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Mapping of water sources available for wildlife

MASTER'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled Mapping of water sources available for wildlife independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 6.8.2021

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Marie Matuštíková

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Abstract

In areas where people and animals live together conflict between them occurs. One of the reasons is water availability during the dry season when animals pass through a populated area. Water deficiency can be improved by creating new or more permanent sources. Reservoirs could serve as a drinking place for wild animals, as a water hole for local people and their animals or with combined use. This thesis is part of one conservation program led by the Save Elephants organization. We were collecting data in three different localities in the south Chad region of Logone Oriental, prefecture Monts de Lam. Localities were mapped in order to locate suitable places where reservoirs could be created. First mapping was done in July 2017 in the area of reserve Kone Lam and 7 places were found. Second was set during March 2018 in the agricultural area around Baibokoum village and 8 places were located. Third mapping was set by the head of the local organization A.L.C.P. and 10 places were located in April 2018. Third location was partially in agricultural land and partially in Kone Lam reserve. During mapping as much information as possible was collected like coordinates, agricultural limits, animal presence and distances from roads. Spatial data were evaluated in mapping software and 25 places were selected and evaluated under different variables important for certain locality. In Kone Lam reserve 4 localities were highlighted from others. In the Baibokoum area 2 localities were selected as the most suitable for creating reservoirs. One locality is suitable as a waterhole for domestic animals and second as a well with drinking water. Area of Monts de Lam is very vast and reservoirs could be helpful at other localities which have not been explored yet.

Key words: waterholes, GIS, mapping, elephants, human-wildlife conflict

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List of the abbreviations used in the thesis

A.L.C.P. - l'Association de Lutte Contre la Pauvreté

CAR - Central African Republic

GIS - Geographic information system

GPS - Global positioning system

HEC - Human elephant conflict

HWC - Human wildlife conflict

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1. Introduction and Literature Review

1.1. Introduction

Lives of animals and humans are highly entwined (Hoare and Du Toit 1999). More than a half of habitable grounds on Earth have been somehow disturb by humans. Numbers of places without human presence are still declining. Increasing population leads to changing forests and savannas into agricultural land, pastures and living areas (Zvidzai et al. 2013; Lhoest et al. 2020). As a resolution to human settlements expansion and more intense agriculture conflicts between animals and humans are arising (Linke et al. 2007; Tangie et al. 2018). Forests and other non-agronomic land are mostly used by local people for collecting firewood, medical plants, wood for building or as a pasture for domestic animals (Nampindo et Plumptre 2005). People have used forest and water resources for hundreds of years before but with a large increase in human population the effect on nature can be devastating. When animal activities cross with the humans that may lead to serious complications, those moments are called human-wildlife conflict (Tagg et al. 2019).

1.2. Human-wildlife conflict

Protected areas and untouched wildlife areas are currently too small for wide-ranging and migratory animals which leads to animals evading agriculture and villages (Selier et al. 2016). Contact respectively conflict becomes when animals are passing through fields and villages while seeking for water, food or during migration (Treves et al. 2006). Definition of human wildlife conflict by IUCN is a situation that occurs when the basic needs of wildlife interfere with those of humans, generating negative consequences for both communities and wildlife. Species responsible for conflicts are sometimes called pests (Tangie et al. 2018). Nyhus (2016) is describing HWC as conflict that occurs between people and wildlife; actions by humans or wildlife that have an adverse effect on the other; threats posed by wildlife to human life, economic security, or recreation or the perception that wildlife threatens human safety, health, food, and property. Those are very wide definitions, and this problematic is much more complex.

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Mostly it refers to hunting of domestic animals or game animals, attacks on human property, spread of diseases and crop raiding (Tangie et al. 2018). These conflicts often result in destruction of property and in worst scenarios can end with deaths of humans and animals (Treves et al. 2006). In order to find solutions large amounts of money are spent every year worldwide (Linke et al. 2007). Problems with wildlife conflicts are not limited only to Africa or Asia but in different forms are present everywhere where people are (Treves et al. 2006).

Crop raiding is one of the most reported types of HWC worldwide (Granados and Weladji 2012). Damage not only has effects on crops and the economy but also on the environment, culture and society. In Africa HWC appears mostly in areas where agriculture neighbours with protected areas or other unprotected wildlife (Linke et al. 2007; Tangie et al. 2018; Branco et al. 2019).

In the area of our interest, the Logon Oriental region, the biggest amount of human wildlife conflict is caused by elephants (*Loxodonta africana*) and hippopotamus (*Hippopotamus amphibius*). Sporadically conflicts with monkeys and small rodents occur (Save Elephants, unpublished data).

1.3. Conflict prevention

In the following time period, the most important thing for survival of some large mammal species will be correct management of conflicts (Graham et al. 2010; Molina-Vacas, 2019). Setting the right conservation policy is important in areas adjoining the protected areas in order to improve living for both people and animals (Tangie et al. 2018). Management of any area is now more political than it used to be as a result of creation of protected areas and different perceptions of animal kills by locals and wildlife protectors (Treves et al. 2006) but in different areas it is tried to start with conservation efforts on community level. Protected areas, reservations and wild landscapes are facing a lot of obstacles, they can be poorly or not at all managed which is unwise because nature and wildlife is not only a source of resources but also a source of employment, income and natural heritage. Bad management, inadequate or lack of official status of protected areas is highly connected to poaching, mismanagement of resources, overgrazing, bush fires, timber exploitation and much more (Tangie et al. 2018). Because of the risk for

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crops, domestic and wild animals and also humans people are trying to avoid these situations (Treves et al. 2006). Conflicts between animals and people can happen without direct conflicts with results such as field or settlement damages (Megaze et al. 2017). Significant number of farmers are not certain how to properly guard their fields or what is forbidden by law (Linke et al. 2007).

1.3.1. Prevention systems

For protection of property, it is possible to use many different strategies such as fires, noises, guarding, physical barriers and chemical or biological repellents etc. (Megaze et al. 2017; Tangie et al. 2018). Every system is different and it is important to collect information before applying any of them. All protection systems have to be chosen after evaluation of the current situation and all possibilities. For successful reduction of conflict, it is important to identify the species, timing and placement of conflicts, work with local people and determine their knowledge, attitudes to animals and suggested changes (Treves et al. 2006). Protective system does not have to be effective for the same species at various places. When selecting the correct system also habituation of animals, funding possibilities, lack of maintenance from farmers or acceptance by the whole community have to be taken into account (King et al. 2017). Seasonal rainfall can affect behaviour of the animals. Studies and applied protective systems have to be aware of this (Dolmia et al. 2007).

1.3.2. Fencing

The most known and used protection worldwide is usage of fences. As a fencing material can be used classical fences made from wood or metal, brick or stone walls, ditches (King et al. 2017) but also some less traditional materials such as plants with thorns (Tangie et al. 2018). Classical fencing has its advantages and disadvantages. Fencing can become a very expensive system. It can be very problematic and sometimes impossible to fence large areas (Linke et al. 2007). Some species of animals can learn how to walk under or through fences, how to break fencing or walk around the area. Fences can be broken also by hunters and local peoples who want to access land behind (Graham et al. 2010). Electrical fences are effective but can be too expensive for some farmers and are not possible to use in areas without a proper electrical network (Linke et al. 2007).

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Another version of fencing is to create buffers with unappetizing plants as coffee or tea (Nampindo et Plumptre 2005). Good results showed protecting crops with chilli peppers buffers. Capsaicin in peppers can cause strong irritation to sensitive animals' senses (Megaze et al. 2017). The same effect is made by ginger. Successful combination was fencing with ginger or chilli oils-soaked rugs (King et al. 2017). Choosing of protective crops must be also established with knowledge about species (Linke et al. 2007). For example, some species of antelopes can destroy chilli plants by eating leaves before peppers are fully grown therefore simple chilli would not be useful (Tangie et al. 2018). In the past few years fencing with honeybees has been expanding (Branco et al. 2019). Animals such as elephants are afraid of possible bee stung. Those fences are made from beehives connected with wire to trigger bee swarms even when animals try to go between them (Figure 1). Beekeeping can bring another source of income to people. Wires connecting hives can be cut by herdsmen to allow the passage of domestic animals (King et al. 2017).

Figure 1 Beehive fence.

1.3.3. Others

Other protective systems are guarding by humans or dogs, fires, chemical or natural detergents, solar lights, flashing, shooting sounds and others (King et al. 2017; Pozo et al. 2019). Direct protection by farmers or guard dogs is highly used mostly in lower educated communities (Linke et al. 2007). Guarding patrols, manual noise making or shooting require the presence of humans and it can be also dangerous, same as with fires, which cannot be set in some areas. Also guarding strategies have proven to be

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ineffective (O'Connell-Rodwell et al. 2000; Linke et al. 2007). In some cases of conflict as with big carnivores it is possible to translocate or hunt problematic individuals. Killing is usually the first solution chosen by local people (Treves et al. 2006). In some areas in Uganda scare shooting was tried, it was used mostly on elephants but around 24 % got used to shooting and were returning also it required equipment and educated people (Nampindo et Plumptre 2005). Some methods such as noises, light shooting can be ineffective in the long term due to habituation (King et al. 2017). Chemical detergents are usually expensive and only last for a short time period. Repellents can be based on pheromones of predators, capsaicin and other substances (Megaze et al. 2017).

1.3.4. Distance from humans

As borders between animals and humans are thinner, sometimes there is no border et all, animals are more habituated to human appearance and some protection as fires or loud sounds, even the shooting. Animals are also starting to be more aggressive towards people (King et al. 2017; O'Connell-Rodwell et al. 2000). Parks or protected areas are not usually all fenced and animals are moving outside of protected areas where they compete for resources with humans (O'Connell-Rodwell et al. 2000). High amount of conflicts occur at borders of protected areas (Treves et al. 2006). Forests located next to villages are highly degraded.

Creation of the buffer zone can be beneficial for wildlife same as for better protection of farmland (Lhoest et al. 2020). Distance recommended by some researchers is 2 to 10 km from animal refugees. In these buffer zones there should not be any agricultural land and around the borders some unappetizing plants can be planted or it could be used for bee farming which can discourage animals from trespassing (Tangie et al. 2018). According to a study by Graham et al. (2010) with HEC most damage happened in a 2 km radius from animals' permanent day refugees. Therefore, it's very important to select the most vulnerable places and focus on them during conservancy strategies. Another problem with distance from humas is when shepherds are feeding herds inside parks or protected areas. Herds are more vulnerable to predation and are competing for resources with wildlife. Domestic animals can spread diseases affecting wild animals (Pozo et al. 2019; Lhoest et al. 2020). Stopping the conflicts cannot be done until people will continue to grow crops and feed domestic animals in areas with natural occurrence

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of wild animals. They can be only limited by the setting of appropriate measures (O'Connell-Rodwell et al. 2000).

