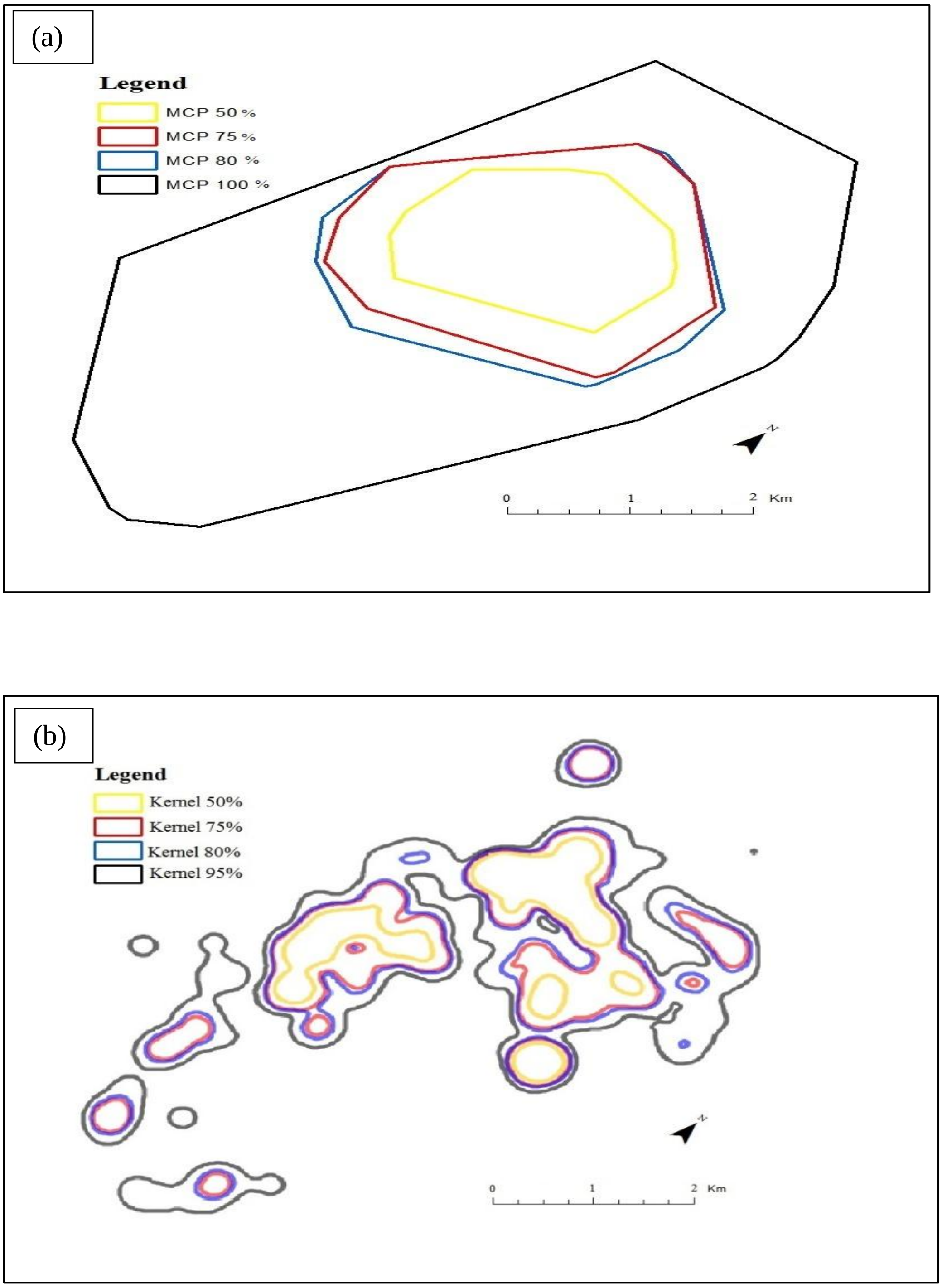


Figure 14. (a) Home range calculated with MCP with 100% of data. Core areas calculated using 80%, 75% and 50% percentages. **(b)** Home range calculated with Kernel analysis with 95% of data. Core areas calculated using 80%, 75% and 50% percentages.

5.3.2. A comparison of chimpanzee study sites

The results of Madina chimpanzees' home range sizes were compared with other chimpanzee study sites (Table 5). A table was created showing different characteristics of the different sites and the methods of home range analysis employed. Kernels analysis and Fourier's transformation (FT) are analogous statistical methods to estimate UD. As in other studies (Bertolani, 2013) the results presented by both analyses will be treated together in order to be compared with other methods. In this dissertation, Kernel analysis and Fourier's transformation will be treated simply as 'Kernel analysis'.

Table 5. Home range sizes of different chimpanzee communities. Different studies employed different methods to calculate home range sizes, including Minimum Convex Polygon (MCP); Kernel (K) analysis, Fourier's transformation (FT) and Grid Cell (GC) methods. All Kernel analyses were made using 95% of the data collected (adapted from Bertolani, 2013). Degree of anthropogenic exposure was categorised as Low, Medium, or High according to site disturbance scores for long-term research sites in Hockings et al. 2015. Based on ratings of 4 different disturbance variables where 1 represents minimum disturbance and 4 represents maximum disturbance for each variable (i.e. disturbance scale of 4 to 16), we classify Low as from 4 to 7 points, Medium as 8 to 11 points and High as 12 to 16 points. Where sites are not included in analyses by Hockings et al. 2015, we estimate anthropogenic exposure levels based on information presented in the associated research article. The community size and the home range sizes of different chimpanzee communities were positively correlated and these values were used to estimate Madina chimpanzees' community size.

Study site	Study Period	Country	Habitat	Anthrop. exposure	Level of habituation	Comm. size	Home range (Km^2)	Method	Reference
Budongo	1994-1995	Uganda	Disturbed moist forest	Med	Habituated	42	6.7	MCP	Newton-Fisher, 2003
							6.8	K95	
Gombe	1975-1992	Tanzania	Disturbed moist forest	Med	Habituated	51	11	MCP	Williams *et al.*, 2004
Tai North	1996-1997	Ivory Coast	Undisturbed moist forest	Low	Habituated	35	16.8	MCP	Herbinger *et al.*, 2001
							7.5	FT95	
Tai South	1996-1997	Ivory Coast	Undisturbed moist forest	Low	Habituated	63	26.5	MCP	Herbinger *et al.*, 2001
							9.5	FT95	
Tai Middle	1996-1997	Ivory Coast	Undisturbed moist forest	Low	Habituated	11	12.1	MCP	Herbinger *et al.*, 2001
							3.1	FT95	
Ngogo	2003-2006	Uganda	Disturbed moist forest	Med	Habituated	143	27.7	MCP	Amsler, 2009
							19.5	K95	

Kanyawara	2007-2009	Uganda	Disturbed moist forest	Med	Habituated	48	27.4 16.2	MCP K95	Bertolani, 2013
Nimba	1 year	Guinea	Disturbed moist forest	Low (est)	Unhabituated	100 estimate	29 35.7	MCP K95	Montanari, 2014
Madina	**2017 (4 months)**	**Guinea-Bissau**	**Disturbed moist forest**	**High (est)**	**Unhabituated**	**-** **-**	**19.2** **8.9**	**MCP** **K95**	**This study**
Kahuzi	5 years	Democratic Republic of Congo	Undisturbed montane forest	Low	Semi-habituated	20	12.8	GC	Basabose, 2005
Fongoli	2001-2004	Senegal	Undisturbed savannah-woodland habitat	Low	Semi-habituated	32	63	-	Pruetz, 2006
Cadique-Caiquene	9 months	Guinea-Bissau	Disturbed moist forest	High (est)	Unhabituated	35	7.93	-	Bessa *et al.*, 2014

It was not possible to determine the chimpanzee community size at Madina from opportunistic observations during the research period. However, as there was a positive correlation between chimpanzee community size and home range size calculated using Kernel analysis across chimpanzee sites (*Spearman's rank correlation* Kernel analysis: *rs*=0.8, n=7; p<0.05) but not MCP method (MCP: *rs*=0.6, n=8; p=0.08), community size at Madina can be estimated as approximately 48 individuals (Figure 15).

