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Population dynamics of rural livestock populations in mopaneveld savanna, Ba-Phalaborwa Municipality, South Africa

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MESPOM

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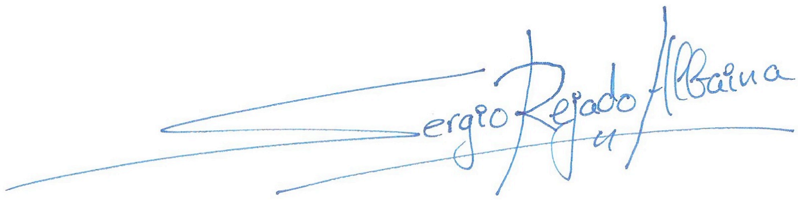
Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.



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ABSTRACT OF THESIS submitted by:
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for the degree of Master of Science and entitled: Population dynamics of rural livestock population in mopaneveld savanna, Ba-Phalaborwa, South Africa

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The population dynamics of livestock in communal rangelands of the Ba-Phalaborwa Municipality (Limpopo Province, South Africa) for the period 2007-14 was conducted. Cattle and goat populations in communal lands were compared with those in commercial ranches. A further analysis compared them with naturally occurring herbivores in Balule Game Reserve. Population change drivers were looked for, comparing the obtained trends with rainfall. Information on livestock management practices in the rural communities was obtained through semi-structured interviews. The data showed different trends in the different communities, including decline and growth, whereas commercial ranches showed stable trends, and herbivores populations in Balule GR were found to be growing. Communal stock rates were found to be 3-9 times higher than those of commercial farms and equivalent measures in Balule GR. In the localities with highest stock rates, livestock management was found to be more intensive, through the provision of winter-feed and/or the creation of artificial water points, while theft was discovered to be most important reason for stock rate change in the communal rangelands.

Keywords: communal rangelands, livestock population dynamics, rangeland degradation, overgrazing, mopaneveld, South Africa, savanna, cattle, goats

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Table of Contents

List of Tables

List of Figures

List of Abbreviations

ANOVA – Analysis of variance
GR – Game Reserve
KNP – Kruger National Park
SADC – Southern African Development Community
SAEON – South African Environmental Observation Network
SANParks – South African National Parks

Chapter 1 - Introduction

1.1 Background

Human activities are currently the cause for unprecedented environmental degradation (Darkoh, 2009), driven by population growth, economic development, energy needs, transport, and globalization (UNEP, 2012). Southern Africa is not an exception to this trend, even thought a shift in concern is taking place: while desertification was the main worry in the 1970s (Darkoh, 1979), the sources of concern have diversified in recent decades: climate change, biodiversity loss, deforestation, land degradation, population growth, waste production, pollution, urbanization, poverty, and health hazards now occupy the agenda (Darkoh, 2009). In the case of South Africa, overgrazing, land degradation and desertification are the main concerns, particularly under the climate change scenario (Hoffman and Ashwell, 2001; Vetter *et al*., 2006).

In South Africa, 72% of the land is unsuitable for arable agriculture and only usable as rangeland for game and livestock, due to low rainfall, including most of the savanna biome (Taiton, 1999). Moreover, the red meat industry contributes 12% of South African domestic agricultural products (Smet and Ward, 2005). In South African communal lands, livestock is an important component of both livelihoods and culture, despite its low economic output (Cousins, 1999; Smet and Ward, 2005). Communal rangeland management is blamed to be unsustainable, leading to a "tragedy of the commons" (Hardin, 1971) situation where personal interest is the cause for often irreversible communal rangeland degradation (Ellis and Swift, 1971; Abel, 1993; Shackleton, 1993; Higgins *et al*., 1999; Smet and Ward, 2005).

This has therefore become a source of concern amongst academics and practitioners, and a number of studies to assess livestock impact in communal and commercial rangeland vegetation in different South African biomes have been undertaken, including the thicket (Hoffman and Cowling, 1991; Hoare, 2003; Lechmere-Oertel *et al*., 2005), karoo (Anderson and Hoffman, 2008; Haarmyer *et al*., 2010), savanna (Teague and Smit, 1992; Scholes and Walker, 1993; Shackleton, 2000; Ward *et al*., 2000; Ginnecchini *et al*., 2007), and grasslands (Tapson, 1990, 1991; *et al*., 2012), as well as some comparative studies across different biomes (Louga *et al*., 2002; Smet and Ward, 2005; Wessels *et al*., 2012; Rutherford and Powrie, 2013). The results varied greatly across and within biomes, reaching no consensus. Studies on livestock population trends in different parts of South Africa (Todd, 1990, 1991; Abel and Blaikie, 1990; de Bruyn, 1998; Vetter and Bond, 2012) showed equally different trends.

1.2 Research problem

There is currently widespread concern over rangeland deterioration in South Africa, particularly for communal rangelands. The research that has been performed in this regard so far is not only inconclusive, but has focused mainly on one indicator of rangeland deterioration (i.e. plants) that, moreover, has been blamed not to be reliable enough (Vetter and Bond, 2012). Research on the alleged cause of the problem (stock rates) is equally inconclusive, which suggests that the rangeland conservation status varies greatly across South African biomes. It is necessary to understand better the main driver of land degradation (i.e. the stocking rates), in order to gain a better understanding of current rangeland deterioration patterns, and to make better predictions of future degradation trends. Therefore, this study aims to address this research gap, focusing directly on communal livestock and its changes over time.

1.3 Aim, objectives and research questions

The aims of this project are:

- *Aim 1*: to study population dynamics of domestic herbivores in communal rangelands in the Ba-Phalaborwa municipality.
- *Aim 2*: to identify drivers of change in livestock populations in Ba-Phalaborwa.

These aims are broken down in the following specific objectives:

- *Objective 1*: To determine current and historical population densities for domestic herbivores on communal rangelands.
- *Objective 2*: To determine the influence of rainfall on livestock population fluctuations.
- *Objective 3*: To compare livestock population with wild ungulates populations, and to compare influence of major drivers of change on both.
- *Objective 4*: To determine the effect of livestock management practices on stock rates.

These aims and related objectives translate into the following research questions:

- *RQ 1*: How does the current density of livestock in rural areas compare with the density of herbivores in comparable, adjacent conservation areas?
- *RQ 2:* How have these densities changed over time?
- *RQ 3*: What are the driving forces behind the observed results?

