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Landscape structure indicators of savanna ecosystems in regard to large herbivores ecology in Chinko Nature Reserve, Central African Republic

BACHELOR'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled “Landscape structure indicators of savanna ecosystems in regard to large herbivores ecology in Chinko Nature Reserve, Central African Republic” 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

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Matouš Hladovec

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Abstract

The global ecological landscape is undergoing rapid transformation, with various environmental phenomena and rising temperatures indicating significant shifts. Human influence on increasing the impact on natural cycles is undeniable in this. In response to such changes, proactive steps are necessary in order to protect vulnerable species and ecosystems. Understanding landscape structure and ecological resources allows for assessing and predicting species distributions and planning consequent conservation measures. This thesis aims to assess landscape structure indicators and ecological resources for large herbivores in the Chinko Nature Reserve, Central African Republic (CAR). The methods used to achieve this include a literature review and data analysis. The study is focusing on understanding the dynamics of large herbivores' ecology within the savanna ecosystems of CAR. Geographic Information Systems (GIS) tool ArcGIS is utilized for data processing and analysis. The data were generously provided by the organization African parks. The study area, Chinko Nature Reserve, situated in the southwestern part of CAR, is characterized by diverse ecosystems, including tropical rainforest and savanna.

The landscape structure analysis examines various components, such as patches, matrix, corridors, and edges, to understand the spatial relationships between different ecological units. Considering that large herbivore ecology varies across spatiotemporal scales (from minutes to years/ from a head movement to home ranges), there is a list of different landscape features in the literature research. Then, I provided a description of basic visualization and map making principles for specific landscape features, namely habitat types and patches with edge assessment.

The study provides further basis for further research of large herbivore movement ecology, resource selection and conservation initiatives aimed at preserving wildlife in the Central African Republic.

Key words:

Landscape structure, African savanna, large herbivores, Chinko Nature Reserve, wildlife ecology

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CAR – Central African Republic

GIS – Geographic information system

1. Introduction

When examining the current trajectory of the global ecology field, or even the dynamics of popular media, it becomes evident that the transformation of our planet's ecology is inevitable. It is apparent that the global ecological landscape is currently changing. Considering the long-term view, mostly the temperature on earth is noticeably rising. Along with this, there are other new phenomena occurring on the short-term scale, such as sea level rising, ocean acidification etc. (Singh et al. 2022; Richardson et al. 2023; WMO 2023). Although Earth is naturally going through cycles of temperature changes, it is undeniable that humans have a big influence on the current temperature change. According to Pyke (2005), when temperature increase and uneven habitat loss, to which humans contribute greatly through different land-uses (Tilman et al. 2017), were to happen in one area, the expected temperature rise is even greater in such area. In the study it is presumed, that the parts of habitat with habitat loss of anthropological origin are going to be the ones with lower temperature in the beginning. If the global temperature was to rise by 3°C, the loss of mentioned parts of the habitat is assumed to cause a further 3°C increase in the temperature, thus damaging the habitat to a greater extent.

In order for humankind to be a proactive participant of such changes and to gain the ability of protecting vulnerable species of our planet, a critical strategy emerges comprehensively grasp the present state and mechanics of the world's ecology in order to be able to facilitate informed prognostication and intervention strategies in species protection and conservation.

The importance of examining the landscape structure indicators, both past and present, has been concluded by multiple sources to be significant in the ability to predict future movements of species and changes to local biodiversity (Turner 1989, Ricotta et al. 2003, Scherreiks 2022).

Adapting to climate change and minimizing its influence on wildlife is a demanding and time-consuming task. Although it is feasible, given humanity's demonstrated capacity to collaborate in the face of severe perils, such as the ones presently discussed. In this thesis, we neither initiate nor conclude the journey. Instead, we compile and analyze data provided by the organization African parks, thereby establishing a base for successive work.

These subsequent efforts should provide the so much needed guideline for protection of large herbivores in the Chinko nature reserve or, at the very least, help us comprehend what landscape features certain species are reliant on.

2. Aim of the thesis

The aim of this thesis was to provide with an assessment of landscape structure indicators and ecological resources for large herbivores in the Chinko Nature Reserve in the Central African Republic.

Partial aims were:

1) To develop an overview of landscape structure indicators, primarily in regard to large herbivores ecology;
2) To visualize Chinko Nature Reserve and its basic habitats, to identify basic indicators of landscape structure in the protected area of Chinko Nature Reserve in Central African Republic, specifically within the home range of the Giant eland (*Tragelaphus derbianus gigas*) as a model area and animal species.

3. Methodology

To achieve the above stated aims of this thesis two approaches were used.

3.1 Literature review

To acquire theoretical background and information on landscape structures and large herbivore ecology, literature research was performed with usage of scientific resources available at the databases Web of science, Scopus and Google Scholar.

3.2 Practical part

To create an overview, visualization, and quantification of habitats present in the Chinko Nature Reserve and animals' (giant eland) home ranges, the ArcGIS Pro computer software (Elkins 2015) was used.

Data on habitat classification, layers on Chinko Nature Reserve borders, and animal tracking data on Giant eland were provided to us by the foundation African Parks (www.africanparks.org). Giant elands home ranges were provided by supervisor P. Hejcmanová calculated using ctmm technique (Calabrese et al. 2016) in the form of rasters.

First, it was needed to select only the habitats located within the areas of interest. For this, the extract by Mask Spatial Analyst Tool. The raster habitat classification, in the form of a map, were used as the Input raster, while the animal tracking data served as Input raster mask data. This step was repeated for every animals' seasonal home range, thus creating 36 individual rasters for. The same was then done for the animals' yearly home range, where both of their seasonal home ranges were added together and used to Extract by Mask again.

Next step was to calculate the proportion of habitats in each seasonal home range. The data used for this were taken from the habitats Attribute Table, where we first calculated the area of every habitat and their total area. With the usage of Microsoft Excel, we calculated the proportion of habitats in the home range. Afterwards, an average of this was also calculated.

Lastly, the user created Handful of Landscape Metrics (Dilts 2023) toolbox was used in ArcGIS Pro to analyze basic landscape structures, mainly edge density, on a chosen model home range. This was done mostly to test the usage of this toolboxes for future use on all the home ranges.

4. Literature review

4.1 Landscape structure

Firstly, it is important to define what a landscape is. Forman and Gordon (1981) define landscape as "a heterogenous part of earth's surface, composed of a cluster of interacting ecosystems that is repeated in similar form in a set area of the surface".

They then state that landscape ecology shifts its focus towards three main characteristics:

- Structure – spatial relations between the specific ecosystems or components.
- Function – interactions amongst the spatial components, i.e. the flow of energy, material, and species in between ecosystems
- Change – conversion of the structure and function of the ecological mosaic in time

Out of these, we will focus mainly, but not exclusively, on structure. Landscape structure is, in other words, a science studying the spatial relationships between functional land units, the abiotic and biotic processes between ecosystems and the change of landscape patterns over time. (Karimi et al. 2021). Landscape structure has, when described broadly, three main aspects. They are composition, configuration, and connectivity. IPBES (2016) defines landscape composition as the abundance of patch types represented within a landscape. It is important to note that composition is not spatial because it refers only to the variety and abundance of patch types, not their placement, location, or dispersion in the landscape. If we want to learn of the patch distribution, we must look into landscape configuration. Landscape configuration is the description of patch distribution, size, and abundance within a landscape.

4.1.1 Landscape features

Probably the most important terms in landscape structure are patch, matrix, corridor, and edge (Figure 1). Through these terms we define the different homogeneous parts of landscape.

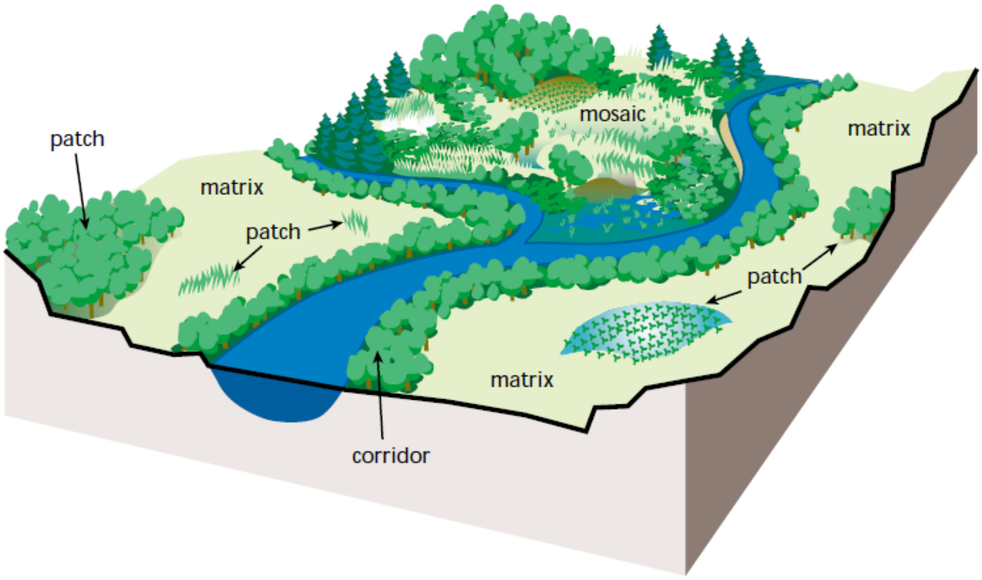

Figure 1. Description of basic landscape structures

(The Federal Interagency Stream Restoration Working Group 1998).

4.1.1.1 Patch

The term patch refers to an area which differs from the rest of the landscape but is in itself mostly homogenous and stands out of the landscape. It is the base component of landscape, which can change in time but has certain values specific to each patch type found in the landscape (Forman & Gordon 1981). We divide patches into five main categories by their origin:

4.1.1.1.1 Disturbance patches

Originating from different disturbances of the landscape matrix, such as storms, heavy winds, earthquakes, herbivore grazing or one of many kinds of human disturbances that occur on a small scale, thus only creating a disturbance in the matches, while not destroying the matrix itself. Disturbance patches (Figure 2) are formed when the events mentioned above change their composition by reducing number of species or simply reducing the number of individuals of each species. These patches go through drastic changes in their animal and plant populations after having their ecology drastically changed in such manner. Some populations or societies may disappear completely from such area, some may grow in size, since their competition or predators were removed. In conclusion, succession in disturbed areas is altered heavily (Levin, Paine 1974).