1.4. Social impact

In the past few years, conflicts are more often due to human expansion into wild animals' habitats. (Zvidzai et al. 2013). Large issues in protection are financial support, used materials, capable workforce and mostly cooperation between locals or organizations and management without damaging biodiversity (Treves et al. 2006). Conflicts are creating problematic relationships between local people and wildlife (Nyhus et al. 2000) and people affected by HWC can see trespassing animals only as a problem which can create an obstacle in wildlife preservation as it is vital to have support from local population (Tagg et al. 2019). News from media and informations going from people to people about attacks are usually negative which also worsen understanding of wild animals (Nyhus et al. 2000). Hostile attitudes toward animals involved in conflicts can lead to killing individuals, aiding poachers and hunters to animals and blocking of tourism (King et al. 2017).

Animal problems are usually more attractive for people than other environmental issues. Successful conservation project had to combine the ecological and sociological needs of locals (Treves et al. 2006; Branco et al. 2019). Relationships between humans and wildlife are complicated and influenced by many aspects such as personal beliefs, experiences, economic, laws, social and ecological situations. Collection of all these aspects which indicate the attitude of peoples is important for understanding and managing the conflicts (Kingdon 2011). More and more animal populations are bound to functional coexistence with human settlements established next to wildlife. It is important to combine animal protection with some benefits such as protection, welfare benefits or economic advantage for locals (Treves et al. 2006). Managing wildlife on local levels such as community forests instead of programs led by state are recommended in central Africa (Lhoest et al. 2020). Some areas can provide compensations for crop damage or animals killed by wildlife. Those compensations can be in the form of money or as indirect compensation as licence to hunt, collect wood, tourist licence etc. (Tangie et al.

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2018). Less developed countries with usually poorer populations are rarely compensating farmers (Linke et al. 2007).

Touristic and research activities seem to have a positive effect on animal abundance also as a result in decreasing poaching pressure (Kely et al. 2021). Long term research and conservation efforts can reduce threats to nature (Lhoest et al. 2020) and all actions should have some partial visible steps and goals as for rural people can be problematic long-term research without any particular results. It is crucial to maintain good relationships with residents and stakeholders as local people can have incredibly important knowledge about animals and areas of research and also for possible evaluation of efficiency and possible changes in attitudes toward animals, settlements of appropriate level of communication are an important place to start (Megaze et al. 2017; Branco et al. 2019). Perception of situations can be different from scientific conclusions because humans tend to believe in family stories and rumours which occur for a long time and their personal experience can be misleading, information from memories are often changed unpurposely and have to be evaluated with caution (Treves et al. 2006; Nyhus et al. 2000). People living in affected areas have to be involved in solutions and should be encouraged to change their behaviour. Changes can't be forced on the local population (Treves et al. 2006; Tangie et al. 2018) communities can refuse to adapt some techniques even if they proved to be successful before, reasons are not often clear (King et al. 2017). Those people are not always aware how devastating the loss of wild animals can be for nature and also for their own living (Lhoest et al. 2020) and farmers inside protected areas may not be aware of some laws against creating new fields or killing animals whether they are raiding crops or not. Communication with these people and proper form of education can improve conservation efforts (Linke et al. 2007).

However, habitat loss is more dangerous to animal populations than poaching; these causes are related (Hoare & Du Toit 1999). People from different locations, of different ages or with different education have various attitudes to wildlife preservation. The younger and more educated people are, the better their approach to nature conservation and researchers is (Megaze et al. 2017). When communities are properly introduced to problems and consequences of inappropriate management of forests and protected areas, they tend to improve sustainability of their behaviour toward wild animals and plants (Lhoest et al. 2020).

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1.5. Savanna elephant (*Loxodonta africana* Blumenbach, 1797)

Taxonomy of species according to Mammal Species of the World (Wilson & Reeder, 2005)

Class: Mammalia

Order: Proboscidea Illiger, 1811

Family: Elephantidae Gray, 1821

Genus: Loxodonta Anonymous, 1827

Species: *Loxodonta Africana* Blumenbach, 1797

Elephants are the biggest land animals with weight from 2200 kg in females to 6300 kg in males (Estes 1992; Kingdon 2011). They have evolved in Africa and inhabited areas from marshy environments or dense forests to dry and open habitats also from lowlands to montane areas (Estes 1992; Kingdon 2011; Molina-Vacas, 2019). Historically elephants inhabited almost the whole African continent. Their distribution began to be more fragmented because of increase in human population and poaching (Estes 1992; Kingdon 2011). Loss of Elephant numbers and habitats are known as one of the important conservation problems of Africa (Hoare and Du Toit 1999; Molina-Vacas, 2019). Decline of population is around 80 %. Currently most of their population survive in shelters and protected areas (Selier et al. 2015). Inhabiting of some areas is affected by food preferences (Estes 1992). Savannah elephants live in the social matriarchal groups from 2 to 24 individuals (Fishlock et al. 2008). Bulls are living mostly solitary (Kingdon 2011). Communication is vocal, olfactory, tactile and by postures (Estes 1992). Elephants are important in nature and can be valuable also as an attraction for eco-tourism (O'Connell-Rodwell et al. 2000). Impact on landscape is very intensive, it can be positive (creating paths and wells, bringing down food for smaller herbivores or negative as landscape damages which can be very dramatic in case of high concentration of a lot of

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animals at one place. Elephants can change the whole ecosystem by taking trees down and massive consumption of vegetation (Estes 1992; Molina-Vacas, 2019).

Elephants are big mammals depending on fresh water during the whole year. Mothers with young are not wandering further than a few km from the water source. Adult bulls can search for water for several tens of km. The longest distance seen during research was 70km (Sinibaldi et al. 2004). Selection of waterholes by elephants is poorly understood and in a study by Weir (1972) it seemed as they prefer water provided with sodium and high alkalinity, but a study by Chamaill´e-Jammes et al. (2007b) did not find the same trend in the same area. Different studies show that elephants are avoiding saline surface water (De Boer et al. 2000). Dependence on water, not only elephants but other species as well, can be also seasonal due to possible drought related mortality. During the dry season elephants can dig craters in soil to obtain subsurface water (Sinibaldi et al. 2004).

Elephants are by IUCN Red List filed as Endangered with decreasing trend. Resident population of elephants in south Chad faces massive decline. This decline is the result of high poaching, habitat loss and unstable political situation not only in Chad but also in the Central African Republic (Gobush et al. 2021).

1.6. Human-elephant conflict

Conflicts with humans are one of the most important threats these animals are currently up to (Granados and Weladji 2012; Selier et al. 2015). In some areas, elephants are responsible for almost 50 % of human-wildlife conflicts. They happen in much larger areas than predator attacks. Predators are mostly responsible for the other 50 % of conflicts (O'Connell-Rodwell et al. 2000). HEC can occur in many forms from crop raiding, infrastructural damages, disturbance of activities to injuries or death of people or animals (Sitati et al. 2003; Tchamba and Foguekem 2012). In some areas where there is less amount of predators the most often HWC is crop raiding by large mammals. Incidents are mostly seasonal (Tchamba and Foguekem 2012) and mostly occur between July to August when the most crops are harvested (Tangie et al. 2018). Crop raiding is more

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connected to males presumably because bulls are more focused on highly nutritious forage than females (Tchamba and Foguekem 2012). Attacks caused by elephants are seen as a major problem even in areas where they occur only exceptionally. During a single elephant visit damage is very extensive and the size of one individual can be intimidating (Treves et al. 2006). During one visit a single animal can damage all crops on small scale farms (Figure 2) and damages are not limited on crops (Figure 3) (Graham et al. 2010).

Figure 2 Damaged crops.

Figure 3 House damaged by elephant.

Perception of animals involved in the crop damages can be sometimes misleading (Branco et al. 2019). Farmers can misidentify the most problematic species because of some personal issues or other factors (Linke et al. 2007). Because of intensive damage during one visit, they are seen as a bigger problem than small animals such as monkeys which cause damage in smaller size but in some areas much more often. After calculation of damages, crop-raiding elephants can be a minor problem compared with other animals but in humans minds the size of one attack exceeds other problematic species and elephants end up in massive dislike (Granados and Weladji 2012).

Humans and animals are living in higher contact. It is mostly the reason for the growing human population. With a growing population also consumption of energy materials and usage of land is higher (Kingdon 2011). Numbers of livestock are also increasing and wild and domestic animals are in direct or indirect contact mostly during the dry season. Contact may lead to disease transferring (Zvidzai et al.2013). Eyesight of elephants is good but best senses are hearing and smell (Estes 1992) For this reason chilli detergents and noise making is a good management tool (Molina-Vacas, 2019). Conflict

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situations change during time. With the increase of conflicts and also with laws for animal protection, the problem grew into political conflict (Treves et al. 2006).

1.7. Hippopotamus (*Hippopotamus amphibius* Linnaeus, 1758)

Taxonomy of species according to Mammal Species of the World (Wilson & Reeder, 2005)

Class: Mammalia

Order: Artiodactyla Owen, 1848

Family: Hippopotamidae Gray, 1821

Genus: Hippopotamus Linnaeus, 1758

Species:*Hippopotamus amphibius* Linnaeus, 1758

Hippos are part of a megafauna (Nyhus 2016). By IUCN hippos are seen as vulnerable with a stable population trend. They are still facing a lot of threats. The main threads are the same as elephants, it is mainly habitat loss and hunting for meat or ivory (Lewison & Pluháček, 2017). Hippos are completely aquatic species with their life bound to fresh permanent water (Sinibaldi et al. 2004). They prefer grazing during the night around rivers and pools they are living in (Mackie et al. 2013). By grazing they are highly affecting vegetation composition. In cases of drought hippos can be eating flash and be carnivorous. These animals are solitary living and territorial but they can share the same water body (Lewison & Pluháček, 2017). Number of individuals depends on the size of the water. Fighting between males happens often due to their mating and territorial behaviour and injuries and deaths are occuring. Populations of hippopotamus are declining for many reasons such as habitat lost, poaching or water pollution (Utete 2020). Hippos are involved in HWC mostly as a crop raiding species (Mackie et al. 2013; Nyhus, 2016). In the last few years more cases of hippos attacking humans have been reported. In Chad hippos are living mostly in Lake Chad, the Chari Riverin, Zakouma National Park and other big water bodies. In Chad they are responsible for HWC and their

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population is estimated at 500 individuals (Lewison & Pluháček, 2017). In Logone Oriental they are also found in rivers as Logone but not in our areas of mapping (Save Elephants, unpublished data). Since 2000 the population of hippos in central Africa has been declining as a result of habitat loss and hunting pressure but in the last few years it seems stable (Scholte et al. 2017).