1.4 Study area

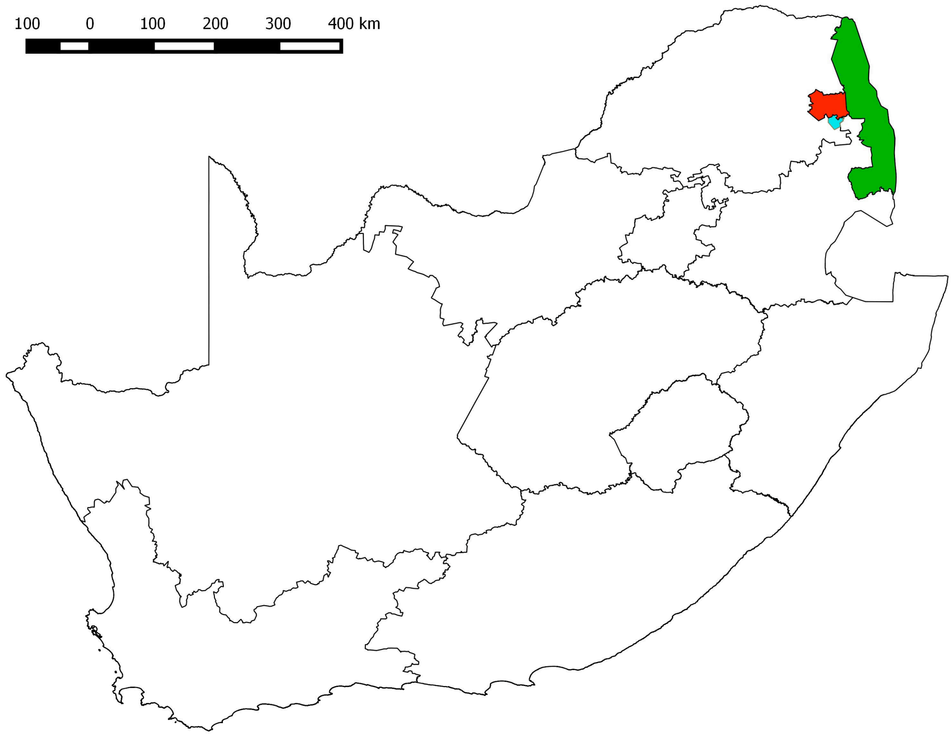

Figure 1. Study area. Ba-Phalaborwa (red) and Balule GR (blue) in reference to KNP (green).

Our area of study comprises the Ba-Phalaborwa municipality and Balule GR. These regions fall within the Mopaneveld bioregion, dominated by the mopane tree (*Colophospermum mopane*). In Limpopo (North-Eastern South Africa) and other parts of southern Africa, the mopane tree (*Colophospermum mopane*) dominates extensive savanna areas characterized as frost-free arid to semiarid climate (Siebert *et al*., 2003). Mopane is a key woody plant species in this ecosystem, used by local communities indirectly for the harvest for food supplement of mopane worms (*Imbrasia belina*) (Makhado *et al*., 2009), and directly for timber, fuelwood, medicine, utensils and tools, and ornamental/religious purposes (Anthony and Bellinger, 2007).

The following constituent vegetation types are present within the research area (Mucina and Rutherford, 2006):

- Phalaborwa-Timbavati Mopaneveld
- Granite lowveld
- Tsende Mopaneveld
- Mopane Gabbro Shrubland
- Gravelotte rocky Bushveld

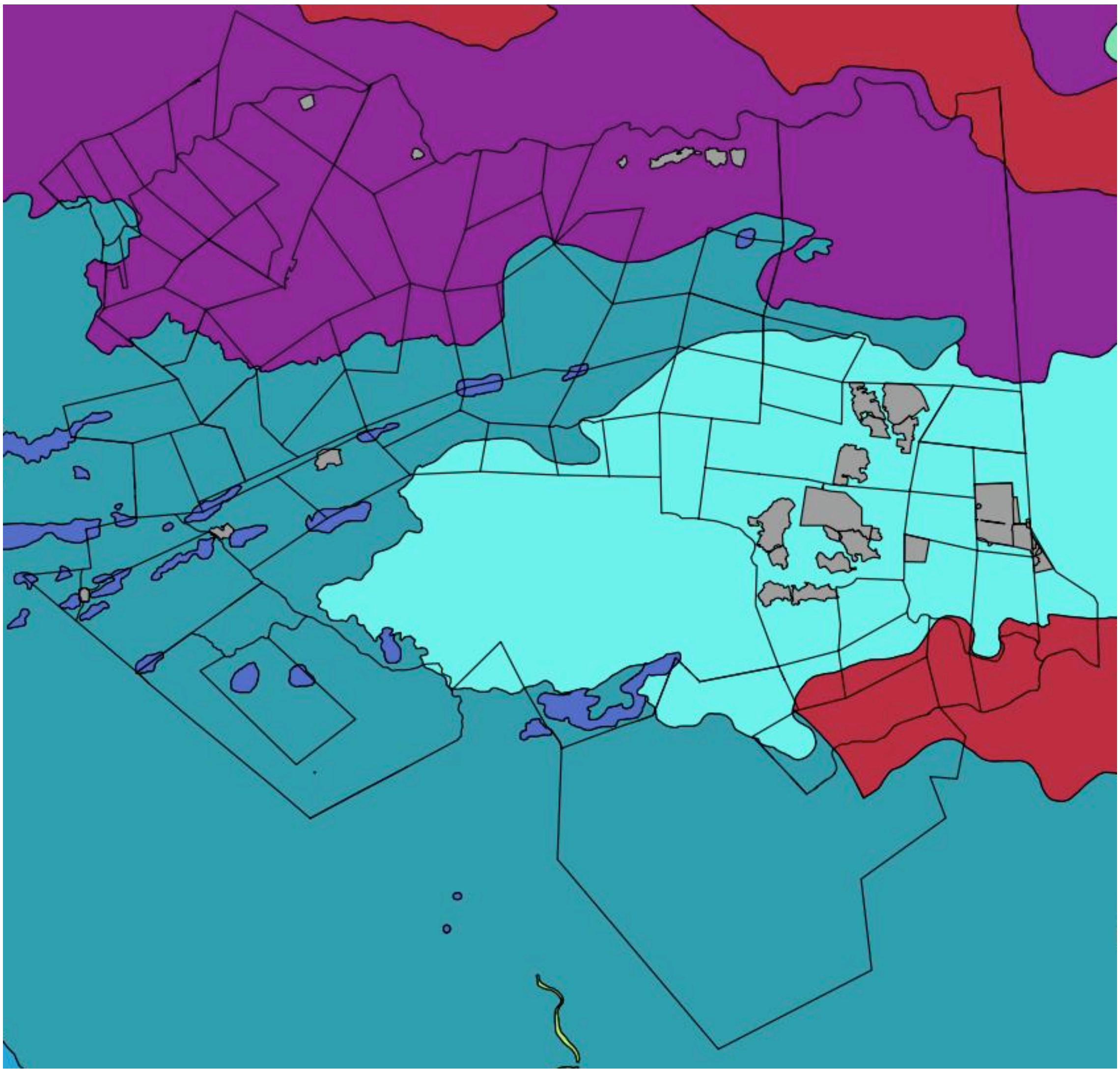

Figure 2. Local vegetation. Tsende mopaneveld (purple), Gravelotte rocky bushveld (dark blue), Phalaborwa-Timbavati mopaneveld (light blue), granite lowveld (red), mopane gabbro shrubland (green).