Figure 2. A disturbance patch created by a forest fire (Landers 2016).

4.1.1.1.2 Residual patches

Created inversely to the disturbance patches, residual patches (Figure 3) are what remains after a huge disturbance changes most of the landscape matrix. In such areas, we may observe the residue of the former matrix, in the form of residual patches (Barbé et al. 2017).

Figure 3. Multiple residual patches left behind by a forest fire (Agence France-Presse 2023).

4.1.1.1.3 Environmental resource patches

While such patches are similar to disturbance patches, they are completely different in their nature. Occurring in chronically disturbed landscapes, they are not dependent on such changes and their succession is uninterrupted by the events of the landscape in which these patches occur. An oasis with green plants and amphibians (Figure 4), a patch of heath on a mountain or simply intentionally a piece of forest left unplowed in the middle of an agricultural field can be good examples of an environmental resource patch.

Figure 4. Environmental resource patch, as a wadi in northern Niger (Scott 2009).

4.1.1.1.4 Ephemeral patches

After an occurrence of fluctuation in the resource availability or in general of the environment factors, an ephemeral path may occur. A cause for these fluctuations might be a flood, migrating species, rain in a desert (Figure 5) or even snow fall. If these changes remain for a longer period of time or if they are too severe, the ephemeral patch may change to a disturbance or residual patch.

Figure 5. Ephemeral patch of blooming flowers in the Atacama Desert (Salina 2022).

4.1.1.1.5 Introduced patch

Mostly dominated by, but not exclusive to, individuals introduced to the matrix by people. Examples of such patches may be fields, golf courses (Figure 6), orchards etc. The introduced population remains present with human disturbance maintaining it. Similar to other patch types small in area, the species from the matrix slowly overtake after the disturbance ceases to act upon a certain area and the patch converges with the matrix (Forman & Gordon 1981).

Figure 6. A golf course as an example of typical introduced patch (Flyguys 2024).

4.1.1.2 Matrix

The dominant landscape feature with high connectivity. Matrix is often described as the “background ecological system” as it usually occupies the biggest part of the area (Forman & Gordon 1981).

4.1.1.3 Corridors

Long and homogenous strips of land, either going through the matrix or separating two different features. For example, corridor can be a line of trees on the bank of a river separating it from the fields surrounding said river (Forman & Gordon 1981).

Corridors are of high importance to the movement of animal and plant species, energy, and materials.

4.1.1.3.1 Corridor functions

Corridors serve many functions in the landscape. Their function, however, is subjective to a species and often their definitions can vary. Here, we list the most basic functions (Figure 7).

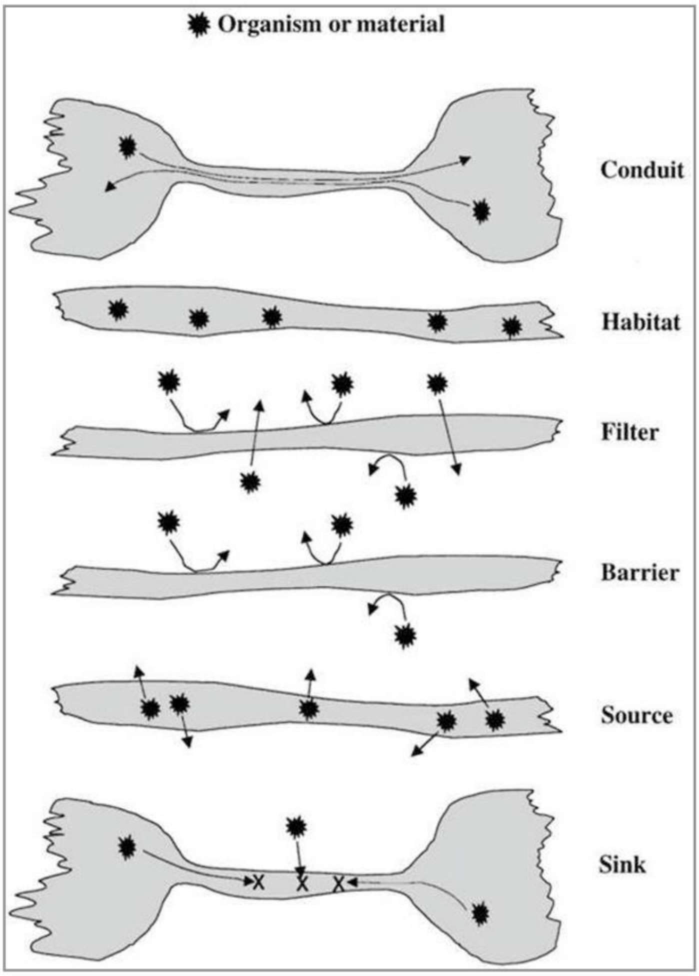

Figure 7. Different corridor functions (Heydari-Guran 2014).

1) Conduit and Habitat

A corridor with conduit function provides for movement between patches but not for reproduction. A corridor with habitat function provides not only the resources needed for movement and survival, but also reproduction of a species (Rosenberg et al. 1995).

It is possible for a corridor to fulfill either just the conduit function, or both the conduit and habitat functions.

The function of a corridor is different for each species. Some might take generations to traverse a corridor, if the corridor is wide and long enough to the relative scale of an animal’s movement, some just minutes. Such species are being referred to as ‘corridor dwellers’ by Beier and Loe (1992).

They then go on to state that if a corridor is capable of supporting multiple generation reproduction, it must perform a habitat function.

According to Harris and Scheck (1991) only the narrowest corridors might fulfill only the conduit function since a corridor of most widths will provide habitat for multiple generations of species and their traversing of the corridor might occur on the scale of years or even centuries in some cases.

2) Filter and Barrier

The difference between the filter and barrier function is the permeability. While a corridor with filter function allows for certain species to pass or, on the contrary, stops certain species from passing through, a corridor with barrier function prevents most passing through (Forman & Gordon 1986). A road is a good example of coexistence of two different corridor functions in one place. It is a conduit for humans but often acts as a barrier for many species. (Forman & Hersperger 1996). The filter function is usually presented on the continental scale in the form of long-term connections, for example land bridges (Simpson 1940). Lastly, we can use windbreakers as an example of a barrier that interferes with the distribution of energy and materials. Windbreakers serve as a barrier for wind and as a filter for wind-borne soil and snow (Johnson & Beck 1988).

3) Source and Sink

Source and Sink functions differ from the remainder of the functions in the sense that they are a being used in a demographic sense. For a corridor to have the source function, the natality rates there must exceed the mortality rates. On the other hand, a corridor with the sink function can be defined as having higher mortality rates then the natality rates (Shmida & Ellner 1984).

4.1.1.3.2 Corridor types

There are different types of corridors, the four basic ones defined by their shape (Figure 8). At times the line corridor and the line corridor with nodes are being regarded as one type.

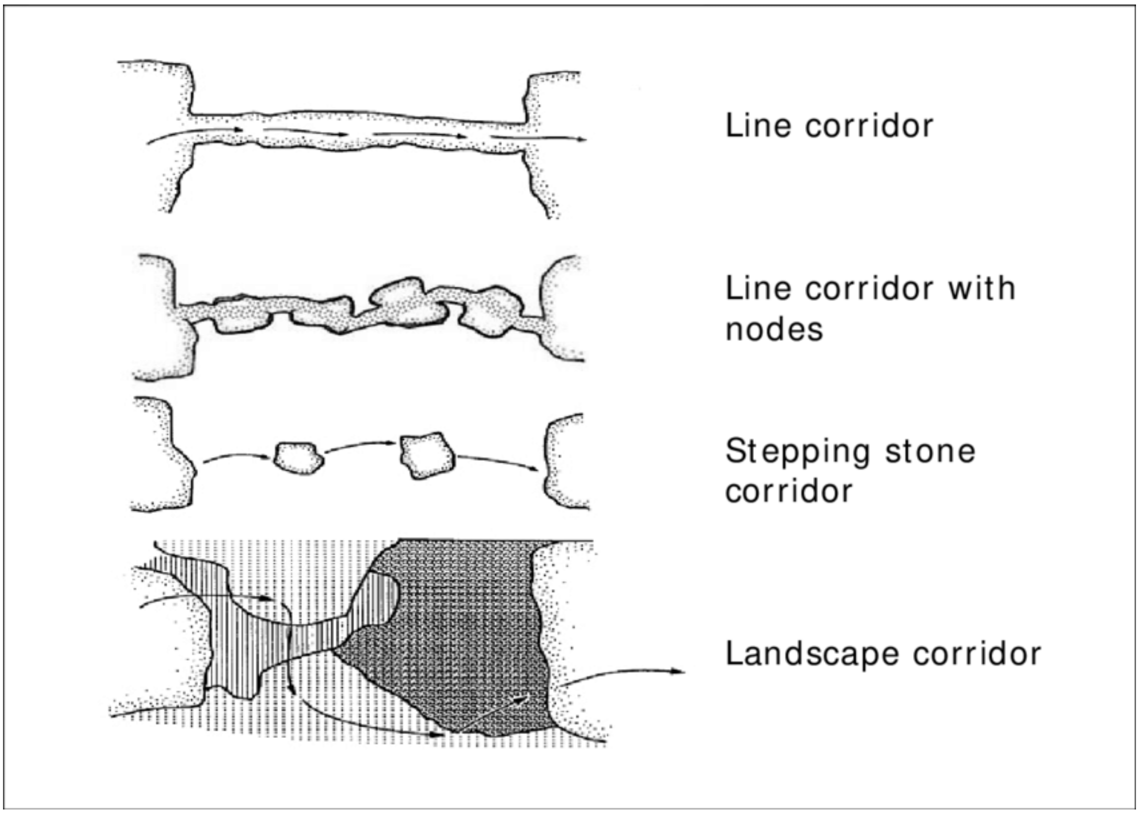

Figure 8. 4 basic types of corridors (Bloemmen et al. 2004).