1.8. Water management

Water is essential for many life forms. More than half of accessible freshwater is used by humans and is often overexploited. As a result there is significant degradation of many freshwater habitats. An index of the health of the world's major freshwater ecosystem shows a decline of 50% between 1970 and 1995 (Sinibaldi et al. 2004).

Food and water availability, variety of plants and distance from water are influencing density of animals (Duffy et al. 2010). Sufficient supply of good quality water is now threatened mostly by human activities and climate change (Sinibaldi et al. 2004). Water dependence is the most important element on which density and presence of animals is based on (Chamaillé-Jammes et al. 2007). Elephants as other animals are highly limited by water. Their presence and health is influenced by water availability but different species are dependent on freshwater in different ways (Molina-Vacas, 2019; Sinibaldi et al. 2004). Dependence of elephants on the water sources is already communicated in legends between people living in their proximity (Gerstang et al. 2014). They are mostly dependent on permanent wetlands (Beirne et al. 2020) daily intake is approximately 200l but they can go up to four days without drinking (Sinibaldi et al. 2004). In Cameroon during the dry season the most HEC were around larger rivers (Granados et al. 2012).

Planning of land-use is the most important tool in management (Graham et al. 2010). With lack of water management many areas may soon be uninhabitable for animals as for humans (Sinibaldi et al. 2004). Water dependence of large mammals and water management used for them is a field with limited information available (Sinibaldi et al. 2004).

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During water management planning it is important to take into account the changes in quality and quantity of water but also the accessibility, population expansion, land tenure issues and possible invasion of alien plant species, terrestrial or aquatic (Sinibaldi et al. 2004).

Creating new water holes has a strong effect on animal distribution (Duffy et al. 2010). During the dry season elephants are trying to stay close to water holes and during wet periods they are moving to greater distances (Beirne et al. 2020). With decreasing precipitation the number of animals and heterogeneity of species around the water hole is increasing. These are the main reasons why surface water management is suggested as a very efficient tool in human-elephant conflict solutions (Granados et al. 2012). In semi-arid areas in Africa people tend to build houses and farms around permanent water bodies. These waters are historically used as a water source by wild animals and new agriculture land is then more vulnerable to HEC (Graham et al. 2010). Water holes with permanent presence of elephants or with frequent returns of the same individual may be connected also with high water and nutrient quality (Chamaillé-Jammes et al. 2007).

When animals are stressed due to human overpopulation, habitat destruction or excessive hunting they tend to create larger groups up to 200 individuals (Estes 1992). HWC involving elephants during the dry season happens during search for water (King et al. 2017). Higher numbers of HEC occur during the dry period of the year when the number of water sources is declining (Zvidzai et al. 2013). As a prevention, creation of water reservoirs which can serve as a source during the dry season was proposed in some areas. Water management can be a very useful tool in solving HWC (Tangie et al. 2018). Animals are mostly trying to avoid contact with people. Interaction between elephants and humans is decreasing when the population density of humans is more than 15-20 person/km^2. Elephants are avoiding larger human settlements and migrate away from people (Hoare and Du Toit 1999). In densely populated areas numbers of attacks declined when the number of settlements was lower than 20 per km^2 Graham et al. 2010). Studies show that the amount of natural habitat changed into agricultural land is not affecting the density of animals in the area (Hoare and Du Toit 1999). Wild animals are still preferring waterholes inside protected areas and visitation of waterholes inside agricultural areas are mostly timed around midnight, waterholes inside protected areas were used by them

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throughout all day (Zvidzai et al. 2013). Elephants are not avoiding waterholes regularly used by stock as some other species (Hoare and Du Toit 1999). In the case of shared waterholes cattle mostly arrived around noon and wild animals in mornings and evenings. Overlap in usage of waterholes is not only in the dry season (Zvidzai et al. 2013).

Effective wildlife conservation should be based on water management with availability of fresh water for all dependent species and human needs. Possible changes in rainfall and water quality should be taken into account as well as other important factors as maintaining of existing water bodies, development planning and effective use of water (Sinibaldi et al. 2004). Creating artificial water bodies may be beneficial but has to be done with consideration and has to be maintained well. Creating as much waterpoints as is possible is not always the best strategy as we can see in a case study from Hwange National Park Zimbabwe where more 50 boreholes were created and animals learned to use these localities as a water source and did not migrate to other permanent water sources as was planned (Sinibaldi et al. 2004). Problem became during the dry season when due to diesel pump malfunction only eight of them remain working. Almost 1000 elephants (which made up 3-5% of population) died. As a precaution 22 critical localities were selected which needed to be maintained but with reduction of elephant population (Owen-Smith 1996).

Water management is not working perfectly on its own; it is important to combine it with other approaches. In a case study from the Waza-Logone region, Cameroon, the combination of water management and the creation of corridor used by elephants for migration led to decline in numbers of HEC (Figure 4).

Percentage of villages affected/not affected by elephants per season and per years (2003, 2004 and 2005)

Years	Number of villages affected per season (N= 13)		Villages affected per year (N = 13)	Villages not affected per year (N=13)
	Dry season (number of villages)	Rainy season (number of villages)	(number of villages)	(number of villages)
2003	30.7% (4)	38.46% (5)	69.23% (9)	30,77% (4)
2004	23% (3)	38.46% (5)	61.54% (8)	38,46%(5)
2005	15.4% (2)	38.46% (5)	53.85% (7)	46,15% (6)

Figure 4 Percentage of villages affected by HEC (Tchamba and Foguekem 2012).

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1.9. Water mapping

Surface water is important in the water cycle for humans and whole ecosystems. Water on land is changing due to global climatic change and human influence (Lu et al. 2011). Most water is used in agriculture and industrial fields. In water management important factors are also politics, finances and local communities (Srdjevic et al. 2002). Management is very important and for that mapping of water bodies is necessary (Lu et al. 2011). Conservation and use of water have been an important theme in the past few years. Mostly in relationship with cities (drinking water supply, sewer systems, floods) and agriculture (supply, water quality, evaporation). Data for mapping of water can be collected by GPS spatial data in the field (Solbø 2003) or satellite images can be used (Panagopoulos et al. 2012) or combination of both (Subramanian et al. 2014). Data are evaluated with various software as GIS (Panagopoulos et al. 2012; Subramanian et al. 2014) or Analytic Hierarchy Process (Srdjevic et al. 2002). Satellite imagery can be used in relatively open areas where water bodies are visibly different with reflection or coloration from surroundings. This method is suitable for larger rivers, lakes, dams etc. Images can be obtained from various databases as Landsat, MODIS, Radarsat, HJ-1A, HJ-1B and others (Solbø 2003; Lu et al. 2011). Satellite images have to be processed and segmented into pixels with correct indexes and settings for current locality as there could be aspects affecting results as clouds, mountain shadows and others (Lu et al. 2011).

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2. Aims of the Thesis

This thesis is part of a conservation project Water for elephants led by Save Elephants organization. This organization has been working on wildlife protection in Central Africa since 2014. Elephants and other wild animals are migrating through villages and agricultural lands in an attempt to find water or food (Zvidzai et al. 2013). By pilot project in reserve Kalfou reserve in Cameroon and few published research (Chamaillé-Jammes et al. 2007; Duffy et al. 2010; Graham et al. 2010; Tangie et al. 2018) was monitored, that creating water holes away from human settlements and agriculture can decline number of invasions of animals into villages and fields, mostly during the dry period of the year.

Aim of this thesis is location of places suitable for building reservoirs which can serve as water holes during the dry period of the year in two areas of interest. In the first location, the Kone Lam reserve, the main purpose of reservoirs is to maintain elephants and other wildlife away from agricultural used land mostly during the dry period of the year. In the second area, which is inside agricultural land near villages Baibokoum and Mbaissaye, reservoirs could have dual purpose. Waterholes can be used by wildlife, mostly during night, and as a water source for humans and their herds during the day. Creation of reservoirs in the second area can also serve as a social benefit for local communities which can gain their positive attitude.

This research was created on request from Save Elephants organization and has a practical value in wildlife conservation.

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3. Methods

3.1. Localities description

Project of mapping for water sources is situated in south Chad in the region of Logone Oriental (Figure 5), prefecture Monts de Lam. South Chad has a tropical savanna clima. Year is divided into dry and wet seasons. Dry season occurs November to April and wet season April to October. Highest temperatures are in March with average temperature around 30 °C, lowest temperatures around 24 °C are during December. The yearly amount of precipitation is approximately 1120 mm. Weather data are from the nearest meteorological station in Béboto around 100 km (Weatherbase, 2021).

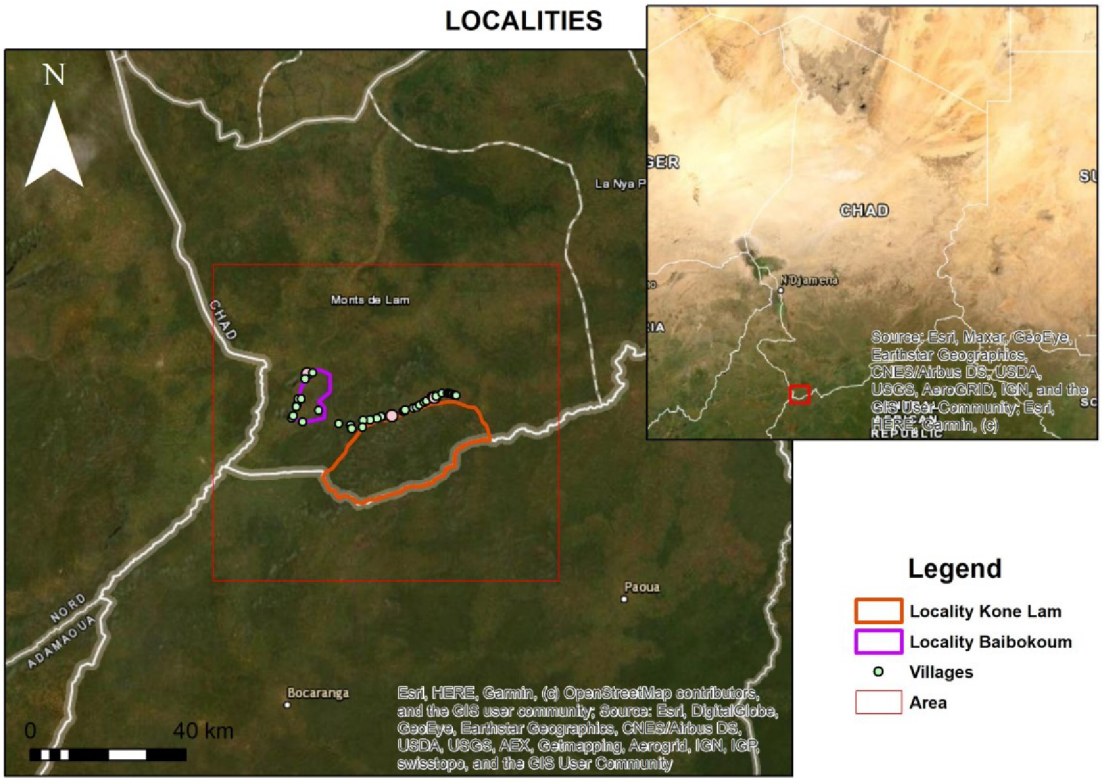

Figure 5 Chad - localization of research.