1.4.1 Ba-Phalaborwa

The Ba-Phalaborwa municipality is located in the East of Limpopo province, adjacent to KNP. It covers 3,300 km^2 and, in 2011, approx. 150,000 persons lived in this municipality (rendering a population density of 45 persons/km^2) (Statistics South Africa, 2013). A diversity of land uses takes place in this municipality, including settlements, mines, communal rangelands, commercial cattle farms, commercial game farms and conservation areas. Figure 2 shows the land uses of the Phalaborwa Municipality, including the main settlements and conservation areas.

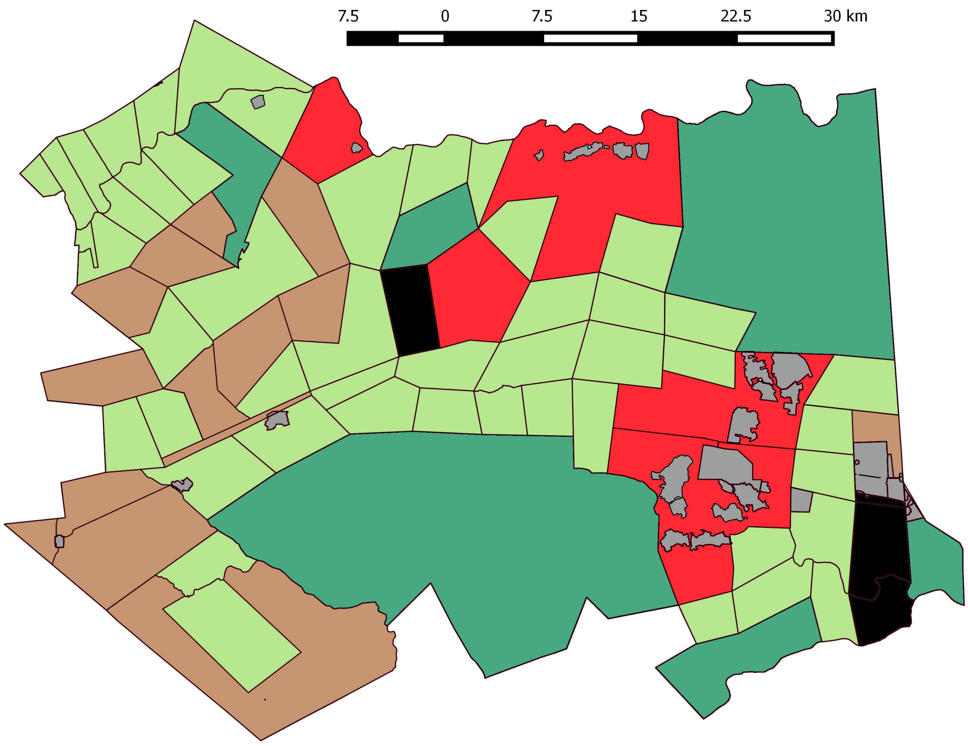

Figure 3. Land use in Ba-Phalaborwa. Settlements (grey), communal lands (red), conservation areas (dark green), commercial cattle farms (light green), mines (black), others (brown).

The main settlements in Ba-Phalaborwa are:

- Phalaborwa, the seat of the Ba-Phalaborwa municipality, lying just next to KNP.
- The villages of Namakgale, Makushane, Mashishimale, Droebult, Maseke, Lulekani and Benfarm, all located west of Phalaborwa.
- Mahale, Selwane, and Nondweni, located in the northern section of the municipality, west of Letaba Ranch.
- Prieska, in the northwest of the municipality, east of Hans-Merensky Nature Reserve.

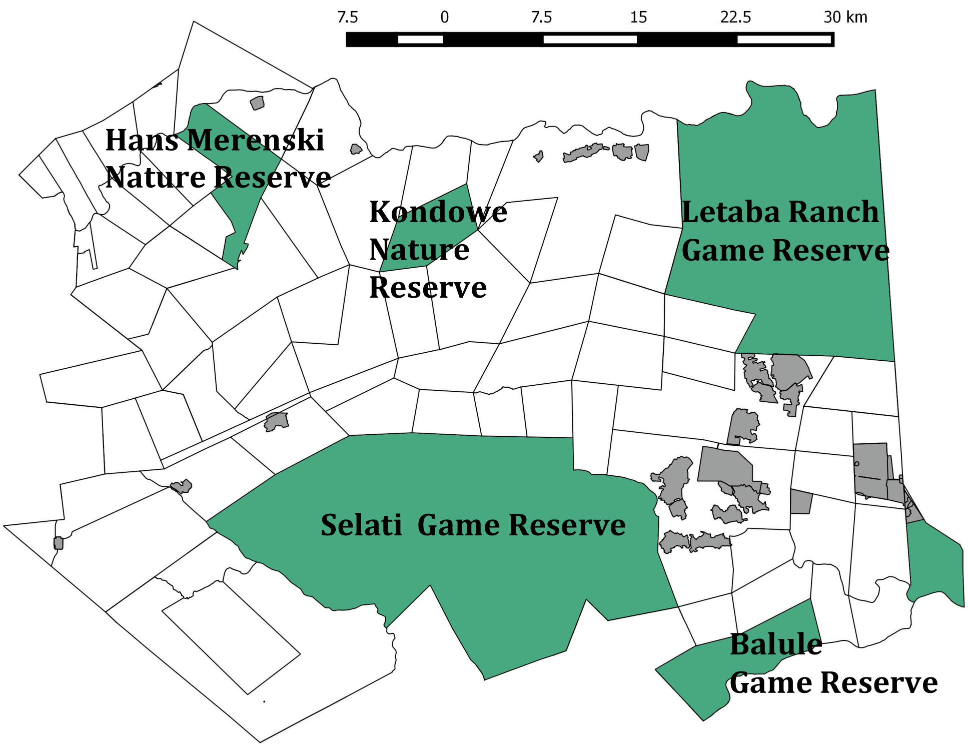

Figure 4. Conservation areas in Ba-Phalaborwa.

A total of six conservation areas lie totally or partially within Ba-Phalaborwa:

- Letaba Ranch Provincial Park (350 km^2): adjacent to Kruger, in the north-eastern corner of the municipality.

- Hans Merensky Nature Reserve (50 km^2) and Kondowe Nature Reserve (35 km^2), two small reserves in the north-western part of the municipality.
- Selati GR (500km^2), which occupies a portion of the southern half of the municipality.
- Balule GR (360 km^2), which extends into Ba-Phalaborwa from Mpulamanga Province to the south.
- KNP (20,000km^2), lying adjacent to the eastern boundary of Ba-Phalaborwa.