1) **Line corridor**

   As the name implies, line corridors are of linear shape, ideally with little to no physical interruptions since such obstacles are uncrossable for many species. For example, if the corridor is a river, which is interrupted by a patch at some point and it continues further down the stream (this might be caused by a dam for example), the fish in the river will not be able to travel down the river. In the case of some other species, such physical interruptions may be crossed. A bird can fly over the dam on the river.

2) **Nodal corridor (or line corridor with nodes)**

   Otherwise known as line corridor with nodes is a linear corridor with spacious areas located on it, which allow different species to reproduce. The location on the corridor is beneficial for expansion of the species, since the nodes are usually similar, ecology-wise, to the corridor itself and therefore the species located in the nodes are adapted to them well.

3) **Stepping stone corridor**

   This type of corridor is made up of discrete patches of any shape and size, which are found in the matrix between the source and target areas. We might describe the stepping stones as environmental resource patches, thanks to their placement in an inhospitable matrix to the species on which they are not dependent. In general, they are identical to the nodal corridor, only without the physical connection between each node. Additionally, in the case of nodal corridors, the movement of a species is inter-generational, while in stepping stone corridors it is often the same individual moving in between the stepping stones. This is mostly caused by the distance of each node/stepping stone, which is usually greater in nodal corridors.

4) **Landscape corridor**

   Consisting of a mosaic of patches with different functions for the species, their quality and composition may vary to a high extent with no absolute barriers and generally a very low resistance for species. Individuals of the species use most parts of such corridors for various purposes like hiding, foraging, or sleeping (Bloemmen et al. 2004).

4.1.1.4 Edge

Interface between different ecosystem types (Harper et al. 2005)

Higher classification terms include network, which is an important network of corridors, and mosaic, describing the combination of patches, corridors, and the matrix.

4.1.2 Landscape analysis levels

A crucial part of landscape structure research is its scale. Scale is of the highest importance in such research, since different processes occur in different metrics and a scale too small or too big might impede acquiring or processing data needed for further work. In general, four different scales, or metrics, are recognized. All of the metrics described below come from McGarigal (2002).

4.1.2.1 Cell–level metrics

Being the smallest unit of on the spatial scale resolution, cells are not tied to the size of patches, rather cells attain their own value and the metrics on this level may be computed for both a targeted set of focal cells showcasing specific locations of interest, or for all cells in the entire landscape. In the first case, the output consists of a vector of cell–based measurements reported in tabular form. When they are used for every cell in the landscape, the output becomes a continuous surface grid or map.

4.1.2.2 Patch–level metrics

Patch metrics are the spatial characterization of the character and context of patches and are defined for each individual patch. Mostly functioning as the basis for computation of several other landscape metrics, some of their indexes reach a higher level of importance and informativeness in the case of landscape–level investigations.

4.1.2.3 Class–level metrics

Class indexes represent the amount and spatial configuration of patch types, offering a way to define each patches extent and fragmentation in the landscape. Class metrics are joining all the patches of one type, which is also known as class. The unification is simply achieved by averaging, or by weighted averaging, if any of the patch types is contributing more or is of higher importance to the overall index. In most cases, the amount and distribution of a particular patch type are of interest.

4.1.2.4 Landscape–level metrics

These metrics integrate all classes or patch types over the entire extent of the data. Similarly to class–level metrics, the landscape-level metrics achieve this by either simple or weighted averaging, in specific cases they may show the summary properties of the patch mosaic. Most of the time landscape composition and configuration of the entire landscape mosaic are important to landscape ecology since its main target is quantification of the relationships between landscape pattern and ecological processes.

4.1.3 Foraging scales

Foraging scales are from the perspective of animal ecology. The following list is of foraging scales for large herbivores organized in an ascending manner by their area. It is important to note that every scale has is described by a specific action that the animal needs to perform in order to navigate said area.

4.1.3.1 Bite

The smallest scale. It is clearly defined by a sequence of herbage prehension, jaw and tongue movement and its definition is severed by head movement. (Laca et al. 1994)

4.1.3.2 Feeding station

An array of plants available to a herbivore without moving their front feet (Novellie 1978).

4.1.3.3 Patch

There are many different definitions of a patch. Here we choose one, that is fitting to the context of large-herbivore foragers ecology. A patch is a cluster of feeding stations separated from others by a break in the foraging sequence when animals reorient to a new location (Jiang and Hudson 1993)

4.1.3.4 Feeding site

A collection of patches in a contiguous spatial area that animals graze during a foraging bout, which we can define as a change from grazing to any activity other than foraging. I.e. resting, ruminating and others.

4.1.3.5 Camp

A set of feeding sites, where animals perform all usual activities related to their style of life. When grazers are moving between sites, the entirety of the social unit will perform relocate. This movement occurs roughly once every few weeks.

4.1.3.6 Home range

A collection of camps, bordered by obstacles like fences or other objects of human origin, extent of migration and natural barriers, for example bodies of water or other unsuitable environments for the specific species.

4.2 Visualization of landscape data

Visualization of landscape data is a two-step process, including:

1) collecting data that is worth and meaningful to interpret into a map projection by either ground or remote means.
2) Transformation of the collected data into two dimensions (map interpretation) or into another form of projection. This is achieved either manually by painting the map or composing the model, but in the last decades it is increasingly more common to use Computer Aided Designs and GIS.

4.2.1 Map projections and coordinate systems

Ervin and Hasbrouck (2001) said that some aspect of "truth" must be distorted to portray a sphere onto a flat plane. No projection of a sphere can accurately maintain both shape and area and all map projections can be classified as maintaining one or the other. Instead, we use projections of the sphere, that allow us to represent it on a flat, 2D surface.

4.2.1.1 Mercator projection

Mercator projection (Figure 9) finds the most usage, since it portrays shape and compass bearings with no distortions, but heavily distorts the size of certain regions, specifically the polar regions. The main reason for this projections use is what it preserves since such qualities are priceless specifically in ocean navigation. Even though this type of projection has apparently been used in the past on a small local scale, Gerardus Mercator was the first to develop and present it on the world scale in 1569 (Keuning 1955).

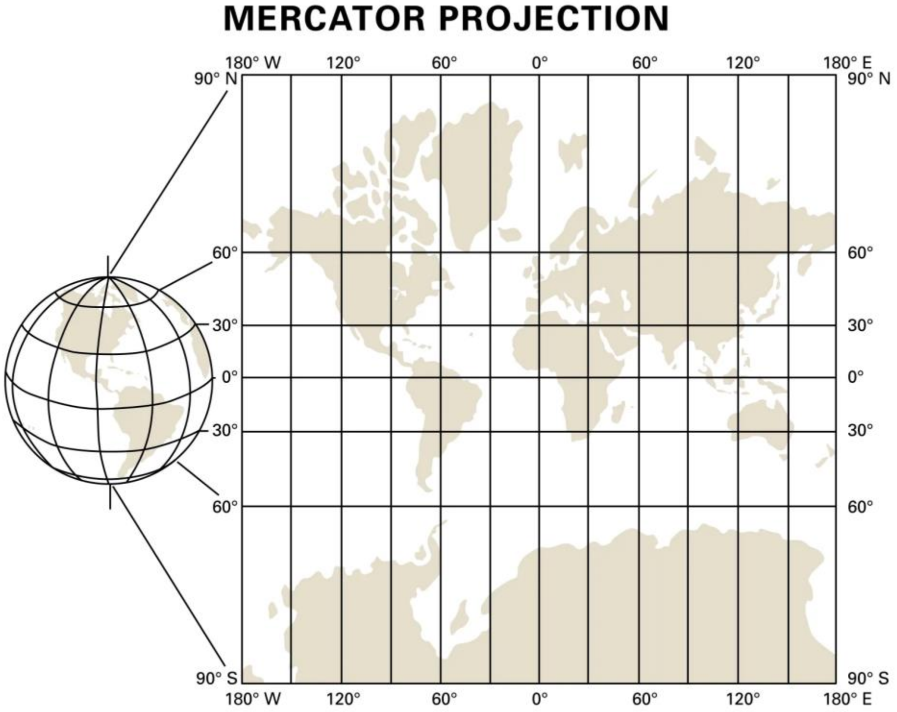

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Figure 9. The Mercator projection of the world (Britannica 2013).

In the Mercator projection, the meridians of longitude are vertical parallel lines, equally distributed and cut at 90° angles by straight horizontal parallels, which are being placed further apart from each other toward each pole in order to preserve the correct shapes of features on the map (Snyder 1987).

Coordinate systems serve an essential role in the design and function of any map or visualization in general. Their use is wide even outside map projections and in the 2D space, it is expressed in the form of two numbers (in the 3D space by three, 4D by four…), each representing a distance from the point zero along a specified line.

For example, along the X and Y lines in planes, most commonly, or along the longitude and latitude on spherical surfaces (Ervin & Hasbrouck 2001).

The latter system is also known as the Geodetic Coordinate System and is well explained by Cai et al. (2011). The longitude, which measures the rotational angle between the Prime Meridian and the measured point, can range from -180° to 180°. Meanwhile the latitude quantifies the angle between the equatorial plane and the normal of the reference point that passes through the measured point and can range from -90° to 90°.

5. Chinko Nature Reserve

The Chinko Nature Reserve lies in the southwestern part of Central African Republic, commonly referred to as CAR, in Central Africa (Figure 1). CAR is a landlocked country surrounded by Chad in the north, Sudan in the northeast, South Sudan in the east, the Democratic Republic of the Congo in the southwest and Cameroon in the west.