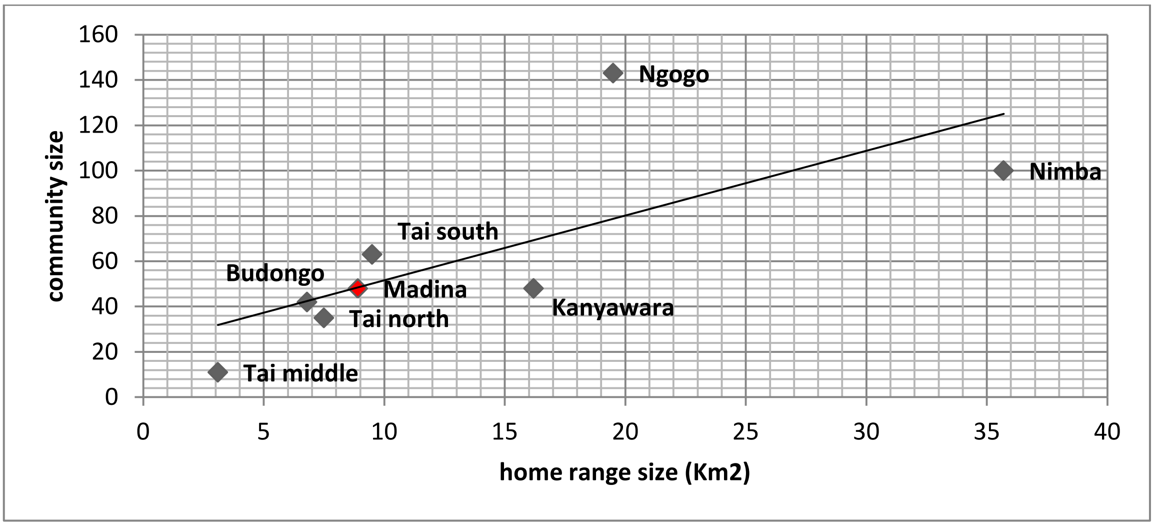


Figure 15. Chimpanzee community size and home range size calculated with Kernel analysis 95% from previously published research at seven sites (see Table 4). Madina chimpanzees' community size was estimated based on the results of this analysis.

5.4. Discussion:

MCP and Kernel analysis analyses estimated very different home range sizes for chimpanzees at Madina, with the MCP estimate over double that of Kernel analysis. However, the estimates of core areas were more similar. Home range calculations obtained using MCP analysis appears to be highly biased due the variable landscape that chimpanzees at Madina inhabit. In addition to anthropogenic features of the landscape, the study area is surrounded by a river and smaller streams, giving it an irregular shape. MCP analysis might be inappropriate for understanding primate home ranges in anthropogenic mosaic landscapes where animals use small fragmented forest blocks. In this study, large areas that are not used by the chimpanzees were calculated as part of their home range. As in other studies, Kernel analysis showed a more realistic estimation for the home range size of this community (Bertolani, 2013; Montanari, 2014). As Kernel analysis has been shown as a very effective method to identify areas of more concentrated use of the space, and in calculating the utilization distribution of a species (Bertolani, 2013), this research recommends that the home range of the Madina chimpanzees is taken as approximately 8.93km^2 with a core area (using Kernel analysis of 75% of the data points) of 4.16 km^2.

The home range estimate at Madina is similar to some other chimpanzee sites in East and West Africa, including Budongo, Tai North and Tai South with varying levels of anthropogenic exposure (Table 5). The relatively small home range sizes of these forest-dwelling communities are probably due to high habitat quality and availability of food, especially in Ngogo, with the largest community (Potts *et al.*, 2009; Potts *et al.*, 2011). In addition to classifying sites with either low, medium or high levels of anthropogenic exposure, it is important to examine the degree of fragmentation. The neighbouring community at Caiquene-Cadique lives in similar mosaic habitat to the Madina community surrounded by forest, mangroves, crops and human settlements, and is estimated to have a similar home range size of approximately 7.93 km^2 and the composed by a minimum of 39 individuals (Bessa, 2014). However, calculations were made using the distribution of peripheral traces and not through recognised methods. Using Kernel analysis, the home range of this community would probably be smaller. Interestingly, the Fongoli community in Senegal inhabits a savannah-woodland matrix habitat and have an extremely large home range of 63 km^2 (Pruetz, 2006). At Fongoli, chimpanzees show a very narrow diet in term of plant and fruit species that they consume (Pruetz, 2006). In order to satisfy their nutritional needs, chimpanzees must move through a much larger area, increasing their home range.

Analysis of the correlation between community size and home range size of different chimpanzee communities showed different results for MCP and Kernel analysis. MCP home range sizes results are not significantly correlated with community sizes. On the other hand, the more accurate Kernel analysis shows that there is significantly and strongly correlation between community size and home range size. Thus, this study suggests that Madina chimpanzee community may have about 48 individuals. As other chimpanzee communities living in habitats with low (e.g. Tai north) or medium human disturbance (e.g. Budongo), and that show relatively small home range sizes (7.5 km^2 and 6.8 km^2 respectively), Madina community probably has a relatively large community with a relatively small home range size, despite high human disturbance and highly fragmented habitat. A fragmented habitat may constrain chimpanzee movements throughout the landscape, and the availability of cultivated resources that are often clumped in distribution may result in chimpanzees confining their activities to a smaller portion of their territory. Further analysis is needed to provide a more precise estimation of the community size of chimpanzees at Madina.

Comparisons between study sites should be done carefully due to the variety of analytical tools used and environmental factors (Vedder, 1984; Hansteen et al., 1997; Fashing, 2001; Cipolletta, 2003; Newton-Fisher, 2003; Bermejo, 2004; Doran-Sheehy *et al*., 2004; Twinomugisha & Chapman, 2008; De Luca *et al*., 2010; Kolodzinski *et al*., 2010). Also, difficulties of standardization amongst sites mean that factors such as sampling effort or study length can influence the results (Börger *et al*., 2006). Analyzing the diversity of habitats in which different chimpanzee communities live, their community sizes, and the methods of estimation make it unclear how much each factor contributes to home range estimates. If more rigorous inter-site comparisons are to be made, it is important to better evaluate habitat quality including degree of anthropogenic exposure and consider comparative measures of year-round fruit availability. For a better estimate of chimpanzee home range size, an improved understanding of the role of different ecological and anthropogenic factors is needed across different habitat types and the impact of these factors on year-round variations of chimpanzee home range use. The present study focused only on the dry season in which fruit availability is assumed to be higher, so with further research that covers the complete year we might expect chimpanzees at Madina to expand their home range in search of additional foods.

6. Madina chimpanzees' habitat use

6.1. Introduction

Food availability, habitat characteristics and predation risk are main factors that influence animal movement and habitat use (Druce *et al*., 2009; Willems & Hill, 2009; Makin *et al*., 2012; Coleman & Hill, 2014; Stears & Shrader, 2015). In addition to these factors, in more anthropogenic areas, human activity also influences wild animals use of space and risk perception (Frid & Dill, 2002; Coleman *et al*., 2008; Tadesse and Kotler, 2012; Blumstein, 2014; Nowak *et al*., 2014). In some mammal species, individuals will show anti-predatory behaviours in response to human presence or will avoid areas with available food due to human activities. [e.g. *Capra nubiana* (Tadesse & Kotler, 2012); *Cervus elaphus* (Ciuti *et al*., 2012)].

Human population growth and increasing human activities in many environments often result in habitat loss and fragmentation, and the decline of primate populations (Chapman & Peres, 2001; Estrada, 2013). These changes can also create forest-agricultural habitats in which the surviving primate species live in very close proximity to humans and their activities. In human-modified environments, primates can change their feeding behaviour, diet, and use of the resources, showing high behavioural adaptability in response to changes in habitat quality (Lee 1997; Tutin, 1999; Singh *et al*., 2001; Wong *et al*., 2006; Riley, 2007; Campbell-Smith *et al*., 2011b; Pozo-Montuy *et al*., 2013; Ménard *et al*., 2014; Guzmán *et al*., 2016).