1.4.2 Balule GR

Balule GR in a private reserve adjacent to Klaserie GR, which is adjacent to KNP. Klaserie is open to Kruger on the eastern side, and to Balule on the western side. The lack of fences between these conservation areas, allows for the free movement of wildlife across them, forming part of the Greater KNP ecosystem.

Balule extends from the southern Ba-Phalaborwa Municipality (in Limpopo province) into the neighbouring Mpulamanga province, with an extension of approximately 36,000 hectares. It is formed by a consortium of private landowners who joined their land to form the current reserve, and hosts a variety of lodges and tourism-related facilities. It is an intensively managed reserve, with abundant artificial water points (4,7/km^2, compared to the 0,1 of KNP), bush clearing, supplementary feeding, and animal translocations and sales (Child *et al*., 2013).

1.5 The South African Environmental Observation Network (SAEON)

SAEON is a governmental organization focussed on long-term ecological monitoring in South Africa, created in response to the 2002 World Summit on Sustainable Development. It encompasses a network of scientists, organization and observation platforms throughout South Africa, thanks to its multi-stakeholder involvement approach.

SAEON's vision: SAEON is a comprehensive, sustained, coordinated and responsive South African environmental observation network that delivers long-term reliable data for scientific research and informs decision-making; for a knowledge society and quality of life.

SAEON is divided in several modules, which specialize in different biomes. The SAEON Ndlovu node is based in Phalaborwa (Limpopo Province), where it is hosted by SANParks in their Phalaborwa gate offices. The Ndlovu node specializes in savanna monitoring and ecology.

This thesis was written under the auspices of SAEON-Ndlovu Node, and falls within their savanna monitoring scope. SAEON provided the office space, academic advice and logistic support without which this work would have never been accomplished. Amongst these, it is remarkable the support provided by SAEON's environmental monitors and field assistants, who accompanied me in many field visits. Thanks to their help as translators (in both linguistic and cultural terms), I was able to communicate better with the local farmers, who in occasions did not speak English.

Chapter 2 - Literature review

2.1 Introduction

2.1.1 Global context: environmental degradation and challenges

Today, we are experiencing a period of unprecedented concern for the future of life caused due to increasing levels of human-induced environmental degradation (Darkoh, 2009). Its drivers are population growth (with and ever increasing demand for land, food, energy, energy and facilities, some of them previously non-existent), economic development, energy, transport, and globalization (UNEP, 2012). These are linked and interdependent, and result in pollution, waste production, stock overexploitation, biodiversity loss, and land degradation (amongst other problems) (UNEP, 2012). Despite the efforts to lessen the impacts, the trend has yet not reverted (UNEP, 2012).

2.1.2 The state of the southern African environment

Southern Africa encompasses the fourteen member countries of the SADC: Angola, Botswana, Democratic Republic of the Congo, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe. The SADC covers 9,4 million km^2 and was inhabited by about 281 million people in 2011 (SADC, 2014). It is a diverse region, with a variety of socio-economical, environmental, and political circumstances, as well as challenges: environmental ones, but also ensuring water, food, energy security, and the provision of sanitation and social services (UNEP, 2012).

In the late 1970s, desertification was the most pressing environmental worry for African countries (Darkoh, 1979). Ever since, many others have become important elements of the agenda (Darkoh, 2009). These are: climate change (3-4ºC temperature increases during the next 100 years are expected, with consequent aridification) biodiversity loss, deforestation, desertification and land degradation, demographic growth, waste generation, pollution, poverty and health hazards (Darkoh, 2009; UNEP, 2012). Poor international trade, political instability, declining economic performance, weak governance, and international debt further undermine southern Africa's environmental sustainability (Darkoh, 2009; UNEP, 2012).

2.1.3 The case for South Africa

South Africa is the third most biodiverse country in the Word, thanks to its combination of tropical and temperate climates, hosting 227 species of mammals, 718 birds, 84 amphibians, 112 freshwater fish, 286 reptiles, 2,150 marine fish, 77,500 invertebrates and 23,456 plants, being many of these species endemic (DEAT, 2009). This biodiversity is threatened by land use change, natural resource use and the introduction of alien species (DEAT, 1997, 1998, 2009; Perrings, 2000; Steenkamp and Urh, 2000).

Overgrazing, land degradation and soil erosion are principal environmental concerns as well (Hoffman and Ashwell, 2001; Vetter *et al.*, 2006). There is also mounting concern about climate change and its future impacts on the local environment (Hulme et al., 2001; Erasmus et al., 2002; Meadows and Hoffman, 2003), with changes in precipitation patterns already detected in parts of the country (Kruger, 2006).

2.2. The savanna biome

2.2.1 Characteristics of savannas

Savanna ecosystems cover 20% of the world's surface (Grace *et al.*, 2006). They characterized by an open tree layer with a continuous grass layer underneath (Sankaran *et al.*, 2005; Murphy and Bowman, 2012), often dominated by shade-intolerant grasses with C4 photosynthetic metabolisms (Ratnam *et al*., 2011). In the South African case, savannas are defined to have a 5-10% of woody plant cover (Shackleton *et al.*, 2001). In this country, the terms "savanna" and "woodland" are used as synonyms (Shackleton *et al.*, 2001). For the purposes of this paper, both terms will be used indistinctively.

Savanna vegetation is divided in two functional and morphological units (the woody and herbaceous layers) (Scholes & Archer, 1997), which coexist in a balance maintained by competition for water and nutrients, while fire, herbivory and precipitation buffer the dominance of any single life form (Sankaran *et al.*, 2004, 2005). Grasses often feed large quantities of large herbivores (particularly in Africa) and are the fuel for frequent fires (Murphy and Bowman, 2012).

Savanna distribution and morphology are determined by climate (O'Connor, 1985; Louga *et al*., 2004), edaphic factors (O'Connor, 1985; Skarpe, 1991; Louga *et al.,* 2004, Fisher *et al*., 2011), precipitation (Sankaran *et al*., 2005), geological substrate, topography, fire and herbivory (Teage and Smit, 1992; Scholes and Walker, 1993; Witkowski and O'Connor, 1996; Venter *et al.*, 2003; and Keeley, 2003; Sankaran *et al.*, 2008; Asner *et al.,* 2009; Levick *et al.*, 2009). A secondary determinant of savanna vegetation is human land use, through deforestation, rangeland management (fire), animal husbandry, and hunting (Kelly and Walker, 1976; Milchunas *et al.,* 1989; Venter *et al.,* 1989; Skarpe, 1991; Coughermour and Ellis, 1993; Higgins *et al.*, 1999; Parsons *et al.*, 1997; Louga *et al.*, 2004): in southern Africa, there is evidence of human population expansion and pressure on savanna resources in South Africa from as early as 4,000 B.C. (Mitchell, 2002; Breman *et al*., 2011).