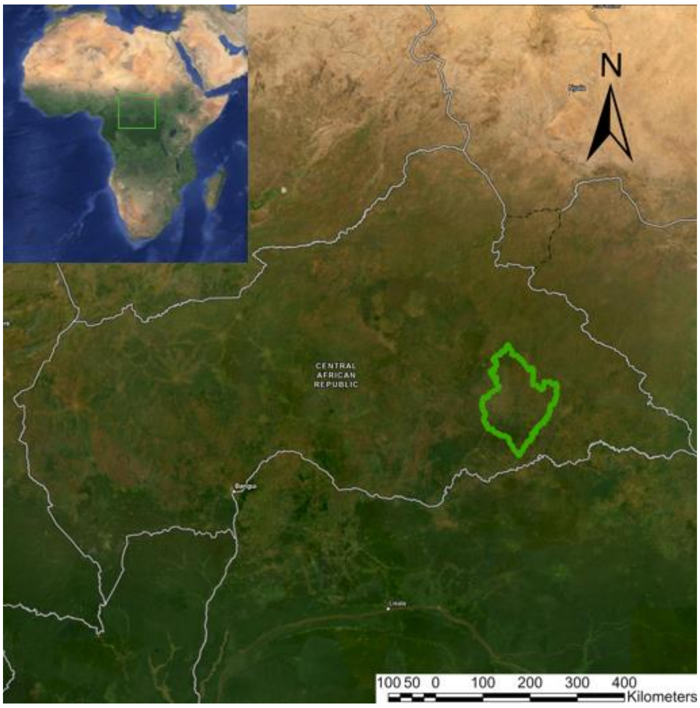

Figure 10. The location of Chinko Nature Reserve in Central African Republic, the reservation is marked with a green outline (author).

With its mean elevation being 635 meters, lowest point 335 meters and highest point, Mont Ngaoui, standing at 1,410 meters, CAR can be regarded as flat, with scattered hills in its northeast and southwest parts. (CIA, 2024).

Regarding CARs climate, most of the country’s area experiences a tropical savanna climate, with smaller areas of tropical monsoon climate spread throughout the south part of the country and a hot semi-arid climate in the northern part. CAR experiences a wet and dry season with the annual average temperature ranging from 23°C up to 26°C.

Some examples of the major ecosystems found in CAR include tropical and subtropical moist broadleaf forests, tropical grasslands, savannas, shrublands, and flooded grasslands.

To find other biologically important areas situated within CAR, we have combined the data provided by the European Commission's site Digital Observatory for Protected Areas, also known as DOPA, and Stuart (1990) in his book Plant-geography upon a physiological basis, to ensure that these areas are actual and to include the non-protected areas, that are still important from a biological standpoint. For every area we will include the name, official designation, and the reported area in km^2 (if the reported area is not available, we will use the calculated area provided by DOPA), according to which we will sort them in descending order (Table 1).

Table 1. List of other protected or biologically important areas in Central African Republic, Chinko Nature Reserve is excluded (author).

	Area name	**Designation**	**Area in km^2**
South-western CAR	Dzanga-Sangha	Special Reserve	6 866
	Ngotto	Classified Forest	1 370
	Mbaéré Bodingué	National Park	866
	Basse-Lobaye	Biosphere Reserve	182
	Botambi	Classified Forest	117
Southern/eastern CAR	Zemongo	Faunal Reserve	13 674
	Bangassou	Forest Reserve	12 082
Northern CAR	Manovo-Gounda St Floris	National Park	18 909
	Bamingui-Bangoran	National Park	11 191
	Zone Pilote de la Sangba	Classified Forest	10 668
	Ouandjia-Vakaga	Faunal Reserve	7 234
	Yata-Ngaya	Faunal Reserve	5 406
	Kaga Bandoro	Classified Forest	5 024
	Gribingui-Bamingui	Faunal Reserve	4 322
	Aouk-Aoukale	Faunal Reserve	3 452
	Avakaba Presidential Park	Private Reserve	2 636
	Nana-Barya	Faunal Reserve	2 329
	Koukourou-Bamingui	Faunal Reserve	1 131

Furthermore, Stuart mentions the forests of Kotto and a large dry forest area south of Oudda, however, we could not find any further information about said areas, therefore we mention them outside the main list.

5.1 Fauna of the Chinko Nature Reserve

With its isolation in the middle of wilderness, Chinko Nature Reserve serves as a refuge to many, often rare, species. Here, we list the most notable once, mostly due to the lack of information about the more common species in the area.

5.1.1 African forest elephant (*Loxodonta cyclotis)*

Although in the past, the genus African elephant (*Loxodonta*) comprised of at least 7 species, 5 are currently listed as extinct. Namely these species are the North African elephant (*L. Africana pharaohensis*) (Deraniyagala 1955), *L. atlantica* (Pomel 1879), *L. exoptata* (Dietrich 1941), *L. adaurora* (Maglio 1970) and *L. cookei* (Sanders 2007). The other remaining species is the African bush elephant (*L. Africana*) (Larramendi 2016).

The African forest elephant is found in the humid tropical forests of West Africa and in the Congo Basin. Weighing between 2 and 5 tons and reaching up to 3 meters, they are smaller than the African bush elephant, which allows for their life in the dense jungle. This also prevents traditional counting methods to be used, thus their populations are usually estimated through analysis of the density and distribution of the elephants' feces.

The preferred food strategy of the African forest elephants is foraging, namely of fruits, seeds, leaves, grasses, and tree bark. In order to have sufficient mineral intake, the elephants tend to gather around mineral licks and mineral-rich waterholes (WWF 2021).

According to African Parks (2022), the estimated numbers of African forest elephants in the Chinko Nature Reserve stand at 100 individuals.

5.1.2 Carnivore species (*Carnivora*)

According to African Parks (2022) there are 25 carnivore species present in the Chinko Nature Reserve. Most notable of these are the African wild dog and the African lion.

5.1.2.1 African wild dog (*Lycaon pictus*)

Contrary to the past belief that African wild dogs occupy mainly open plains, they have been observed in semi-deserts, upland, forests and Lhotse (1946) described sightings in deserts.

While wild dogs hunt mostly medium-sized antelope, the weight of their prey may reach up to 200 kilograms, while they weigh no more than 30 kilograms. Most often, their prey consists of Common Wildebeest (*Connochaetes taurinus*), Greater kudu (*Tragelaphus strepsiceros*), Impala (*Aepyceros melampus*) and Thomson's gazelle (*Eudorcas thomsonii*) (Woodroffe & Sillero-Zubiri 2020).

With the pack size of three to twenty adults, up to forty, when younglings are included (Creel & Creel 1994), African Parks (2022) report around ten packs in the area.

5.1.2.2 African lion (*Panthera leo leo*)

In terms of habitat, lions mostly prefer savanna, grassland, open woodland, and dense scrub habitats.

Usually living in smaller groups called prides, who may hold anywhere from four to thirty-seven individuals, the prides unite only to hunt or share a meal and are territorial with territory size based on the prey abundance in the area.

Their prey mostly consists of medium to large sized hooved animals, such as Common Wildebeest (*Connochaetes taurinus*), Zebras and Antelopes (Kays 2024).

The African Parks (2022) survey reveals around 100 individuals present in the Chinko Nature Reserve.

5.1.3 Primate species (*Primates*)

African Parks (2022) report 14 primate species, some of these include the Olive baboon (*Papio anubis*), Common patas monkey (*Erythrocebus patas*) or Eastern chimpanzees (*Pan troglodytes schweinfurthii*).

5.1.3.1 Eastern chimpanzee (*Pan troglodytes schweinfurthii*)

The Eastern chimpanzee usually live in forest galleries, savanna woodlands and lowland and submontane tropical forests. The dietary preferences are often different by the population and season. But generally, their diet consists of fruit, leaves, stems, and bark, with different mammals making up a small but important proportion of the diet.

The Eastern chimpanzee communities usually compose of twenty to one hundred and fifty individuals (Plumptre et al. 2016).

In Chinko Nature Reserve, around 1,300 eastern chimpanzee individuals can be found (African Parks 2022).

5.1.4 Even-toed ungulates (*Artiodactyla*)

Chinko Nature Reserve sees 24 species of even-toed ungulates residing in its area. The most notable being the Eastern giant eland (*Tragelaphus derbianus gigas*), African buffalo (*Syncerus caffer*), Roan antelope (*Hippotragus equinus*), Bongo (*Tragelaphus eurycerus*), and Defassa waterbuck (*Kobus ellipsiprymnus defassa*) (African Parks 2022).

5.1.4.1 Eastern giant eland (*Tragelaphus derbianus gigas*)

The Eastern giant eland is traditionally located within woodlands and Sudanian to Guinean savannas.

Their diet consists of leaves, shoots, herbs, and fruits, on occasion grasses. The elands are known to use their horns to break off unreachable branches for consumption. (IUCN SSC Antelope Specialist Group 2017).

African Parks (2022) put the number of individuals in the Chinko Nature Reserve at 1,500.

5.1.4.2 African buffalo (*Syncerus caffer*)

With the habitats inhabited by the African buffalo ranging anywhere from semi-arid bushland, through Acacia woodland, all the way to coastal savannas and moist lowland rainforests, they are a versatile species that avoid only deserts and sub-deserts.

Their diet comprises almost exclusively of grasses, with a similar lifestyle to that of a free roaming kettle, consisting mostly of grazing and chewing their cud. (IUCN SSC Antelope Specialist Group 2019).

The African buffalo is known for its big herds. These can reach anywhere from fifty individuals to five hundred. This behavior is especially useful for discouraging predators (Sinclair 1977).

In the Chinko Nature Reserve, up to 6,000 African buffalos can be found (African Parks 2022).

5.1.4.3 Roan antelope (*Hippotragus equinus*)

The Roan antelopes main choice of habitats is quite simple. With grasslands and savanna woodlands, it is evident that woody plants and high grasses are of high importance, specifically for grazing and calving (Chardonnet and Crosmary 2013).

While its diet consists mainly of grasses, the Roan antelope sometimes feeds on the foliage of bushes and trees (Theodor 1992). Kingdon (1997) even reports sightings of the Roan antelope feeding on mushrooms.

