Mapping wilderness like areas in Tanzania based on the Norwegian INON methodology

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Abstract

The purpose of this master’s thesis was to produce a national wilderness map of Tanzania by using a Norwegian method for mapping wilderness like areas, called *Inngrepsfrie naturområder i Norge* (INON). In English this means Areas without major infrastructure development in Norway. There are currently no national wilderness maps of Tanzania, just maps on regional or global scale. The INON methodology was assessed in relation to Tanzanian conditions, and to some degree compared with Landscan population data, protected areas from World Database on Protected Areas (WDPA), as well as the Last of the Wild dataset from the Human Footprint project.

The INON methodology is based solely on distance from elements defined as major infrastructure development by the Directorate of Nature Management (DN) in Norway, and its methodology is much simpler than other methods for mapping wilderness, such as for instance GLOBIO and the Human Footprint. Its simplicity makes it easy to use, but also insufficient for decision making. It can be used as a reference map, indicating where to find possible wilderness like areas, but additional information is needed before making a decision.

As the INON methodology is based on distance from infrastructure, this raises some issues in a Tanzanian context. This works in Norway because people usually live in close proximity to infrastructure. However, this is not always the case in Tanzania, where the infrastructure is not yet fully developed. Many people live in villages not connected to the road network or other infrastructure defined by DN. These areas will show up in the map as wilderness like areas, when they are actually filled with human settlements. To solve such issues, the INON methodology must be adapted to Tanzanian conditions before it can be used in land use management and planning.

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Part 1 - Introduction and background

1 Introduction

The continuing loss of wilderness areas around the globe is by some considered to be a problem. Wilderness areas are connected to biodiversity, as a lot of species requires a certain size and type of habitat (Cox & Moore 2005). Not all species thrive in urban environments or populated areas.

Today, the extinction of species is happening in a pace that's 100-1000 times faster compared to the period before the human era (Pimm et al. 1995). Countries situated around the equator have a higher density of species compared to countries in higher latitudes. Many "hotspots", which are defined as areas with an extra high concentration of species, are also situated in countries around the equator (Cox & Moore 2005). In addition, hotspots have been estimated to have the highest human population growth rate in the world (Cincotta et al. 2000). Cincotta et al. (2000) estimates that in 1995, 20 % of the world's population lived in hotspots, even though these hotspots only cover about 12 % of the earth's surface (Fig. 1.1).

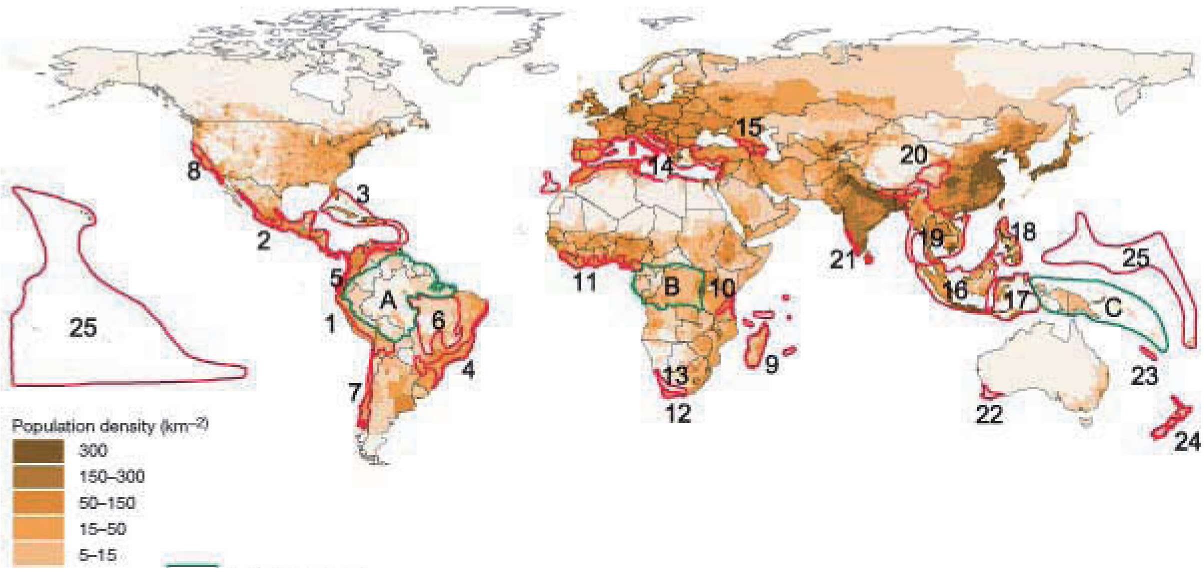

Figure 1.1: Biodiversity hotspots and wilderness areas compared to population density as of 1995 (Cincotta et al. 2000).

Because areas with high biodiversity is often coupled with high population density (Cincotta et al. 2000), there is naturally a higher pressure on the animal and plant life in these areas. Human beings and their infrastructure take up a lot of space, and the animals have to give way to the humans (Mittermeier et al. 2003). Due to the continuing population growth there has been a decrease in areas with little or no human activity, putting ever more pressure on the conservation of biodiversity. According to Fahrig (2003) there is a difference between habitat loss and habitat fragmentation, where the former has the largest negative effects on biodiversity. Even so, habitat fragmentation, which means a division of larger areas into smaller areas, is still a challenge for species in need of large habitats. Fragmentation of habitat usually implies that human activity cuts through the habitat, dividing it into fractions. This means that especially larger mammals are more prone to being hunted by humans, as well as more unwanted contact with humans due to smaller areas to roam (Cardillo et al. 2005).

In order to maintain biodiversity and manage the remaining wilderness areas in the best way possible, it is important that these areas are mapped. Current wilderness maps of Tanzania are not available on national level, just regional (Africa) and global. There is, however, an ongoing project between Tanzania Wildlife Research Institute (TAWIRI) and the Zoological Society of London (ZSL) to make a national wilderness map of Tanzania using the Human Footprint method (see chapter 5). Maps produced on a regional or global scale give a more generalized overview of wilderness areas in Tanzania, as only the largest areas are included. A wilderness map on a national scale would be very useful in land use planning and management, as well as an indicator for biodiversity and land use development over time.

The aim of this thesis is to map wilderness areas in Tanzania based on a Norwegian methodology called INON, meaning Areas without Major Infrastructure Development in Norway (*inngrepsfrie naturområder i Norge*). This method was chosen because of its relative simplicity, thereby increasing the probability of attaining relevant data on a national scale. It only considers distance from major infrastructure development, and not factors such as pollution and population density. The INON map can work as a base map, which can then be expanded with other factors such as pollution, or assigned different values depending on the degree of influence on nature, as, for instance, giving a higher human disturbance factor for highways than a smaller dirt road.

The first INON map was produced in 1995 by the Directorate for Nature Management in Norway to get a national overview of existing areas without major infrastructure development. Up until then there was little knowledge of the national distribution of such areas, and it was decided that the work with mapping these areas should continue. The main purpose of the INON maps is to monitor the land use development over time, and to some degree assist decision makers when deciding where to build new infrastructure (Directorate for Nature Management 2010b; Directorate for Nature Management & Norwegian Agricultural Authority 2010). This thesis will use the terms *areas without major infrastructure development* and *encroachment free areas* to describe the wilderness like areas derived from the INON methodology.

The INON methodology has been under much debate in Norway, mainly because of its simplicity and a tendency among decision makers to accept the maps at face value and not be critical enough to the method and the output data. Although this thesis mentions some of the points of this debate, this is not the main goal. The aim is to investigate the results this method would produce in a Tanzanian context, and to some degree compare these results with existing maps from the Human Footprint project and Landscan population data. In addition to the text, the thesis also consists of datasets for the INON map produced of Tanzania, as well as maps. All maps can be found as appendices in this thesis, as well as on the accompanying CD.

1.1 Research questions

The Norwegian method for mapping wilderness, INON, operates with a term called *inngrepsfrie naturområder*. In English, this means encroachment free areas. The concept of wilderness areas is based on the location's distance from infrastructure, and the wilderness areas are put into categories depending on how far the area is from infrastructure and other technological development (roads, railroads, dams etc.). This analysis will be carried out using geographic information systems (GIS), and then compare the results to the Last of the Wild data from the Human Footprint project, as well as population data retrieved from the Landscan project. In addition, I will discuss how the wilderness like areas derived by using the INON methodology overlap with existing protected areas and how the method transfers to a Tanzanian context. The research questions for this thesis are as follows:

- Can the INON methodology successfully be implemented in a Tanzanian context, and what kind of issues may arise from such an implementation?
- To what extent do protected areas in Tanzania overlap with wilderness like areas generated by the INON methodology?
- How do the wilderness areas generated by the INON methodology overlap with the Human Footprint analysis?
- How do the wilderness areas indicated by the INON methodology correspond to Landscan data on population density?

2 Tanzania as study area

The United Republic of Tanzania was established in 1964, after a merge between the then recently independent states of Tanganyika and Zanzibar. The country is located in East Africa, and is a former German and British colony. Apart from Zanzibar, there are several other islands belonging to Tanzania, the largest ones being Pemba and Mafia (Aschehoug og Gyldendals Store norske leksikon 2010).

Conservation of wildlife areas in Tanzania started during the colonial era, and was developed further after the country gained its independence. The protected areas in Tanzania are divided into different categories, with different governmental organizations being responsible for each of them. Tanzania National Parks (TANAPA) is responsible for national parks, the Game Department is responsible for game reserves, the Forestry Department is responsible for forest reserves, and Ngorongoro Conservation Area Authority is responsible for the country's only conservation area, which is Ngorongoro (Mtahiko 2007). An overview of what the different categories of protected areas imply can be seen in table 2.1. Game controlled areas is also a category of protected area, but the data needed for table 2.1 were not found, so this is left out. Because of this the total percentage will of course be larger than seen in the table.

Table 2.1: Facts about protected areas in Tanzania (Mtahiko 2007; Tanzania National Parks National Policy Committee 1994).

Protected area	**Responsible institution**	**Purpose**	**Total land area of the country**
National park	TANAPA	Highest level of conservation. Consumptive use of resources	4 %

		and tourist hunting are not allowed. Human habitation is not allowed, except from park and tourism staff.	
Game reserve	The Game Department	Protected area where tourist hunting is allowed	10 %
Forest reserve	The Forestry Department	Conservation of forests, including catchment forests.	15 %, including which 3 % overlap with areas devoted to protection of wildlife.
Conservation area	Ngorongoro Conservation Area Authority	Protected area where human habitation (Masaai people) and wildlife coexist.	Unknown

Tanzania is high in biodiversity, and especially regarding mammals. Serengeti National park alone has the highest concentration of mammals in Africa, and the highest number of different types of carnivore in the world (Tanzania Mammal Atlas Project no date). There are several large protected areas in addition to the Serengeti ecosystem. National parks include Arusha, Ruaha and Tarangire, among others (Hansen no date). In total, about 15 % of Tanzania consists of protected areas with the intention of preserving biodiversity and wilderness, and almost 25 % of the country has some form of protective status (Tanzania Mammal Atlas Project no date). An analysis performed by Pelkey et al. (2000) shows that vegetation increases in the national parks, and decreases in unprotected and partially protected areas. The results indicate that full protection of wilderness areas is most efficient in order to best control human influence on nature.

Part 2 - Theory and related research

3 INON

In Norway, a method for calculating wilderness areas has been developed by the Directorate for Nature Management. This method is called INON, meaning Areas without Major Infrastructure Development (*Inngrepsfrie naturområder i Norge - INON*), and estimates wilderness areas based on distance from infrastructure. Distance from infrastructure is measured as the crow flies, and does not consider variations in the terrain. The land area is divided into four categories depending on their distance from major infrastructure development (Directorate for Nature Management 2010a; Directorate for Nature Management no date(a)). Table 3.1 gives an overview of these categories.

Table 3.1: INON categories (DN, 2010a).

Distance from infrastructure	**Description**
<1 km	Areas close to major infrastructure development
1-3 km	Encroachment free zone 2
3-5 km	Encroachment free zone 1
>5 km	Wilderness like areas

The INON methodology focuses on specific types of infrastructure as a measure of human activity, hence other measures of human activity, such as tracks, cabins and smaller power lines are not considered. The maps produced by the Directorate of Nature Management using this method, is being implemented in land use planning and management (Directorate for Nature Management & Norwegian Agricultural Authority 2010). The INON maps show a decrease in wilderness like areas over the years, and the aim is to reduce this decline to a minimum in order to maintain a certain amount of areas that are less influenced by human impact (Directorate for Nature Management 2010b). Based on the measurements of the INON methodology, 11,7 % of Norway (not including Svalbard) is classified as wilderness like areas in 2008 (Directorate for Nature Management, 2010e).

3.1 Terms in the INON methodology

Major infrastructure development is defined by the Directorate for Nature Management as seen in table 3.2. The criteria for something to be defined as major infrastructure is that the infrastructure alters the original state of the nature in a way that makes it difficult or impossible to bring it back (Skjeggedal et al. 2005).

Frame 3.1: Infrastructure included in the INON methodology (Directorate for Nature Management 2010a).

Elements included in the INON methodology:
- public roads and railroads longer than 50 meters. Tunnels are not included.
- forest roads longer than 50 meters.
- tractor-, agricultural-, construction- and mountain pasture roads in addition to other private roads longer than 50 meters.
- old roads renovated for tractor use, equivalent to tractor road class 7/8 (roads used for transportation of lumber and agricultural products (Ministry of Agriculture (Landbruksdepartementet) 2002)) or roads with better standard.
- approved bare ground courses (in the county of Finnmark)
- massive towers and wind turbines
- larger stone quarries and soil extraction sites
- larger ski tows, ski hills and ski slopes
- power lines built for voltage of 33 kV or more.
- reservoirs (all water at highest regulated water level), regulated rivers and streams. → Applies to regulated rivers and streams where the water flow is increased or decreased → Mainly applies reservoirs where periodic regulations involves increased or decrease of water levels of one meter or more → The water flow all the way down to the sea is considered as infrastructure
- power stations, utility lines above the ground, canals, retaining walls and flood protection.

As seen from the frame, not all kinds of infrastructure are included. Cabins and smaller dirt roads, for example, are not considered to be major infrastructure development by the Directorate for Nature Management. Most cabins are within five kilometers of at least one road, and if not, they are considered to be such a small impact on nature that it does not qualify as major infrastructure development. Areas defined by INON as wilderness like (more than five kilometers from major infrastructure) are not necessarily untouched by human activity (Directorate for Nature Management & Norwegian Agricultural Authority 2010).

Another term used in the INON methodology is *wilderness like*. It is debatable whether or not there are areas that are still untouched by human activity at some point in history. Pollution and climatic change, for instance, affects the entire globe. Because of this, wilderness like is used instead of wilderness. Wilderness like is a softer term, used because a lot of the areas that today would fall under the “wilderness” category of the INON methodology, have often been used by humans before. The cultural landscape is always changing, forest roads being overgrown and put out of use, pastures and crop land laid fallow and so on. In addition, indigenous people may have used, or still use, the wilderness areas. In this case, there will be human activity in a wilderness like area.

Bearing the wilderness like term in mind, the focus of the INON methodology is actually not wilderness areas, but areas *without major infrastructure development*. These two terms sometimes seem to be used as if they mean the same thing, and it can be difficult to separate between them. If an area is more than five kilometers away from major infrastructure development, it is considered to be wilderness like. The idea behind this is that where there is major infrastructure development, there is usually people, and vice versa. Most human activity in Norway is connected to infrastructure of some kind. The INON methodology aims to show the extent of technical interference on nature, not all other kinds of influence (Directorate for Nature Management 2010b). According to Washington (2007) no current definition of wilderness actually excludes humans, only their infrastructure. In that sense, the use of areas without major increment as an equivalent to wilderness areas, may not be as far off as many critics claim.

4 Wilderness

Wilderness is a qualitative and elusive term, which is defined and interpreted in many different ways. According to Skjeggedal et al. (2005), wilderness is today considered to be a positive term. Wilderness is thought to be untouched by humans and developed as nature intended it to. It is separated from culture and other aspects of human life. Others, however, perceive “wilderness” as yet another Western idea, separating “civilized” people and places from the “uncivilized”. Large natural areas do indeed exist all over the world, but the perception and feelings towards these areas vary in different cultures (Washington 2007). The Sahara desert for instance, is a large wilderness area, but because of its barren state it may not be as attractive as an area such as the Serengeti in Tanzania.

There have been many attempts to find a suitable definition of wilderness, resulting in various interpretations of the term. The definition set forth in the American Wilderness Act of 1964, which will be elaborated in chapter 4.2, is perhaps the definition which has been most influential over the last 50 years or so. Many governments have used this Act as their foundation when defining laws to protect the wilderness areas of their own countries. This includes the Tanzanian government (Tanzania National Parks National Policy Committee 1994).

International Union for Conservation of Nature (IUCN) defines wilderness as ”a large area of unmodified or slightly modified land, and/or sea, retaining its natural character” (IUCN 1994). The IUCN hereby includes areas previously influenced by human activities into the definition of wilderness, by also defining “slightly modified” land/sea as wilderness. As very few areas of the world are completely untouched by human activities, including the slightly modified areas is necessary in order to include areas into the wilderness category that are in fact perceived as wilderness today. Such an example could be a savannah in Africa, were indigenous people once lived, or still lives. A small tribe of people living in unison with nature would only slightly affect the perception of wilderness in the area. These indigenous people might even be considered to be part of the wilderness.

4.1 The history of wilderness

The term wilderness is subjective and its implications seem to have differed throughout history and in different cultures. One theory is that the wilderness term date back to the first agricultural revolution, when people started settling in a specific area instead of being nomads. It is natural to think that the term wilderness did not hold any meaning until people wanted to separate between the civilized land on the inside of the fences, versus the “wild” and often unknown on the outside of the fences (Skjeggedal et al. 2005; Nash 2001). Controlled and uncontrolled animals and vegetation became separated from another, and (civilized) humans were separated from nature. Indigenous people were seen as savages. Wilderness became the uncontrolled and often dangerous areas, and the aim for man was to control these areas, as well as exploit its resources. Wilderness was seen as the opposite of “paradise” because paradise would be places that were perfectly suited to fit human needs. When the humans were nomads, there was no such ting as wilderness, because practically all land was considered to be possible habitat (Nash 2001). Nash (2001) raises an interesting point, but there still might have been some notion of wilderness even when people were nomads, because not all areas were habitable. Vast deserts with no water or vegetation, areas covered in glaciers and inhospitable steep mountains would be examples of such uninhabitable areas that might be thought of as wilderness. However, according to Nash (2001) the Native-Americans did not think of nature as wilderness or uncontrollable. Nature was not feared, but worshipped. Hence, wilderness can be though of as a “white man’s term”.

Even though wilderness is a positive term today, this was not always the case. In past times, wilderness was associated with “primitive” peoples like Native Americans, in addition to supernatural creatures like witches and werewolves. Wilderness represented something primitive and frightening that was wild and uncontrollable by “civilized” people (Skjeggedal et al. 2005; Nash 2001). The Bible speaks of wilderness in terms of wastelands and deserts where people are tempted or face trials (Deuteronomy 32:9-10; Luke 4:1-2; Deuteronomy 8:2-3). These places should be feared, and hence the term has a negative connotation (Washington 2007).

In the Middle East, there are examples of wilderness being defined as areas without water, or even cursed areas (Skjeggedal et al. 2005). In the Quran, it says: “Had it not been that favour from his Lord had reached him he surely had been cast into the wilderness while he was reprobate” (Al-Qalam 68:49). This suggests that wilderness was thought of as a place for the damned where they had to serve their penance. The notion of wilderness as areas without water can to some degree be transferred to today’s view of the term, in the sense that wilderness is often represented by areas which are remote and sometimes infertile. Hence, no one wants to live there. The biblical story of Moses wandering the desert made wilderness a more positive term, even though it was a trial. By facing the challenges the desert offered, the Israelites came closer to God and “the promised land” (Skjeggedal et al. 2005).