Large herbivores (including domestic livestock) are essential in the shaping and maintenance of savannas and grasslands (van Langevelde *et al.*, 2003). They can alter standing biomass (Beschta, 2003; Fleischner, 1994; Mcnaughton, 1984), diversity and composition of both woody and herbaceous vegetation (Belsky *et al.*, 1992; Hayes and Hool, 2003; Hickman *et al.*, 2004; Oba *et al.*, 2001; Augustine and McNaughton, 1998), spatial vegetation heterogeneity (increasing it by means of altering canopy cover) (Olff and Ritchie, 1998; Adler *et al.*, 2011), and even the characteristics of the soil (Fleischner, 1994; Frank and Groffman, 1998 McNaughton *et al.*, 2001). The effects of herbivory are regulated by the degree of defoliation, number of animals, species, and availability of the resource (Allred *et al.*, 2011). Browsing has an effect through the prevention of woody plant regeneration, and impalas (*Aepyceros melampus*) play a central role in woody vegetation recruitment (O'Kane *et al.*, 2012).

Savannas evolved under a combination of fire, animal and human-related disturbance, juxtaposed with climate (Bond *et al.*, 2005). It is a resilient ecosystem, able to cope with large but short surges of utilization (Walpole *et al.*, 2004). If wildlife utilization is low, if the rainfall allows, savanna woody vegetation becomes denser and can potentially become forest (Walpole *et al.*, 2004), but high animal and human utilization can transform woodlands into grasslands (Western and Maitumo, 2004; Western, 2007).

2.2.2 Equilibrium or non-equilibrium systems?

There is a debate over whether savannas can be described as equilibrium systems or not (Smet & Ward, 2005). Clements postulated the equilibrium concept in 1916, within his plant succession theory. According to him, a system would move towards an equilibrium/climax stage determined by environmental constrains, passing through a series of previous intermediate states, a process called succession in which vegetation is driven by biotic factors (Clements, 1916).

Dysksterhuis adapted the succession theory to his classic rangeland condition concept in 1949 (Smet and Ward, 2005). This theory explained how the alleviation of grazing pressure would trigger plant regeneration, which would lead to the climatic stage/equilibrium. From this framework derived the concept of livestock ecological carrying capacity, which would be determined by the quality and quantity of vegetation at the equilibrium stage (Smet & Ward, 2005). Ever since, savannas have been described as equilibrium systems (Smet and Ward, 2005).

Noy-Meir (1973) and Ellis and Swift (1988) challenged this point of view, postulating that arid and semi-arid ecosystems are highly variable in space and time, and vegetation structure was regulated by abiotic events (such as rainfall and drought) rather than herbivore density. This kind of systems is called non-equilibrium systems (Smet and Ward, 2005). The stochastic characteristics of the climate prevent them from tending towards the equilibrium (Behnke and Scoones, 1993), lacking of the density-dependence regulation between plants and herbivores that characterizes equilibrium systems (Ellis and Swift, 1988; Behnke and Scoones, 1993). These systems alternate between different states (Folke *et al*., 2004) where vegetation change is triggered by an event that catalyses the transition towards a new state, which may be transitory or even irreversible (Westoby *et al*., 1989 a, b; Milton and Hoffman, 1994). In savanna ecosystems, this could be due to a substantial reduction in the tree density caused by elephants or fire, which fosters the transition to a different state (Dublin *et al*., 1990).

The large inter-annual variation in vegetation availability prevents herbivore populations from tracking plant biomass, and the density effects of herbivores on vegetation are small or non-existent (Smet and Ward, 2005), which implies that herbivores cannot cause any significant land degradation in these systems (Ellis and Swift, 1988; Behnke and Scoones, 1993). This would render the carrying capacity concept not applicable, triggering criticism amongst the academics on this subject (Smet and Ward, 2005). Extrapolating it to rangeland management: because abiotic factors are variable, and this determines vegetation, and this carrying capacity, the stocking rates would be so variable that it would be impossible to implement them (Bartels, *et al*., 1993; Tapson, 1993). The carrying capacity and stocking rate concepts would fall off utility as regards land degradation as well, because degradation due to excessive herbivore density could be "reversed" by the very same variability that keeps the system out of the equilibrium (Ellis and Swift, 1988; Tapson, 1993; Ward *et al*., 1998).

Nevertheless, this theory has also received criticism. Illius and O'Connor (1999) consider there is no dichotomy between equilibrium and non-equilibrium. They agree that rainfall may be a determining driver in arid and semi-arid ecosystems, and that the density-dependency association between herbivory and vegetation may be weak or non-existent, but they think that the population of herbivores is still coupled to key resources, such as water, on which they depend during times of drought and food scarcity, and which limit the population size at these times.

Currently, a new theory is developing: the generalized dynamic equilibrium model or grazing reversal hypothesis (Milchumas *et al*., 1988; May *et al*., 2009; Oesterheld and Semmartin, 2011). It states that the effect of grazing intensity on plant species diversity depends on the levels of habitat resources and the length of the evolutionary history shared between a given plant community and grazing: the longer the common evolutionary history and the lower the aridity, the more positive the effect of grazing in species richness is, whereas short evolutionary histories and higher aridity render the effect of grazing more pernicious to the ecosystem. However, this model is very recent, and it is still to be tested on the ground (Rutherford and Powrie, 2013).