The Roan antelope forms herds of up to twenty individuals (Spinage 1986), with marked being enforced by the males (Theodor 1992).

According to the African Parks website (2022) the latest survey reveals 1,400 individuals located within the Chinko Nature Reserve.

5.1.4.4 Bongo (*Tragelaphus eurycerus*)

The Bongo tends to inhabit rainforests, forest disturbance patches and forest-savanna edges. Its preferred food source are transition vegetations after disturbances in the area.

Even though the Bongo are mostly browser species, they can at times graze on grasses (Elkan & Smith 2013).

African Parks (2022) states there are roughly 1,400 individuals of the Bongo present in the Chinko Nature Reserve.

5.1.4.5 Defassa waterbuck (*Kobus ellipsiprymnus defassa*)

As the name implies, the Defassa waterbuck inhabits mostly areas close to water in either riverine woodlands, gallery forests or savanna grasslands.

Their diet consists mostly of coarser grasses species, which are traditionally avoided by other grazers. At times, they might feed on tree or bush leaves.

In the Chinko Nature Reserve, there were reported around 1,600 individuals by the African Parks (2022).

5.2 Landscape structure indicators in Chinko

5.2.1 Ecosystems of Chinko

The Chinko Nature Reserve lies in two major ecosystems. In this chapter, we compile basic information about these ecosystems.

5.2.1.1 Congo rainforest

According to Schimper's (1903) definition of the tropical rain forest, we can think of it as an evergreen area, which is wet in character, at least 30 meters high, contains many thick-stemmed lianas and experiences the presence of many woody, as well as herbaceous epiphytes. This brief definition was then extended by Richards (1952), who describes the tropical rainforest as being mostly dominated by woody species, except for the sparse undergrowth, with the richness of the tree species exceeding that of any other biome.

The rainforest found in the south Chinko is a part of the Congo basin, which encompasses an expanse of 528 799 000 hectares. Congo basin contains the second largest forest in the world with an area of around 301 807 000 hectares, which is only surpassed by the Amazon rainforest with an area of roughly 799 394 000 hectares. (FAO, 2011)

Tropical and Subtropical moist broadleaf forests, also known as "jungles", are areas with hot and humid climate. The Worldwide Fund for Nature divides the Congo basin into six ecoregions, namely Atlantic Equatorial coastal forests, Northwestern Congolian lowland forests, Western congolian forests, Western Congolian swamp forests, Eastern Congolian swamp forests, Central Congolian lowland forests, and Northeastern Congolian lowland forests. Out of these, only two lie in CAR, these being the Northwestern Congolian lowland forests and the Northeastern Congolian lowland forests. Of these, only the Northeastern congolian lowland forest is found in Chinko Nature Reserve, the Northwestern congolian lowland forest lies in the southwestern part of the country and therefore is not as relevant to this thesis.

5.2.1.2 Congolian forest-savanna mosaic

According to Burgess et al. (2004), the Congolian forest-savanna mosaic, which spans across parts of Cameroon, Central African Republic, Democratic Republic of the Congo, South Sudan and Uganda, is a transitional zone in between the equatorial Guineo-Congolian forests and the dry ecosystems of the more northerly parts of Africa.

This region experiences a single dry and a single wet season. The annual precipitation ranges around 1,200 to 1,600 millimeters per year. The topography is mostly flat, sitting on a plateau at around 500 to 700 meters above sea level (Martin 2021).

5.2.2 Habitat types

According to Aebischer et al. (2016), there are 5 major habitats found in the Eastern Central African Republic. Namely closed canopy forest, open savanna woodland, wet moist grassland, dry Lakéré grassland and permanent surface water. In Figure 10 is a showcase of the habitats mentioned above, however, wet moist grasslands are merged with permanent surface water, due to their low quantity.

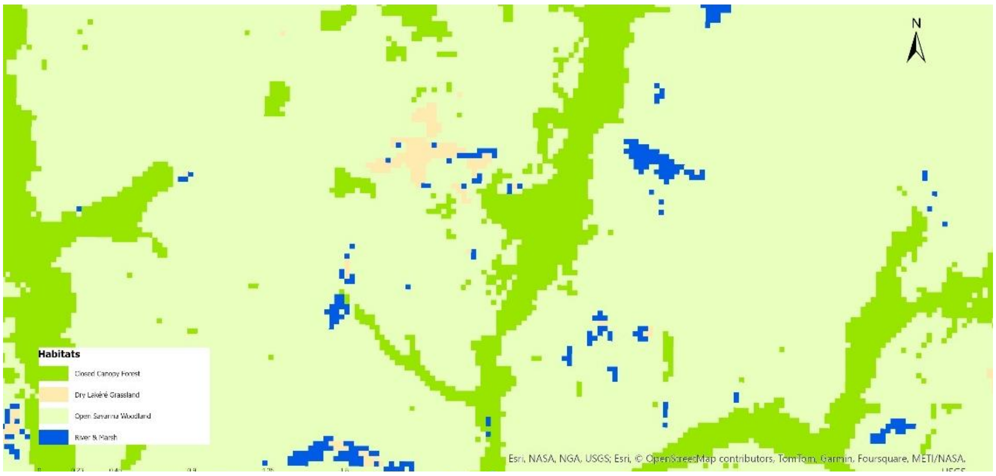

Figure 11. Showcase of habitats in Chinko Nature Reserve.

5.2.2.1 Closed canopy forest

The primary driver for tree cover type and distribution in Africa is considered the climate (Bucini & Hanan 2007), with fire and herbivores being important in reducing the tree from its maximum capacity (Sankaran et al. 2005). Lastly, human land-use is generally of great impact on the scale and distribution of forests on the continental scale (Aleman et al. 2016).

Generally, the closed canopy forests are defined as habitats dominated by trees, lianas and shrubs, with a fully or mostly closed canopy and multiple different height layers (Aebischer et al. 2016).

5.2.2.2 Open savanna woodland

Burgess et al. (2004) state, that the main species most commonly forming the open savanna woodland are *Anonna senegalensis*, *Burkea africana*, *Combretum collinum*, *Hymenocardia acida*, *Parinari curatellifolia*, and *Stereospermum kunthianum*.

The most notable differences between closed canopy forests and open savanna woodland are density of their canopy, height of the vegetation and ground layer composition. While the closed canopy forests have their ground mostly covered with rotting leaves, the open savanna woodland is overgrown with grasses (Aebischer et al. 2016).

5.2.2.3 Wet moist grassland

Although not very extensive and mostly dispersed in the form of patches across the Chinko Nature Reserve landscape, it is an important habitat regarding the reservations' biomass and biodiversity. One of the important roles of the wet moist grassland comes from the high dependability or liking, certain animal species have created towards them (Aebischer et al. 2016).

5.2.2.4 Dry Lakéré grassland

During the dry season, these grasslands are barren, dry and hot, even catching ablaze, during the wet season they usually accumulate large quantities of humidity, even flooding at times (Aebischer et al. 2016).

5.2.2.5 Permanent surface waters

The most prominent river of Chinko Nature Reserve are the Chinko river, running through the very reservation, and Mbari river, which forms its western border. No larger lakes are present in the reserve, however water is permanently available in the valleys (Aebischer et al. 2016).

5.2.3 Landscape structure indicators example

In preparation for future work, with use of the Handful of Landscape Metrics toolbox, we created a test visualization of edge density (Figures 12 & 13).

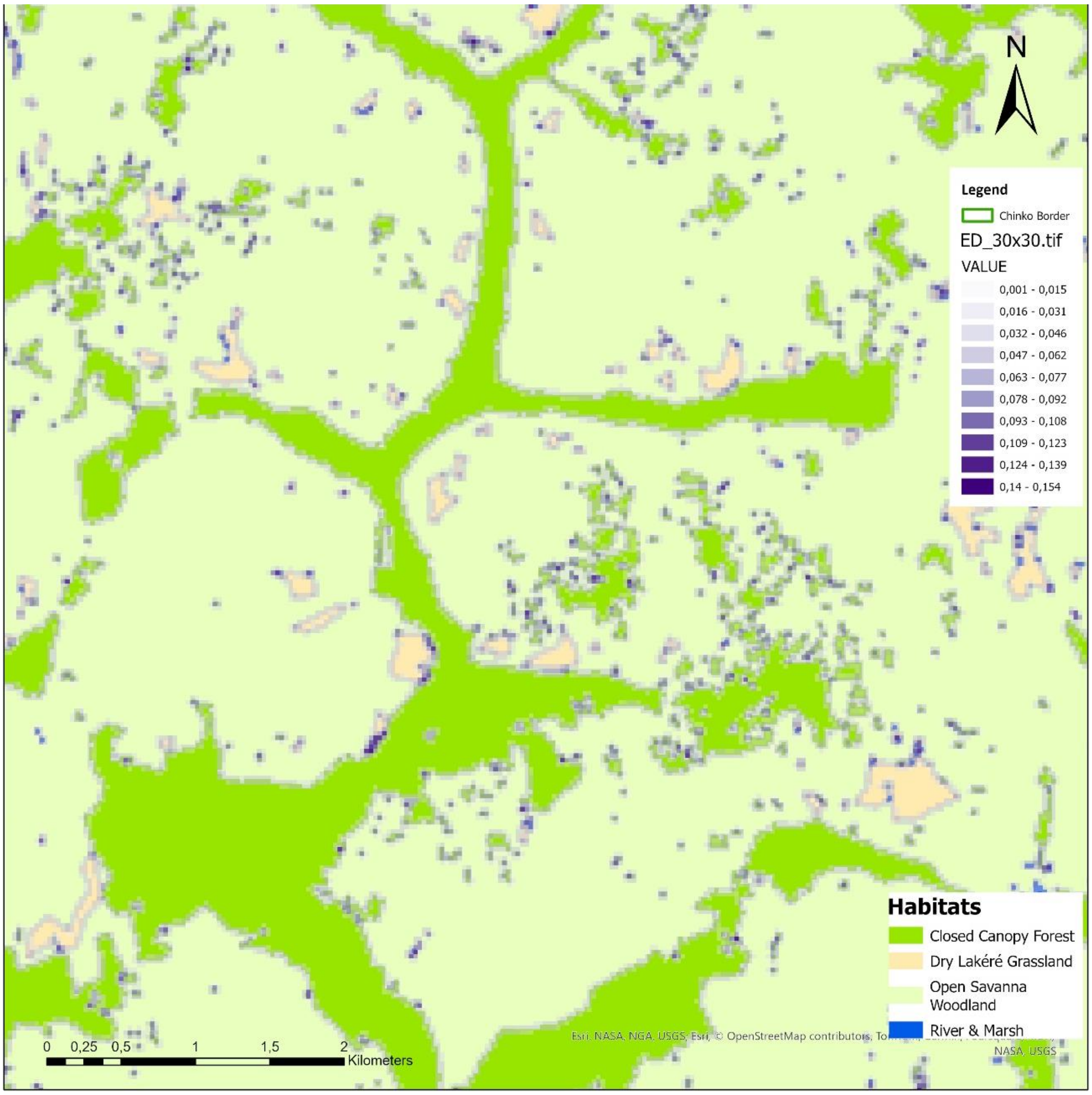

Figure 12. Edge density analysis with habitats underneath. Values stand for density of edges inside each 30 by 30 meters pixel (author).