Some primate choose to spend most of their time in areas with low human activity [*Cercocebus atys (*Brncic *et al*., 2015); *G. beringei beringei* (van Gils & Kayijamahe, 2010); *Gorilla spp*. (Junker *et al*., 2012); *Pan paniscus* (Hickey *et al*., 2013); *Pan troglodytes* (Plumptre *et al*., 2010); *Pongo pygmaeus* (Wich *et al*., 2012)]. However, some anthropogenic areas, such as touristic areas and religious sites, might offer optimal conditions for some primate genera, including as macaques (*Macaca spp.*) and baboons (*Papio spp.*), to thrive (Fuentes, *et al*, 2005; Strum, 2010; Hoffman and O'Riain, 2011; El Alami *et al.*, 2012; Brotcorne *et al*., 2014). Compared to primates that mostly feed on natural foods, those that regularly feed on cultivars tend to have small home range sizes, travel and forage less, and spend more time resting and socializing [*Chlorocebus pygerythrus* (Saj *et al*., 1999)]. Primates can also change their habitat use, including sleeping locations, that may allow them to have easier access to human foods [*Macaca fascicularis* (Brotcorne *et al*., 2014)], or to avoid areas of high human activity [*Hylobates moloch* (Reisland & Lambert, 2016)].

As with other primate species, chimpanzees also choose to spend most of their time in areas with low human activity (Plumptre *et al*., 2010; Brncic *et al*., 2015; Bryson-Morrison *et al*., 2017). Chimpanzees are highly selective regarding the location of nesting sites and the tree species in which they build their nest, using only a small proportion of available trees (Furuichi & Hashimoto, 2004; Ndimuligo, 2007; Stanford and O'Malley, 2008; Koops *et al*., 2012). Although, chimpanzees can live in very close proximity to human settlements (Duvall, 2008; McLennan, 2008; Hockings *et al*., 2012; Hockings & Sousa, 2013), nests are usually found in areas further away from human settlements (Carvalho *et al*., 2013, 2015). The utilization of anthropogenic parts of the habitat can be risky for chimpanzees, for example during crop foraging (Hill, 2005; Tweheyo *et al*., 2005; Hockings *et al*., 2009; Brncic *et al*., 2010; Hockings & Sousa, 2013; McLennan, 2013), and road-crossing (Cibot *et al*., 2015; McLennan & Asiimwe, 2016). Chimpanzee show elevated perception of risk in human-impacted parts of the habitat, and often display signs of anxiety and stress such as increased rough self-scratching (Hockings *et al*., 2006; Hockings, 2011), as well as increasing anti-predatory behaviours such as increased vigilance and reduced vocalisations (Sakura, 1994; Takemoto, 2002; Hockings *et al*., 2006; Wilson *et al*., 2007; Hockings, 2011; Krief *et al*., 2014; Cibot *et al*., 2015). When choosing to exploit anthropogenic parts of the habitat or not, chimpanzees will account for their nutritional requirements whilst avoiding human-associated risks. Incorporation of human cultivated food in their diet can be in response to wild food scarcity but also high crop availability (Naughton- Treves *et al*., 1998; Hockings *et al*., 2009; McLennan & Hockings, 2014). Chimpanzee in forest-agricultural habitats will forage on nutrient rich and easily digested cultivated fruits, despite also relying on forest food resources (Bessa *et al*., 2015; McLennan & Ganzhorn, 2017).

To gain insight into the factors influencing this community's responses to a fragmented human-influenced environment, I will examine their use of space and habitat preferences. I predict that the Madina chimpanzee community will avoid anthropogenic areas and mostly use more natural parts of the habitat for nesting and foraging, due to a reliance on wild food and in order to avoid human-associated risks. Although this community is not hunted by local people due to local cultural beliefs

(Sousa and Frazão-Moreira, 2010; Sousa *et al*., 2014b), it is likely that they perceive interactions with humans as risky. The methodology used has been described in Chapter 3.

6.2. Data Analysis:

In total, 53 days of data collection were conducted. During every study day, all the eight habitats were crossed and examined for the presence of chimpanzee signs. Firstly, to examine whether natural or anthropogenic environments are used more by this community, habitats were divided in two main groups (as explained in Chapter 4):

1. **Natural habitats**: mature forest; young forest; palm groves and mangrove.
2. **Anthropogenic habitats**: field; orchard; road and village

An exploratory data analysis was done to compare the distribution of the data along different habitat types and between 'Natural' and 'Anthropogenic' groups. A *Shapiro-Wilk* test was used to check normality of the data set. As the data were not normally distributed, a non-parametric *Mann-Whitney* test was used to compare both independent samples and evaluate if there were significant differences on the use of the two environments.

Secondly, a more detailed analysis comparing the use of the eight habitat types available to the Madina chimpanzee community across all activities (feeding, nesting, moving etc) was conducted. For these analyses, the complete set of chimpanzee signs were used (i.e. nests, feeding traces, faeces, encounter, signs of tool use, and knuckle prints). A *Kruskal- Wallis* test was used to examine if there was a significant difference between chimpanzees' use of the eight different habitat types. To analyse where the differences existed, *Mann-Whitney* was used as post hoc test comparing each pair of habitats.

Thirdly, to examine chimpanzee habitat preferences by Madina chimpanzees for nesting and foraging, the locations of nests and feeding traces in different habitats were analysed using descriptives. The composition of feeding traces was also analysed, and plant species identified in order to understand which cultivated or natural fruits made part of the Madina chimpanzees' diet. All statistical analysis was done using Rx64 3.4.1 program and Microsoft Excel tool.

6.3. Results:

6.3.1. Chimpanzees in Natural and Anthropogenic habitats

A total of 659 chimpanzee signs were found during the study period. The number of signs found per habitat was highly variable. A total of 448 signs were found in the natural habitats of chimpanzees' home range and 211 signs were found in the anthropogenic areas. The number of signs found per day varied with a mean number of signs of 1.55 ± SD 4.08 (Natural habitat: 2.11± SD 4.68, N= 448; Anthropogenic habitat: 0.99±SD 3.29, N= 211).

In natural habitats, palm groves were the most represented, followed by young forest, mature forest and mangrove habitats. In anthropogenic habitats, orchard had the highest percentage of signs found, followed by field; road and village habitats (Figure 16). There was a significant difference in the utilization of Natural and Anthropogenic habitats by chimpanzees at Madina (*Mann-Whitney* test, W= 17798; $p < 0.05$). More signs were found in Natural than Anthropogenic habitats (Figure 16), but variation also occurred between different habitat types within those categories (Figure 17), suggesting that although chimpanzees are using natural habitats more often than anthropogenic ones, some anthropogenic areas are also used regularly.