During the 15th and 16th century, wilderness as a positive term was developed further. The mountains were seen as the work of God himself, and nature was utterly beautiful. Following the independence of the United States of America, the American people needed something they could build their national sentiment on, something they could be proud of. Due to lack of history and architecture, they looked to the nature surrounding them. Most countries have a beautiful nature, so they needed to find something that was special about the American nature. Their answer was the wilderness. Being a “new” country, most of the nature had not been affected by human life (Skjeggedal et al. 2005). The American wilderness is vast and breathtaking, and inspired the Wilderness Act of 1964, which will be discussed in the next chapter.

Today, people often visit the wilderness to get away from the stress of city life, and to find peace and quiet (Skjeggedal et al. 2005). Discovery Channels “Ultimate Survival” and other TV-shows about nature give a taste of the wild, without the viewers having to actually visit the wilderness. Most people may have a relatively distant relationship to the wilderness. It’s “out there”, but not part of our every day lives. Wilderness represents the “untouched” nature, and is separated from society and human activity. This separation of nature and society is termed external nature (Castree 2001).

4.2 The American Wilderness Act

To ensure protection of the wilderness areas in America, the American Wilderness Act of 1964 was established. The purpose of the act was to manifest by law that people could not settle wherever they wanted to, and hereby ensuring the continued existence of wilderness areas in the United States. The definition of wilderness areas used in the American Wilderness Act is as follows:

A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammelled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this Act an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man’s work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value (The Wilderness Act of 1964).

As can be seen from the definition above, the American Wilderness Act operates with a minimum size of 5000 acres, which is approximately 20 square kilometers. Areas smaller than this may not be worth protecting, unless the biodiversity in the area is very special. It also would not fit the view of wilderness as a vast area.

4.3 Wilderness in Tanzania

Tanzania National Parks (TANAPA) is the governmental organization responsible for managing national parks in Tanzania, and their view on wilderness preservation is clearly influenced by the American Wilderness Act of 1964. TANAPA has adopted the definition of wilderness used in the American Wilderness Act, making the foundation of wilderness preservation the same both in Tanzania and USA. One would, however, think that TANAPA would consider the national parks and other protected areas to be wilderness areas, but according to the Tanzania National Parks National Policy Committee (1994) wilderness areas are areas within the national parks which are even more important to protect. While tourists and locals can drive through the national parks and look at the animals, cars and other motorized equipment or transportation are forbidden in the wilderness areas, except in emergency situations. The term “wilderness area” is here used about an area within a national park or other protected area which fulfils the requirements set forth in the definition of wilderness, hence separating the terms wilderness and protected area (Tanzania National Parks National Policy Committee 1994; Mtahiko 2007). According to Mtahiko (2007) a national park or other protected area can be divided into eight different zones, depending on the level of conservation appropriate for the areas. The names of the zones are listed in frame 4.1.

Frame 4.1: Conservation zones within national parks (Mtahiko 2007).

Conservation zones within national parks
Wilderness Zone
Semi-Wilderness Zone
Conservation General Use North Zone
Conservation General Use South Zone
Core Preservation Zone
Conservation Limited Use Zone
Transit Road Zone
Park Administration Zone

The parts of protected areas termed wilderness zones have specific uses attached to them, in addition to preserving resources like the rest of the protected area. It is not considered to be a category of conservation, but rather an area which will be used in a certain way, and usually have less human activity. Hence, these areas are not part of the regular tourist safari routes with the use of cars, but can be visited on foot. To keep large parts of protected areas as wilderness zones is important to secure the future of biodiversity and wild nature. Roads are allowed (to some degree) within national parks, but by keeping certain areas classified as wilderness zones, there can be road free zones within the parks. They form core bases for biodiversity and can also be used for a number of recreational activities, allowing people to get closer to nature. However, there are several challenges to maintaining these wilderness zones. Among other things are limited funding, and illegal hunting and use of resources (Mtahiko 2007).

4.4 Wilderness and conservation

Our relatively positive view on wilderness, and the way we consider it to be separate from human settlements, has had an effect on how we think about conservation of the nature. Even though today human activity and nature are seen as two entities, this was not always the case. In past times, humans lived as part of nature, using its resources, but not draining them as much as we do today. Protecting the wilderness is also about protecting our history, and the life we once led (Skjeggedal et al. 2005).

Although wilderness is considered untouched and inherently wild, humans most likely have marked these areas in some way. As Skjeggedal et al. (2005) point out, what we define as wilderness might have been used for agricultural purposes, and then laid fallow. Therefore, these areas are not untouched in the sense of never being manipulated by humans.

Before the rise of the modern civilization and permanent settlements, people lived scattered across large parts of the globe. These people probably affected the nature surrounding them, although probably not as much as today's modern western civilization. When one considers wilderness to be untouched, despite people having previously lived there, one assumes that these people lived in harmony with nature, without draining its resources. There is, however, circumstantial evidence which suggests that these "primitive" people have played a part in the extinction of several plant and carnivore species after the last ice age. This theory is called

Pleistocene overkill, where human activity and not climatic change is to blame for extinction of species (Martin 1984). Truly untouched wilderness is therefore a very rare phenomenon on a global scale.

The idea of preserving wilderness areas is a conflicted matter. On one hand, we want to conserve the natural beauty and ecosystem of a landscape or area, but on the other hand, we want to use the vast resources that are so often present in these areas (Washington 2007). Especially in developing countries, such as Tanzania, one must weigh the pros and cons against each other. As seen in Fig. 1.1, wilderness areas and biodiversity hotspots are often found in developing countries on the southern hemisphere. The need for using the vast resources in these areas is often bigger here than in Western countries, hence conservation issues become conflicted.

IUCN is a global environmental network whose purpose is to promote conservation of nature, and work as a neutral forum for governments, non-governmental organizations (NGOs), scientists and others to solve issues regarding conservation (IUCN 2011). The IUCN has prepared some guidelines for categorizing protected areas through a management perspective. A protected area is defined by IUCN as "A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (Dudley 2008). These two definitions are basically the same. The protected area management categories are shown in table 4.1. An important point here is that even if a government calls an area a national park, it does not have to be managed under the criteria of the national park category. The most suitable management system for the area should be applied, regardless of the name of the protected area. The categories are general because they are international, so countries are encouraged to add details that fit their own conditions (Dudley 2008).

Table 4.1: IUCN Protected Areas Management Categories (IUCN no date).

CATEGORY Ia:	Strict Nature Reserve: protected area managed mainly for science
Definition	Area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring.
CATEGORY	Wilderness Area: protected area managed mainly for wilderness

Ib	protection
Definition	Large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.
CATEGORY II	National Park: protected area managed mainly for ecosystem protection and recreation
Definition	Natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.
CATEGORY III	Natural Monument: protected area managed mainly for conservation of specific natural features
Definition	Area containing one, or more, specific natural or natural/cultural feature which is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities or cultural significance.
CATEGORY IV	Habitat/Species Management Area: protected area managed mainly for conservation through management intervention
Definition	Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.
CATEGORY V	Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation
Definition	Area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance and evolution of such an area.
CATEGORY VI	Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems
Definition	Area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.

5 Related research and projects

There has been some previous work on GIS-analyses of remaining wilderness areas, or areas not as influenced by human activity. Many of these analyses are on a global or continental scale, and I will give an outline of these below.

5.1 The human footprint

The Human Footprint is a project lead by the joint effort of the Wildlife Conservation Society (WCS) and the Center for International Earth Science Information Network (CIESIN). Their aim is to produce maps showing the effects on human influence, or footprint, on the world (SEDAC 1997-2010). According to Sanderson et al. (2002), ‘the Human Footprint is a global map of human influence on the land surface’, and suggests areas where human influence can be more or less responsible for what happens to nature and biodiversity.

The Human Footprint project has three categories of maps; the Human Influence Index, the Human Footprint and the Last of the Wild. Maps are produced by overlay of several global data sets representing locations of various human influences, e.g. roads, rivers used for transportation, urban areas (also indicated by lights at night) and agricultural use of lands. The Human Influence Index is the result of these combined factors. After adjusting for the different global biomes, the Human Footprint is produced (SEDAC 1997-2010). Biomes are different types of ecosystems, recognized by similarities in vegetation and life forms (Cox & Moore 2005). Examples of biomes are tundra, flooded grasslands and temperate coniferous forests (Sanderson et al. 2002).

The score in the Human Footprint ranges from 1 to 100, where 1 is the “wildest” in the biome (SEDAC 1997-2010). In each biome, 1 was assigned to the grid cell with lowest influence, and the value 100 was assigned to the cell with the highest human influence. Based on these two extremes, the intermediate values were spanned linearly between them, creating an ordinal ranking of the grid cells. However, because this is done in each biome, the actual influence differs between biomes. The score of 1 is an indication that the grid cell belongs to the 1 % least influenced area in its biome. The least influenced areas in a tundra biome and in a temperate coniferous forests biome could have different meaning, as the degree of human influence varies between biomes. The tundra biome, for instance, could have areas that where practically untouched by human activity, while the temperate coniferous forests biome could have some degree of human influence in the entire biome. Hence, the value of 1 would represent “wilder” areas in the tundra biome than in the temperate coniferous forests biome (Sanderson et al. 2002).

The Last of the Wild includes those areas with a score of 10 or lower in the Human Footprint analysis, that is ‘the “10% wildest areas” in each biome in each realm around the world’ (Sanderson et al. 2002, 897). Of these areas, the ten largest contiguous areas in each biome were included in the Last of the Wild data set, mainly because large areas are especially important in maintaining and preserving biodiversity (Sanderson et al. 2002).

The first version of the Human footprint and Last of the Wild data sets were produced in 2002, and is available both on global and continental scale. However, the Human Footprint analysis is based on data collected mostly in the 1990s, and the data sets are not perfect. Among the imperfections are that not all roads have been included, the mapping of land use areas may be inaccurate, and so on. The resolution is 1 square kilometer, but only wilderness areas greater than 5 square kilometers are included in the final result. Because of these inaccuracies, the Human Footprint is not optimal for drawing conclusions on a local scale (Sanderson et al. 2002). Version two of the Last of the Wild, published in 2005 (SEDAC 1997-2011), is based on data sets collected in or around 2000 (SEDAC 1997-2010).

The results from the Human Footprint project indicates that 17 % of the earth’s surface (not including water), is not directly influenced by human activity in the form of infrastructure, human land use or settlements (CIESIN 1997-2002). Antarctica and many small oceanic islands were excluded from the analysis because relevant data for these areas were not available (Sanderson et al. 2002).

5.2 GLOBIO

The Global Methodology for Mapping Human Impacts on the Biosphere (GLOBIO) was developed by the United Nations Environment Program (UNEP) as a tool to predict, to some degree, the future implications of human activity on our globe. These “predictions” are called scenarios. They give possible future situations based on different developments (UNEP 2001). In the GLOBIO report released in 2001 (UNEP 2001) concerning the Arctic 2050 scenario, the affects of infrastructure on wildlife is emphasized. About 200 studies concerning the impact of infrastructure on wildlife has been included in the method. Based on these studies, a probability factor of human influence was assigned to different types of infrastructure, such as roads, pipelines and settlements. This means that a highway would have a higher influence on nature than a small dirt road, for instance. The climate and ecological zone of the area being mapped is also taken into consideration. Additional information, such as pollution, can also be added to the map.

The GLOBIO method is based on distance from infrastructure as it is today, but also an estimate of infrastructure development based on different growth rates. Because no one can be certain about how the development of infrastructure will evolve, the GLOBIO report operated with three different growth rates; 50 % reduced growth rate, current growth rate, and a 200 % increased growth rate, based on the growth rate recorded between 1940 and 1990. The growth rate of the infrastructure development between 1940 and 1990, are calculated using old maps, and assuming that new infrastructure is rooted in already existing infrastructure and spreading from those areas. Adding the situation today with the estimated infrastructure development, the result is a possible human influence scenario for the arctic region in 2050 (UNEP 2001).

Data used in the analysis come from Digital Chart of the World (DCW) with a scale of about 1:1,000,000. The DCW data were published in 1992, but the actual collecting of the data sets happened between the mid 1960s and up to the publication of the data. According to the GLOBIO report (UNEP 2001) the DCW data is less accurate than regional and national data, at least in the Arctic. Still, the data was chosen because it gave the best available coverage for the Arctic region as a whole. Table 5.1 shows the general criteria used by GLOBIO for defining environmental impacts, based on about 200 scientific studies.

Frame 5.1: General criteria for defining environmental impacts (UNEP 2001).

Criteria for defining environmental impacts:
1) ***Reduced survival and/or abundance of birds***: A zone within which there is a high risk of reduced survival or abundance of birds based upon studies of more than 50 bird species.
2) ***Reduced survival and/or abundance of large mammals***: A zone within which there is a high risk of reduced survival or abundance of larger mammals based upon studies of most of the larger predators and ungulates.
3) ***Cumulative effects on flora and fauna****:* A zone within which there is a high risk of cumulative effects on ecosystem function, such as changes in proportions of organisms

affecting food chains, increased numbers of generalist (“pest”) species, vegetation changes, overgrazing, increased risk of predation etc.
4) ***Low levels of disturbance***: No or few studies have documented or reported possible impacts. Increase in hunting pressure, tourism and human traffic must, however, be expected.

The general criteria listed in table 5.1 are meant to be used in any part of the world. The distance from infrastructure can vary, but when making the Arctic scenario map, everything more than 20 kilometers away from infrastructure was considered to be areas with low or no disturbance (UNEP 2001).

5.3 LandScan

LandScan is one of the most spatially accurate global population distributions available, and is based on satellite imagery, infrastructure and census data, as well as night-time lights. The first version was published in 1998, and is updated regularly. Unlike most population distribution data, which estimates distribution based on where people reside, LandScan gives an idea of where people are located during a 24-hour period. This method of estimating population distribution is useful in case of emergencies, because some areas might contain a lot of tourists, for instance. They might increase the number of people in a given area substantially, but will not be taken into consideration if the population estimates are based on residential numbers alone (Dobson et al. 2003).

The method begins by placing the earth’s surface in a 30 arcsec resolution grid (3 arcsec for the USA alone), and give values to the surface according to how attractive the area is for people to be in (Dobson et al. 2003). Arcsec refers to the term arcsecond, which is the same as 1/3600 of a degree. Latitude and longitude are often measured in degrees, minutes and seconds, where one degree is 60 minutes, and one minute is 60 seconds. 30 arcsec therefore means that LandScan has a resolution of 30” x 30” (30 seconds x 30 seconds), which is a little less than one kilometer at equator.

Population values are assigned to the locations based on where it would be likely that people are. Only land surface is considered, so oceans and lakes are removed. Places where people are unlikely to be are also excluded, such as high mountain peaks, very steep slopes and wetlands. Areas where people are very likely to be, such as urban areas, roads and near water sources, are given higher values. Because what kind of variables are considered attractive vary between regions, the values are determined based on individual assessment for approximately 100 different geographic regions (Dobson et al. 2003).

All vector data is converted to raster format, placing each cell into its corresponding census area. Census data are collected on the finest scale available, such as municipality, district, province and so on. Each of these census units consists of one polygon, hereby making one polygon for each municipality. The total sum of people living within each census unit is used as a means to control the final result of the distribution of people suggested by the LandScan analysis. For instance, the total sum of people in the LandScan distribution cannot exceed the world's total population, or even the number of people expected to be found in a given area. A population total must be given for each census unit used in LandScan. The whole point of the analysis is to determine the likeliness of where people are located at a given time, so that estimations of people at risk in an emergency are as accurate as possible (Dobson et al. 2003).

LandScan is a global database, and depends on data collected by others. Census data accuracy depends, among other things, on the collector's resources. Some countries do not have the time or money to publish updated census data each year. Because of this, census data for parts of the world may be several years old, while other parts of the world can provide up to date census data. According to Dobson et al. (2003), the administrative level two divisions below the national level provides the most accurate census data for most of the world. In addition to the age of the data, quality of the census counts, as well as the size of census levels (national, regional etc.), it is also important that the cartographic data are accurate. Polygons containing census units (different regions or municipalities) must be of good quality, and are not always available. For countries where adequate polygons for census units are not available, paper maps must be scanned and digitized by others.

Varying quality in census data across the globe is a major problem when estimating population distribution. In order to be eligible for use in LandScan, census data must be obtained from published, good quality sources. Data obtained "under the table" may not be used. For a number of reasons, such as political interests or lack of resources, not all census data are correct. Hence, conflicting or suspicious data is adjusted by demographers based on the overall consent in the academic field of demography (Dobson et al. 2003).

5.4 World Database on Protected Areas (WDPA)

The World Database on Protected Areas is a project between UNEP and IUCN, where governments and NGOs also contribute to the result. WDPA contains the most comprehensive global dataset on terrestrial and marine protected areas. An area which is to be entered into the WDPA database has to meet the criteria set forth in IUCN's definition of a protected area. To ensure global consistency, the protected areas in the WDPA database are classified according to the IUCN Protected Areas Management Categories (see chapter 4.4) (WDPA no date(a)). The names of these categories differ somewhat from the names used by authorities in Tanzania. Table 5.1 gives a "translation" between IUCN category names and names used in Tanzania.

Table 5.1: "Translation" between names used on protected areas in Tanzania and IUCN categories. Forest reserves do not fit in any one category, and is placed in the category that makes the most sense for each area (IUCN 1994; IUCN & UNEP-WCMC 2010; Tanzania National Parks National Policy Committee 1994; Burgess & Rodgers 2004[1]).

IUCN categories	**Names used on protected areas in Tanzania**
Ia	Unknown
Ib	(Forest Reserve)
II	National Park (Forest Reserve)
III	(Forest Reserve)
IV	Game Reserve (Forest Reserve)
V	Unknown
VI	Conservation Area and Game Controlled Area (Forest Reserve)

WDPA datasets are used for many reports and projects, among others the UN Millennium Development Goals (MDGs). The UN has eight MDGs, stretching from ending poverty and hunger to global partnership. The WDPA was used for goal number seven; ensuring

[1] Burgess, N. & Rodgers, A. 2004. Protected area categories: Why they matter for the Eastern Arc and coastal forests in Tanzania – Briefing Note. *Conservation and Management of the Eastern Arc Mountain Forests Project.*

environmental stability (WDPA no date(b)). Fig. 5.1 shows the development in protected area coverage in Tanzania from 1990 to 2009.

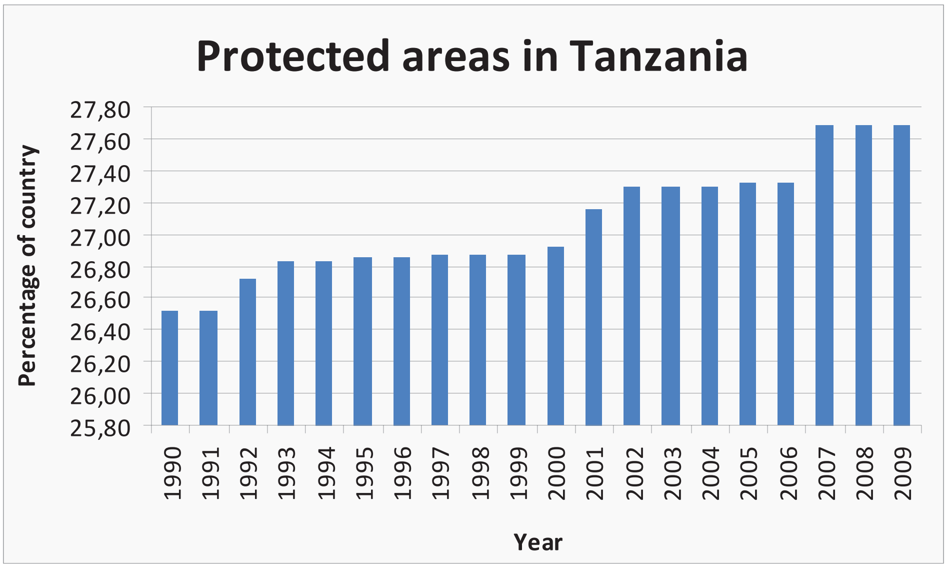

Figure 5.1: Total area of Tanzania covered by protected areas for the years 1990-2009 (IUCN & UNEP-MCMC 2010).