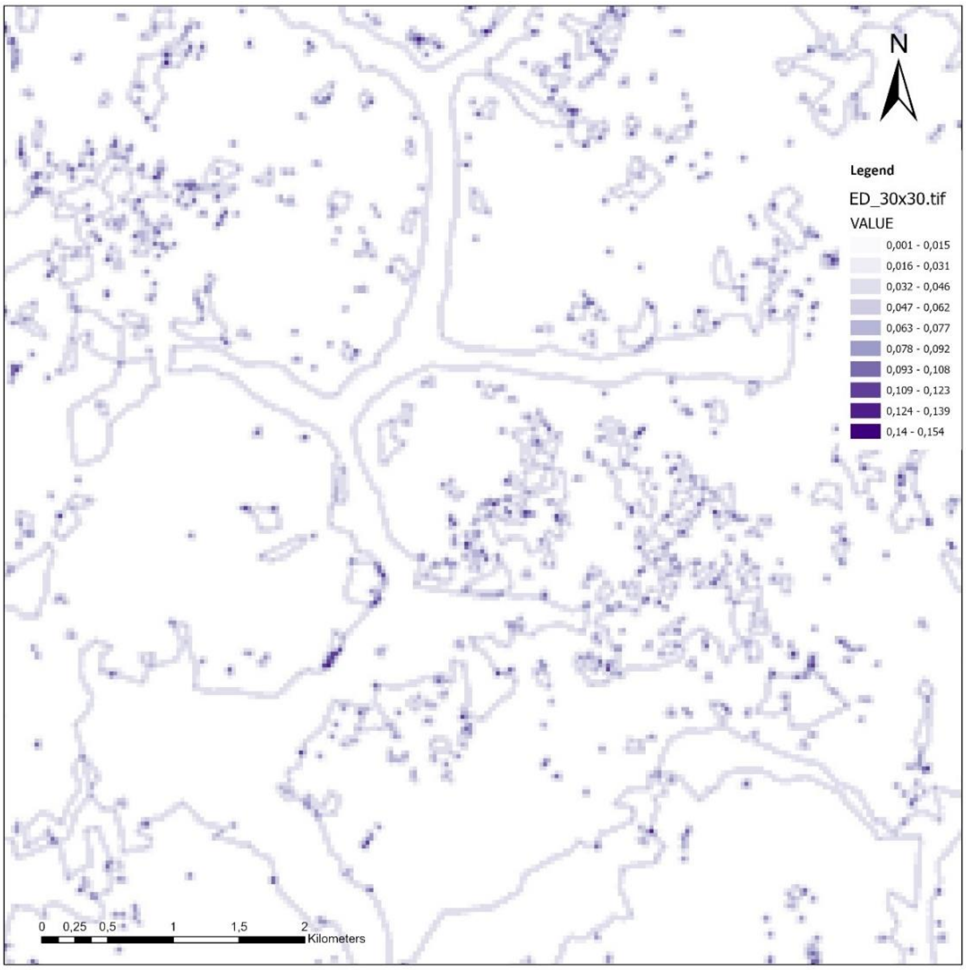

Figure 13. Edge density analysis. Values stand for density of edges inside each 30 by 30 meters pixel (author).

In this demonstration, the value of edge density is per each 30 by 30 meters pixel, such resolution has been chosen after consideration of the extent of Chinko Nature Reserve and the computing capabilities within authors possibilities.

5.2.4 The importance of landscape parameters for large herbivores

The investigation of landscape structures and of landscape parameters lies in the further understanding of species ecology. In the case of this thesis, the edges are of importance for two reasons. The edge habitat may provide entirely different conditions for species, thus being of interest only to a small selection of species. The other important specification of the edge is its position in between to habitats. Many animal species tend to prefer multiple habitats. They may feed in one habitat with open plains which allows for simple movement in between feeding sites, rest in another habitat, which provides shelter from harsh conditions like rain or sun, and search refuge from danger in a third habitat with denser vegetation, which is not suitable for everyday life.

Understanding the preferences of these animals allows for simpler predictions of their movements and behavior.

5.2.5 Habitat types in regard to seasonal home ranges of the Giant eland

After calculating the proportions of habitats in each seasonal home range, Table 2 was created. It contains proportions of habitats (Closed Canopy Forest, Dry Lakéré Grassland, Open Savanna Woodland, and River & Marsh) for both seasons (dry and wet) for fifteen Giant elands situated within Chinko Nature Reserve in percent. Additionally, the area in km^2 is mentioned for every seasonal home range.

After averaging the data from Table 2, Table 3 was created.

Table 3 includes averages of proportions of each habitat in seasonal home ranges of the analyzed animals in percent and an average area of the seasonal home range in km^2.

Table 2. Proportions of habitats in seasonal home ranges of individual elands

	Habitat	Dry season (%)	Wet season (%)	
f1578	Closed Canopy Forest	22,6128	26,86633	overlap
	Dry Lakéré Grassland	3,856130697	5,170276849	0,5066
	Open Savanna Woodland	68,5968693	63,70158315	
	River & Marsh	4,93419	4,26180792	
	area in km^2	4146,81	7850,23	
f1582	Closed Canopy Forest	8,881776	10,26159	overlap
	Dry Lakéré Grassland	1,446361931	2,098503154	0,1254
	Open Savanna Woodland	88,51518807	86,06724685	
	River & Marsh	1,156677	1,572661	
	area in km^2	357,29	2849,67	
f1583	Closed Canopy Forest	11,13158	9,789441	overlap
	Dry Lakéré Grassland	2,810396696	2,271131407	0,7111
	Open Savanna Woodland	84,0667933	86,32671859	
	River & Marsh	1,991232	1,612708	
	area in km^2	3161,68	2593,18	
f2108	Closed Canopy Forest	18,84998	20,37966	overlap
	Dry Lakéré Grassland	2,465631046	3,298933548	0,3283
	Open Savanna Woodland	78,12333895	71,80554645	
	River & Marsh	0,561043	4,515855	
	area in km^2	342,35	1042,77	
f2109	Closed Canopy Forest	19,69177	20,99733	overlap
	Dry Lakéré Grassland	3,238570802	3,764132264	0,3264
	Open Savanna Woodland	72,55081749	73,53327	
	River & Marsh	4,518842	5,469394	
	area in km^2	863,18	2644,61	
f2112	Closed Canopy Forest	8,176684	7,525038	overlap
	Dry Lakéré Grassland	2,162494977	2,162668507	0,7863
	Open Savanna Woodland	88,58932502	89,41739149	
	River & Marsh	1,071495	0,894902	
	area in km^2	784,02	653,98	
f2115	Closed Canopy Forest	11,98584	9,600819	overlap
	Dry Lakéré Grassland	2,208828037	2,178871604	0,4026
	Open Savanna Woodland	84,18838196	86,4513884	
	River & Marsh	1,616956	1,768919	
	area in km^2	3933,53	1583,65	
f2116	Closed Canopy Forest	18,65763	19,37042	overlap
	Dry Lakéré Grassland	3,735270513	2,949775998	0,8011
	Open Savanna Woodland	73,28046949	73,031934	
	River & Marsh	4,326634	4,647868	
	area in km^2	1135,46	1079,93	
f2117	Closed Canopy Forest	18,78167	21,72936	overlap
	Dry Lakéré Grassland	2,359739023	3,251566418	0,2012
	Open Savanna Woodland	78,37492098	69,71342358	
	River & Marsh	0,483664	5,305645	
	area in km^2	264,16	1313,02	
m1580	Closed Canopy Forest	17,32106	24,56836	overlap
	Dry Lakéré Grassland	3,885639974	4,069726745	0,3083
	Open Savanna Woodland	74,60607003	64,27384326	
	River & Marsh	4,187234	7,088072	
	area in km^2	1147,82	921,5	
m1584	Closed Canopy Forest	17,28308	16,88957	overlap
	Dry Lakéré Grassland	3,179561231	2,607805783	0,4201
	Open Savanna Woodland	76,72689877	76,05390422	
	River & Marsh	2,810452	4,448724	
	area in km^2	1443,27	663,54	
m1585	Closed Canopy Forest	20,48411	18,10106	overlap
	Dry Lakéré Grassland	1,602263058	2,524025102	0,2642
	Open Savanna Woodland	76,39249694	78,2296549	
	River & Marsh	1,521131	1,145254	
	area in km^2	3480,55	919,83	
m2110	Closed Canopy Forest	13,56701	6,953827	overlap
	Dry Lakéré Grassland	4,425046658	3,348736913	0,2249
	Open Savanna Woodland	78,68602334	87,70972309	
	River & Marsh	3,321921	1,987715	
	area in km^2	4516,48	1015,93	
m2119	Closed Canopy Forest	24,6577	13,36168	overlap
	Dry Lakéré Grassland	3,22615035	2,03556478	0,4839
	Open Savanna Woodland	69,18115965	83,22970522	
	River & Marsh	2,934989	1,373049	
	area in km^2	15090,62	7905,31	
m2120	Closed Canopy Forest	19,73464	15,08527	overlap
	Dry Lakéré Grassland	5,638841102	4,617441884	0,4995
	Open Savanna Woodland	69,2801089	77,16161812	
	River & Marsh	5,346402	3,135678	
	area in km^2	2785,29	2018,91	

Table 3. Average proportion of habitats in seasonal home ranges of all analyzed animals

	Average (%)
Closed Canopy Forest	16,44323617
Dry Lakéré Grassland	3,086336235
Open Savanna Woodland	77,59552712
River & Marsh	3,000370464
Area in km^2	2616,952333

6. Conclusion

We developed a general overview of the basic landscape features, analysis levels, and foraging scales. Furthermore, we then developed a summary of basics regarding the ecology of the species found in Chinko Nature Reserve and ecology of the reserve itself.