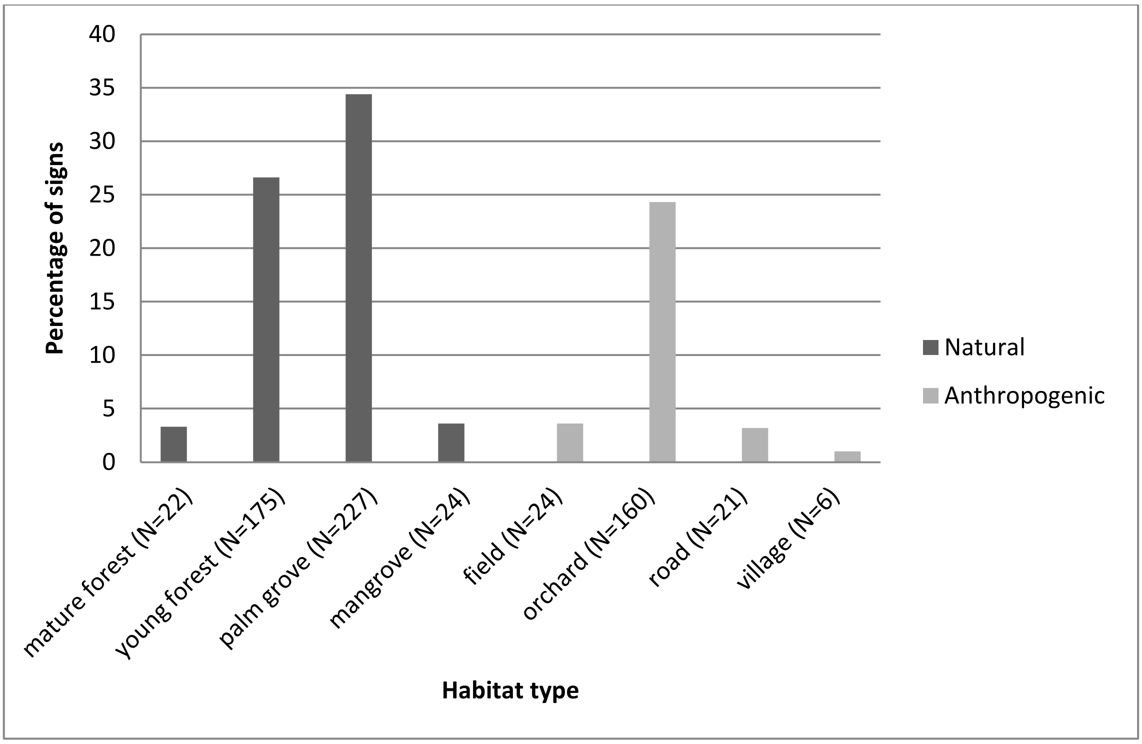


Figure 16. Percentage of signs found in different habitats during the study period. Habitats were divided into natural and anthropogenic.

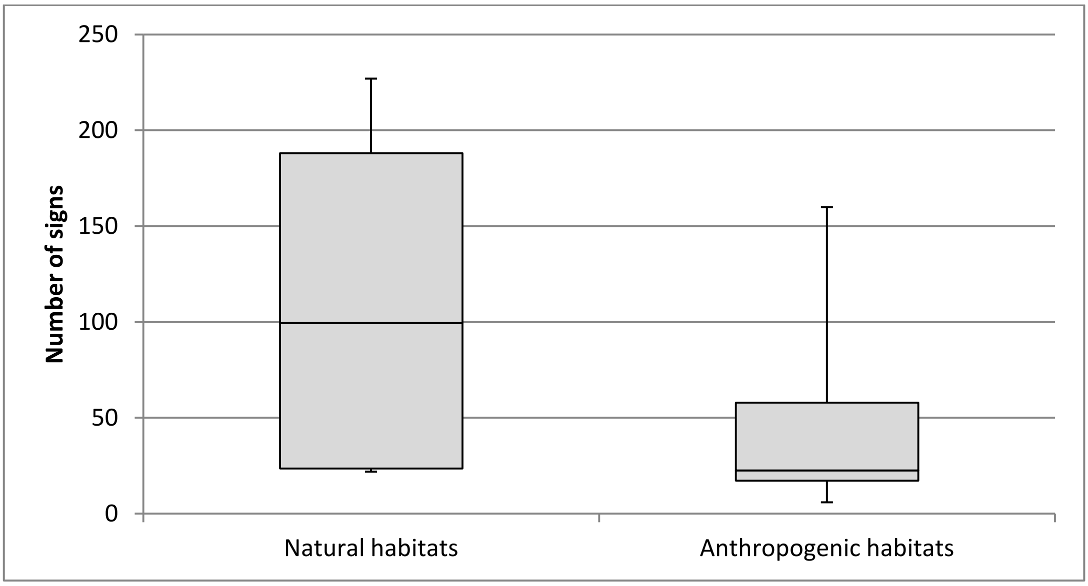


Figure 17. Distribution of the number of signs collected in different natural and anthropogenic habitat types during the study period. Natural habitats showed more variation on the number of signs found per habitat, while in anthropogenic habitats variation on the number of sings found is much lower, suggesting that some anthropogenic habitats are also used regularly, despite natural habitats are used more often.

6.3.2 The use of different habitat types

There was a significant difference in chimpanzee use of different habitats (*Kruskal- Wallis*, Q^2=106, 07; df=7; p< 0.05). Palm grove are used significantly more than all other habitat categories (Table 6). Young forest and orchard habitats showed similarly high levels of utilization when compared with the other habitats (Figure 16). There are no significant differences in the amount that mature forest, mangrove, plantation, road and village habitats are used by chimpanzees (Table 6) and that these habitats show considerably lower levels of utilization than palm areas, young forest and orchard (Figure 16).

Table 6. Comparison of use of different habitats. As post hoc, a *Mann-Whitney* test was used in each pair of habitat in order to analyze significant differences on use.

	mature forest	**young forest**	**mangrove**	**palm grove**	**field**	**orchard**	**road**	**village**
mature forest		W=952 **p<0.05**	W=1447.5 p =0.66	W=519 **p<0.05**	W=1505.5 p =0.28	W=1095.5 **p<0.05**	W=1424 p= 0.85	W=1540.5 p=0.13
young forest			W=1857 **p<0.05**	W=1060.5 **p<0.05**	W=1923 **p<0.05**	W=1522 p=0.40	W=1868 **p<0.05**	W=1967 **p<0.05**
mangrove				W=519.5 **p<0.05**	W=1456.5 p=0.55	W=1062 **p<0.05**	W=1383.5 p=0.83	W=1491.5 p=0.30
palm grove					W=2341.5 **p<0.05**	W=1877.5 **p<0.05**	W=2287.5 **p<0.05**	W=2401 **p<0.05**
field						W=1018 **p<0.05**	W=1327.5 p=0.39	W=1435 p=0.69
orchard							W=1730 **p<0.05**	W=1826 **p<0.05**
road								W=1517 p=0.19
village								

6.3.3 Habitat preference:

6.3.3.1. Foraging:

A total of 198 feeding traces were found in 42 of the 53 study days (mean per day: 4.73± SD 3.94). Feeding traces were found in six habitat types, with most found in orchards, followed by young forest; palm grove; mangrove; mature forest; road and field (Figure 18). They were located throughout the study area, but were particularly clumped close to cultivated areas around Madina village (Figure 19).

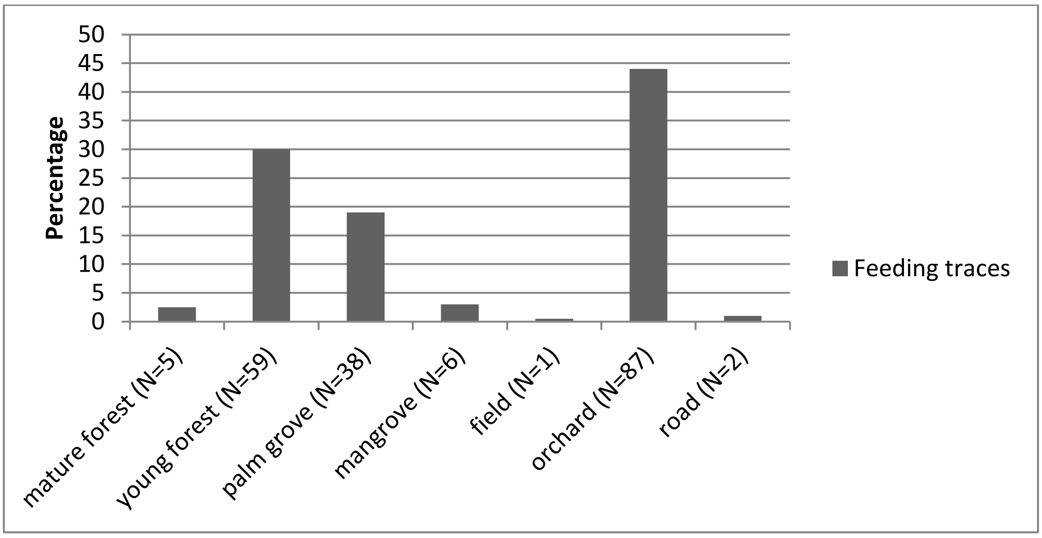


Figure 18. Distribution of the number of feeding traces across habitat types.