5.5 Wilderness map of Tanzania

It should be mentioned that there is an ongoing project lead by Tanzania Wildlife Research Institute (TAWIRI) and the Zoological Society of London (ZSL) to produce a map of wilderness areas in Tanzania. The method is the same as used by the Human Footprint, but adapted to a national scale instead of the global and regional ones used by the Human Footprint project. The map has not yet been published, as of August 2010 (A. Lobora, personal communication 2009-2010).

Part 3 - Methodology

6 Mapping with GIS

This thesis uses Geographical Information Systems (GIS) to map wilderness like areas in Tanzania and other maps. ArcGIS version 9.3 is the software used, and all datasets are secondary. Chapter 6.1 will give a closer presentation of the datasets used in this thesis.

6.1 Datasets and metadata

Due to financial and time constraints as well as a wish to make this study replicable for others, all data sets used in this thesis are freely available secondary data. Most of the data sets have been downloaded from various digital sources, and used “as they are” after converting to a common spatial reference (UTM coordinates). Most of the original data are unprojected using geographic coordinates based on the datum World Geodetic System from 1984 (WGS84). The data set on roads (TanRoads) was digitized on-screen based on images of roads in each region downloaded from the TanRoads website (TanRoads 2011a). This process is described in chapter 6.2 below.

Good data for Tanzania were not easy to come by, so most data are a few years old. Ideally, I would have liked to find more recent data, but I eventually had to end my search for better data. In addition to data downloaded from different organizations, such as Digital Chart of the World (DCW) and Africover, I also acquired a substantial amount of datasets through non-official channels, meaning contacts in Tanzania. I chose not to use any of these data, however, because they were not readily available to others and the metadata for many of the datasets were scarce or non-existent.

To make the INON map of Tanzania the following datasets for infrastructure were used (see appendix F for a complete list of all the data):

- Roads
- Railroads
- Dams
- Downstream rivers from dams
- Utility lines

For the roads I decided to use three datasets; one for the entire country including islands (Digital Chart of the World [DCW]), one for the Serengeti area (Serengeti-Mara), and one of the screen-digitized regional roads managed by Tanzania National Roads Agency (TanRoads). The DCW data set is the basis, but I decided to add the other two as well as a supplement. The Serengeti-Mara dataset included a lot of roads in the Serengeti area that were not included in the DCW dataset. Because of the many researchers (and other people) in this area, it may create a bias in the dataset because the roads here are probably better mapped than in areas with fewer researchers and tourists. The maps in part 4 will show Serengeti as filled with infrastructure, probably because of these roads. It might be that even tracks have been included in the Serengeti-Mara dataset, but I chose to include it anyway.

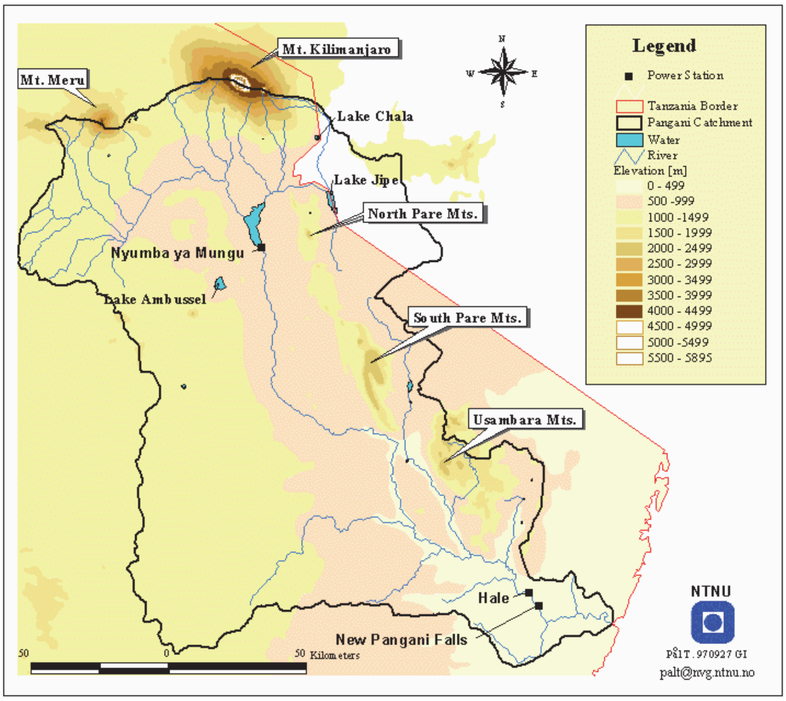

Figure 6.1: Map showing the power stations Nyumba ya Mungu, Hale and New Pangani (Tengesdal 1998).

I downloaded a dataset on hydroelectrical power stations in Africa from FAO, but this dataset only included three of the six power stations. In addition, Nyumba ya Mungu power station was positioned at the north end of the dam instead of the south. I corrected this by using the map by Tengesdal (1998), and was also supported by Tanzania Electric Supply Company (TANESCO) who operates the power station. According to them the Nyumba ya Mungu power station is “positioned at the foot of the dam” (TANESCO 2011), meaning the south end. The missing power stations were digitized after Tengesdal (1998) and coordinates found at Wikipedia (Kihansi power station) (Wikipedia 2011). As the INON methodology also considers downstream rivers from power stations and other dams as major infrastructure development, these were digitized using river data from DCW. Utility lines from DCW were also included in the analysis, but the dataset included very few utility lines. Either the dataset is incomplete, or most utility lines are underground.

6.2 Digitizing

The methodology of generating buffer polygons that represent encroachment free areas does of course heavily depend on what is used as input infrastructure data, particularly roads. Because of the difficulty of finding adequate data sets of roads, regional and trunk roads administered by Tanzania National Roads Agency (TanRoads) were downloaded from the TanRoads website as pictures, georeferenced and screen digitized into shapefiles using ArcMap. This helped me at least to be sure that I had a sufficient picture of regional (larger) roads in most of Tanzania. TanRoads is an official Tanzanian agency under the Ministry of Infrastructure Development managing regional and trunk roads on the mainland (TanRoads 2011b), and should therefore have the most complete and consistent data set on main roads in Tanzania. However, road maps of the Tanzanian islands Pemba, Zanzibar and Mafia are not posted on the TanRoads website and consequently have not been digitized.

TanRoads has published the roads under their administration as of 2008 for almost every region on their website (TanRoads 2011a). The regions omitted are Ruvuma in the south and Mara in the north. The Rukwa region was represented, but because this particular map did not have visible region borders, georeferencing became very difficult. Since I could not get a good enough match when geoferencing, I decided not to digitize the roads in the Rukwa region. The maps for the rest of the regions were more or less successfully digitized using ArcMap.

Digitizing on-screen is called heads-up digitizing, and can easily be done within a GIS programme using the computer mouse (Longley et al. 2005). The pictures downloaded from the TanRoads website of the roads, were originally raster data. When digitized in ArcMap, the features of interest (the roads) in the picture were stored as vector data.

In order to digitize the roads from the TanRoads maps, the maps first had to be georeferenced. Georeferencing refers to the process of assigning from a source layer the coordinates of a specific location to a feature in a target layer (Longley et al. 2005), in this case by pinpointing locations that are easily recognizable both in the scanned map (target layer) from TanRoads and in the region layer from Africover (source layer). The TanRoads maps were georeferenced by co-locating the region border of the downloaded map to a shapefile downloaded from Africover (see appendix H) containing regional boundaries, fitting the two layers on top of each other. The region border shapefile from Africover was originally in geographic coordinates using the WGS84 datum, but was projected to UTM Zone 36S coordinate system (also based on the WGS84 datum) prior to the georeferencing. This was done because metrical data, such as UTM, is in many cases easier for GIS software to handle instead of degrees/minutes/seconds (geographical coordinates). UTM Zone 36S was chosen because this is the UTM zone most often used in Tanzania when mapping the entire country (A. Lobora, personal communication 2009).

The INON methodology also considers infrastructure adjacent to the national borders, in case there is infrastructure less than five kilometers from a “wilderness” area in the country in question (Directorate for Nature Management 2008). I have not obtained infrastructure data from Tanzania’s neighboring countries, so this element is not included in the map of wilderness like areas in Tanzania (appendix A).

6.3 Making the map

As mentioned earlier, the INON methodology for mapping wilderness like areas is based on a five kilometer distance from infrastructure. To make the wilderness map based on the INON methodology I used the data sets described in appendix F. For most of the infrastructure categories (roads, railroads etc) I had a few data sets to choose from. When deciding which ones to use, I considered the reliability of the source, availability to the public, metadata and of course the comprehensiveness and completeness of the data set. For most datasets I could easily see which ones were the most comprehensive and had the best coverage. For the roads, however, I used GIS to calculate the total length of roads for each dataset, to check which of the data sets was the most comprehensive (see Table 6.1 and Fig 6.2). The roads that were not included in the analysis are not included in the metadata table nor on the accompanying CD with datasets and maps.

Table 6.1: Total length of road data sets

Dataset	Roads in km	Name of shp-file
National Geospatioal Intelligence-Agency (NGA)	16724,52	trans_road_l_tz
Africover	36959,3	tz-roads
FAO	38191,16	tanz_rd
Original source uncertain(1)	39363,54	tz_awfrd_dd
Original source uncertain(2)	57804,72	tz_twrrd_dd
DCW	95209,8	rdline

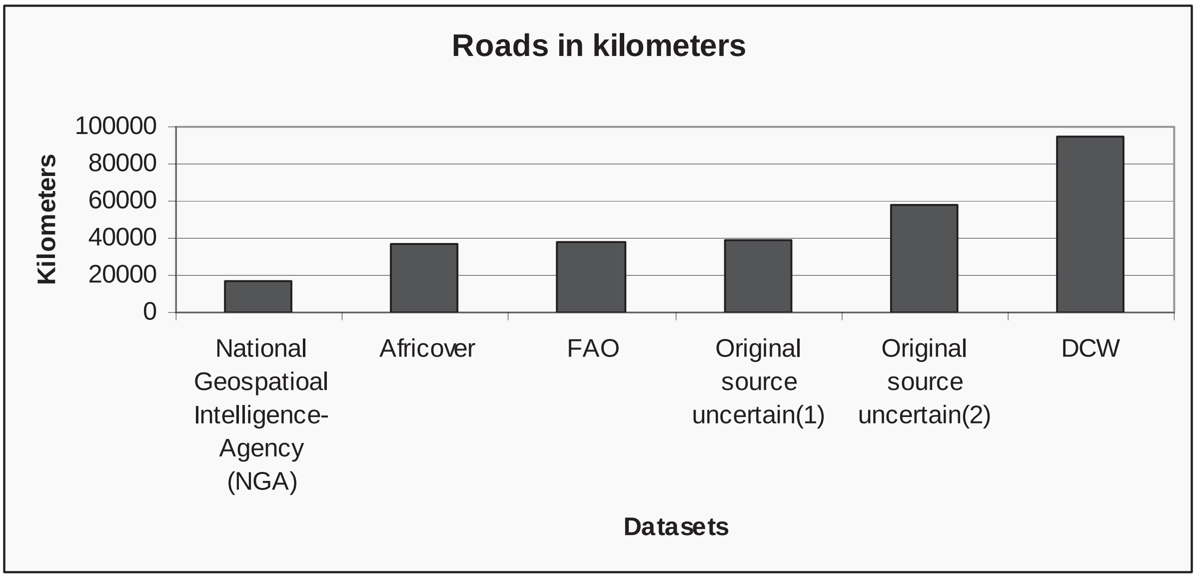

Figure 6.2: Graph showing total road length in kilometers for relevant data sets.

As seen in table 6.1 and Fig.6.2, the data set *rdline* from Digital Chart of the World (DCW) is the most comprehensive. It also has good coverage, covering the whole country, including the larger islands.

The analysis was performed in ArcGIS 9.3 using the steps in the flowchart (Fig. 6.3). I used an approach based on vector data and buffering. As mentioned in chapter 3, INON is based on distance from major infrastructure development and is classified into four categories (see table 3.1). The INON methodology actually contains three buffer zones; one, three and five kilometers from major infrastructure development. The category which is most interesting for the Tanzanian analysis is the wilderness like category, in which areas more than five kilometers away from major infrastructure development are considered important for biodiversity and recreational use of nature. I chose to use just this category. After making a buffer zone of five kilometers around all the infrastructure features, the buffers were merged and dissolved to make them into one buffer. All buffer

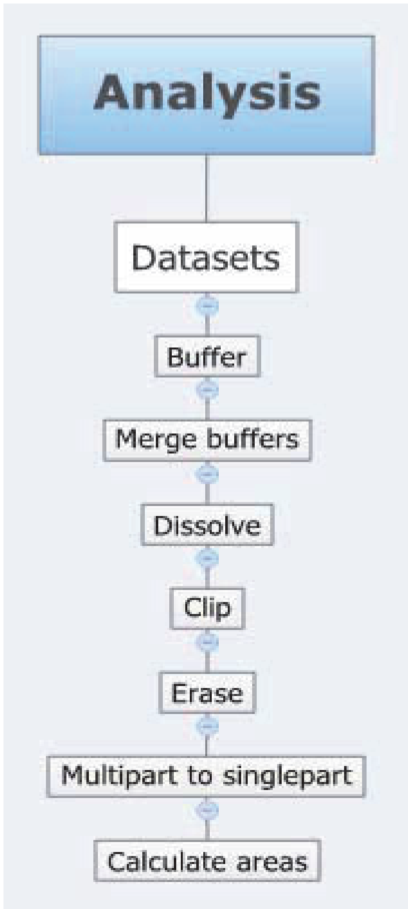

Figure 6.3: Flowchart of the operations used in creating the wilderness map.

parts outside the Tanzanian borders were removed using the *Clip* operation. Then the areas within the buffer zone (less than five kilometers from infrastructure) were removed by using the *Erase* operation, leaving a polygon feature class containing just the wilderness like areas. *Multipart to singlepart* was used to split the one polygon into one polygon for each wilderness like area. This was done in order to have the chance to create wilderness statistics on a regional level at a later time. Finally, the size of each wilderness like area was calculated in square kilometers using *Calculate Geometry*. These steps produced the basic map of wilderness like areas in Tanzania. Although following the same principles, I did not use the same operations as the makers of the Norwegian INON maps. The official INON approach is described in chapter 7.

The map of wilderness like areas was then coupled with data on population density. LandScan population density data from 2002 was used in the analysis. The map of wilderness like areas in Tanzania was also compared to the Human Footprint Last of the Wild version 2 data set from 2005, containing the 10 % “wildest” areas in Tanzania.

7 INON – the official map

The last official INON map of Norway was made in 2008. In the following I will present the methods used making this last edition, which, according to the Directorate for Nature Management (2008), should be the same as the methods used in earlier analyses.

Data sets of relevant infrastructure are mostly gathered through the official databases and then supplemented with data acquired through municipalities and county authorities. The Directorate of Nature Management also has its own database with infrastructure data which often is not included in the national official databases. Tractor roads, for instance, are often excluded. Norway is bordering to Sweden, Finland and Russia, so data on infrastructure along the Norwegian border in these countries are also included in the analysis (Directorate for Nature Management 2008).

Before performing the official INON analysis, data is converted from vector to raster. Polygons, lines and points are separated from each other, and the grid cell size is 50x50 meters. A function in ArcGIS called Euclidian distance is used to calculate the distance to infrastructure. This operation is the raster version of the buffer function, calculating distance from the source raster on a cell to cell basis (ArcGIS Desktop Help 2008). The cells get a value between 1 and 4, depending on their distance from infrastructure. These values represent the four zones in the INON map, encroachment free, wilderness like and so on (se table 3.1). Then, the raster data are converted back to vector format. Total areas of encroachment free and wilderness like areas are calculated for municipalities and counties (Directorate for Nature Management 2008).

8 Fieldwork and GPS

This thesis is basically a desktop assignment. It is computer based, and strictly speaking, does not really need any fieldwork. However, seeing as I have never been to Tanzania, let alone Africa, I felt that it would be vital to my understanding of the analysis and the thesis to experience the country. I stayed in Tanzania for four weeks, three of them spent in the area around Arusha. The first week was spent in Dar es Salaam.

At the University of Dar es Salaam, I met with Dr Sokoni at the Institute of Resource Assessment. I got in contact with him through Deus Komba, a Phd-student at the Department of Geography at NTNU, Norway. We discussed various sources for data sets portaying the current infrastructure situation, as well as historical maps. As all the cartographers were gone for the day, the maps could not be obtained until later. Nothing further came out of the meeting.

Arusha was chosen as one of the destinations because of proximity to several national parks and conservation areas. In addition, there are several organizations working with conservation and biodiversity located in and around the city. Arriving in Arusha, I met my secondary supervisor, Ragnvald Larsen. We did a couple of reconnaissance surveys in the area around Arusha, looking at the infrastructure and landscape. The Tanzanian landscape is quite different

Figure 8.1: Dirt road outside of Arusha. The landscape makes it possible to drive practically anywhere, independent of existing roads.

from the Norwegian landscape, and in some areas people are not dependant on existing roads for driving. The landscape is so flat and sparsely vegetated that it is possible to drive practically anywhere (Fig.8.1). If people drive in one place often enough they can even make a "track" for cars, which will not be officially registered. We also made a trip to a small village just outside Arusha, and took a look at the seasonal roads with a local guide. A good portion of the roads in Tanzania are seasonal, and cannot be used in the rain season (J. Nyahongo, personal communication, 2009). I also did a reconnaissance survey with my Tanzanian contact, Julius Nyahongo, who is employed at the University of Dodoma. The majority of roads in Tanzania are unpaved (TanRoads 2011). The paved roads are mostly within the cities or the big highways connecting the larger cities. Hence, most of the roads a few kilometers outside the centre of Arusha are unpaved (even though many of them are primary roads), and consequently either very dusty or very muddy, depending on the season (Fig. 8.2 and Fig.8.3). In the rain season, one can risk getting stuck in the mud. Because of this, it is wise to bring food and water for two days when taking a drive in the rain season (J. Nyahongo, personal communication, 2009).

Figure 8.2: Unpaved primary road a few kilometers outside of Arusha.

Figure 8.3: In the dry season the dirt roads are extremely dusty.

During my stay in Tanzania I got in contact with some people working in the conservation management field. Among them were Dassa and Bakari at the Conservation Research Center, and Alexander Loboro at TAWIRI. I found it very useful to actually meet and talk to people who worked with conservation of nature and biodiversity in Tanzania. Alexander Lobora told me about some of the projects at TAWIRI, and also suggested where I might find relevant data for my analysis and thesis.

Figure 8.4: One of the ”main” roads in Tarangire National Park

I also visited the national parks Tarangire and Lake Manyara, and Ngorongoro conservation area. These areas are very different, and it was interesting to observe how nature and biodiversity is conserved in Tanzania. Tarangire national park seemed to have small dirt roads running through it everywhere in addition to the "main" roads (fig.8.4), while Lake Manyara had few roads and a lot of dense forest (fig.8.5). The Ngorongoro crater, inside the conservation area, seemed to have fewer roads than Tarangire, even though Tarangire has a higher protective status (WDPA 2010). Since I have not acquired datasets of roads specifically related to national parks, this cannot be verified, and is therefore just my subjective observations

Figure 8.5: Road in Lake Manyara.