Lastly, the proportion of each habitat in the seasonal home ranges was calculated and averaged. These calculations revealed that the habitat, which is of biggest area in the selected giant elands seasonal home ranges, is the Open Savanna Woodland habitat.

Through this, the study provides basis for further research of large herbivore movement ecology, resource selection and conservation initiatives aimed at preserving wildlife in the Central African Republic

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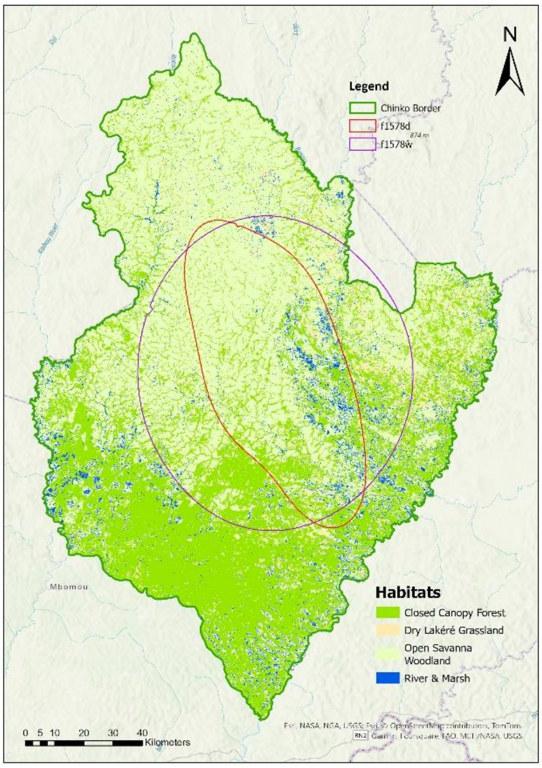
APPENDICES

Appendix 1: Seasonal home ranges for fifteen individual animals

f1578



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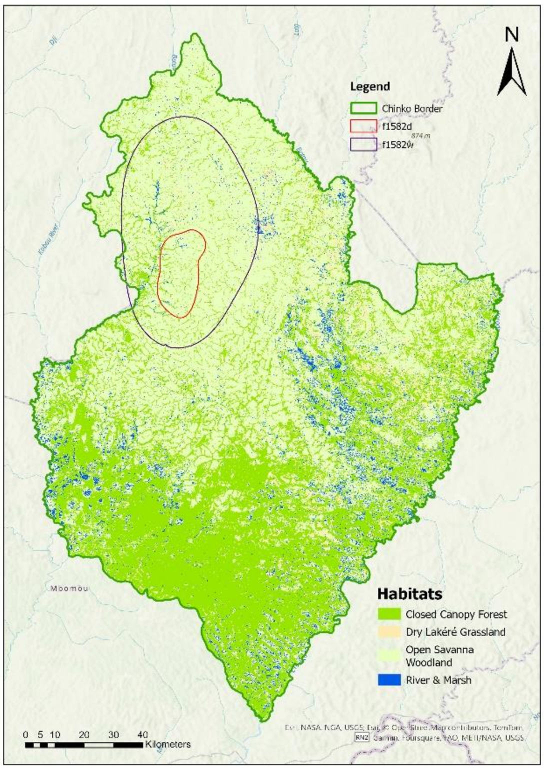

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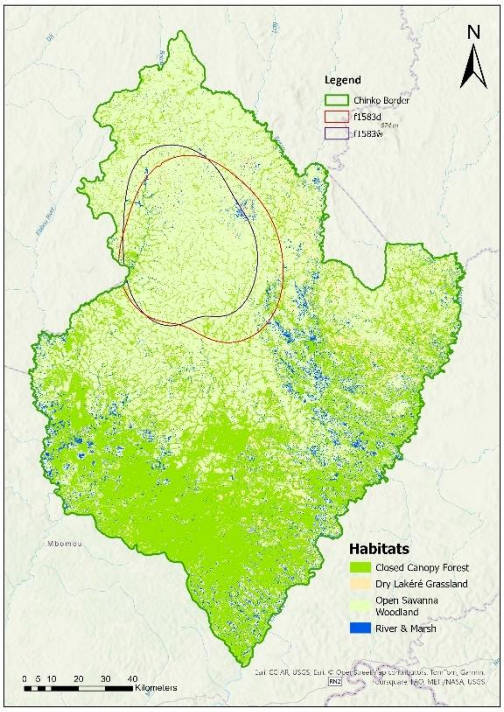

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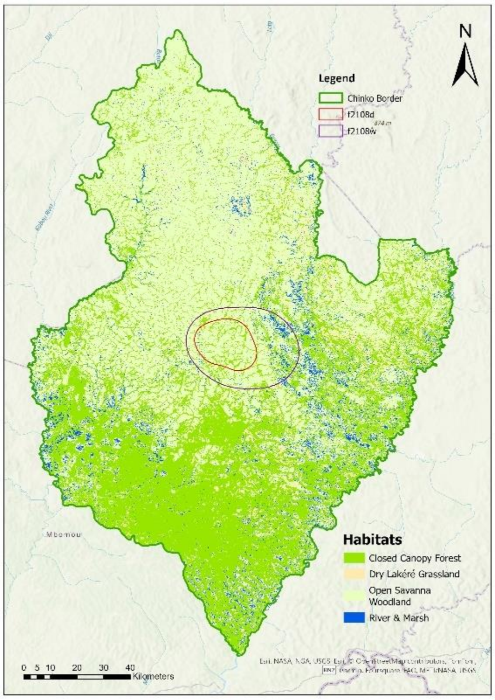

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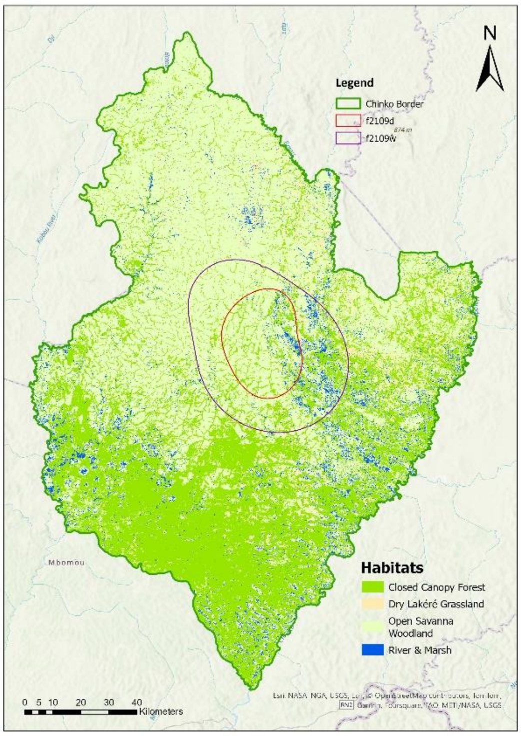

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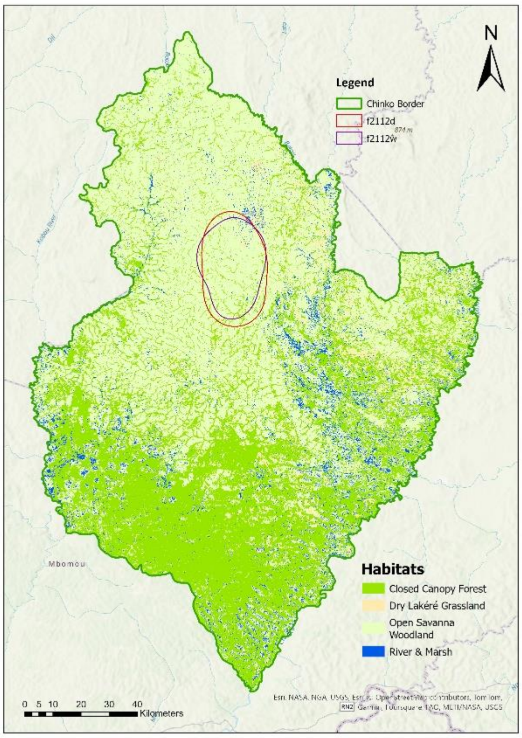

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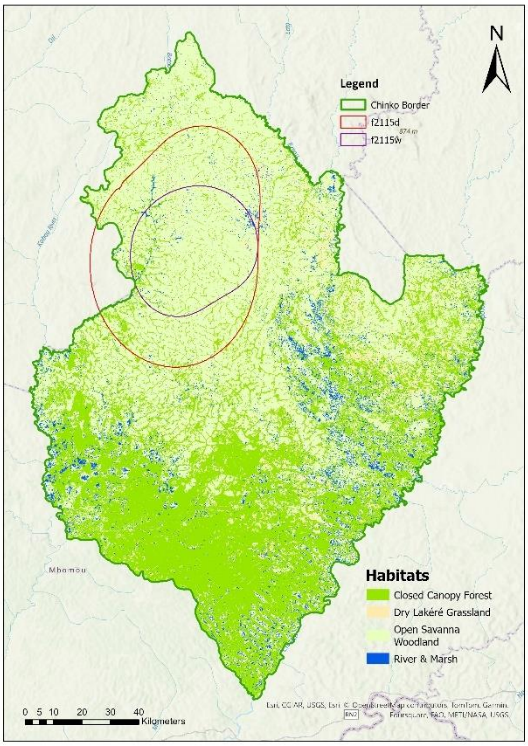