2.2.3 South African savannas

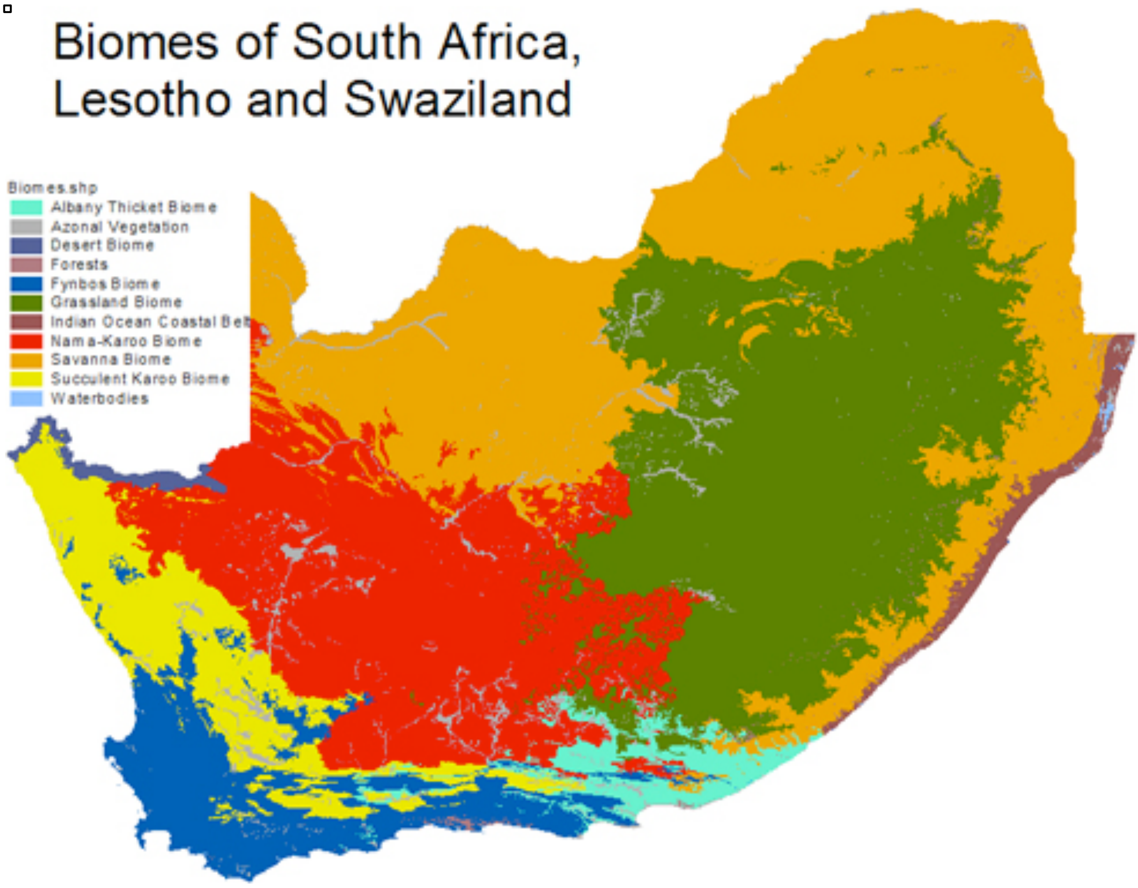

Figure 5. **Biomes of South Africa, Lesotho and Swaziland** (Source: Mucina and Rutherford, 2006).

In South Africa, savannas are the largest biome (Figure 1), covering about one third of its land surface (Shackleton *et al.*, 2001). Low and Rebelo (1996) estimated that woodlands cover 41,7 million hectares, and divided them into 25 vegetation types. They are home to 6,000 plant species, of which 43% are endemic, and their mammal diversity larger than that of other biomes (Cowling *et al.*, 1989). Although the number of species per unit area is lower than that of forests, the total number of plant and animal species is over two times higher (Siegfried, 1989). Woodlands are also home to one quarter of the South African population, since 70% of the former "homelands" were placed in these areas (Shackleton *et al.*, 2001): it is estimated that 9,2 million rural inhabitants live in South African savannas (Shackleton *et al.*, 2001).

In 1997, the National Forestry Action Programme (NFAP) and the new National Forests Act (NFA) in 1998 finally recognized savannas as part of the South African forest resources (Shackleton *et al.*, 2001). The late and poor implementation of these policies led to a widespread unsustainable utilization of South African woodlands (Shackleton *et al.*, 2001). Between 21 (Fairbanks *et al.*, 2000) and 40% (MacDonald, 1984; Low and Rebelo, 1996) of South African savannas are thought to have been degraded of transformed to other land uses.

2.3. Land uses of southern African savannas

2.3.1 Savanna land uses

Grass-dominated ecosystems (savannas and grasslands) cover 40% of the Earth's emerged land (Loveland *et al.*, 2000), and millions of people depend on the ecosystem services they provide, such as grazing land, fuel wood, timber, edible fruits and traditional medicinal plants (Higgins *et al.*, 1999; Twine *et al.*, 2003; Shackleton and Shackleton, 2004; Shackleton *et al.*, 2007) In Africa, savannas and grasslands account for more than two thirds of the vegetation, being essential for the livelihoods of millions of persons (Scholes and Walker, 1993, Mucina and Rutherford, 2006). Also, savannas provide important ecosystem services, such as carbon storage, climate change mitigation, biodiversity, or water yield (Shackleton *et al.*, 2001).

Tainton (1999) estimated that low precipitation renders most of South Africa's land not suitable for cultivation, 72% of it being only suitable as rangelands for game and cattle. However, woodlands have the potential to significantly contribute to the formal and informal sectors of the national economy (Shackleton *et al.*, 2001). Currently, the main land uses of South African savannas are commercial livestock farms, commercial game farms, communal livestock farms and conservation areas, as shown in Table 1.

Table 1. Savanna land uses in southern Africa. Adapted from Smet and Ward (2005), with additions from Grossman and Gandar (1989) and Parsons *et al*. (1997).

	Communal livestock	**Commercial cattle**	**Commercial game**	**Conservation areas**
Management structure	Multiple managers	Single manager	Single manager	Diverse management regimes
Animal diversity	Multi-species	Single-species	Single- or multi-species	Multi-species
Management of grazing resource	Continuous grazing, diverse vegetation	Rotational grazing, uniform vegetation	Continuous grazing, diverse vegetation	Continuous grazing, diverse vegetation
Products	High quantity, big diversity of products mostly for personal use	High quality, single product for domestic and international markets	High variety, strong, healthy, big animals for trophy or ecotourism	High variety, strong, healthy, big animals for conservation and ecotourism

2.3.2 Animal husbandry in Southern Africa

In grasslands and savannas around the world, livestock production is a common and important economic activity (Allred *et al.*, 2012). In southern Africa, livestock husbandry has been regarded as the keystone of rural development, due to the problems that arable agriculture encounters in this region (Thomson *et al.*, 2013a,b). Dating from colonial times, policies and subsequent measures were put into place in order to increase the commercialization of livestock, particularly beef, in high-value European markets (Thomson *et al.*, 2013a, b). Moreover, livestock is important for Southern African rural communities' cultures (Thomson *et al.*, 2013): in 2002 in the SADC, an estimated 10 million people (4,3% of the region's population) were entirely dependent on livestock for their livelihoods, living in an area of approximately 2,87 million km^2, of which 75% is either arid or semi-arid (Thronton *et al.*, 2002), while up to 100 million persons were partially dependent on livestock in the region (Thornton *et al.*, 2002).

In 2010, global beef exports reached a value of US $ 6,6 billion (Agritrade, 2012; FAOSTAT, 2012). That year, Southern Africa produced a 1,5% of global beef, but only participated of a 0,34% of global exports (FAOSTAT, 2012). Despite the 50-year long efforts, transboundary animal disease (TAD) free areas in the SADC are still ineffective, and southern African beef production is still uncompetitive at the global level (Thomson *et al.*, 2013a).