In this research two main areas of interest were selected, Kone Lam and Baibokoum, (Figure 5). First location is Kone Lam reserve. During mapping in 2017 this reserve was unofficial. In the year of 2020 reserve acquired official status by local authorities and the Ministry of Agriculture, thanks to work of Save Elephants and A.L.C.P. Dimension of the reserve is approximately 635 km^2. According to Chad law in

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the natural reserve it is not permitted to use weapons to hunt unless it is defence of property or people (Decret 380, Fixant les modalites d´application du regime de la faune. 2014).

Analysis was conducted only on a limited area of 7164.82 km^2. Land cover of the area is mostly formed by closed to open shrubland which make 91.5 % of all cover (Figure 6). This land cover also includes agricultural used land. Second most represented cover is open broadleaved deciduous forest /woodland with 7.2 %. Rest 1.3 % is formed by mosaic cropland and forest and water bodies. In Baibokoum locality main land cover is open shrubland but most of land is agricultural used. In Kone Lam around 90% is forested area.

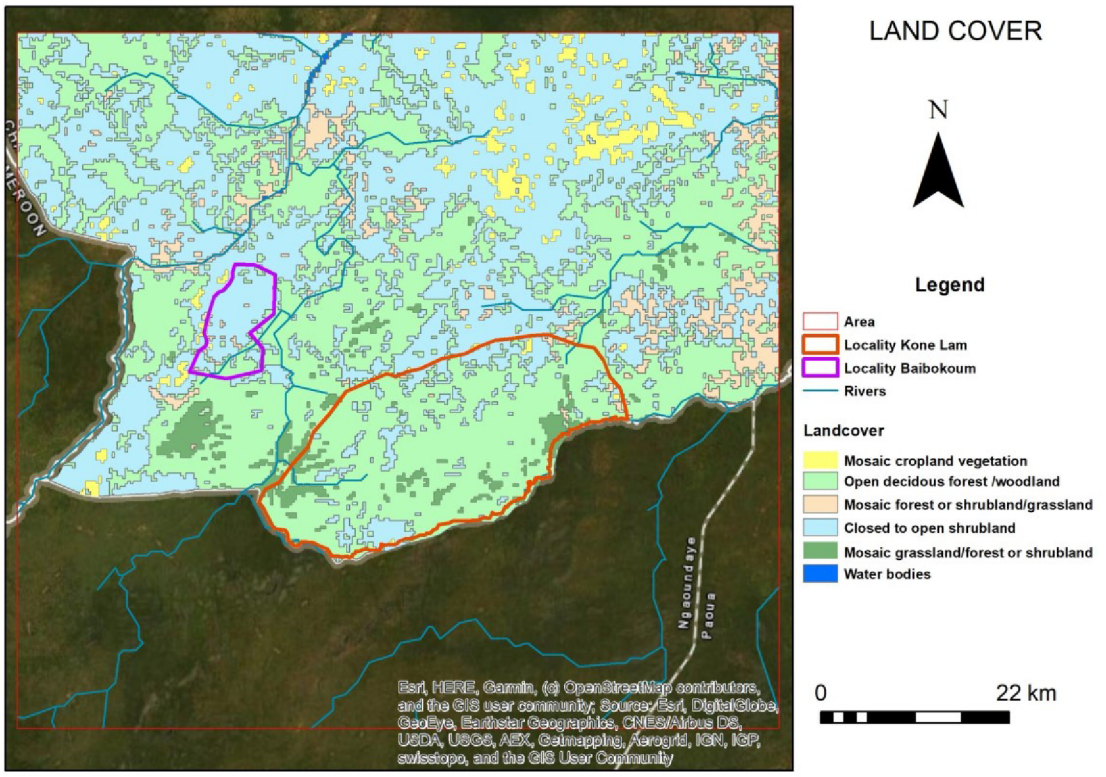

Figure 6 Land cover.

Mapping in Kone Lam was conducted around villages Dagbao and Toumbao and Bidanga. Reserve is a large mountain area bounded on the northern side by road with small villages and on the southern side by borders with the Central African Republic. Vegetation is continual consisting of shrubs, tall grasses and deciduous trees (Figure 7). Geologically it is an area formed by Precambrian basement rocks, especially granites,

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gneisses and migmatites (Schlüter, 2006), which have low aquifer productivity (<0.5 l/s; MacDonald and Davies, 2000), locally with intrusions of Paleozoic basalts. Water sources are in form of the streams and rivers of different sizes and swamp areas.

Figure 7 Kone Lam vegetation cover.

Second mapped area was conducted around the Baibokoum and Mbaissaye villages. Area is around 8 km from the border with Cameroon. Size of the area is approximately 83 km^2. Mapping was set during March 2018. The area is mostly agricultural land with villages of different sizes surrounded with fields and pastures.

Mapping of area still continues, and the third mapping was conducted in April 2018 on the west end of Kone Lam reserve inside and also outside of the reserve. Appearance of this area is a combination of both previous locations.

People are living in small clay huts to larger ones made from bricks and sheet metal. Houses are concentrated into villages, but some buildings are located in the fields and around roads or footpaths. Small part of population is living nomadic. In larger villages electricity is introduced by the national grid but only the wealthier people have access to it. Crops are mostly single grown crops on one field, mostly maize, cotton, peanuts, sorghum and cassava in moisture areas.

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3.2. Data collection

All mapping activities were conducted under authorization of Chief of Logone Oriental, Gendarme and local police forces. For mapping GPS devices (Garmin Dakota 20, 64s) was used. GPS coordinates were set to WGS 84. During mapping we were looking for animal presence or signs of animal presence as footprints (Figure 8), dungs (Figure 9), paths etc. At places suitable for reservoir constructions were recorded information about size, water quality, animal abundance etc.

Figure 8 Elephant footprint.

Figure 9 Elephant feces.

We had four photo traps for possible documentation of animal presence or usage of located ponds. We tried to use them in both areas but were not successful. In Kone Lam reserve we were not able to set them deeper inside the forest because we were not revisiting places. Inside agricultural areas around Baibikoum a camera which could have possibly captured elephants was stolen.

Mapping of streams, rivers and water holes was done in August 2017 by Marie Matuštíková from CULS and Samuel Benou, who is the head of local organization A.L.C.P. cooperating with Save elephant. Two terrain expeditions lasting 3 and 5 days were organized. Only a central third of Kone Lam reserve was examined as a result of political and safety situation and also due to weather conditions of the wettest month of the year. Some of the expeditions had to be cancelled because of the heavy rains occurring during the days and one was terminated earlier due to illness of a local guide. Inside the reserve are only small paths accessible by walk. For that reason, reserve was explored by foot as far as possible. During one expedition the border with CAR was reached. Mapping was realized with assistance of local guides from nearby villages to locate water sources

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and animal refuges. First task was location of rivers or streams behind agricultural areas, located waterbodies were mapped by following the stream as much as was possible due to the terrain obstacles. Two localities with permanent elephant presence were found called elephant refugees.

During the end of the dry season in 2018 the second area was mapped by Samuel Benou and Arthur Sniegon, founder of Save elephants. Searching for water was done in 3 days between 16th and 18th March during the end of the dry season. Surveys among local people were done to locate remaining water in dry creeks and other water bodies. Roads in these areas were accessible by foot and by motorcycles. Second mapping, based inside agricultural areas, was focused on water sources available to the local population and wildlife living inside or crossing these areas.

Third mapping was conducted only by Samuel Benou during April 2018 in eastern end of Kone Lam. Mapping was done partially inside the reserve and partially outside around villages.

In April 2021 localities were visited by A.L.C.P. to verify permanence of water sources.

3.3. Data analysis

Data was analysed by ArcMap 10.7 software. Coordinate system was set to WGS 1984. As a base map was used World Imagery (WGS84) for satellite images and World Boundaries and Places for country boundaries determination. To mark all discovered localities from all three mappings, point shapefile was created as Shapefile_from_XYTable. In this layer attribute table with all gathered information about the places were created from the table below (Table 1). Layers with two main mapped areas were marked as a 1. locality_Kone Lam and a 2. locality_Baibokoum and transform into polygon shapefile. Determination of agricultural limits in the Kone Lam reserve were based on satellite images from online base map and compare with GPS points collected during first mapping. Images were in accordance with satellite images. Difference between fields and unmanaged land in reserve is clearly visible on satellite images based on different coloration. Using satellite images from online ArcGIS maps and Mapcarta

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maps, villages and routes in the areas of interest were marked. Maps of land cover and rivers were obtained from Food and Agriculture Organization of the United States (https://data.apps.fao.org, 2021) and satellite images for elevation model were downloaded from the USGS science map database (EarthExplorer, 2021).

Localities from first two mappings were evaluated by weighted average for determination of most suitable location. Categories evaluated were buffer distance, animal presence, water quality, distance from roads and permanence of water source. Categories were numbered from 1 as the best and 5 as the worst mark. Mapped areas (A and B) were evaluated separately as a result of different conditions.