Because the method used in this thesis is developed in Norway, it was important for me to see and experience the landscape of Tanzania in order to better evaluate the transferability of the INON methodology to a Tanzanian context. I also needed to talk to people in order to understand more about the culture in general and the way wilderness is being conserved in the country. Implementing a method developed for a rich and developed country like Norway in Tanzania raises some issues about the compatibility between these countries, in this case infrastructure development. In Norway, most settlements have roads leading up to them. This is not always the case in Tanzania, as many people do not have cars, and hence, do not need roads to the same extent as we do in Norway. In addition, the landscape in some places of the country makes it possible to drive wherever one wants, so just because a road is not registered, it does not mean that there is no traffic and human activity in the area. During my reconnaissance surveys, I observed several settlements that did not have roads leading up to them, just paths.

The landscape in Tanzania is quite different from Norway, even though there are mountains and valleys in both countries. Tanzania has many dry, sand covered areas, allowing people, and of course cars, to make their own roads as they go. These “roads” are often not registered by authorities, and even though they might have an impact on the surrounding nature and biodiversity, they will not be included in the analysis. Some roads simply end in the middle of nowhere as tire tracks in the dirt, because there is no need to drive any further (J. Nyahongo, personal communication, 2009). Such a road was seen at a quarry (Ngiro) outside of Arusha.

Because of this, it is somewhat difficult to assess the level of completeness a data set of roads may have. It may look awkward and wrong with bits and pieces of roads everywhere, but based on my reconnaissance surveys in Tanzania, this may be the case in reality as well. Roads are established where there is a need for them, for example from one village to another, or between two factories. Maybe only a part of the road is actually classified as a road, and the rest is just tire tracks. Of course, it could also be bad digitizing. It is difficult to tell.

While driving in the areas around Arusha and the protected areas, I recorded a few waypoints using a Garmin 12 XL GPS to get an overview of where I had been. The waypoints can be seen in Fig. 8.6, and show that most of the waypoints are located in close proximity to roads, which means that they probably (in the field) are directly on top of the roads shown in the map as the measurements in question were made on main roads. The roads in the map (Fig.8.6) are from DCW. The digitized roads from TanRoads could not be used in this case because their actual location is too uncertain due to the very general maps the roads were digitzed from. Fig.8.6 also shows that some waypoints are located outside the road network. These are the registrations made on dirt roads or road tracks. These roads are within a five kilometer radius of mapped roads, but this may not always be the case, especially for areas of the country with few larger roads.

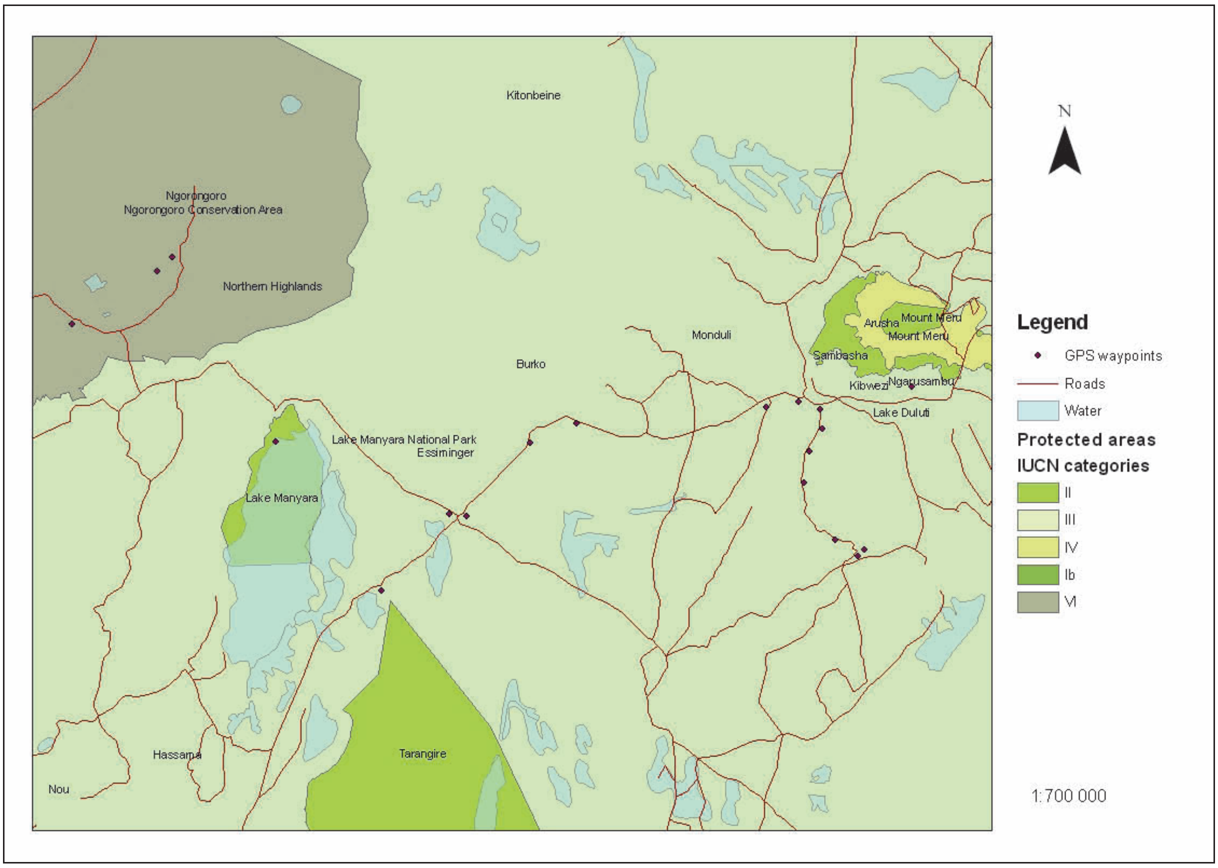

Figure 8.6: GPS waypoints plotted while driving in the area surrounding Arusha.

Part 4 - Results and analysis

9 INON map of Tanzania and wilderness areas

Figure 9.1 shows the map of wilderness like areas in Tanzania created according to the INON methodology. Appendix A shows the same map ready for print out or presentation. As the INON methodology operates with a cell size of 50x50 meters, all areas smaller than 2500 square meters (2.5 square kilometers) were excluded. The map indicates that there are approximately 378 321 square kilometers of wilderness in Tanzania, or approximately 40 % of Tanzania's total land area. In comparison, protected areas in Tanzania (national parks, game reserves and conservation area) take up about 18 % of the total area (this would be larger if game controlled areas were included). The largest coherent wilderness like area measures 43 926 square kilometers (approximately 5 % of Tanzania) and is located in the south, partly overlapping the habitat/species management area Selous. This southern area is more than twice as big as the second largest coherent wilderness like area, measuring approximately 22 705 square kilometers. This area is located in the northwest, and is comprised of several habitat/species management areas.

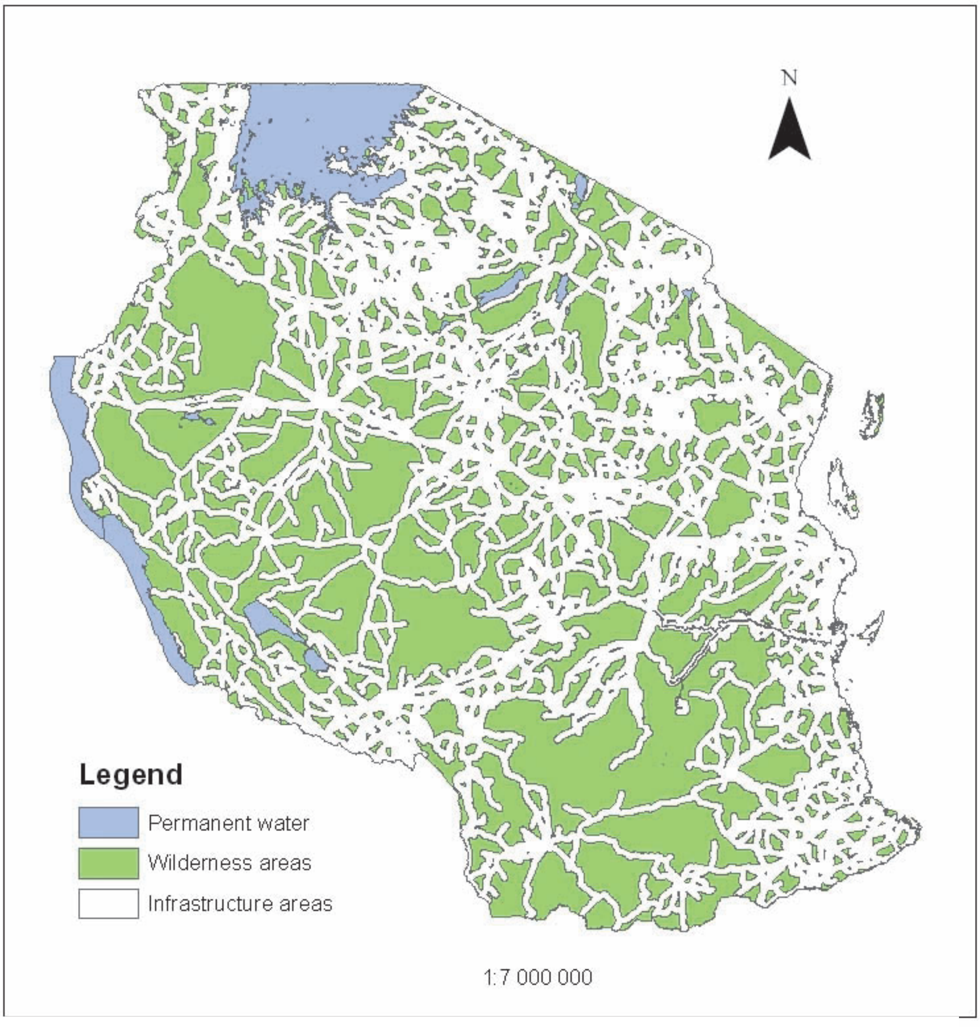

Figure 9.1: Map of wilderness areas in Tanzania based on the INON analysis.

There are 775 separate wilderness areas according to the INON analysis, with an average size of approximately 488 square kilometers. Figure 9.2 shows the distribution of the size of all the wilderness areas paired into size categories.

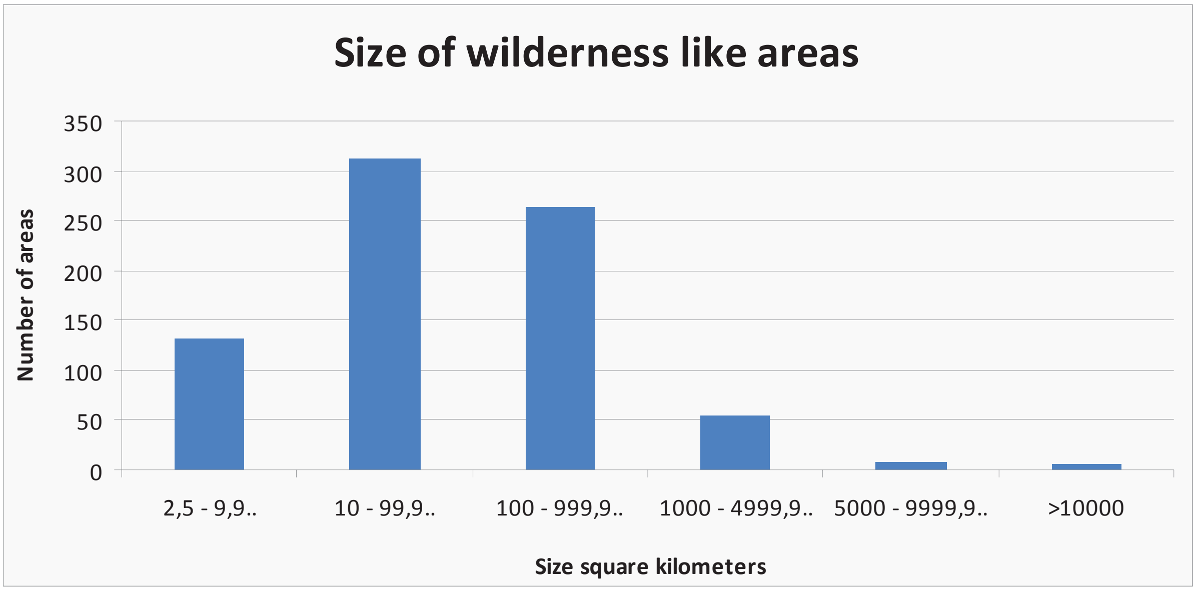

Figure 9.2: Diagram showing the distribution of size of the wilderness areas derived from the INON analysis.

Fig.9.3 shows the wilderness like areas in relation to protected areas retrieved from WDPA (IUCN & UNEP-WCMC 2010b). Areas without a defined IUCN category were excluded because some of the polygons looked unnatural and made it difficult to visualize the protected areas (see Fig. 9.4). As can be seen from Fig.9.3 a lot of the protected areas are highly affected by infrastructure areas, especially Serengeti national park (see also Fig.11.3). There is some degree of overlap, but as can be seen in Fig.9.3 there are also large INON wilderness areas that are not encompassed by protected areas. These could be encompassed by protected areas excluded from the dataset, or it might be unprotected wilderness like areas.

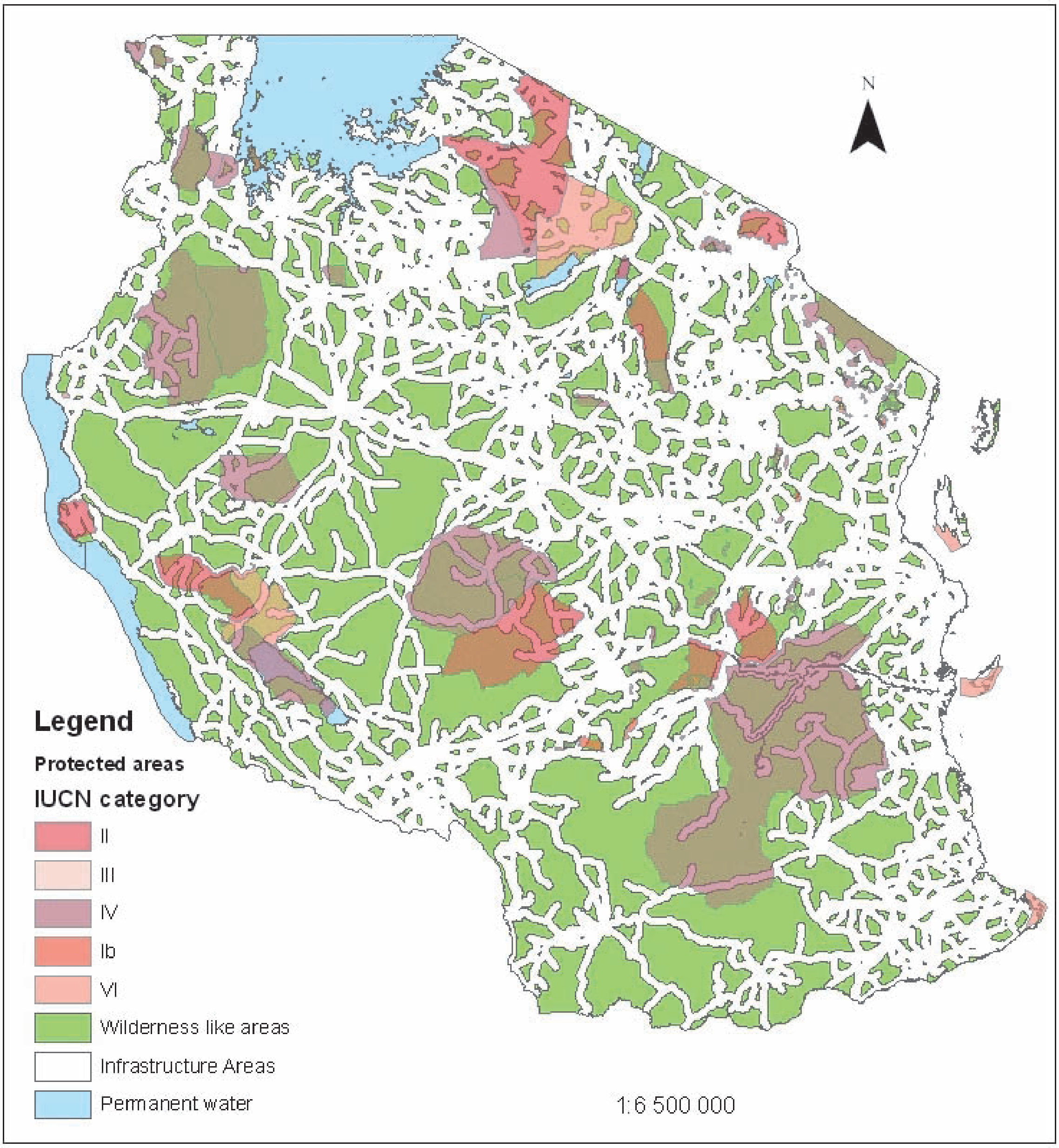

Figure 9.3: INON map of Tanzania and national parks and game reserves.

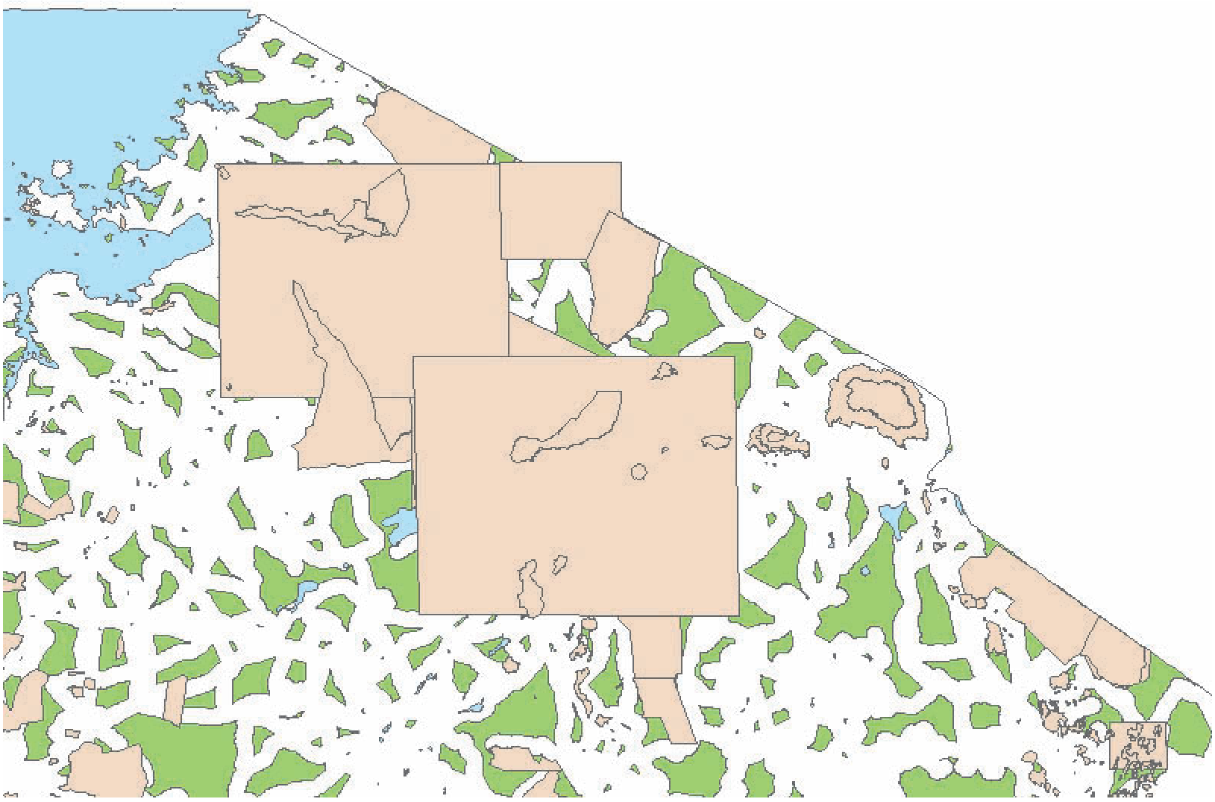

Figure 9.4: Odd looking polygons in category "unknown" in the WDPA data.