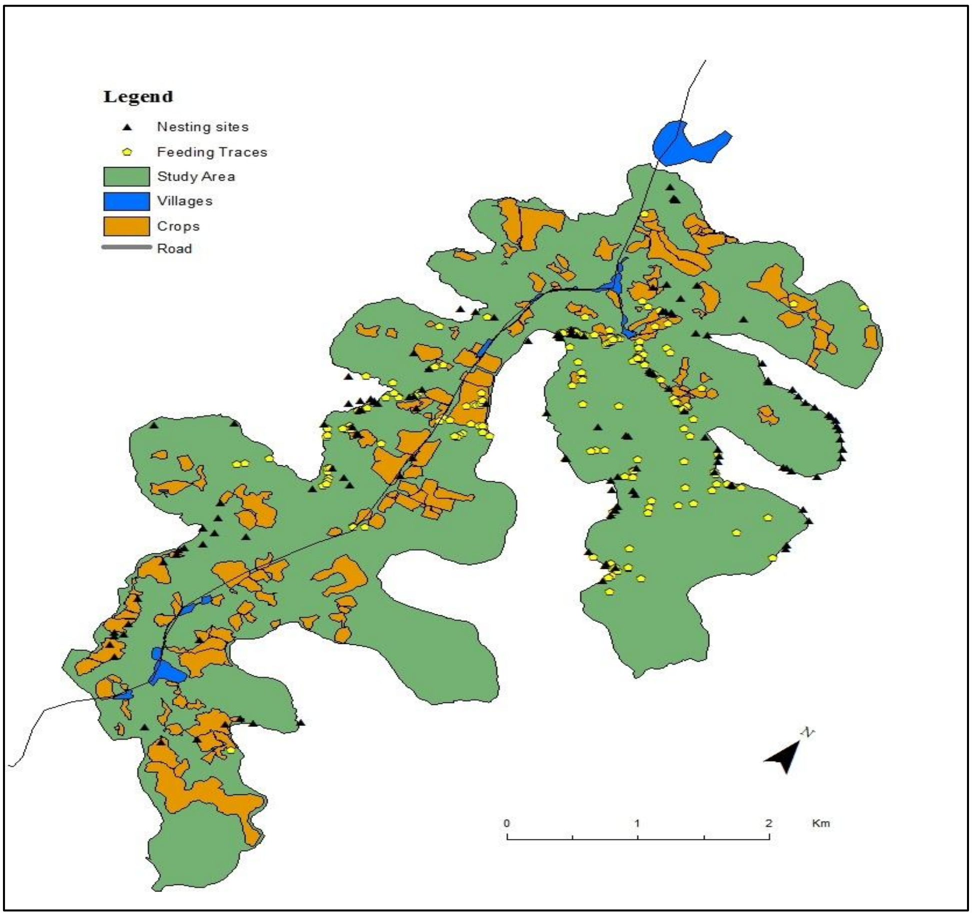


Figure 19. Distribution of nesting sites and feeding traces across the study area.

Using traces, chimpanzees at Madina fed on 19 different plant species and various different plant parts (three plants remain unidentified to the species level) (Table 7). Approximately 42% of traces were cultivars which were found in orchards or plantations, while 58% of the traces were from natural parts of the habitat. The oil-palm was the most represented wild plant species, with almost every part, including fruits, pith and flower, present in the feeding traces. During opportunistic encounters with chimpanzees it was possible to see individuals feeding on other non-plant items, including honey (Figure 20).

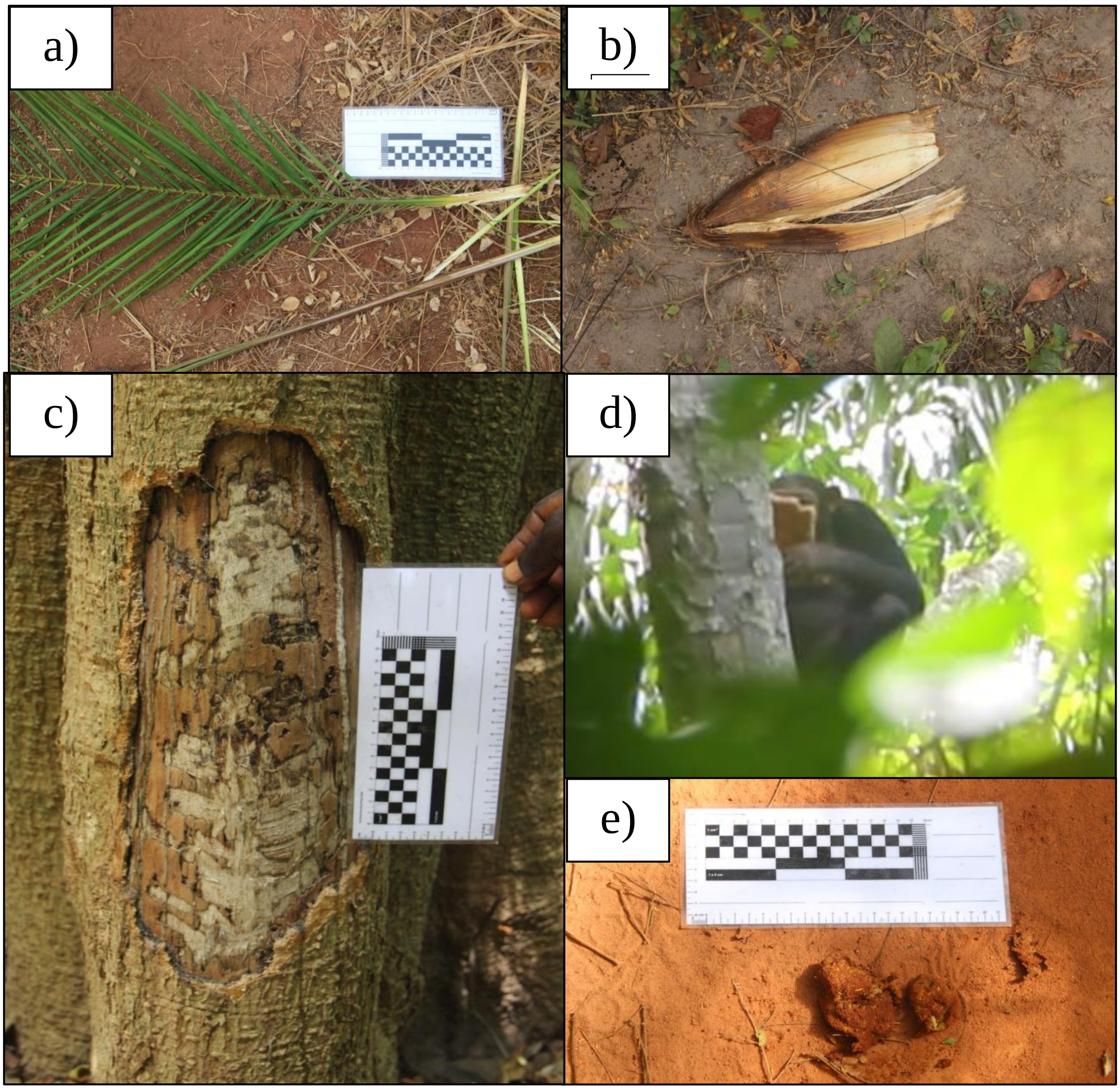


Figure 20. Example of chimpanzee food. a) Oil-palm tree leaf (*Elaeis guineensis*); b- Oil-palm tree flower (*Elaeis guineensis*); c) bark (*Alstonia congensis*); d) Opportunistic encounter with a chimpanzee feeding on honey; e) cashew (*Anacardium occidentale*).