The most important variable in the first area of interest is the distance from agricultural land in Kone Lam reserve. Distance is important to offer water sources to animals during the dry period of the year, so they are not migrating to fields for this purpose. The Analysis tools were used in this search. For this determination only localities from first mapping were used since the second area is located inside agricultural fields. These localities were selected in the Attribute table. The Buffer tool analysis was used. Buffers were created for distances of 1 km, 2 km, 3 km, 4 km, 5 km, 6 km, 7 km and 8 km. Selection by Location was used to highlight locations outside the buffers. Setting of the Selection tool is shown at figure below table (Figure 10). Selection By Location was set manually for every Buffer layer.

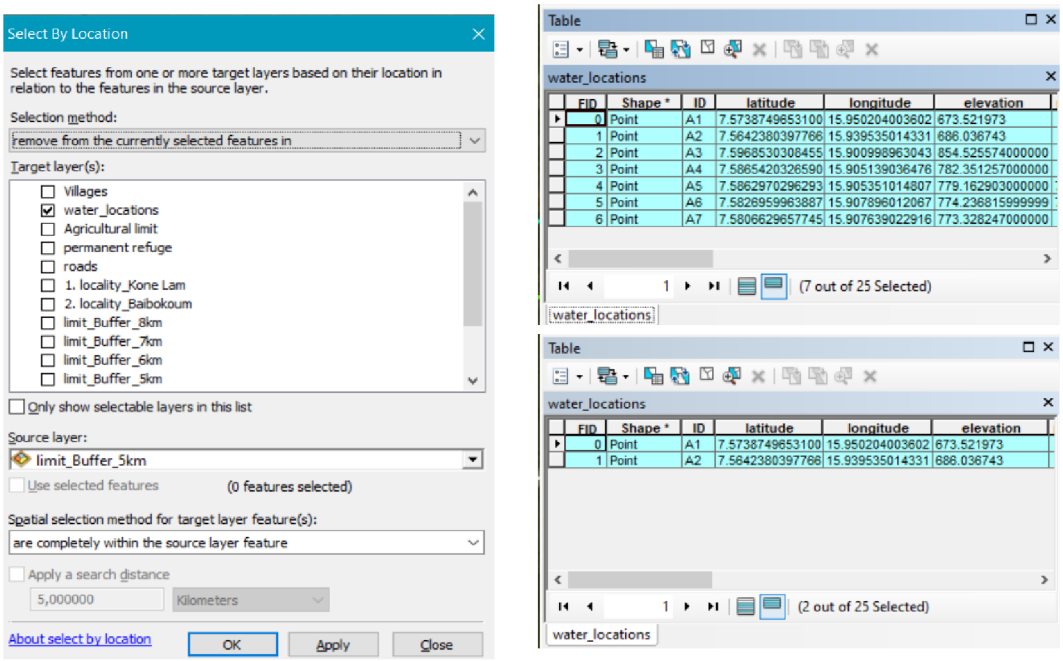

Figure 10 Select By Location setting and results.

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Table 1 Attribute table

	latitude	longitude	elevation	distance_road	W_A_seen	W_A_Sign	A_Domest	permanence	Mapp_Area
A1	7.573874965310097	15.95020400360226	673.52197	800	YES	YES	NO	NO	Kone Lam
A2	7.564238039776683	15.93953501433134	686.03674	1300	NO	NO	YES	YES	Kone Lam
A3	7.596853030845523	15.90099896304309	854.52557	5	NO	NO	NO	NO	Kone Lam
A4	7.586542032659054	15.90513903647661	782.35125	1	NO	NO	NO	NO	Kone Lam
A5	7.58629702962935	15.90535101480782	779.16290	1	YES	YES	NO	NO	Kone Lam
A6	7.582695996388793	15.90789601206779	774.23681	1	NO	NO	NO	YES	Kone Lam
A7	7.580662965774536	15.90763902291655	773.32824	750	NO	YES	NO	YES	Kone Lam
B1	7.7307	15.70411667	484	1700	YES	NO	NO	NO	Baibokoum
B2	7.720266667	15.69448333	503	60	NO	NO	NO	YES	Baibokoum
B3	7.72028	15.70856	503	660	NO	NO	NO	NO	Baibokoum
B4	7.72017	15.70652	504	900	NO	NO	NO	NO	Baibokoum
B5	7.6644	15.69448333	550	10	NO	NO	YES	NO	Baibokoum
B6	7.666883333	15.69225	550	130	NO	NO	YES	YES	Baibokoum
B7	7.657616667	15.70268333	505	130	NO	NO	NO	NO	Baibokoum
B8	7.65805	15.70471667	468	10	NO	NO	NO	NO	Baibokoum
C1	7.70601	16.02813							
C2	7.64649	16.05393							Kone Lam
C3	7.67686	16.07033							
C4	7.72277	16.00833							
C5	7.66102	16.13792							
C6	7.68571	16.14503							
C7	7.71728	16.1819							
C8	7.669	16.20251							
C9	7.63406	16.217							
C10	7.61947	16.24945							

Another distance in the first area used as a variable to select places was distance from permanent refugees. By one of the Analysis tools, the Point Distance tool, we were able to automatically calculate distances of localities in Kone Lam from permanent elephant refugees. Radius of 10 km was used to calculate distances only for localities from first mapping as the other localities are in too far distance to have some value for this setting. Results were evaluated in the form of tables.

Third variable was the permanence of water. Places were determined by Select by Attribute tool with formula "Mapp_area" = 'Kone Lam' AND "permanence" = 'YES' to established places in first area of interest and "Mapp_area" = 'Baibokoum' AND "permanence" = 'YES' for second area.

Distances from roads and paths (Dist_roads field in Attribute table) were established by a Measure tool in ArcMap when possible and in the area of the first mapping measuring tape and GPS distance were used. This variable was also used as a selective in the first area.

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With ArcMap tool Select by Attributes we can separate localities according to other variables. All variables were entered in the Attribute table of Water_locations shapefile. As the most suitable places are those where animals are already used to come, we were selecting places by the presence of wild animals. Command for selection was used: "Animals__by" = 'YES'. For larger selection localities with direct presence and signs of presence of wild animals was used command: "Animals__1" = 'YES' OR "Animals__by" = 'YES'.

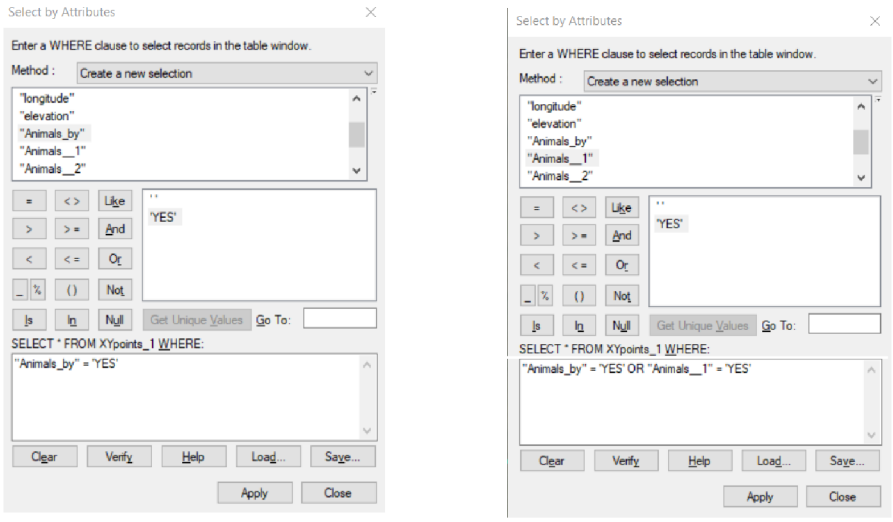

Figure 11 Select by animal presence.

Places with the seen or signs of domestic animals are not preferable due to possible disease transmission. To select only places with presence or sign of wild animals but not those with use of domestic animals we used a different method of Select by Attributes. Method is Remove from current selection. From selection "Animals__1" = 'YES' OR "Animals__by" = 'YES' we removed localities with the presence of domestic animals with command: "Animals__2" = 'YES' (Figure 11).

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4. Results

4.1. Localities found

Different localities were found during all mapping expeditions. In total 7 suitable places were found in Kone Lam reserve. Places were named A1-A7. In the agricultural area Baibokoum 8 localities were found and named B1-B8. During the last expedition 10 more localities were found in agricultural and forested areas. These localities were named C1-C10.

Locality A1 is a shallow puddle (Figure 12). It is away from paths but serves as a drinking place for cattle and sheep herds which we met grazing in this area (Figure 13). It is also used as a water hole by wild animals. In this area signs of the presence of elephants, gazelles and wild boars were noticed. According to locals more species of wild animals are using this location. Water permanence is depending on the weather, but mostly this water source is not permanent. Puddle is next to a marshy area.

Figure 12 Locality A1.

Figure 13 Herd of cattle.

Locality A2 (Figure 14) is area ground out by water based on permanent spring. Location is away from footpaths and none herds of domesticated animals or signs of them were visible around the waterhole. On the way to the water source few buffalos were seen. Presence of wild animals according to locals should be similar to the place A1.

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Figure 14 Locality A2**.**

Water source A3 is located on a stream which is permanent only during more rainy years placed inside the forest up on the hill. Shape of the stream can create up to 17 m long reservoir (Figure 15). The stream is adjacent to a path that is about 5 m away.

Figure 15 Locality A3.

Locality A4 (Figure 16) and A5 (Figure 17) are located on the same stream named Danga Koi only a few meters away from each other. Both are on a rocky basin with one side open to the forest. Between A4 and the A5 path leading to Central African Republic is located. Path is frequently used. Danga Koi is permanent. Ungulate footprints were visible around and a monkey of unrecognized species was seen.

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Figure 16 Locality A4.

Figure 17 Locality A5.

Locality A6 is a shallow place with a wide river creek and the possibility to create a pond as long as 7 meters (Figure 18). It is located inside a forest with grass meadow on one side and steep hillside on the other. Occasionally used footpath leads around one side of the stream.

Figure 18 Locality A6.

Locality A7 (Figure 19) is a place away from human paths with a small natural pond between a short cascade (Figure 20). Grassy meadow with very good access to the pond on one side and a forest on the other. During the rainy season there is a high flow rate. Place with a permanent elephant presence is very close and marks of the presence of elephants are visible around the stream.

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Figure 19 Locality A7.

Figure 20 Cascade under A7.

Places in the second area of Baibokoum were found in two groups. First group with localities B1- B4 is located in the southwest from the Baibokoum Village. Second group of B5 - B8 is near Mbaissaye village. Both are highly agricultural areas.

First locality named B1 (Figure 21) is approximately 1 km from Baibokoum village in between small farms. Water residues from the stream were found in the creek. Water was used for watering near the field. Large group of small amphibians (Figure 22), probably genus Xenopus, were found living in mud.