Southern Africa hosts a variety of diseases that evolved and are associated with wildlife (such as foot-and-mouth disease) and can infect livestock and, sometimes, even humans (such as Rift valley fever) (Bengis *et al.*, 2004). These infectious agents have always been at the centre of the wildlife-livestock conflict (Thomson *et al.*, 2013a, b). Historical disease control has focussed on physical separation of wildlife and livestock with fences, with the aim of preventing infection, although vaccine development has introduced new management systems in the second half of the twentieth century (Thomson *et al.*, 2013a). This dividing approach made its way into national and international trade standards and policies concerning animal products, such as the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) of the WTO (WTO, 2012) and the Terrestrial Animal Health Code (OIE, 2012) (Thomson *et al.*, 2013 b). The fences were successful, but at huge ecological costs and damage to wildlife populations (Osofsky *et al.*, 2008; Ferguson and Hanks, 2010; Cumming and Atkinson, 2012). However, they failed in obtaining the desired access to markets, constrained by international sanitary standards, while becoming less effective over time

(University of Pretoria/Agricultural Research Council, 2012; SADC/EU/USAID, 2008). This caused under-investment in the sector, leading to productive capacity and efficiency deficiencies (Rich, 2009; Rich and Perry, 2011). The consequences were biodiversity loss (due to the detrimental effects of fences on wildlife's migration routes and, therefore, access to resources) and limited access to the high-value markets that were aimed for, while the perspectives of ever achieving competitiveness in those markets are low (Thomson *et al.*, 2013).

2.3.3 Rangeland management theory

Traditional rangeland management uses grazing as a management tool aimed towards a maximization of animal production (Ebrahimi *et al.*, 2010) through the maintenance of certain stability in the ecosystem, driven by grazer pressure, species composition and regime (Ebrahimi *et al.*, 2010). In grassland and savanna conservation areas, grazing is used similarly with the objective of optimizing biodiversity (Ebrahimi *et al.*, 2010). At low to moderate grazing intensities, differential feeding and habitat preferences of large herbivores favour spatial heterogeneity in landscapes (van Oene *et al.*, 1999). Vegetation succession is affected by the removal of tall and dominant plant species (Fuhlendorf and Engle, 2004), while the removal of late-successional or invasive plant species results in higher species and structural diversity (van Oene *et al.*, 1999). Whereas this should be the driving mechanism, rangelands often suffer from overgrazing, vegetation deterioration, soil erosion, and reduced biodiversity (Fleischner, 1994; Sansom, 1999). This may result in overall rangeland deterioration and lower animal production (Danckwerts and King, 1984; Friedel, 1991), undermining the objective of rangelands management. It is therefore necessary to correctly estimate the grazing capacity and its seasonal dynamics in order to properly manage these areas and the grazing that takes place on them, (Ebrahimi *et al.*, 2010). Grazing capacity is defined as "the optimum level of (a combination of) livestock (and/or wildlife) that may be maintained sustainably on a management unit and is compatible with the management objectives of that unit" (Holecheck *et al.*, 2004; Ebrahimi *et al.*, 2010). This would be below the levels that cause animal mortality and environmental deterioration (Ebrahimi *et al.*, 2010).

In South Africa, however, the carrying capacity concept has been given preference for conservation and rangeland management purposes (Benjaminsen *et al.*, 2006). This concept is based on the idea that plants and animals coexist in a balanced equilibrium state (Benjaminsen *et al*, 2006) and has two different understandings: "the point reached when the production of forage equals the rate of its consumption by animals, and the livestock population ceases to grow because limited feed supplies produces death rates equal to birth rates" (Behnke *et al.*, 1993) and "the theoretical limit that marks the number of livestock units that pastoral resources in a certain area can support in order to attain a certain management objective" (Hiernaux, 1982). These deterministic models are based upon assumptions of stable plant growth and predictable plant succession under certain grazing levels, which derives in a stable equilibrium between plant and animal productivity and populations, therefore being suitable for environments with stable and predictable conditions and plant growth (Ebrahimi *et al.*, 2010).

Nevertheless, this is generally not the case in African drylands (including grass and woodland savannas), which are usually described as non-equilibrium systems (Sandford, 1983; Behnke *et al.*, 1993; Scoones, 1995), where external factors (for instance climate) are more important than herbivory in determining vegetation composition and cover, and hence rainfall may be more important for the herbivore population size than density dependent factors (Benjaminsen *et al.*, 2006). However, there is discussion with regard to whether South African drylands can be described as non-equilibrium systems or not (Hoffman *et al*., 1999; Illius and O'Connor, 1999; Todd and Hoffman, 1999; Sullivan and Rohde, 2002; Riginos and Hoffman, 2003). This is an important issue due to its implications with regard to carrying capacities and, therefore, stocking rates and rangeland management frameworks.

In the second half of the twentieth century, many of South Africa's agricultural policies favoured white farmers and land owners (Benjaminsen *et al*., 2006). Equilibrium-and-succession-based research lead to the application of maximum sustainable yield frames on farming systems based on private property, with fences and conservative stocking rates (Benjaminsen *et al*., 2006). The perception that soil and vegetation degradation were occurring as a consequence of overgrazing (Beinart, 2003) led to state-promoted infrastructure grants, stock reductions schemes, and drought relief programs that aimed to modernize and support the commercial livestock system (Hoffman and Ashwell, 2001). In communal lands, these policies meant land fencing and livestock culling to match the calculated carrying capacities (Beinart, 1984, 2003; Jacobs, 2003).

Yet, the "need" for livestock keepers to adhere to a defined carrying capacity in order to conserve rangeland resources and to achieve economic development remains an institutional fact in contemporary South Africa (Benjaminsen *et al*., 2006). Moreover, stocking rates in black rural areas in southern Africa are two or three times above the estimated carrying capacities (Cousins, 1996; Smet and Ward, 2005), raising concern about the ecological sustainability and overgrazing (Cousins, 1996).

2.3.4 Communal rangeland management

Communal livestock ranching based on traditional management systems is also an important land use form in South Africa (Smet and Ward, 2005). Rural communities in drylands of southern Africa are "vulnerable to extreme poverty and appear to be surviving more on wages, remittances, and government transfer payments than on local production" (Child *et al.*, 2012) and, as in many developing countries, the pressing need for environmental resources is of a more urgent nature than long term environmental considerations (Mwavu and Witowski, 2008).

There are two competing descriptions for this management system: are communal rangelands a common pool resource, or a common property regime? On the one hand, common pool resources are "those that are used or can potentially be used by more than one agent, either simultaneously or sequentially, and where exclusion from the resources is difficult of costly to achieve" (Ostrom, 1986). On the other hand, a common property regimes is that in which "(1) no single individual has exclusive rights to the use of the resource, (2) group members have secure expectations that they can gain access to future use of the resource, (3) there are functioning membership criteria, (4) there are communally-defined guidelines for resource use, and (5) there is an enforcement mechanism for punishing deviant behaviour" (Swallow, 1990). Lawry (1990) provides a shorter definition: clearly defined membership rules and exclusion of non-members is in place.