Table 7. List of plant species identified from chimpanzee feeding traces. Table adapted from Bessa *et al*., 2014.
Part eaten: FR= Fruit; FL= Flower; L= Leaf; B= bark.
*-Cultivated plants

No.	Plant species	Family	Life Form	Part Eaten	N	%
1	*Adansonia digitata*	*Bombacaceae*	Tree	FR	7	3.5
2	*Alstonia congensis*	*Apocynaceae*	Tree	B	2	1
3	*Anacardium occidentale**	*Anacadiaceae*	Tree	FR	19	10
4	*Avicennia germinans*	*Avicenniaceae*	Tree	L	4	2
5	*Ceiba petandra*	*Bombacaceae*	Tree	B	2	1
6	*Citrus lemon**	*Rutaceae*	Tree	FR	19	10
7	*Citrus sinensis**	*Rutaceae*	Tree	FR	14	7
8	*Dialium guineense*	*Leguminosae / Fabaceae - Caesalpinioideae*	Tree	FR/B	6	3
9	*Elaeis guineensis*	*Palmae / Arecaceae*	Tree	FR/FL/L	52	26
10	*Ficus sp.*	*Moraceae*	Tree	B	1	0.5
11	*Landolphia hirsuta*	*Apocynaceae*	Climber	FR	2	1
12	*Mangifera indica**	*Anacardiaceae*	Tree	FR	27	13.5
13	*Parinaria excelsa*	*Chrysobalanaceae*	Tree	FR	12	6
14	*Phoenix reclinata*	*Palmae / Arecaceae*	Tree	L	1	0.5
15	*Psidium guava**	*Myrtaceae*	Tree	FR	1	0.5
16	*Rauvolfia vomitoria*	*Apocynaceae*	Tree	FR	4	2
17	*Saccharum officinarum**	*Gramineae / Poaceae*	Herb	P	2	1
18	*Strombosia postulate*	*Olacaceae*	Tree	FR	2	1
19	*Treculia africana*	*Moraceae*	Tree	FR	9	4.5
20	Unknown #1	-	Shrub	FR/L	10	5
21	Unknown #2	-	Tree	B	1	0.5
22	Unknown #3	-	Tree	B	1	0.5

6.3.3.2. Nesting

In 38 of the 53 study days nests were found. In these 38 days, a total of 431 individual nests of different ages (mean per day 12± SD 13.32) and 164 nest sites (mean per day 4.23± SD 4.84) were recorded. Nests were only found in three types of habitat: palm groves, young forest and orchards. Nests were found along the edges of the forest (Figure 19). Most nest sites and individual nests were located in palm groves (Figure 21).

Nests were identified in 5 different tree species, with 98% (n=422) of the nests made in oil-palm trees (*Elaeis guinneensis*), and 2% (n=9) found in tree species in young forest, including *Parinaria excelsa* (n=1); *Strombosia postulata* (n=4); *Dialium guineense* (n=3) and *Anysophyllea laurina* (n=1).

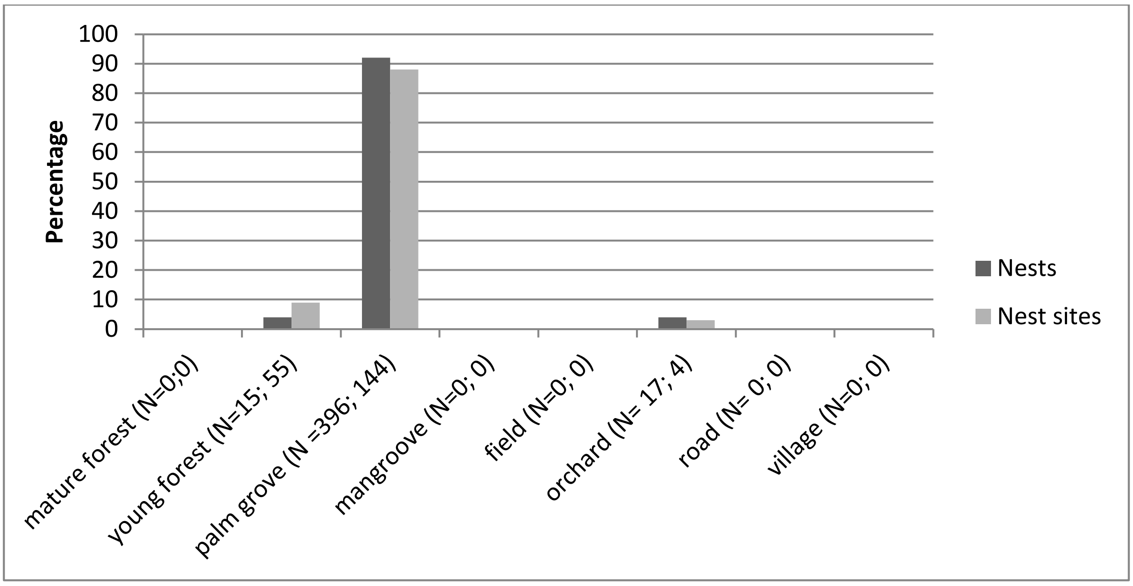


Figure 21. Distribution of the number of nests and number of nest sites across all habitat types. The number of nests and nest sites are shown respectively in brackets.

6.4. Discussion:

Overall chimpanzees mostly use more natural parts of the habitat for their activities, supporting the first prediction. When comparing the Natural and Anthropogenic environments, most of the chimpanzee signs were found in the natural habitats. Chimpanzees in Madina might be avoiding anthropogenic areas that are more open (less shade) and where they are more likely to encounter humans. This might be driven by chimpanzees perceiving higher levels of risk in human influenced habitats (Hockings *et al*., 2006; 2011). This pattern is found in other chimpanzee communities living in human-influenced habitats. At Bossou in Guinea, chimpanzees spend more time in forest habitats; despite using cultivated fields to forage for food during the dry season, when natural and cultivated fruit availability is higher (Hockings *et al*., 2009; Bryson-Morrisson *et al*., 2016; 2017). However a more detailed analysis of the use of different habitats shows that some anthropogenic habitats have high numbers of chimpanzee signs, particularly orchard habitat, with similar levels of utilization as young forest habitats. As in other studies, young forest habitat may contain high densities of tree species that chimpanzees' feed on (Bryson-Morrison *et al*., 2016), it is expected that, considering the risk, they would prefer to avoid anthropogenic parts of the habitats. Unlike what was shown by Bryson-Morrison (2017), crop-foraging by chimpanzees in Madina may not be a substantial risk since local people show high levels of tolerance towards the chimpanzees and some of the crops consumed by chimpanzees at Madina are considered ‘low conflict’(e.g. cashew) (Sousa & Frazão-Moreira, 2010; Hockings & Sousa, 2012). The analysis of the feeding trace composition helps to support the findings that chimpanzee prefer to forage in young forest and orchard habitat. Similar percentages of natural and cultivated plant species were found in the feeding remains.

Most of the cultivated and natural fruits in this region are available during the dry season (Bessa *et al*. 2015). As has been shown in other studies, despite the high fruit availability in the forest, results show that chimpanzees are using cultivated fields as part of their feeding strategy as well (Naughton-Treves *et al*., 1998; Hockings *et al*., 2009; Mckinney, 2011; McLennan & Hockings, 2014; Bessa *et al.*, 2015; McLennan & Ganzhorn, 2017). By balancing the low risks of foraging in orchards and the nutritional benefits of cultivated fruits, chimpanzees in Madina are integrating cultivars into their natural diet.

Chimpanzees are known to prefer to nest in mature forests, far away from human settlements (Carvalho *et al*., 2015). At Madina, palm grove habitat showed the highest numbers of chimpanzee signs, particularly nests. Sousa *et al*. (2011) reported that in southern Cantanhez forests, chimpanzees have a preference for nesting in oil-palm trees, localized on the forest edge. The author also suggests several hypotheses based on the available literature to explain oil-palm tree nesting preference, such as predator avoidance; wider view of the surrounding habitats; and to facilitate communication amongst community members, due to similar heights of oil-palm trees, particularly if the palm-groves are located in the forest edge. Despite there is no consensus about the factors influencing this preference, in Madina chimpanzees might be nesting in palm groves due to easy access to food and low risk of persecution by humans. Furuichi *et al*., (2001) suggested that preference for certain trees to nest is more related with food resource availability than with the type of habitat. Oil-palm trees are a year round source of food for chimpanzees, and almost every part of the plant is eaten by the species (Bessa *et al*., 2015). During this study, palm tree was the most frequent plant species found in the feeding traces, which suggests that might be a plant frequently consumed by the chimpanzee and possibly an important part of their diet in times of fruit scarcity (Table 6). Leciak *et al*. (2005) suggested that this species is particularly important to chimpanzees at Kanfarande in Guinea due to providing oil-palm fruit that chimpanzees feed on times of lower fruit availability. Oil-palm trees are also an important resource to human communities and are used on a daily basis. Although humans are often present in palm groves, the chimpanzees are not deterred from using them. The high availability of this resource and the low risk presented by humans, as well as the fact that this tree species is often used for nesting during the night, when human activity is lower, might explain this.