Figure 21 Locality B1.

Figure 22 Amphibian found at locality.

At locality B2 are two primitive wells filled with rainwater and presumably with underground water (Figure 23, 24). Water is very high quality and is used as a drinking water. There are no gardens or fields in the immediate vicinity. High quality of water is also suggesting water seeps from underground. The wells are located in between fields and only a few meters from a smaller road. Water supply is permanent in these wells.

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Figure 23 Well at locality B2.

Figure 24 Other well at locality.

B3 and B4 are located in terrain lowland. There are two types of water bodies. Residues of water in the creek (Figure 25) and pools in marshy areas (Figure 26). Small ponds are used mostly for agriculture and laundry. These locations are in a small tree-covered area which is surrounded with fields.

Figure 25 Locality B3.

Figure 26 Locality B4.

B5 are residues of water in the creek artificially created as a consequence of pipeline construction (Figure 27). Locality is near the Mbaissaye village only a few

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meters from the road. Place is hidden in trees with lots of stones left there during pipeline construction.

Figure 27 Locality B5.

B6 (Figure 28) is located 400 meters from B5. During a dry period of year remains of a larger pond in fields used as a water source for cattle and other domestic animals was found. Place is not hidden under any vegetation but is permanent.

Figure 28 Locality B6.

B7 and B8 are located near to Bagodoro village. B7 (Figure 29) is a pond in a dried creek. This is possible water sources for domestic herds and agriculture. B8 (Figure 30) is located on the same stream as B7. It is also pond in deeper part of stream. This locality is according to locals used as trap for smaller animals. This trap is based on poisoning water in pond during evening with “Firadoua” poison and collecting dead animals in the morning. This place is poisoned repeatedly.

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Figure 29 Locality B7.

Figure 30 Locality B8.

For places located during the third mapping named C1-C10 locations are visible at map below (Figure 31) no further information is currently available. Some basic information we could estimate from satellite images. C1, C4 and C7 are located inside agricultural areas. C2, C3, C5, C6, C9 and C10 are behind agricultural limits. C2 is inside the Kone Lam reservation. Last locality C8 is on the border between agriculture and forest.

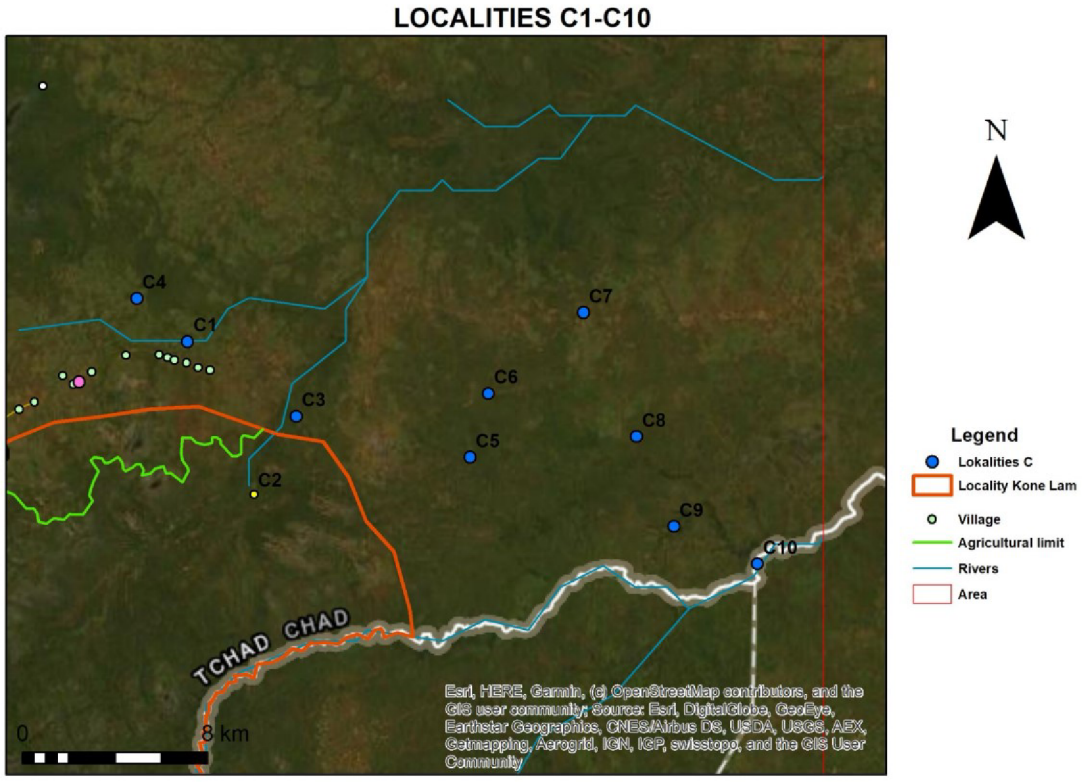

Figure 31 Localities C1-C10.

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In Kone Lam reserve are two localities which elephants are inhabiting permanently (Figure 32). Those are very marshy areas during the wet season, for people it is complicated to go through a swamp but animals' presence was heard and signs of the presence of elephants were clearly visible. These areas are marshy even during the dry season with a high amount of crop. Both localities are away from paths used by people.

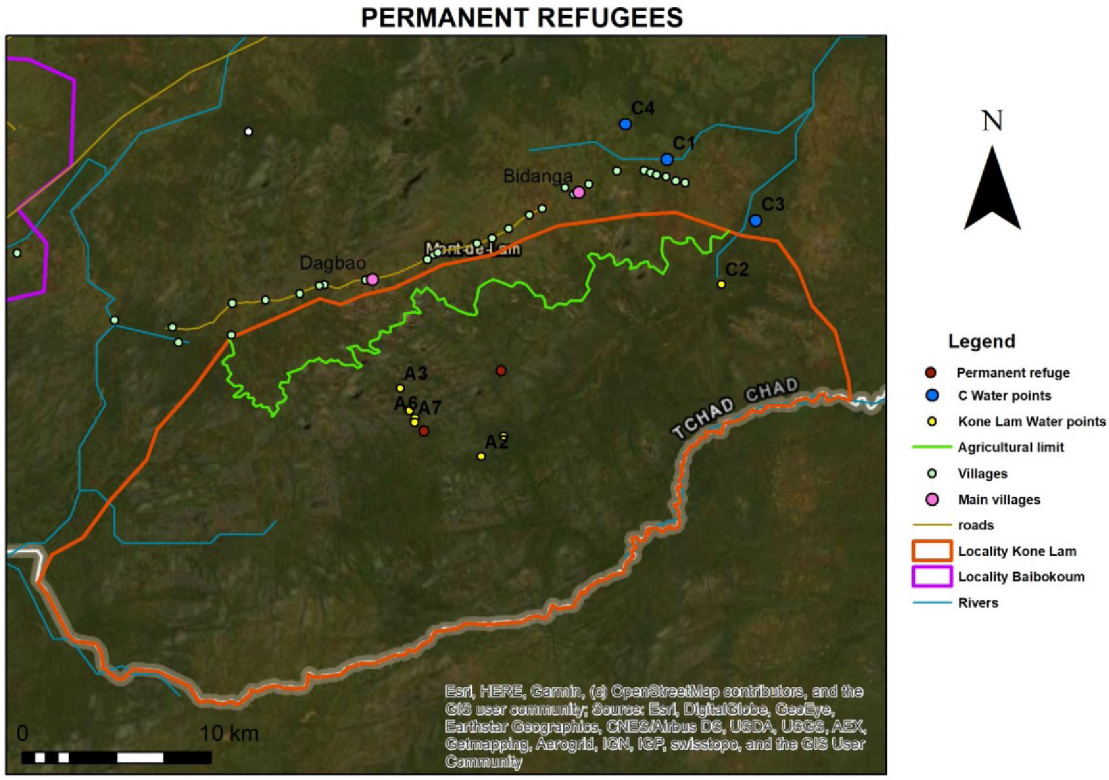

Figure 32 Permanent refugees.

4.2. Localities by distance

4.2.1. Distance from agriculture

Inside the first mapped area, Kone Lam, the most important element for selection of suitable places is distance from maintained land. To maintain animals from agriculture it is important to create dams in sufficient distance from humans. Authorities of prefecture Monts de Lam and closest villages will have the jurisdiction to decide what is minimal distance from fields. This distance is not known at this time for that reason different buffers were set (Figure 33).

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After application tool Select by Location for Limit_Buffer_1km and Limit_Buffer_2km inside Kone Lam area all 7 out of 7 places were still selected. With Limit_Buffer_3km 6 out of 7 places from this area were selected. Locality A3 was sorted out. With a distance of 4 km away from the limit, Limit_Buffer_4km, only 3 localities A1, A2 and A7 remain as suitable. Limit_Buffer_5km and Limit_Buffer_6km sorted out 5 out of 7 places. Only A1 and A2 were further than 6 km from limitation. With a limitation of 7 km from agricultural land only the last location the A2 is suitable. After applying Limit_Buffer_8km none place from the Kone Lam area was selected.