While the size of the wilderness areas is important for wildlife habitat and biodiversity, the shape of the areas is also of importance. An area shaped like a circle will have a better core area than an area which is highly distorted. In a circle there is equal distance from the center to all edges of the area, while in a highly distorted shape animals might have to cross infrastructure areas or be close to them when moving within the wilderness area, meaning that the core of the wilderness area is smaller or practically non-existent. A habitat with a large core area is best for wildlife and biodiversity (Longley et al. 2005). To calculate the shape or compactness of the wilderness areas, I used this formula retrieved from Longley et al. (2005, 327):

$$Shape = Perimeter/3.54\sqrt{Area}$$

A circle is the most compact shape and will return the value 1.0 using the constant 3.54 in the formula above. The most distorted shapes will return much higher values. Square root of the area is used to ensure that both the numerator and denominator are measured in the same units (Longley et al. 2005). As can be seen in Fig.9.5 most areas are relatively compact, with the most distorted displaying a value of about 3.9. The most compact shape in the analysis has a value of 1.08, which is very close to a circle. These two areas can be seen in Fig.9.6. Most values, however, have a value between 1 and 2. This is good in relation to habitats, because these areas are very compact.

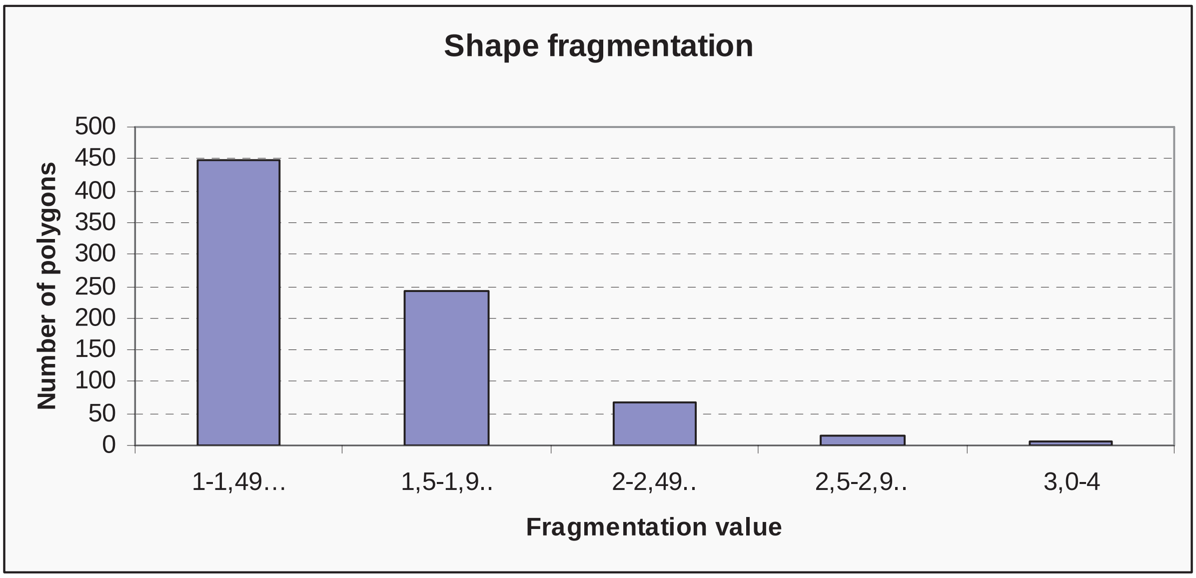

Figure 9.5: Overview of shape fragmentation values for the wilderness areas.

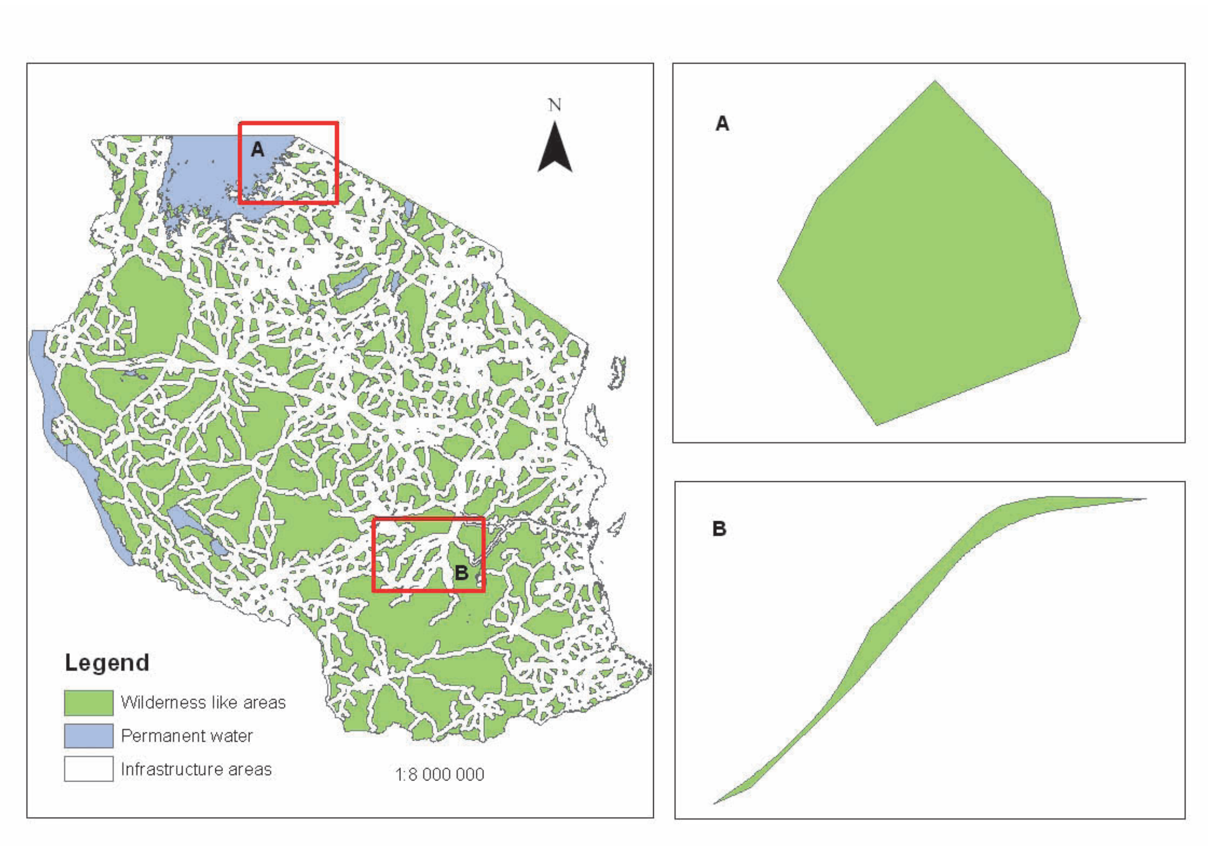

Figure 9.6: Map showing the most compact area (A), and the most distorted area (B). Both areas are small; A is approximately 2.7 square kilometers, and B is approximately 4.8 square kilometers.

10 Landscan and the INON map

Based on the LandScan (2002) dataset I have been able to derive the estimated population numbers for protected areas, all of Tanzania, and the wilderness like and encroachment areas found in Tanzania through the INON analysis (see Fig.9.1). As Fig.10.1 shows, the encroachment areas, meaning areas within five kilometers of infrastructure, have the highest population number per pixel. Wilderness like areas determined by the INON analysis follow closely behind, and then protected areas and the country as a whole.

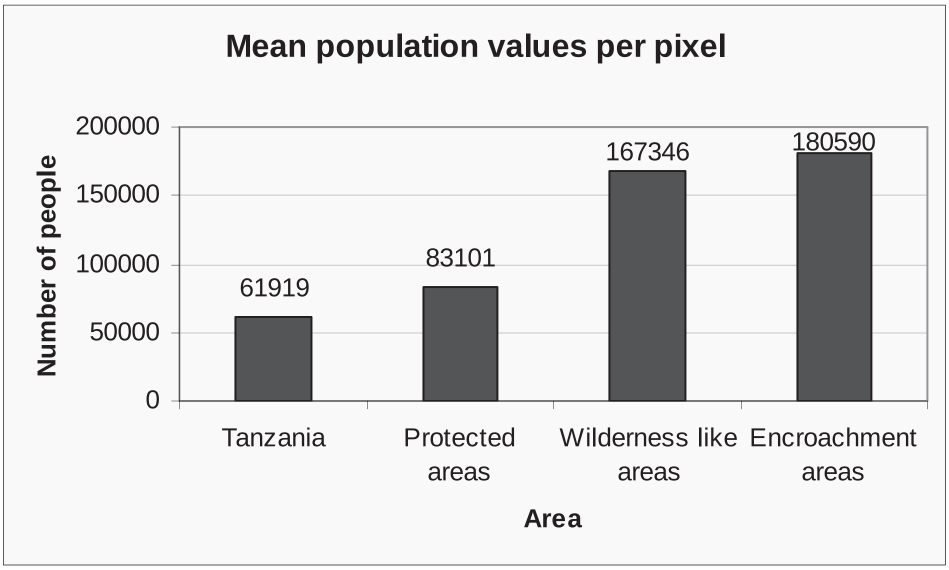

Figure 10.1: Diagram showing population numbers per pixel for various zones based on the andscan 2002 data.

The fact that wilderness like areas have nearly the same mean population value per pixel as encroachment areas (areas with major infrastructure), indicates that the infrastructure data used in this INON analysis is not sufficient, or that infrastructure data alone is not adequate for calculating wilderness like areas in Tanzania. As the Landscan data is based on an ambient population, this could explain the population values for protected areas. During the day there are a number of tourists, scientists and others in the protected areas, in addition to residents in some protected areas, depending on the level of conservation.

There is, however, some evidence suggesting that human population growth rates in areas within a ten kilometer buffer zone of protected areas in Africa and Latin America display almost double average population growth in rural areas (Wittemyer et al. 2008). Wittemyer et al. (2008) suggest that protected areas attract human settlement, which, to some degree, is supported by Cincotta et al. (2000). As mentioned in chapter 1, areas high in biodiversity (hotspots) have been estimated to have the highest population growth rate in the world. Protected areas are, in fact, often areas rich in biodiversity and resources, and will, based on this theory, attract people. Wittemyer et al. (2008) have taken the possibility of accelerated population growth due to exploitation of resources rather than the value of the protected area (PA) itself into account by comparing the areas around the Pas to other areas with the same ecological prerequisites, but without borders to a protected area. Even with this adjustment areas bordering to protected areas have a higher population growth rate than comparable areas. Wittemyer et al. (2008) suggest that one of the reasons for this might be that areas surrounding protected areas receive considerable funds from international organizations compared to communities further away from protected areas. These funds benefit the community through school, health facilities and job opportunities.

Joppa et al. (2009), on the other hand, claim that there is no evidence to prove that population growth in areas surrounding protected areas is greater than other rural areas in the same country. According to Joppa et al. (2009), the findings by Wittemyer are based on incompatible datasets, causing misleading results. There is, however, an increasing population growth in these areas, even if it is not higher than in other rural communities. This creates pressure on the biodiversity and resources of the protected areas.

Supposing that there is in fact a higher human population growth rate in areas surrounding protected areas there is cause for concern when it comes to biodiversity and conservation. An increasing population puts pressure on natural resources in the area, such as poaching and illegal timber (Wittemyer et al. 2008). TAWIRI has an ongoing project trying to count animals in protected areas not frequently visited by tourists. They use motion activated cameras to snap pictures of the animals, but pictures of people with hunting or timber gear also show up on a regular basis (A.Lobora, personal communication 2009). There is conflicting evidence concerning deforestation in areas surrounding protected areas. Wittemyer et al. (2008) claims that there is increased deforestation in areas with a high population growth rate, while a study done by Joppa et al. (2008) suggests that there is no evidence supporting an increase in deforestation in these areas. If, however, human settlements surround the protected areas, it becomes more difficult for plants to spread and animals to migrate. The protected area becomes an “island” from which it is difficult to leave or get into (Wittemyer et al. 2008).

11 Comparison to the Human Footprint

As mentioned in chapter 5.1, the Human Footprint consists of three data sets; the human footprint, human influence index and the last of the wild. The last of the wild data set represents the 10 % “wildest” areas in the world, based on human influence. The criteria for qualifying as a wilderness area in the last of the wild data set is visibly stricter than for the INON wilderness like areas. In the last of the wild data set, a total of approximately 30 352 square kilometers are considered wilderness, while in the INON analysis 378 506 square kilometers are considered wilderness. An overview of the last of the wild wilderness areas compared to the INON wilderness areas can be seen in Fig.11.1.

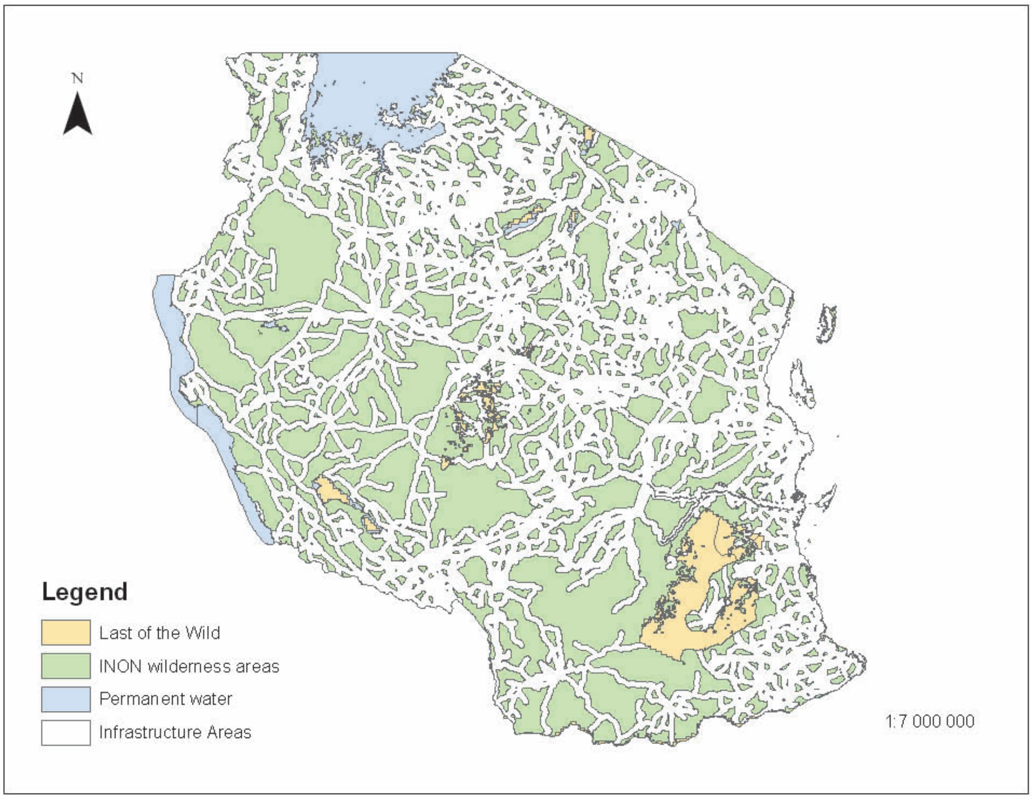

Figure 11.1: The Last of the Wild wilderness areas for Tanzania seen in relation to the wilderness areas derived from the INON analysis.

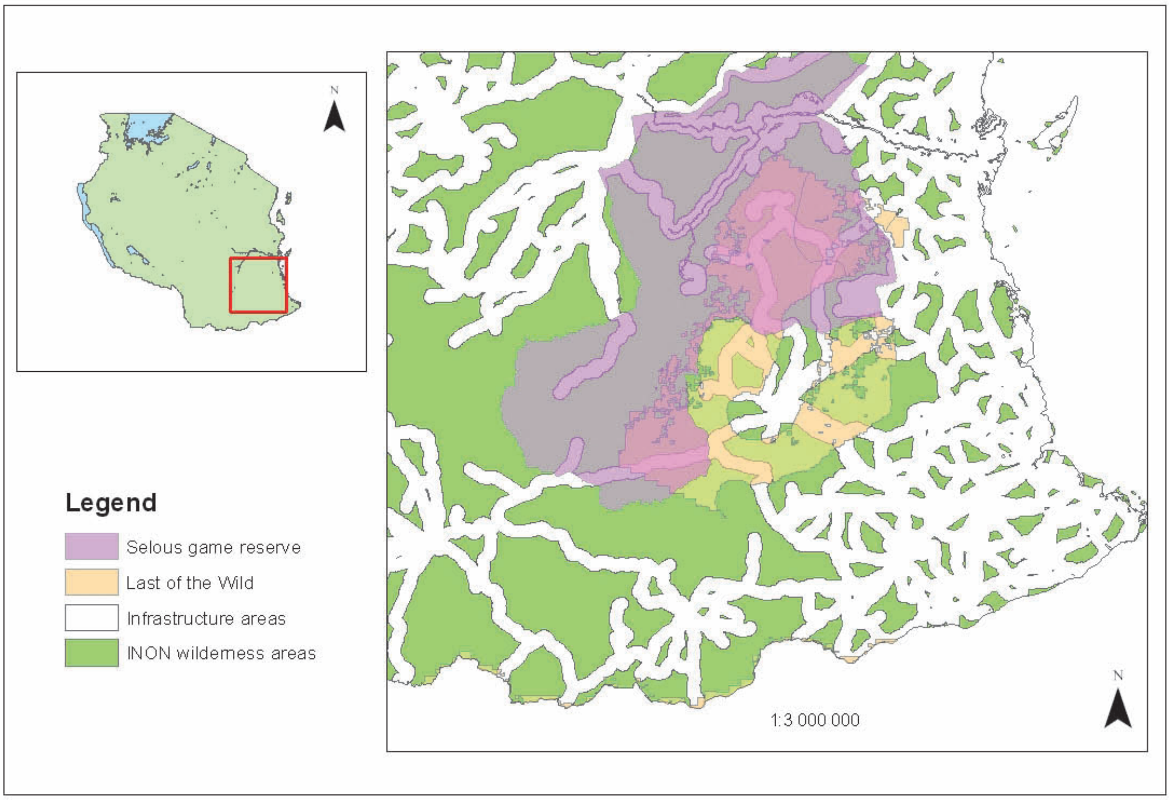

Figure 11.2: Map showing the largest last of the wild wilderness area, as well as the Selous game reserves, and wilderness like and infrastructure areas according to the INON analysis.

The largest coherent wilderness area according to the last of the wild data set is approximately 20.089 square kilometers, and is situated in southern Tanzania, partially overlapping Selous game reserve, which is one of the largest remaining wilderness areas in Africa (UNESCO World Heritage Centre 2010). The wilderness area from the last of the wild is situated in the eastern outskirts of the largest INON wilderness like area and also of the Selous game reserve. It is interesting that the last of the wild wilderness area is situated in an area with a lot of infrastructure development, instead of further west, which is a large area classified as wilderness like according to the INON analysis (Fig.11.2).