Despite the results, this study took place during a period of high fruit availability. Other studies suggested that chimpanzees will show seasonal differences on habitat use according with food availability (Bryson-Morrison *et al.*, 2017). Further research on Madina chimpanzees' habitat use should examine fruit availability year-round as well as the patterns of habitat preference during time of lower fruit abundance. The present study provides a 'snap-shot' about how this unhabituated chimpanzee community are adapting their behaviour to exploit and survive in this human-influenced environment.

7. Conclusion:

The present dissertation explores the home range and habitat use of an unhabituated chimpanzee community (*Pan troglodytes verus*), inhabiting on a human-influenced habitat, along with the human activities in the same landscape. The results are based on 4 months of field work (From February to May 2017), which took place at Madina de Cantanhez in Cantanhez National Park, Guinea-Bissau. Here, the main findings and conclusions of this research are summarized.

7.1. Summary of findings:

The interviews showed that during the period of this project, was the time of higher levels of human-influenced changes on the landscape due to slash-and-burn agriculture. Cashew and peanuts are the most cultivated plant species planted in orchards and fields, respectively, both of them cash-crops. There is a tendency for the increasing of the levels of cultivation of cashew and increasing of its' value which may change agricultural traditional activities and peoples' perceptions on chimpanzees. However, human-chimpanzee interactions remain as 'low-conflict' due different utilization of the cashew and due to traditional beliefs.

The map of the study site showed that Madina chimpanzees live on a highly fragmented habitat. Chimpanzee signs were found all across the area of Madina, Farim and Catomboi villages showing that chimpanzees are highly exposed to human activities all across their distribution.

There was a significant difference on the results from the two methods (MCP and Kernel analysis) used to calculate home range and core areas of chimpanzee communities. This is the first time that these methods of home range estimative are used on an unhabituated chimpanzee community living on an anthropogenic habitat. Kernel analysis is very effective on indentify areas of more concentrated use of space and utilization distribution of the species. It showed more realistic results suggesting that the Madina chimpanzee community might have and home range of approximately 8.93 km^2 with a core area of 4.16 km^2.

Comparing the home range of Madina chimpanzee with other chimpanzee communities, results showed that this community have a relatively small home range size as other chimpanzee communities living on less disturbed environments. Also, home range sizes (calculated with Kernel analysis) and community sizes of different chimpanzee communities were positively correlated. By analysing this correlation, it is estimated that Madina chimpanzee community may have 48 individuals. Despite the high levels of anthropogenic activities and fragmentation, chimpanzees in Madina show a relatively small home range with a relatively big community size surviving in highly fragmented human-influenced habitat. Although, more research is needed to fully understand the main factors that allows chimpanzees to thrive in this landscape.

Madina chimpanzee community is present mostly in more natural parts of their home range. Notwithstanding, some anthropogenic habitats are often used as well. Direct and indirect evidences of chimpanzee presence showed that this community use palm grove habitats on a much higher level than other habitats. This habitat showed to be preferred by the chimpanzees as a nesting site possibly due to food availability, as the oil-palm trees are a year around source of food to this species. Young forest habitat was highly preferred by the chimpanzee to forage, along the orchard habitat. As the dry season is the ripping period to several forest and cultivar species, it shows that cultivars are fully integrated on chimpanzees' foraging strategies. Supporting this, the results of feeding trace analysis showed that chimpanzees are feeding on similar proportions of forest and cultivar food. However, these proportions and the species that Madina chimpanzees are feeding on might be underestimated due the fact that faeces analysis and direct observations on chimpanzees feeding behaviour are not listed on the analysis.

This study took place during the dry season and chimpanzees might change their home range, habitat use and feeding strategies along the year. A year around study is necessary to fully understand Madina chimpanzee community adaptations to anthropogenic environments. Yet, this is a preliminary study on a community that wasn't systematically studied before. The findings of this research enlighten some of the strategies used by this chimpanzee community on forest-agricultural mosaic habitat.

7.2. Future research:

Nowadays, western chimpanzee is listed as *Critically endangered* by the IUCN (2016). The main threats to chimpanzees' survival are habitat loss due slash-and-burn agriculture, commercial agriculture and extractive industries, disease transmission, bushmeat and wildlife living trade, and retaliatory killing (Humle *et al*., 2016a). The increase of human population is shrinking chimpanzees on continually fragmented habitats, increasing their risk of extinction. Chimpanzees at Madina live on the protected Cantanhez National Park area. Even though, the territory suffers high anthropological pressure due to slash-and-burn agriculture and the continued increment of the Park population. During the study period it was possible to observe the clearing of forest patches to give place to cultivars during the slash-and-burn agriculture process. The continuous fragmentation of Madina chimpanzee habitat may clear forest corridors decreasing their capacity of moving through their home range. Habitat loss will certainly diminish 'natural' fruit availability as well. Even with the increment of available cultivars and the low 'conflict' between humans and chimpanzees in this area, the increment of crop-foraging by chimpanzees might be problematic in the future. During this research, the increment of the price of the cashew nuts made local people to complain about chimpanzees damaging cashew trees to access to the fruits. The dynamic nature of human-influence habitat makes it difficult to predict how it will change and if chimpanzees will be able to adapt it.

In the future, more cross-disciplinary research is needed to understand human and chimpanzee necessities. Other chimpanzee study sites across the African continent are becoming more exposed to human activities. Along with other studies with wildlife living on human-influenced habitat, this research aims to help to design conservation strategies, particularly to chimpanzee and great ape species living in anthropogenic habitats. In these contexts, human views have to be understood and incorporate on the conservation strategies along with chimpanzee necessities to a better management on ecosystems' conservation.

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Appendix I
Interview questionnaire

Data (date):

Hora (hour):

1- Número de morança (Number of the household);

2- Nome de entrevistado (Name of the interviwee);

3- Numero de pessoas da murança (Number of inhabitants in the household);

- Nº homens grandes (No of old man);
- Nº mulheres grandes (No of old woman);
- Nº homens (No of man;
- Nº mulheres (No of woman;
- Nº rapazes/ raparigas/ crianças (No of boys/ girls/ children):

4- Etnia da morança (household ethny):

5- Tipos e número de campos agrícolas (type and number of cultivated fields):

6- Nº de cabras (No of goats):

7- Qual fruto ou madeira retira do mato (tipo, mês e objectivo) (What kind of fruito or wood you find in the forest? Type, month and objective):

Appendix II

Feaces analysis

List of plant species identified (n=26) from chimpanzee feaces (n=138). Table adapted from Bessa *et al*., 2014. Some faeces were composed by several plant species.
Part eaten: FR= Fruit; B= bark.
*-Cultivated plants