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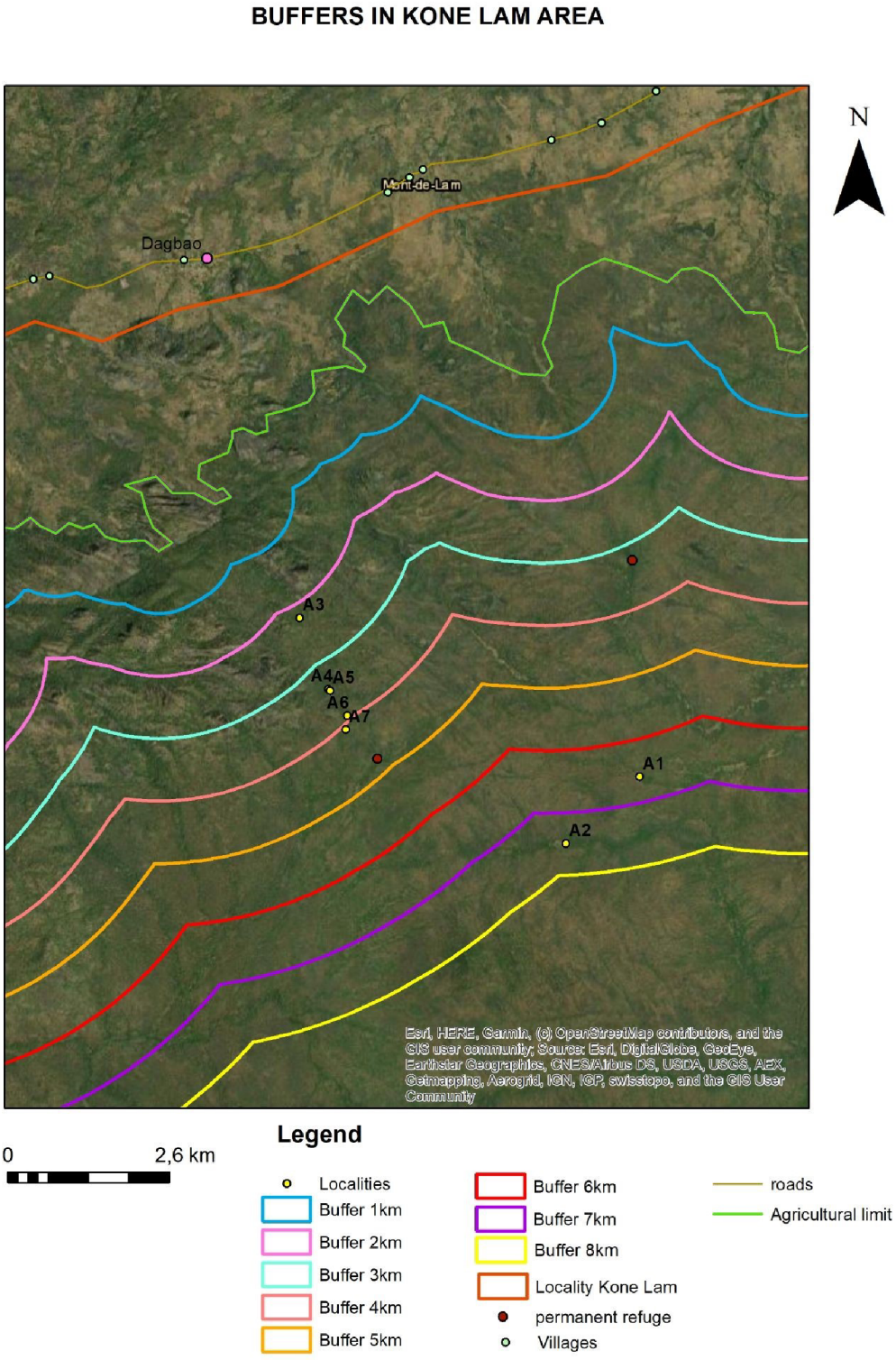

Figure 33 Buffers in Kone Lam.

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4.2.2. Distance from refugee

Another variable based on research on elephant distribution (Graham et al. 2010; Tangie et al. 2018; Lhoest et al. 2020) is distance from permanent elephant refugees. Those places were found 2 in the Kone Lam area. Both refugees were in swampy areas far from agricultural land. Distances were calculated for every locality A from both refugees found in reservation. The closest locality from refugee 0 was A1 with distance 3.1 km. Rest of localities were from 4.2 km to 4.8 km away. Closest locality to refugee 1 was A7 with distance 0.6 km. Other distances were from 0.8 km to 3.8 km away. Closest distance from any refugee was between refugee 1 to locality A7. All distances are visible in table below (Table 2). Refugees are in Near FID columns.

Table 2 Distances from refugees

XY FID	Near FID	Distance	XY FID	Near FID	Distance
A1	0	3.1322	A7	1	0.6232
A2	0	4.2046	A6	1	0.7596
A6	0	4.6955	A5	1	1.2005
A5	0	4.7667	A4	1	1.2328
A4	0	4.7765	A3	1	2.3280
A7	0	4.8183	A2	1	2.9900
A3	0	4.8835	A1	1	3.8040

4.3. Select by Attributes

4.3.1. Selection by permanence

As a permanent source even residues of water were counted as permanent if they occur during the whole year. In Kone Lam 3 out of 7 places were selected by permanence. Those are localities A2, A6 and A7. In the Baibokoum area 2 places B2 and B6 were selected.

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4.3.2. Selection by animal presence

In total 3 locations were selected with direct wild animal presence, 2 of them in Kone Lam area A1 and A5 and one in Baibokoum B1. Wider selection of localities, with direct presence and signs of presence of wild animals, chooses 4 locations, 3 of them in Kone Lam A1, A5 and A7 and 1 of them, the B6, in Baibokoum area. By widening selection only one locality was added.

From these places none of the localities was eliminated by the presence of domestic animals. Herds were seen at different places than wild animals. This could be because wild animals are avoiding contact with domestic animals.

4.4. Elevation model

After applying the elevation model (Figure 34) based on satellite images we can see that dark green colour shows low elevated valleys and red coloration is representing hilltops. After comparing our water points and model, it is clearly visible that founded water sources in the third locality are following darker coloration of the valleys. Hilltops are rock outcrops without vegetation and therefore location of water sources in these areas is not probable.

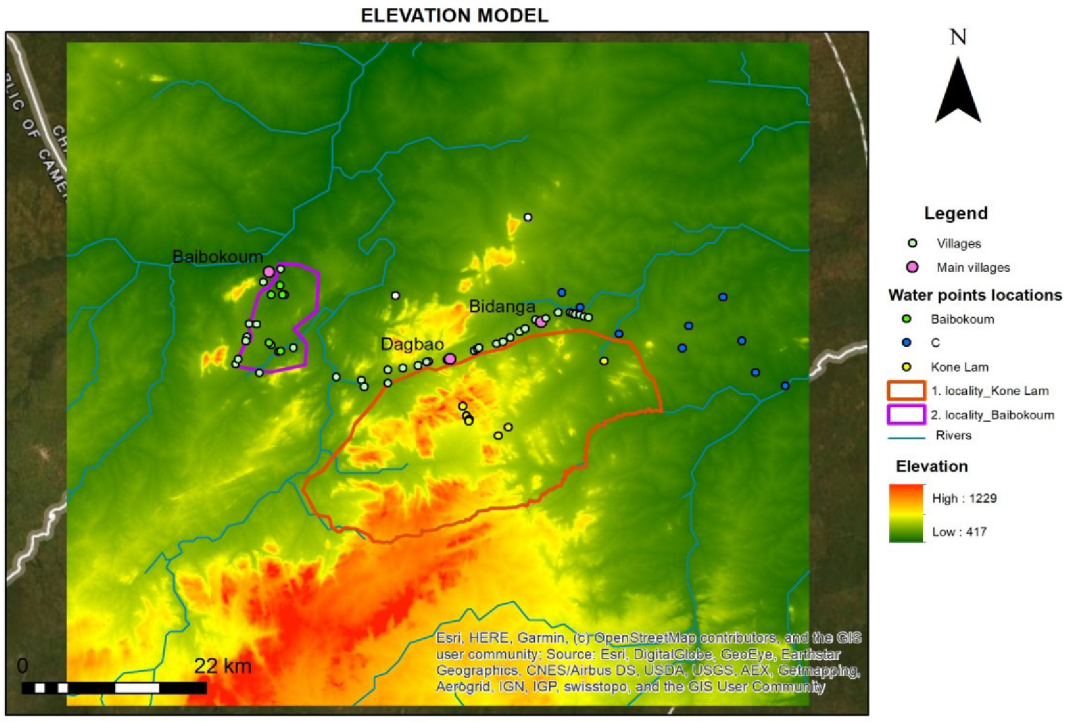

Figure 34 Elevation model.

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4.5. Weighted average

For Kone Lam locality the most important variables were distance from agriculture (buffer) and permanence of water because stabile water source will be more likely used by animals and to prevent migration to fields and villages. Permanent sources got value 1 and not permanent got value 5. Localities in closest buffer were evaluated as 5 and locality in the farthest buffer got 1.

Second important variables were distance from refugees and from roads. Animals don't tend to travel far from refugee when not needed which keeps them inside reserve and should be away from footpaths to not interact with people et all if possible. Values for distance from refugee was 1 for 0-800 m, 2 for 801-1600 m, 3 for 1601-2400 m, 4 for 2401-3200 m, and 5 for 3201 and more. Distance from footpaths got values as 1 for 0-50 m, 2 for 51-100 m, 3 for 101-500 m, 4 for 501-1000 m, and 5 for 1001-1800 m.

Last categories were animal presence and presence of domestic animals. These categories got smaller weight because presence or absence of animals could be different from what we observed at place. Localities with presence of domestic animals got 5 because of possible transmission of diseases. When animals were seen around locality and signs of wild animals were found these places got 1, only signs of animals or got 3 and no signs or presence of animals got grade 5.

As the most suitable is locality A7 with total value of 1.85. Evaluation of localities is visible in table below (Table 3).

Table 3 Weighted average for area Kone Lam.

locality	buffer	animal presence	refugee distance	permanence	domestic	distance footpath	WEIGHTED AVERAGE
A1	2	1	5	5	1	2	**3**
A2	1	5	4	1	5	1	**2.25**
A3	5	5	3	5	1	5	**4.3**
A4	4	5	2	5	1	5	**3.9**
A5	4	1	2	5	1	5	**3.5**
A6	4	5	1	1	1	5	**2.75**
A7	3	3	1	1	1	2	**1.85**
weight	**0.25**	**0.1**	**0.15**	**0.25**	**0.1**	**0.15**	

For localities around Baibokoum village three parameters were selected for evaluation. The most important variable was permanence of water. Those water sources

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are used all year by local communities. Value for permanent sources was 1 and for not permanent 5.

Second important variable was quality of water. Water was not laboratory analysed. Evaluation was based on method of use by local people. Drinking water was graded as 1, utility water was graded from 2 to 4 according to impurity and as 5 was graded repeatedly poisoned water.

Last variable was distance from roads. Localities in close proximity of roads are worse because of possible pollution from roads, also in case of use of water by wildlife. Distribution of values according to distance was the same as for first localities.

The most suitable locality is B2 with total value of 1.6. Results are visible in table below (Table 4).

Table 4 Weighted average for area Baibokoum.

locality	water quality	permanence	distance roads	WEIGHTED AVERAGE
B1	2	5	1	**3.3**
B2	1	1	4	**1.6**
B3	3	5	2	**3.8**
B4	2	5	2	**3.5**
B5	4	5	5	**4.7**
B6	4	1	3	**2.3**
B7	3	5	3	**4**
B8	5	5	5	**5**
weight	**0.3**	**0.5**	**0.2**	

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5. Discussion

Evaluating results had to be divided for each area of mapping. Those areas are significantly different. Therefore, one variable could be more or less important than the same in the other area. Both areas of interest have some issues with HWC mostly caused by elephants. Kely et al. (2020) in his research shows that forest elephants tend to live in distance from fields unless they are not searching for resources. Therefore, creating dams further from the agricultural limit would be more suitable. Similar discoveries show research from Graham et al. (2010), Tangie et al. (2018) and Lhoest et al. (2020). According to them the most important area is from 2 km to 10 km from residential areas. Followed discussed localities are therefore sorted by distance from agricultural land.