Fig.11.3 shows that Serengeti is also infiltrated by infrastructure areas, and only a few smaller areas within the national park are considered to be wilderness areas based on the INON analysis. Fig.11.3 also shows that the last of the wild analysis hardly considers the Serengeti as a wilderness area at all. This is very interesting, as Serengeti has been on UNESCO's World Heritage list since 1981 (UNESCO World Heritage Centre 1992-2011). Why this area has not made the last of the wild list is unclear, but it might be for the same reasons as for my INON analysis. There are many roads going through Serengeti, and because of a high number of scientists and others with mapping interests, these roads are probably better accounted for than roads in other areas of Tanzania. As seen in Fig.11.3, Serengeti is fragmented by roads, leaving only smaller areas as wilderness like areas. This is probably why Serengeti National Park was excluded from the last of the wild.

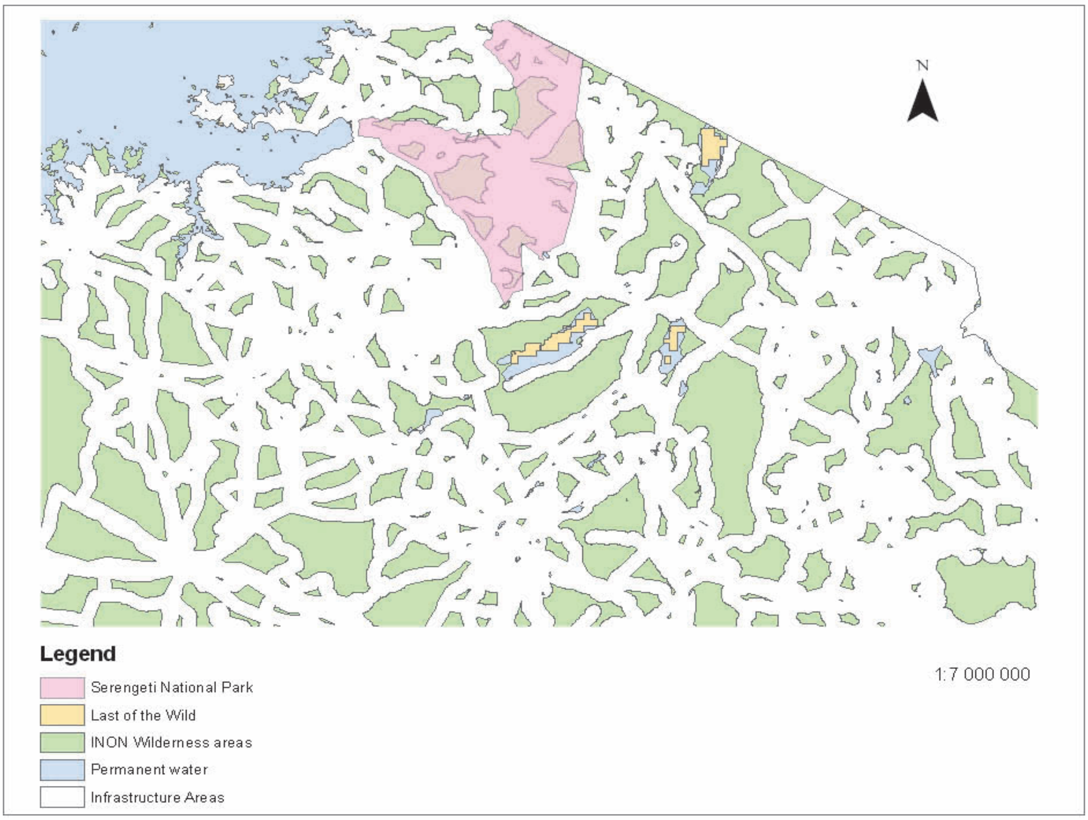

Figure 11.3: Serengeti national park (pink area) is here made semi transparent to show that this protected area is infiltrated by infrastructure.

12 Discussion

12.1 Datasets

As mentioned in the methodology chapter, obtaining adequate datasets for the infrastructure in Tanzania was not an easy task. GIS is a relatively new tool in Tanzania, and most datasets used and collected by Tanzanian government organizations are not publicly available. The data I was able to obtain from governmental organizations was often missing spatial reference and metadata. In addition the datasets were often not adjacent to one another, especially at region borders (Fig.12.1). These issues made the datasets from government organizations more difficult to integrate with other GIS datasets for analytical purposes.

The easiest way to obtain the datasets needed is to find them online through different organizations operating in Tanzania. This is also where one is most likely to find complete datasets with specification on map projection used and other metadata. However, it is my impression that datasets collected by different non governmental organizations are usually less comprehensive than data collected by Tanzanian governmental organizations, especially concerning the road network in Tanzania. For a while, I was debating the choice between comprehensive coverage and available metadata. The issue of reliability came to mind when debating this problem. According to Kitchin and Tate (2000), “reliability refers to repeatability or consistency of a finding”. Data sets from governmental organizations were mostly obtained during my fieldwork in Tanzania through contacts I met with, and hence, would be difficult for other people to obtain in order to test the repeatability of my analysis. Luckily, after spending more

Figure 12.1: Illustration of mismatch between roads digitized from the TanRoads maps. The red line on the Morogoro side of the border (left) and the blue line on the Pwani side of the border (right) are probably supposed to be connected.

time searching the web, I found some data sets that were both comprehensive in coverage and metadata.

In order to at least have a somewhat decent picture of the main roads in Tanzania, I decided to georeference and digitize the road maps found on the TanRoads website (TanRoads 2011a). The result was not a perfect match between TanRoads maps and the regional borders dataset from Africover (see appendix C). The maps (pictures) downloaded from the TanRoads website had very general regional borders with few details and poor resolution. Often neighboring regions did not fit very well together in the pictures, and some borders also had features that were not in the region data set from Africover.

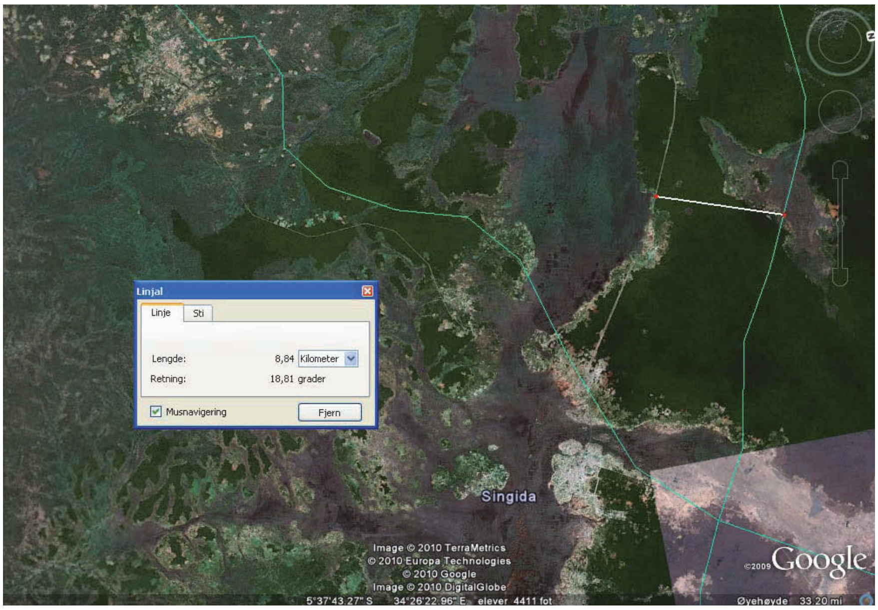

Figure 12.2: Distance between digitized road from TanRoads (turquoise) and satellite image from Google Earth (grey). Source: Google Earth

Because of the mismatch between regions, some roads that were obviously meant to be continuous between the regions were placed relatively far from each other and had to be tied together in an awkward manner, or left "hanging" by themselves. This problem is illustrated in Fig.12.1.

Figure 12.3: Digitized road from TanRoads (turquoise) located in green area in Google Earth. Source: Google Earth

The road maps from TanRoads are, in fact, meant for visualizing purposes only, not detailed observations. I exported the digitized roads to Keyhole Markup Language (KML) format to view them in Google Earth. A good portion of roads does not seem to fit with the satellite imagery of Google Earth. There are examples of roads located as far as eight kilometers from the assumed same road in Google Earth (Fig. 12.2). There is also a road in the Dodoma region passing right through an area with much vegetation, possibly a forest. No road is visible in Google Earth, but it is possible that the road in question is hidden by heavy vegetation (Fig. 12.3). Thus, the roads digitized from these maps are not perfect, but considering that I'm looking for an overall picture for the whole country, and not accuracy down to the last meter, this is acceptable. The total length of roads corresponds approximately 75 % to the official number provided by TanRoads[2]. Considering that roads from three regions were left out from the digitizing, the total length of the roads I have digitized is probably close to the official number of kilometers TanRoads operates with.

12. 2 Limitations

As mentioned in chapter 12.1, the location of digitized (and possibly the other) roads are not exact, and must be treated as such. It is important to note that the datasets and maps derived from performing this INON analysis in their current state is just for reference on a national scale, and not detailed local scale because the placement of wilderness like areas is not exact. An overview of wilderness like areas in Tanzania and their approximate location can be derived from the maps, but because of the uncertainty of the data sources, one must be careful to draw final conclusions based on the maps. In order to be used efficiently in land use planning and management, the datasets need to be verified and updated. As the datasets used in this thesis are a few years old, there have probably been some changes which will affect the outcome of the analysis. There are also several improvements and features that can be added to the INON analysis and base map to better adapt the method to a Tanzanian context. This will be discussed further in chapter 12.5.

12.3 Comparisons with other wilderness maps

The INON map of Tanzania (appendix A) was compared to wilderness data from the Human Footprint project (Last of the Wild dataset), and population density data from the Landscan project. This was done to try and assess the transferability of the INON methodology to a Tanzanian context. Due to the relatively high population density in wilderness like areas based on the INON methodogoly, the Landscan data implies that there probably are human activities in these areas that have not been captured in the INON methodology. Other

[2] By using the ArcGIS function *Calculate Geometry*, the total length of roads I have digitized is approximately 22 251 kilometers, while the official TanRoads number is 29 847 kilometers (TanRoads 2011b).

inclusion criteria or datasets have to be considered in order to get as correct an answer as possible.

The Last of the Wild areas also include water bodies in the wilderness analysis. Water is not included when calculating wilderness like areas in the INON methodology, and must be considered when comparing the two datasets. A good portion of the Last of the Wild wilderness areas in Tanzania is actually water bodies (Fig.12.4). Other Last of the Wild areas in Tanzania are situated in the middle of what is defined by the INON methodology as infrastructure areas (Fig.12.5). These issues must be further examined, as it is strange that the Last of the Wild areas are placed in an infrastructure area when there are seemingly many "green" wilderness like areas where they would be more likely to be located. Assuming these wilderness like areas are in fact areas without major infrastructure that is. In any case, it could be interesting to field validate some of the wilderness like areas to check if they can be classified as wilderness like. If the areas are properly validated, the INON map could perhaps be used as a tool in decision making regarding which areas to protect and other land use management issues.

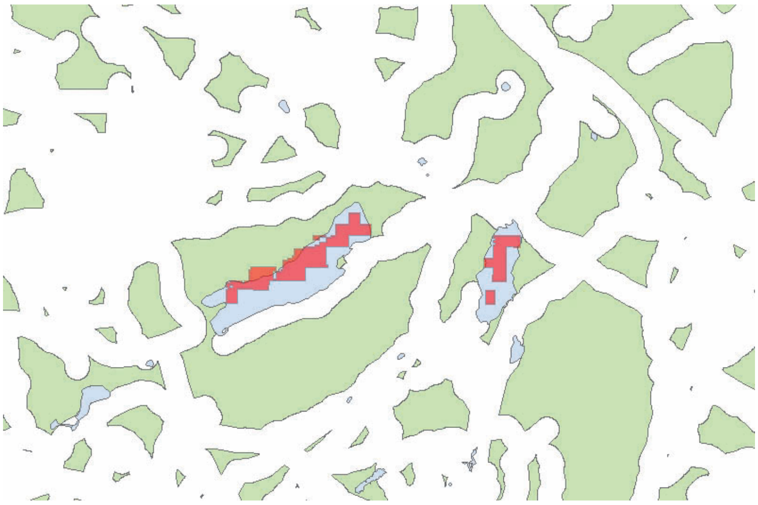

Figure 12.4: Last of the Wild areas (marked in red) in water bodies.

Figure 12.5: Last of the Wild areas (marked in red) in areas with much infrastructure (white).

12.4 Problems and limitations with the INON methodology

The INON methodology has been a topic of much discussion in Norway where it is being used for nature management purposes. As mentioned in chapter 3, INON is supposed to give an outline of the development over time, visualizing how much of the wilderness is lost as the infrastructure expands. Fig.12.6 shows the development of areas without major infrastructure development as of 1900, 1940 and 2008. However, mapping of these areas did not start until 1994 (Directorate for Nature Management 2010c), thus making comparisons with the earlier versions of the INON maps less reliable. The maps portraying the situation between 1900 and 1940 are based on historical printed maps, which may not be complete regarding the infrastructure at the time of interest as they have been made for different purposes. There are, however, no mentions of these uncertainties when the maps are presented on the Directorate of Nature Management's website. According to Skjeggedal et al. (2005) a major problem is that the more current INON maps have broader inclusion criteria for which types of infrastructure to include. Critics of the INON methodology claim that because of this uncertainty, there may not have been as much loss of wilderness as depicted in Fig. 12.6.

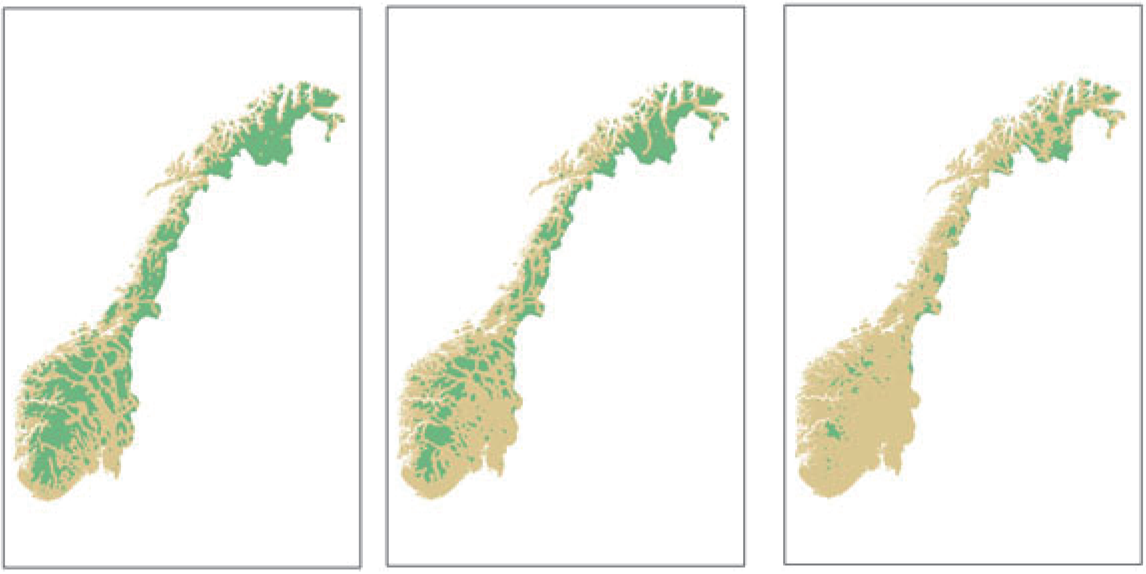

Figure 12.6: The development of areas without major infrastructure development (more than five kilometers from major infrastructure) as of 1900, 1940 and 2008 (Directorate for Nature Management 2010c).

However, according to the Directorate for Nature Management & Norwegian Agricultural Authority (2010) the definition of what is to be considered major infrastructure development has not changed much since the mapping started in the early 1990s. Before publishing the newest INON map (from 2008), a few new infrastructure types, such as wind turbines and larger ski jumps and alpine resorts, were included in the definition. The new infrastructure types are usually within five kilometers of other infrastructure already included in the analysis (roads, power lines etc.), but have been incorporated into the analysis because some of them are located in areas without major infrastructure development and because it is natural (for the public) to see these installations as part of the definition of infrastructure. The incorporation of the new infrastructure types did not lead to much decrease in wilderness like areas. In addition, when publishing a new INON map, the datasets from previous publications (1988, 1998 and 2003) are updated and corrected. All new registered infrastructures are registered to the year it was built, not the year it was reported to the authorities, and reported errors are corrected. Hence, the maps and statistics for previous publications are also updated to give a more correct overview of the infrastructure development (Directorate for Nature Management & Norwegian Agricultural Authority 2010).

The original purpose of the INON methodology was to raise awareness of changes in the Norwegian landscape which had an effect on the everyday outdoor life, such as hiking and camping (Directorate for Nature Management & Norwegian Agricultural Authority 2010). In time, however, the INON maps became a mean to protect the remaining remote areas, and were used as an argument for building less and conserving more (Skjeggedal et al 2005).

INON is based solely on measuring distance as the crow flies, and does not consider variations in the terrain (Directorate for Nature Management 2010b). Neither does it consider the value of the areas termed wilderness like. All types of nature are included in the term, as long as it is located more than five kilometers from major infrastructure (Directorate of Nature Management 2010c). Because of these limitations, the Ministry of the Environment uses INON maps together with other measured environmental factors, and other interests are taken into consideration. However, in spite of these precautions concerning the interpretation of the INON maps, the areas without major infrastructure development are often seen as synonymous to wilderness when managing decisions are to be made. According to Skjeggedal et al. (2005) the interference of past cultures with low technology equipment is downplayed, and the nature which has once been influenced by human activity is considered to be wilderness like. There seems to be an agreement of some sort that these areas must be protected in order to maintain the current level of wilderness like areas (Skjeggedal et al. 2005). The Directorate for Nature Management, on the other hand, claims that absence of infrastructure has value in itself, and that human activity at least five kilometers from major infrastructure development is usually not very intrusive (Directorate for Nature Management & Norwegian Agricultural Authority 2010). However, there are some major infrastructure developments that have not been, or are in the process of being mapped. According to Kiær (2009) these features may have existed a long time, but when added to the INON analysis, they will contribute to a steeper decline in wilderness like areas, even though the interference with nature has not been as high over the last time period as suggested by the INON map. This should, however, be prevented because earlier versions of the INON maps are corrected and updated when new information is available, as described earlier in this chapter.

Some of the information from the Directorate of Nature Management is conflicting. For instance, it is said that the category of wilderness like areas (more than five kilometers from major infrastructure) contains all sorts of nature, including nature which has previously been influenced by human activity. In addition, it is not part of INON's task to assess the quality of the areas labelled as wilderness like (Directorate of Nature Management 2010c). In spite of this, these wilderness like areas are considered to be very important to biodiversity, outdoor life and teaching, and the loss of these areas are a negative consequence of expansions in infrastructure development (Directorate for Nature Management 2010d). The term *untouched nature* is also used as a synonym for the wilderness like areas (Directorate for Nature Management 2010b). This is conflicting with the statement mentioned earlier that the wilderness like areas also include nature which has been influenced by human activity. Such an example can be overgrown farmland where the old fences are still visible within the vegetation.

The inclusion criteria of what can be defined as major infrastructure development have received much criticism. According to Skjeggedal et al. (2005) there are no inclusion criteria. At least nothing that can be clearly operationalized. In order for a feature to be termed as major infrastructure, it has to make such a substantial impact on nature that it makes it difficult or impossible to bring nature back to its original state (Skjeggedal et al. 2005). Looking back at what is considered to be major infrastructure (frame 3.1) some of the infrastructure does not seem to match the inclusion criteria. Power lines, for instance, can in most cases be removed with relative little impact on nature. It should, in any case, be able to return to its original state given a little time. One can also discuss if there are other features that should be included in the analysis, for example cabins, as mentioned earlier. The point is that the inclusion criteria does not clearly include and exclude what can be termed as major infrastructure development, and that is a flaw in the method.