No	Plant species	Family	Life form	Part eaten	N	% Total samples
1	*Anacardium occidentale**	*Anacadiaceae*	Tree	FR	5	3.6
2	*Citrus lemon**	*Rutaceae*	Tree	FR	1	0.7
3	*Dialium guineense*	*Leguminosae / Fabaceae - Caesalpinioideae*	Tree	FR	92	66.6
4	*Elaeis guineensis*	*Palmae / Arecaceae*	Tree	FR	3	2.1
5	*Ficus spp.*	*Moraceae*	Tree	FR	124	89.8
6	*Mangifera indica*	*Anacardiaceae*	Tree	FR	1	0.7
7	*Parinari excelsa*	*Chrysobalanaceae*	Tree	FR	9	6.5
8	*Strombosia postulate*	*Olacaceae*	Tree	FR	55	39.8
9	*Treculia africana*	*Moraceae*	Tree	FR	3	2.1
10	Unknown #1	-	-	FR	2	1.4
11	Unknown #2	-	-	FR	6	4.3
12	Unknown #3	-	-	FR	1	0.7
13	Unknown #4	-	-	FR	2	1.4
14	Unknown #5	-	-	FR	1	0.7
15	Unknown #6	-	-	FR	1	0.7
16	Unknown #7	-	-	FR	1	0.7
17	Unknown #8	-	-	FR	1	0.7
18	Unknown #9	-	-	FR	1	0.7
19	Unknown #10	-	-	FR	1	0.7
20	Unknown #11	-	-	FR	1	0.7
21	Unknown #12	-	-	FR	1	0.7
22	Unknown #13	-	-	FR	1	0.7
23	Unknown #14	-	-	FR	1	0.7
24	Unknown #15	-	-	FR	8	5.7
25	Unknown #16	-	-	FR	1	0.7
26	Unknown #17	-	-	FR	1	0.7

Appendix III

História da fundação da *tabanka* de Madina

(Abdulai Camará, Maio 2017)

O fundador da *tabanka* (aldeia) de Madina foi Bakar Dumbuiá, que era do grupo étnico Mandinga. Mas Bakar Dumbuiá não veio logo fundar a *tabanka*, ele estava em Cacine. Havia um branco que estava em Cacine que se chamava Ramalho. Ele (Bakar Dumbuiá) era cozinheiro dele (Ramalho). Bakar estava lá há muito tempo, até ao dia em que saiu de Cacine, trazido na canoa, e chegou aqui para vir caçar animais. Naquele tempo havia muitos animais e muita floresta aqui. Ele vinha caçar perto de onde é hoje a *bolanha* de Madina (cultivo alagado de arroz junto ao mangal) e levava os animais de volta para Cacine.

No momento em que andava por aqui, ele perguntou às pessoas: *Quem é que tem direito deste lugar?* Ao que as pessoas responderam: *Se queres saber quem tem aquele lugar ali, tens de ir ter com alguém que está em Cautchinque que se chama Semakedo Kunumodu*. Semakedo é que tinha direito sobre este lugar. Um dia Bakar saiu de Cacine e falou para esse homem: *Eu tenho muita família lá (em Cacine), não posso ficar aqui. Tu podes pagar-me o trabalho que eu vou fazer aqui em dinheiro mas esse dinheiro não vai beneficiar-me. Eu quero um lugar para fazer uma horta, para ficar aqui com a minha família*. Depois de ouvir isso, Semakedo disse: *Não há problema*. Então Bakar foi para Cautchinque e ficou ao cuidado de Sumakedo Kunumodu. Ficou lá muito tempo.

Como Sumakedo Kunumodu é Nalu, naquele tempo os *brancos* pagavam os direitos de fundura de rio no chão Nalu. Esse direito estava a ser pago, mas aqueles que tinham direito sobre aquele dinheiro não estavam a usá-lo. Quem quis usar aqule dinheiro era Bakar Dumbuiá mas ele disse: *quem tem terra é que tem direito de receber esse dinheiro, ao contrario de quem veio de Cacine*. Depois de dizer isso, Sumakedo recebeu aquele dinheiro da mão de *brancos* portugueses. Aquele dinheiro depois de ser recebido, Sumakedo não ousou utilizá-lo por respeito aos outros Nalu. Foi Bacar que vira a situacao e dissera: *Ele é régulo, não pode ficar assim, ele é chefe, tem de usar o dinheiro como ele quiser*. Bakar Dumbuiá, é que fez com que ele (Sumakedo) usasse aquele dinheiro. Ele (Bakar) disse: *tu és chefe, e recebes muitos hóspedes. Esse dinheiro* *que recebeste, não está a ser usado na casa de seu dono. Isso não é bonito. Tu és régulo, esse dinheiro é para comprar a tua roupa e para comprar muita comida para ter lá em casa. Se o hóspede vem, podes dar-lhe de comer e recebê-lo na casa do chefe.*

Assim que foi fazendo, sempre conversando com Sumakedo, até que o teve coragem de falar em frente às pessoas da aldeia. As pessoas aceitavam-no e estava lá há muitos anos. Então disse: *eu quero que me dêem outro sítio, porque tenho muita família. Então quero ter outro lugar e ficar lá. A minha família não está aqui, mas ela vem e fica aqui.* Eles responderam: *Se tens bom hospede que te está a tratar bem, não vais querer largá-lo.* E*stás aqui há muito tempo, e como os teus filhos foram criados aqui perto, podes fazer isso*. Depois perguntaram: *Onde é que queres ficar?*Bakar respondeu: *Eu vou ver outro lugar por aqui*. Sumakedo respondeu então falando para seu filho: *Vai la adiante para ele (Bakar) te mostrat o lugar*.

Bakar anda e vai até Camarempo. Depois sai de Camarempo e vem até aqui. E diz: *É este lugar que eu quero. É aqui que quero ficar*. Então o outro (filho de Sumakedo) disse: *Aqui tem muitos animais, como podes ficar aqui*? E Bakar responde: *eu arranjo uma maneira*. O filho de Sumakedo volta e vai contar ao seu pai: *Ele mostrou-me o lugar e tem uma horta lá em Camecômbulu*. Assim é que os Nalu chamavam a este lugar. Ele (Bakar) é que pós o nome de Madina, mas na língua Nalu chama-se Camecômbulu. O filho de Sumakedo volta (a Camecônbulu) e diz a Bakar: *Não tem problema*. Bakar volta para se despedir na aldeia de Caitchinque e diz: *eu vou embora*, e as pessoas responderam: *vai e trabalha no lugar que queres*. Então Bakar veio, ficou em Camarempo e saiu de lá para vir trabalhar aqui. Abriu um lugar, queimou e fez casa. Não estava a dormir lá mas ficava até ao final do dia e voltava na manha seguinte. Não era bom para ele ficar no mato. Estava sozinho, sem mulher, sem filho, então ficava até ao final do dia e voltava para Camarempo. Naquele tempo, muitos animais estavam aqui: elefante, leão, muitos leopardo, muitas hienas. Mas assim que comecou a trabalhar neste lugar apareceu um homem que saiu de Boé. Esse homem era pai de Mutaru Cantê (homem-grande de Madina) e o seu nome era Mussa Bailó (pertencia ao grupo étnico dos Fulas.

Ele (Bakar) cumprimentou-o, e conversaram muito. Então Bakar disse: *eu quero fazer um sítio para morar, mas só eu é que estou aqui*. Então Mussa diz: *eu também,* Mas Mussa estava ao cuidado de um homem em Boé e ele não queria ficar. Foi Bakar Dumbuiá motivou-o e falou: *voce pode vir com ele*. O homem grande de Boé não quis, mas aceitou para que Mussa viesse. Bakar Dumbuiá ficou aqui e Mussa veio. Outras pessoas vieram e ajudaram no trabalho das hortas. Mas naquele tempo os Nalu eram sagrados (pois eram donos do chão), se eles diziam algo tu tinhas de fazer. Outros (Mussa) vieram fazer um trabalho que os Nalus não queriam. Havia então um rapazinho que os Nalu mataram por engano devido a um trabalho mau que Mussa fez (é segredo, não pode ser revelado) e disseram que esse rapaz não ia ser enterrado ali e para o levarem a ser enterrado em chão de Fulas. Mussa chegou e pediu para chamar Bakar Dumbuiá para lhe explicar o que aconteceu. Bakar pediu aos Nalus para enterrarem aquele rapaz naquele lugar. Sem ele, os Nalus não iriam aceitar, porque Mussa veio fazer algo que os Nalu não aceitavam. Depois disso, o rapaz pôde ser enterrado em chão Nalu e Bakar Dumbuiá ficou na aldeia com Mussa.. Assim que foi fundada a *tabanka* de Madina.