Location closest to the agricultural limit in the Kone Lam area is the A3. Close distance to the limit of this locality is inconvenient. This water is not always permanent depending on precipitation. Permanence of this source could be achieved by creating a reservoir. This place is very suitable in shape and size of river basin and could be easily dammed into a long water hole not very close to a footpath. Water was very clear and could be possibly used as drinking water. Creek is hidden under the trees and has easy access to water. Source is not permanent during some years. Creating a deeper water hole could create a permanent source.

Next eliminated location by distance from agriculture were A4, A5 and A6 which were closer than 4 km to limitation. Localities A4 and A5 were not outstanding. They are positioned on a footpath leading to CAR. Path is small and only suitable for walking or riding on donkey or horse but could be used by poachers and hunters and for human presence it is not a very reasonable place to create a water hole for wild animals as animals tend to avoid humans (Graham et al. 2010). Localities are close to refugee 1 around 1.2 km which is beneficial, but no signs of animals were seen and the creek is not permanent. A6 is a suitable locality with close proximity to elephant refugees. It is on permanent creek with very good access from one side. Footpath is very close to this stream, but it is not used very often, it's only a small trampled path. No signs of animals were found.

Distance of 5 km did not eliminate any localities but A7 was cut out by a 6 km buffer. A7 is a very good locality. Locality is in large distance from agriculture and path and near to this stream is an elephant path leading to permanent refugee. Water quality

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was not as good as others and after storms it could be coloured by suspended clay particles. Stream is permanent with high discharge during the wet season.

Between 6 km and 7 km buffer is located A1. Clear signs of elephant presence was detected in the area, some wild animals, possibly gazelles and buffalos were seen by us during mapping and the closest footpath used is almost 1 km away. But around this area nomadic herds of cattle were met and according to their herdsman they use this locality steadily. This location is from this reason not very suitable due to possible parasite and disease transmission. Water quality is not very high, water is strongly colored by mud from the area and source is probably filled from nearby swamp, for that reason it is not permanent. Mud could be eliminated during construction of reservoir, but elimination of domestic animals is problematic.

The farthest locality from agricultural land is A2. It is close to both elephant refugees, 4.2 km and 2.9 km, animals' presence around the area is highly visible with also elephant marks and large mammals were spotted during mapping but they were not properly seen to establish species. Water hole is permanent and probably filled by some underground source due to the large amount of water in hole and only limited surface inflow. Locality is almost 2 km away from a footpath. Limitations of this place are possible complications during building a reservoir caused by unstable natural walls which had to be firmly reinforced.

Localities found in the second area of mapping in agricultural land around Baibokoum village were very similar. All of them inside agricultural area. These reservoirs would not probably serve to a wild animals but could be beneficial at a social level for this research. As a not suitable place was suggested B8 which was poisoned by poachers more than one time, and it is not permanent. In this area locals are digging small holes around creeks and ponds (Figure 35) to obtain water from underground after the creek is dried. Based on this technique it would be possible to create more primitive wells in suitable places as are those on locality B2. Propriate places can be found by small drill holes located around streams. Due to low productivity of the basement the water holes can supply smaller amounts of households or animals. It will be important to create larger amounts of holes. The B6 is also very suitable. It is mostly used as a drinking place for domestic animals therefore is not recommended for wildlife for possible disease transmission. This locality is suitable for agricultural use, and it could maintain domestic

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animals from wandering into forests. This locality is a permanent water source. In other localities it is possible to create water holes for local communities even if they were not permanent during our research, because it is probable that after creating pond water will last longer. Creating reservoirs for people living around Kone Lam reserve should be also considered as beneficial action at localities where permanent sources are missing.

Figure 35 Water hole.

To better establish locations of ponds monitoring of animal movement habits would bring valuable information. These observations cannot be made during this research due to lack of time, equipment and human forces and limited access to areas of interest. During first mapping some different surveys for the Save Elephant organization was done in the neighbourhood of Baibokoum village, during these visits we recorded 3 cases of conflicts. Significant crop damages and damages on cottages happened during these visits. More projects are running in these areas. Many villages around Kone Lam are participating in Beekeeping project. Monitoring of poaching is also a part of long-term conservation efforts in these areas and with cooperation with other organizations in whole Chad. In the year of 2016 two cases of poaching, location of cases are visible in Figure 36, were discovered between two mapped areas. First case was 31.12.2016 and a group of four individuals was killed. Second case probably happened on the same day as the first and one big male was killed. Cases were around 18 km apart from each other

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(Sniegon 2017). This forested area could be another locality for some future conservation effort as a monitoring of poaching with camera traps.

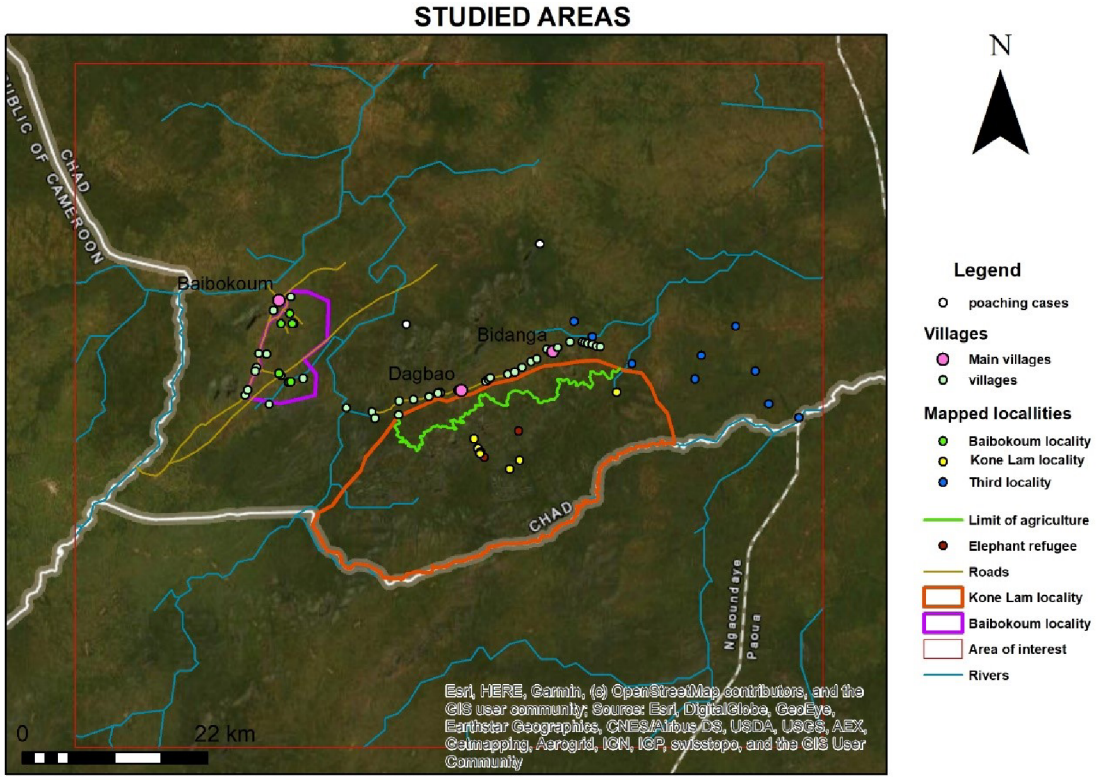

Figure 36 Poaching localities.

Reservoirs should be built as much as possible from natural materials, mostly from wood, rocks, clay which can be found in available distance and in cases of need cement could be added. Use of machinery would not be possible inside the reservation for the reason of difficult access. Reservoirs will be therefore created manually by people from communities willing to participate in protection. Some of these communities are already working with the Save Elephant and A.L.C.P. on ongoing projects as a field protection with beehives. Manual construction serves as a tool to involve local people into creation, give them a paid job connected with conservation and increase their connection to programs and animals. Project would be financed by the Save Elephant organization and by a conservation grant awarded for the A.L.C.P. organization. Building should be done during the peak of the dry season when there is less water and reservoirs would be filled quickly by rain. Probable start of building could be in March and April 2022 according to political and financial situation.

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6. Conclusions

Water availability is not the only important aspect to maintain elephants away from humans but is high on the priority ladder. Water management should be combined with other protection systems and efforts to lower poaching pressure and pressure from human expansion. In total we found 25 places for building reservoirs. 7 of them in Kone Lam reserve. From those 3 were located on permanent water sources. 8 localities were found in agricultural areas near villages Baibokoum and Mbaissaye. From 8 localities 2 of them were permanent. Last 10 localities were found in the last area combining agriculture and forested area, but with no further information so for evaluation in this research they were omitted.

After evaluation of all information from areas Kone Lam and Baibokoum we selected 6 localities with weighted average smaller or equal to 3. The most suitable localities in the Kone Lam area are A7, A2, A6 and A1 which are close to permanent animal refugees, in proper distance from agricultural limits and away from footpaths used by people transitioning from CAR to Chad. They are located on permanent streams and the shape of the water bodies is suitable for easy building of dams. The presence of animals is confirmed in close proximity. Localities B2 and B6 in Baibokoum area were more suitable for water holes than the others mostly because both are permanent water sources. B2 is especially important source as it is drinking water.

For all localities, long term observation should be set on various aspects. Collection of information about use of the sources by animals, domestic or wild, or people, permanence in years long period, since the permanence could change between years, quality and quantity of water is vital for proper management and better understanding of people's water behaviour. Localities should be monitored afterwards to see if changes had any impact on behaviour of animals or on downstream.

Cooperation of conservation organization Save Elephants and A.L.C.P. with local communities and authorities is based on long lasting relationships and this conservation effort would not be possible without proper communication and involvement of local people. Local people will be a big part of the planned building of reservoirs which should take place in the year of 2022, when political and financial situations will be convenient.

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Overall, more research should be conducted about the importance of water as a factor affecting wildlife populations. This importance is clearly not often fully appreciated. Aspects of research should include animal requirements regarding quantity, quality and timing of water availability, as well as water effects on food and rest and reproductive areas for wildlife.

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