The problem with the INON methodology arises when it is being used as a tool for managing nature without much consideration to its limitations (Strand 2009). The Directorate for Nature Management (no date (b)) states on their INON website that their task is to provide advice regarding land use management, and that information concerning where natural assets are located is very important to planning issues. This indicates that the INON maps are being used as a tool in land use management, and not just as an indicator on where there might be areas worth protecting from major infrastructure development. The Directorate of Nature Management also states that INON is, in fact, an indicator, but at the same time it is a tool to ensure that “wilderness like” areas are maintained and do not decrease considerably (Directorate for Nature Management 2010f). According to Strand (2009) there is nothing wrong with using INON as an indicator. It is easy, relevant and understandable, and its limitations can easily be identified. However, when INON is used as a tool for land use planning and management, problems arise because of its inaccuracy. INON was developed as an indicator, and is too simple to fully encompass all factors that go into management decisions. The use of the maps produced by the INON methodology must be used more cautiously because visual instruments such as maps can be very powerful and easily misinterpreted (Strand 2009).

12.5 Tanzania and wilderness like areas

The INON maps of Tanzania show that 40 % of the total land area is more than five kilometers from major infrastructure development, and hence, considered to be wilderness like areas. Approximately 17 % of Tanzania is defined as protected areas according to IUCN & UNEP-WCMC (2010b). Although areas without major infrastructure development do not by any means automatically qualify for conservation, it is interesting to compare the overlap between these encroachment free areas and protected areas. As shown in Fig.9.3 many protected areas are infiltrated with roads, and especially Serengeti national park. Even though it has a high protective status, because of the roads the wilderness like areas within the park are much smaller than they should be.

Lately, there has been much debate on whether or not to build a highway through Serengeti to better connect the people living on the east side of Lake Victoria with the eastern part of the country (Frankfurt Zoological Society 2010). This has raised some issues regarding the protection of Serengeti National Park (SENAPA) and the great wildebeest and zebra migration across the border to Masai Mara in Kenya. As shown in Fig.12.7 the proposed road will cut right through the migration route. Holdo et al. (2011) estimates that a barrier to the migration could cause a decrease in the wildebeest population of about a third. This is not due to loss of habitat, just fragmentation. The Frankfurt Zoological Society claims that the wildebeest population will be reduced by as much as ¾ of its current population if the new road is built (Frankfurt Zoological Society 2010).

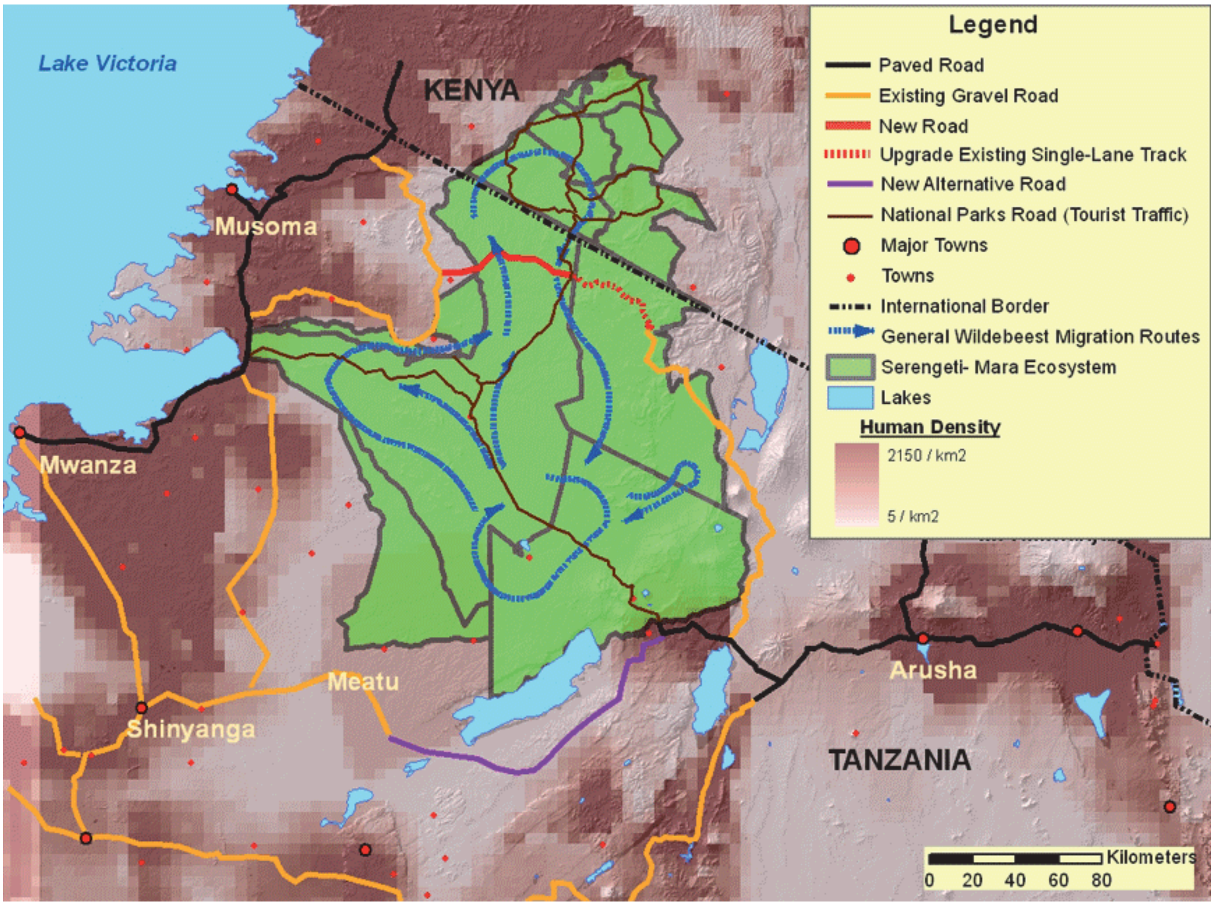

Figure 12.7: Map showing the proposed new road (red), the suggested alternative road (purple), as well as wildebeest migration routes (Frankfurt Zoological Society 2010).

Doing an analysis on wilderness areas based on distance from infrastructure, such as the INON methodology, raises a few ethical questions in cases like this. Previous chapters have shown that Serengeti National Park is already filled with infrastructure, leaving relatively few areas left to be classified as wilderness like. This does not just apply to the INON methodology, but also other methods based (partially or in full) on distance from infrastructure, like the Last of the Wild dataset. By not classifying large areas of the Serengeti as wilderness or wilderness like, this could work as ammunition for the Tanzanian politicians wanting to construct the Serengeti highway. It may arise thoughts such as “the area is already filled with infrastructure, why not pave an existing road or build a new one in areas already defined as infrastructure areas?”. This is by far not the purpose of this analysis. The roads mapped in Serengeti National Park probably include everything from barely visible dirt tracks, to safari vehicle roads, and other gravel transportation roads. If roads all areas in Tanzania had been mapped as extensively as this, there would not be much wilderness like areas left.

12.6 INON’s transferability to Tanzanian conditions and suggestions for further work

The INON methodology is, of course, developed with Norwegian conditions in mind, and therefore includes elements that are not relevant to Tanzanian conditions. Examples are some of the infrastructure types included in the definition of major infrastructure development, such as skiing facilities. The road network in Tanzania is quite different from the Norwegian one, containing a larger amount of dirt roads and the possibility to drive off-road. This creates a problem when making an INON map, because not all roads may be included in the official datasets, and people may often live in villages/clusters more than five kilometers from a road or other major infrastructure development. The influence such villages or clusters have on the surrounding nature can be debated upon, but considering the theory that even indigenous people have had a substantial effect on nature (Martin 1984) one might assume that these settlements could have an effect on the nature around them. If implementing the INON methodology in a Tanzanian context, one might consider including villages in the definition of major infrastructure development.

The advantage of the INON methodology compared to other methodologies is its simplicity. It is less time-consuming than other methods, and it creates a base map on which other elements, such as for instance pollution, accessibility and biodiversity, can be added. Unfortunately, the simplicity of the INON methodology is also a disadvantage. Additional information is needed to make good decisions regarding land use planning and management, while for methods such as GLOBIO and the Human Footprint the analyses contains so many different factors that the maps themselves can be sufficient in a decision making process. The

INON map is more an indicator of where one might find areas worth preserving, and then these areas must be explored in the field to evaluate if they are expendable for construction or should be preserved. The problem of basing a “wilderness” analysis on infrastructure in Tanzania is that human activity is not as dependant on infrastructure as it is in Norway. Much of this issue, however, might be solved by adding a dataset with villages into the analysis.

As mentioned earlier, the datasets used to perform the INON analysis in this thesis are a few years old, and need to be validated (and preferably updated) to make the results as accurate as possible. If fieldwork is too expensive and time-consuming, validation of the datasets can be done by using Google Earth. Google Earth is composed of many satellite images (the dates these were taken may vary), and can be used to check if the roads in the datasets actually exist, are placed correctly and also to digitize roads seen in the satellite pictures that are not present in the datasets.

Because the INON methodology is developed to show the development in land use and infrastructure, further work would include making INON maps showing the historical decrease in wilderness like areas. This can be done by creating a time-line where wilderness areas “disappear” as new infrastructure is built. To do this year of construction is needed, which can be difficult for the road network. The year of construction for power stations (TANESCO 2011) and railroads should, however, be relatively easy to find. The historical development of the road network, and possibly utility lines, could be reconstructed by digitizing roads from historical maps. It would require some work, but it should be possible to make INON maps showing the development of infrastructure in Tanzania.

13 Conclusion

With this thesis I have tried to assess the INON methodology, and evaluate its transferability to Tanzanian conditions. I have produced maps of wilderness like areas in Tanzania based on the INON methodology, and compared these results with protected areas in Tanzania (IUCN & UNEP-WCMC 2010b), population data from Landscan (2002) and Last of the Wild data from the Human Footprint project, in order to try and detect possible errors in the INON wilderness like areas map (Appendix A).

As have been discussed in previous chapters, there are some issues when it comes to implementing the INON methodology in Tanzania. In Norway, most people live in close proximity to some form of infrastructure, but this is not always the case in Tanzania. Infrastructure is less developed, and roads are not always needed to connect villages to the rest of the road network. Many people do not have cars, and use their legs or bicycles instead. These settlements are not included in the INON methodology, unless they happen to be located near other infrastructure than roads. If the method were to be implemented in Tanzania, it would have to be modified to match Tanzanian conditions. A layer of villages could be included in the analysis to make sure that these settlements were included in the result.

Comparisons between the Last of the Wild areas and the wilderness like areas derived from the INON methodology (Appendix D) show that a good portion of the Last of the Wild areas is located in water bodies. Water bodies are not considered when calculating wilderness like areas in the INON methodology. Other areas are located in areas seemingly filled with infrastructure, instead of areas classified as wilderness like areas. This suggests that there might be errors in the INON datasets, or that these infrastructures have not been included when calculating the Last of the Wild areas.

The largest Last of the Wild area (Appendix E) partially overlaps Selous game reserve, as well as parts of a wilderness like INON area. The INON area actually seems to correspond better to the borders of the game reserve than the Last of the Wild data, which is interesting. In addition, the Last of the Wild area is seemingly located in an area with infrastructure.

The comparison between wilderness like areas and protected areas from WDPA (IUCN & UNEP-WCMC 2010b) shows that there is a relatively good overlap between the two datasets (Appendix B). Some protected areas are, however, covered in infrastructure, such as Serengeti national park. There are also large INON wilderness like areas that are not under any protective status according to the map. This mostly applies to areas in the western and southern part of Tanzania. As all protective areas with unknown IUCN categories were excluded, some of these wilderness like areas might be encompassed by a protective area with unknown IUCN category.

Landscan population data were used to calculate mean population value per pixel in infrastructure/encroachment areas, wilderness like areas, protected areas and Tanzania as a whole. Fig.10.1 shows these values. Not surprisingly, the encroachment areas display the highest population value per pixel. It is natural to think that there would be a higher population density in areas with developed infrastructure. What is a little surprising, though, is that the wilderness like areas have such a high population density per pixel, almost as high as the encroachment areas. This suggests that some infrastructure data is missing from the INON datasets. The Landscan population data is also based on villages, which could help explain why population density is so high in wilderness like areas.

All in all, the INON methodology can be implemented in Tanzania, but some adjustments have to be made to adapt it to the local conditions. The INON methodology can be useful when a simple method and easy to read map is needed. For more complex tasks, however, a more comprehensive method such as the Human Footprint or GLOBIO might be better suited, as most of the information needed to make a decision is already in the map. Better datasets on infrastructure in Tanzania that are both comprehensive and updated should be more easily available, so maybe this should be the first step when making a new national wilderness map of Tanzania. Such data would contribute to much better and more accurate maps and information, which is very important in land use management and planning.

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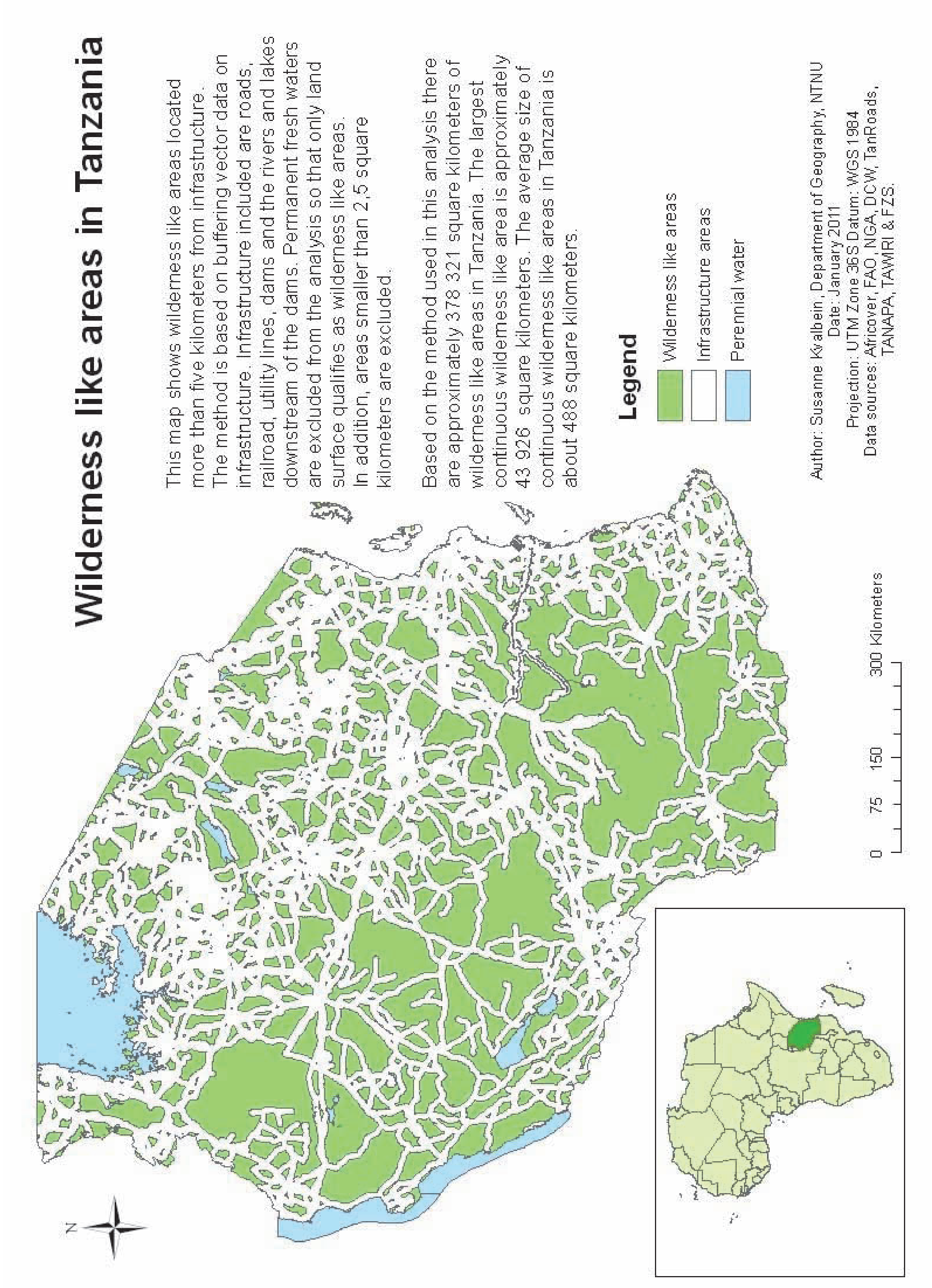
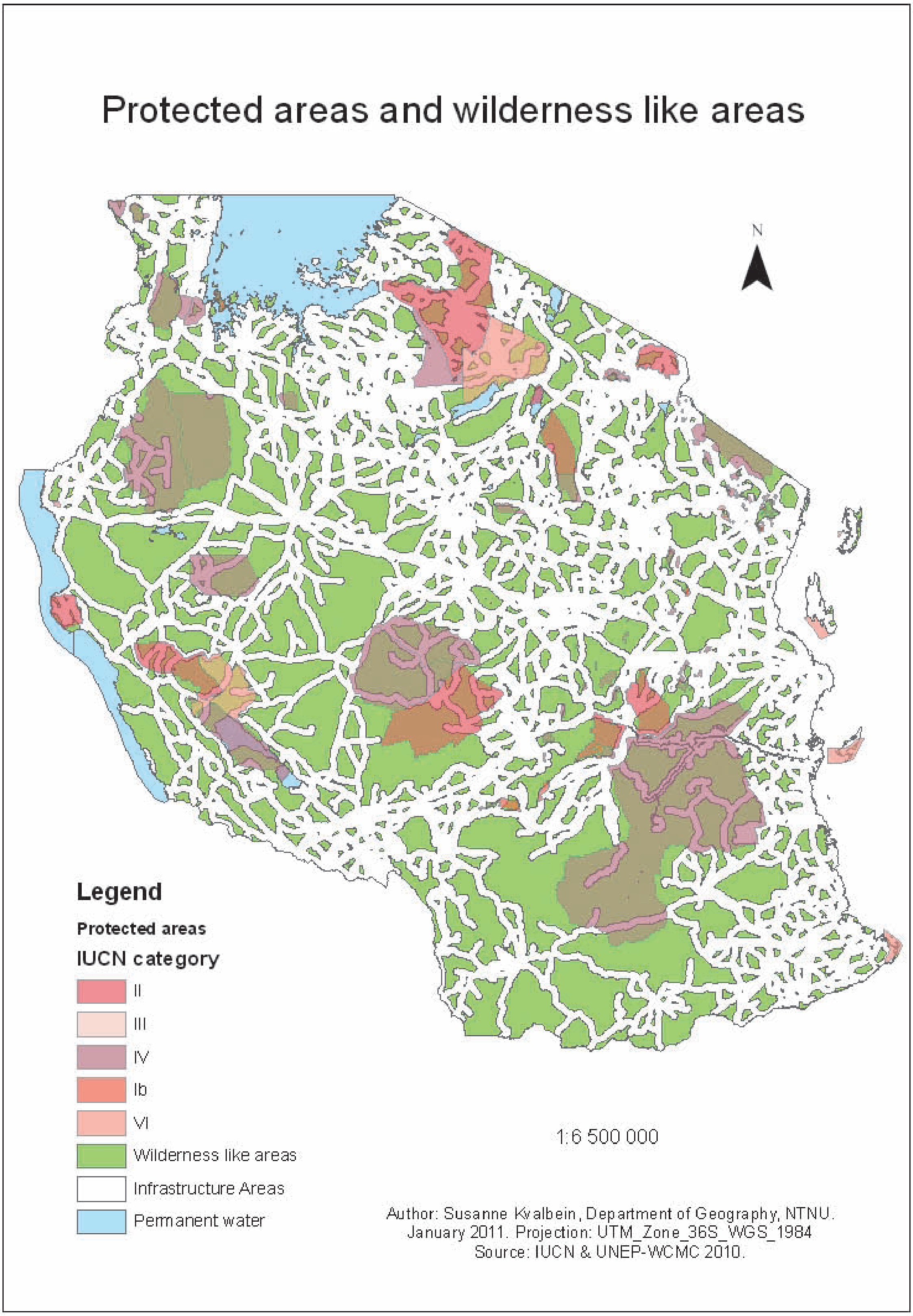
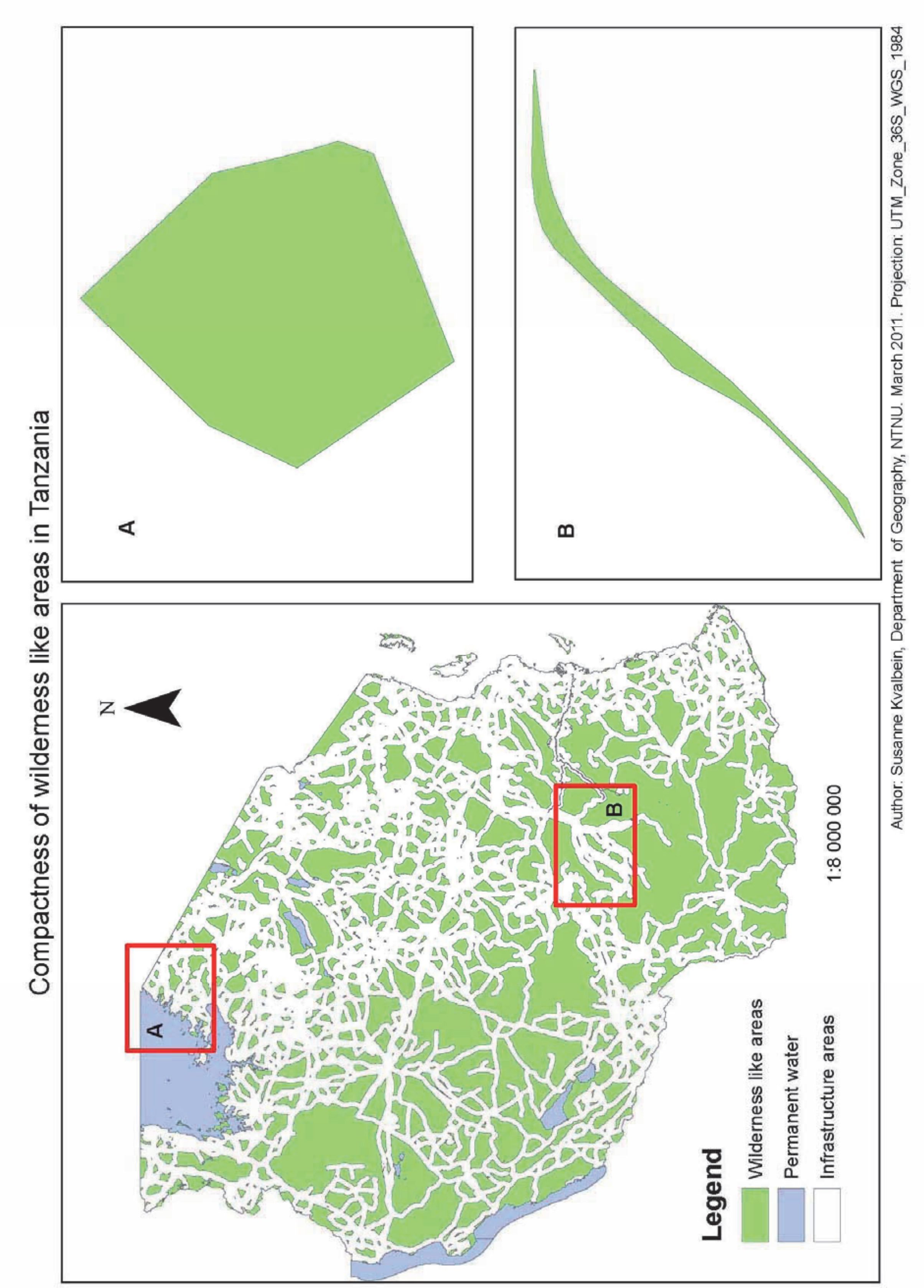
Appendix A: The INON wilderness map for Tanzania