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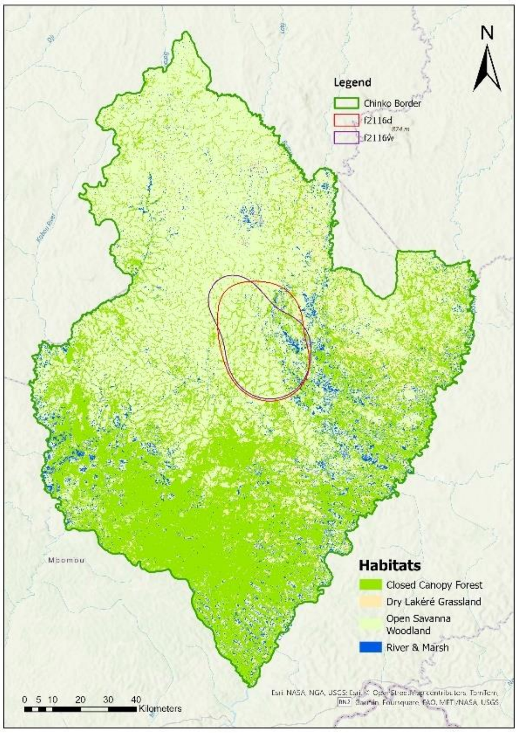

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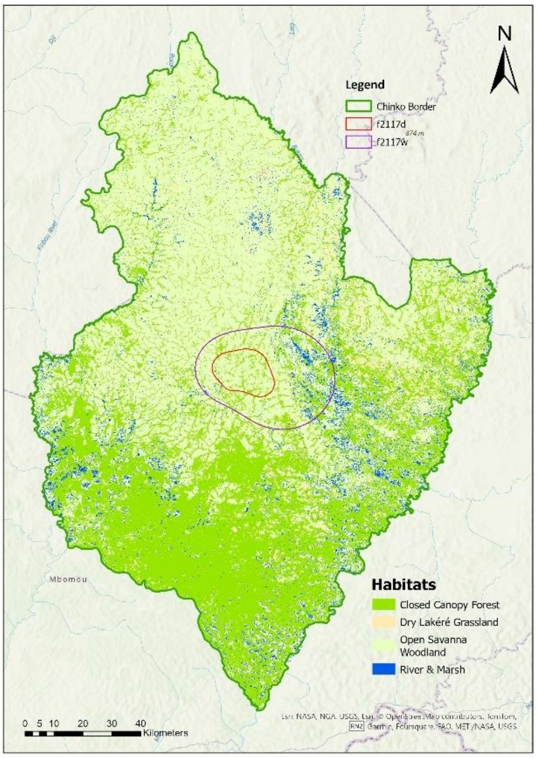

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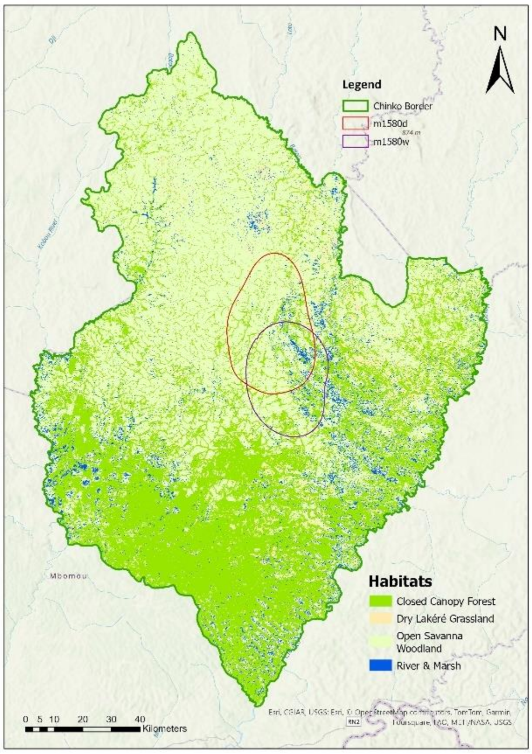

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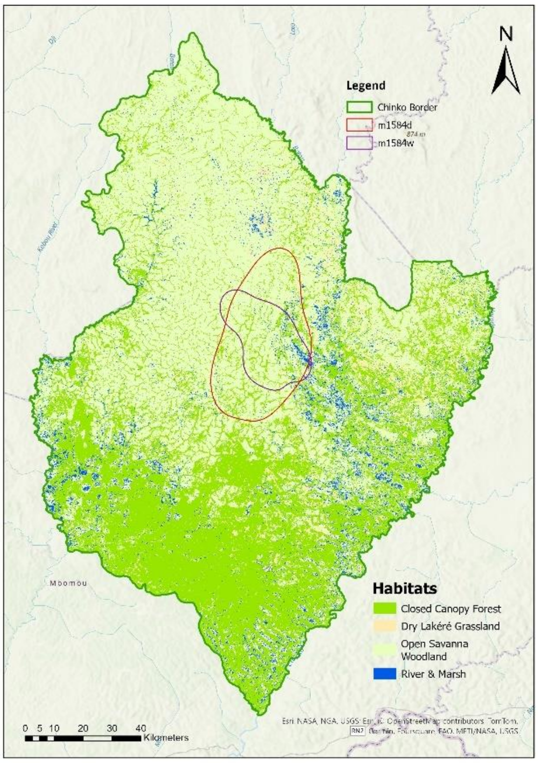

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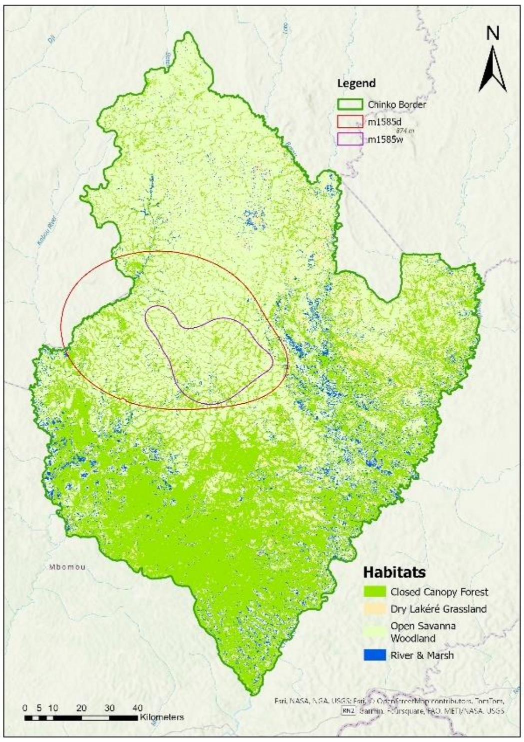

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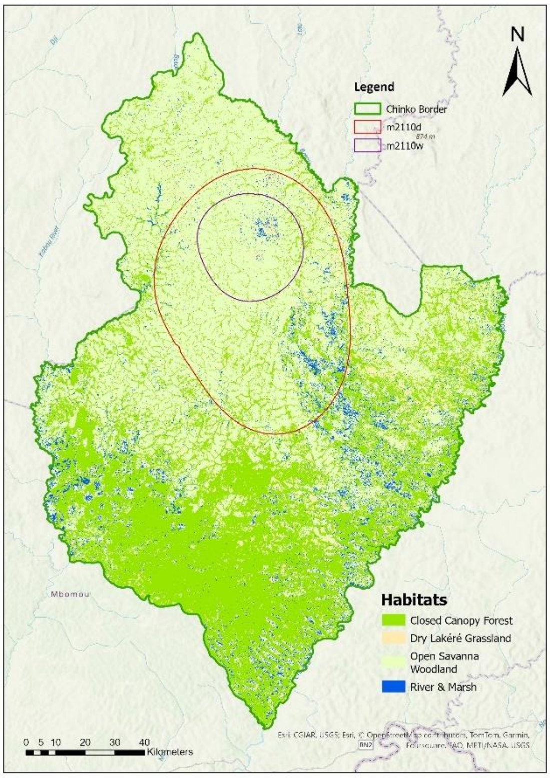

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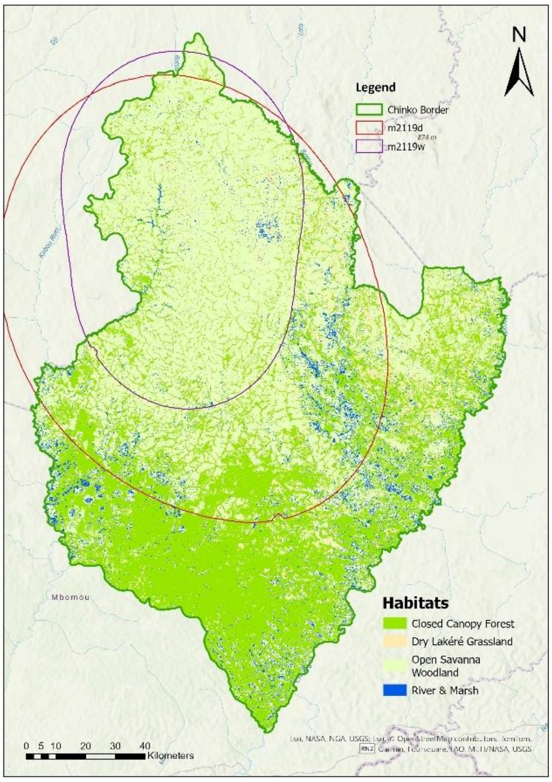

m2120