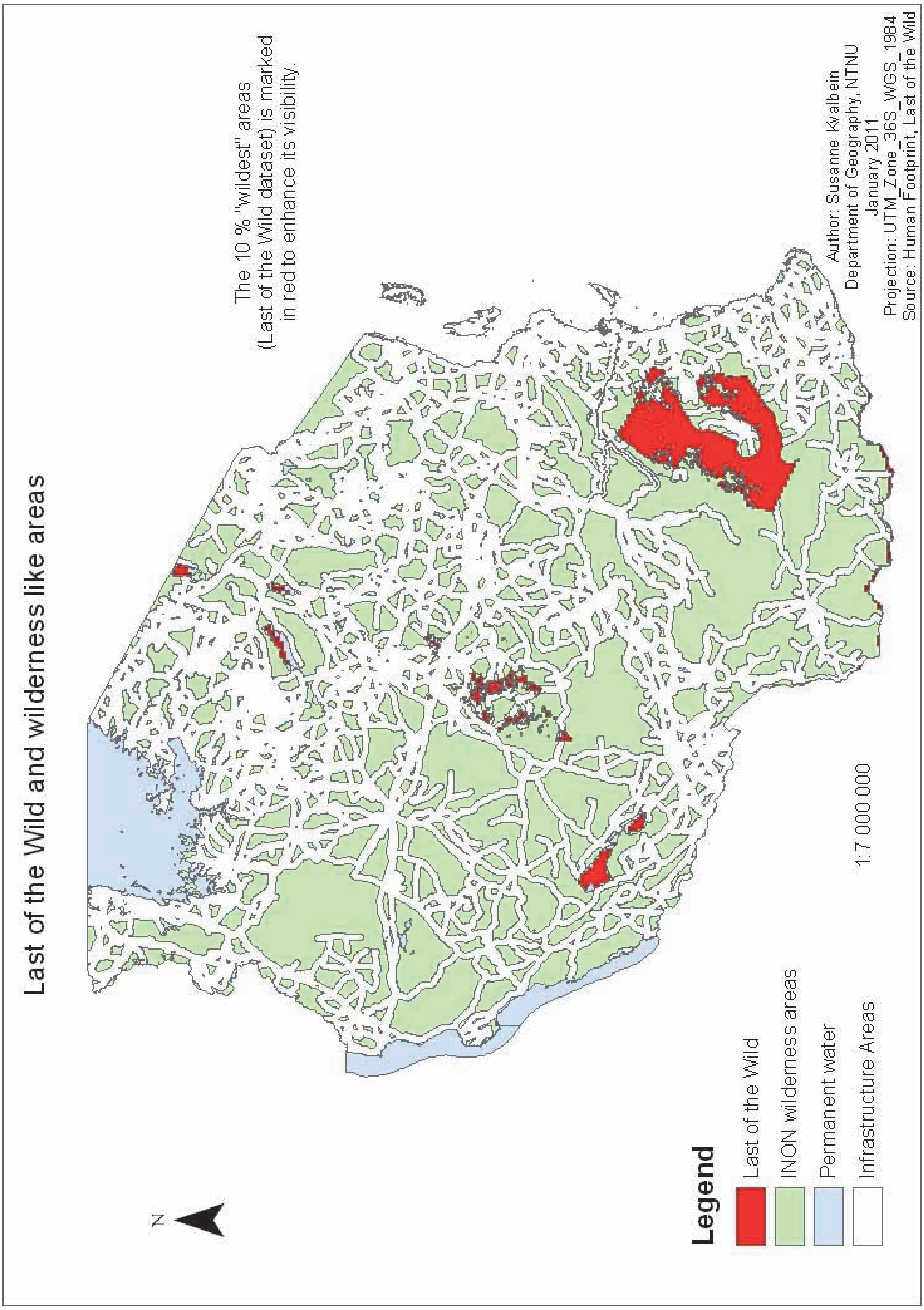
Appendix B: Protected areas and INON wilderness like areas



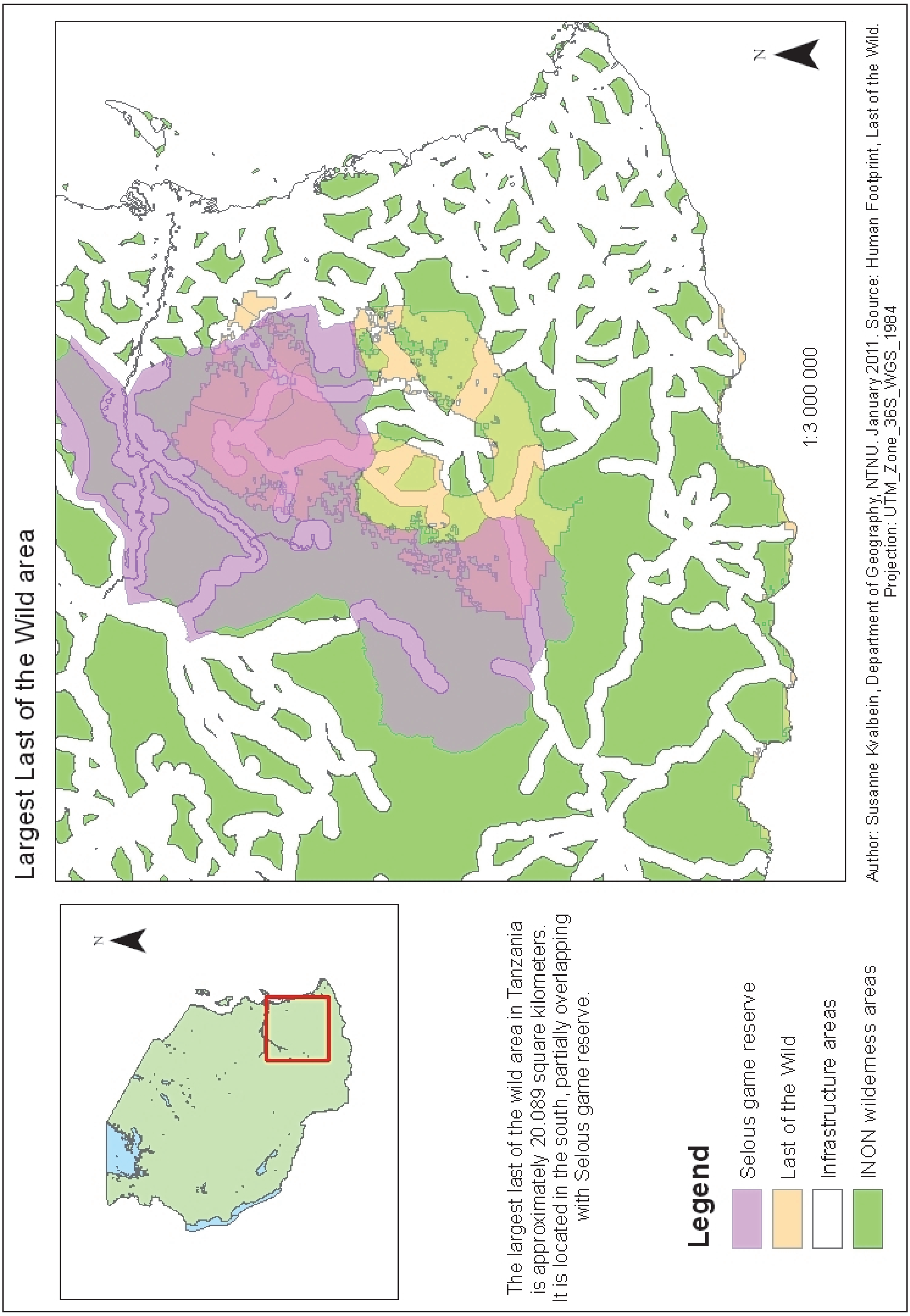
Appendix C: Compactness of wilderness like areas



Appendix D: Last of the Wild and wilderness like areas



Appendix E: Largest Last of the Wild area



Appendix F: Infrastructure data used for the INON analysis

Name of shapefile	Description and feature type	Original coordinate system/Datum	Source	Comments
Ponet	National boundaries (polygon)	GCS[1] WGS 1984[2]	DCW[3] 1997. Available from: https://gist.itos.uga.edu/data/africa/countries/tanzania/datasets/ponet.zip	National boundaries of Tanzania, including larger islands. Used for reference.
Tz-rivers	Rivers (line)	GCS WGS 1984	Africover 2002. Available from: http://africover.org/system/metadata.php?metadataid=104	Rivers in Tanzania, not including islands. Used for reference/digitizing.
Hydro-inland-water-a	Waters in Africa (polygon)	GCS WGS 1984	National Geospatioal Intelligence-Agency (NGA) Available from: http://gis-lab.info/qa/vmap0-eng.html	Was clipped to the Tanzania borders (ponet)
Downstr_nyumba_p_utm36	Waters extracted from hydro-inland-water-a (polygon)	UTM Zone 36S WGS 1984	Extracted from hydro-inland-water-a.shp	Waters downstream of nyumba ya mungu dam
Downstr_kidatu_p_utm36	Waters extracted from hydro-inland-water-a (polygon)	UTM Zone 36S WGS 1984	Extracted from hydro-inland-water-a.shp	Waters downstream of Kidatu dam
Downstream_mtera_utm36	Rivers extracted from tz-rivers (line)	UTM Zone 36S WGS 1984	Extracted from hydro-inland-water-a.shp	Rivers downstream of Mtera dam
Downstream_nyumba_utm36	Rivers extracted from tz-rivers (line)	UTM Zone 36S WGS 1984	Extracted from hydro-inland-water-a.shp	Rivers downstream of Nyumba ya Mungu dam

Downstream_kidatu_utm36	Rivers extracted from tz-rivers (line)	UTM Zone 36S WGS 1984	Extracted from hydro-inland-water-a.shp	Rivers downstream of Kidatu dam
Africa_dams	Hydroelectrical power stations for Africa	GCS WGS 1984	FAO[4]. Available from: http://www.fao.org/geonetwork/srv/	Hydroelectrical power stations for Africa. Had to be clipped to Tanzania (ponet). Only 3 registered power stations in Tanzania in the data set, but according to Wikipedia, there are 6.
Tz_dams	Hydroelectrical power stations for Tanzania	UTM Zone 36S WGS 1984	Based on Tengesdal 1998, TANESCO 2011 & Wikipedia 2011. See reference list.	Hale, Kihansi and Pangani digitized. Nyumba ya Mungu corrected.
Rdline	Roads in Tanzania	GCS WGS 1984	DCW 1997. Available from: https://gist.itos.uga.edu/data/africa/countries/tanzania/datasets/rdline.zip	Road network for the entire country, including islands.
Roads_tanroads	Regional and trunk roads	UTM Zone 36S WGS 1984	TanRoads[5] maps 2008. Available from: http://tanroads.go.tz/index.php?option=com_content&view=article&id=110&Itemid=114	Main roads in Tanzania screen digitized from images/maps of the roads on the TanRoads website.
V4_Roads_Arc1960 selection	Roads in the Serengeti Mara area	UTM Zone 36S Arc 1960	Serengeti – Mara Data. Acknowledgement to TANAPA[6], TAWIRI[7] and FZS[8]. Available from: http://www.serengetidata.org/	Roads in the Serengeti Mara area, roads missing from the other data sets. Clipped to Tanzania (ponet).
Rrline	Railroad	GCS WGS 1984	DCW 1997. Available from: https://gist.itos.uga.edu/data/africa/countries/tanzania/d	

			atasets/rrline.zip	
Utline	Utility lines	GCS WGS 1984	DCW 1997. Available from: https://gist.itos.uga.edu/data/africa/countries/tanzania/datasets/utline.zip	Not many utility lines in the data set, so either the data set is not complete or most utility lines are underground.

[1] Geographic Coordinate System (latitudes and longtitudes)
[2] World Geodetic System of 1984
[3] Digital Chart of the World
[4] Food and Agriculture Organization
[5] Tanzania National Roads Agency
[6] Tanzania National Parks
[7] Tanzania Wildlife Research Institute
[8] Frankfurt Zoological Society

Appendix G: New datasets for INON Tanzania

Name of shapefile	Description and feature type	Coordinate system/datum	Source	Comments
Wilderness_like_areas_over_2500m2	Wilderness like areas (polygon)	UTM Zone 36S WGS 1984	Based on data in appendix F.	Wilderness like areas based on the INON methodology, more than five kilometers from major infrastructure development. Areas smaller than 2500 square meters (2.5 square kilometers) have been excluded.
Infrastructure_areas_final	Infrastructure areas (polygon)	UTM Zone 36S WGS 1984	Based on data in appendix F.	Infrastructure areas; within five kilometers of major infrastructure development.
Water_permanent	Perennial water	UTM Zone 36S WGS 1984	Based on Hydro-inland-water-a. See appendix F.	Seasonal water excluded, only perennial inland water.

Appendix H: Datasets used for reference

Name of shapefile	Description and feature type	Original coordinate system and datum	Source	Comments
Waypoints_correct	GPS waypoints (point)	GCS[i] WGS 1984[ii]	My GPS (Garmin 12 XL)	Controlpoints taken while driving outside of Arusha
Ponet	National boundaries (polygon)	GCS WGS 1984	DCW[iii] 1997. Available from: https://gist.itos.uga.edu/data/africa/countries/tanzania/datasets/ponet.zip	National boundaries of Tanzania, including larger islands.
Tz-rivers	Rivers (line)	GCS WGS 1984	Africover 2002. Available from: http://africover.org/system/metadata.php?metadataid=104	Rivers in Tanzania, not including islands
Utmzone2	UTM Zones (line)	GCS WGS 1984	ESRI Data & Maps 2002 (CD 1) Environmental Systems Research Institute, Inc. (ESRI) Redlands, California, USA	UTM[iv] zones for the entire world. Used to determine which zone to use.
Hydro-inland-water-a	Water in Africa (polygon)	GCS WGS 1984	National Geospatioal Intelligence-Agency (NGA) Available from: http://gis-lab.info/qa/vmap0-eng.html	Inland water in Tanzania.
Tz-boundaries	Borders for regions and districts (line)	GCS WGS 1984	Africover 2002. Available from: http://africover.org/system/metadata.php?metadat	Used for reference when digitizing roads.

			aid=103	
WDPA_2010_Tanzania	Wilderness areas (polygon)	GCS WGS 1984	IUCN & UNEP-WCMC 2010. Available from: www.protectedplanet.org	WDPA[v] wilderness areas for 2010
Ltw_africa	Last of the Wild areas (polygon)	GCS WGS 1984	Last of the Wild Data Version 2, 2005 (LWP-2): Global Last of the Wild (LTW). Wildlife Conservation (WCS) and Center for International Earth Science Information Network (CIESIN). Available from: http://sedac.ciesin.columbia.edu/wildareas/downloads.jsp#last	Last of the Wild Areas for Africa from the Human Footprint project.
Ispop2002	Landscan (raster grid)	GCS WGS 1984	Landscan 2002. Oak Ridge National Laboratory.	Landscan population data from 2002.

[i] Geographic Coordinate System (latitudes and longitudes)
[ii] World Geodetic System of 1984
[iii] Digital Chart of the World
[iv] Universal Transverse Mercator
[v] World Database on Protected Areas