According to Cousins (1996), common property regimes show economic and ecological advantages in areas where extensive livestock production is important for local livelihoods (such as in the case of southern Africa):

- “livestock herds within village economies are often multi-purpose in character (sales for cash, milk for home use, saving or “store of wealth”, status and prestige, transactions between households, bridewealth, cultivation, manure, transport, wool, meat, investment) and yield high rates of economic return per hectare when all their functions are valued, being their economic value much higher than that from commercial ranches;
- for multi-purpose herds high stocking rates make economic sense. An optimum stocking rate will be higher than those in single purpose production systems. The herders pursue opportunistic strategies based on mobility to optimise the use of the variability of African rangelands;
- environmental variability means that higher stocking rates will be facilitated by a property regime which allows flexible access to different habitat patches within rangelands by numerous individually-owned herds, that is within a common property regime; and
- ecological dynamics in arid and semi-arid rangelands with particularly high rates of variability in rainfall may be non-equilibrial in character” (Cousins, 1996, pp. 171-172).

However, these systems are institution-mediated, and if the institutions or the common property rules break down or do not adapt to the evolving circumstances, undesirable outcomes may happen, leading to a “tragedy of the commons” (Hardin, 1971) situation:

- increased resource degradation as the property regime slips towards open access (Vedeld, 1992);
- spontaneous enclosure/privatisation (Behnke, 1985; Graham, 1988);

- capture of the commons by groups of commercial producers (Lawry, 1990; White, 1992) who may pursue private accumulation strategies in the name of community development (Cousins, 1992, b), or may do it even illegally (Anthony *et al*., 2011).

2.3.5 Conservation areas

Biological diversity is recognized to have importance as natural resource capital for economic development and for human welfare that is being lost at ever increasing speed worldwide, and especially in developing countries (Ehrlich and Ehrlich, 1992; Constanza et al., 1997; de Groot et al., 2002). Therefore, biodiversity conservation has been receiving an increasing amount of attention over the last 20 years, being acknowledged to be a key indicator of sustainable land use (Shackleton, 2000). Most nations are signatories of the Convention on Biological Diversity, and significant efforts are put to implement policies that may revert the global, regional and local declining biodiversity trends (Shackleton, 2000). This approach initially focused on protected areas (Margules and Pressey, 2000; Bruner et al., 2001), which are "a clearly defined geographical space, recognised, dedicated ad managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values" (IUCN, 2008). These were intended to "insulate biodiversity from the impacts of human development" (Rai and Sundriyal, 1997), and most conservation areas in the world cite the preservation of biodiversity (explicitly or implicitly) as one of the primary reasons for their existence"(Shackleton, 2000).

The emphasis has shifted towards conservation outside of conservation areas and, mostly, on agro-ecosystems (Scoones et al., 1992; Halladay and Gilmour, 1995). Protected areas are usually surrounded by territories that have been transformed by humans to different extents (Shackleton, 2000) and whose communities are linked with them through a variety of means (ecological, economic, cultural) (Wells, 1996; Shyamsundar and Kramer, 1997). There is a perception that human impacts have lead to a decline in biodiversity surrounding protected areas (Shackleton, 2000) and despite the fact that agro-ecosystems are usually very species-rich (Alverez-Buylla Roces et al., 1989). This has lead to a growing concern over biodiversity loss, which has come to be an element of resource economics, and considerable effort is being put onto accounting for biodiversity loss and assessing the value and costs of maintaining diversity (Ehrenfeld, 1988; Aylward, 1991; Adger et al., 1994).

Southern and eastern Africa's wilderness areas and wildlife, including their wild ungulates, are an irreplaceable global resource that plays a key role in global tourism (Thomson et al., 2013a, b). Nature-based tourism in southern Africa is estimated to contribute to the regional GDP as much as agriculture (including livestock), fisheries and forestry combined (Scholes and Briggs, 2004), and its role in regional economic growth keeps on increasing (Osofsky et al., 2008; Thomson et al., 2013a, b). Southern African governments are progressively realizing their comparative advantage on the global level with regard to wildlife-based tourism (Osofsky et al., 2008; Thomson et al., 2013 a, b). This has led to the creation of 14 terrestrial transfrontier conservation areas (hereby referred to as TFCAs) in southern Africa, which cover a surface of 750,000 km^2 (Cumming, 2008). These are "multiple land use areas with an emphasis on biodiversity conservation and mobilization of the economic benefits of nature-based tourism and related activities" (Cumming, 2011). However, unrestricted wildlife movement, although a vital part of large ungulate conservation, increases ungulate-livestock contact in areas where livestock is a key element of local livelihoods. It is therefore necessary to accommodate both in order to ensure the success of these initiatives (Osofsky et al., 2005; Thomson et al., 2013a, b). Local livestock owners must be able to generate returns from their animals, for most farmers receive no income from tourism whatsoever: livestock and conservation are hence fundamental pillars of rural development in southern Africa (Thomson et al., 2013).

2.4. Communal rangelands in South Africa

2.4.1 The former homelands

In 2002, almost half of the black rural population of South Africa still inhabited the territories that formed the apartheid-time homelands (Els, 2002). This meant 17 million people dependent on subsistence agriculture and living with a mean agricultural annual income of around 6000 ZAR per household in a communal organization system that encompassed more than 800 tribal areas. In these areas, population growth is 2,7% per year, and most of the population is less than 16 years old (Els, 2002). These regions suffer also of a social and economic crisis fuelled by falling formal sector employment, HIV/AIDS, and the collapse of the agricultural support services of the former homelands. The 40-80% unemployment rate makes people dependent on local natural resources (Els, 2002).

The Apartheid regime placed the homelands in areas that were already resource-poor, and that moreover were not equitably distributed and were often controlled by elites (Homer-Dixon and Percival, 1998). Populations depended on subsistence agriculture and remittances from relatives working in industries or mines (Homer-Dixon and Percival, 1998). Agriculture suffered from a lack of capital investment, access to markets, and knowledge of appropriate land management, all derived from discriminatory education and agricultural policies (Homer-Dixon and Percival, 1998). Emigration out of the homelands was extremely controlled, which in combination with the high fertility rates caused high population densities (Callimanopoulos, 1984). Poverty in these areas therefore increased rapidly, water and energy needs became progressively more difficult to meet, and agricultural and grazing productivity began to decline due to land degradation, which lead to "resource capture" by local elites who wanted to secure their access to local resources, generating migration to progressively more marginal lands (Homer-Dixon and Percival, 1998).

After South Africa's first democratic elections in 1994, the local authorities based on traditional cultures have seen their control over natural resource in some communal lands weakening (Kaschula *et al*., 2005; Twine, 2005). This diminished control facilitated unrestricted access, discouraging individuals to self-control their use and consumption of the common resources (Scholes, 2009). Given that communal resources buffer adversity and poverty, the demand is forecasted to continue increasing (Dovie *et al*., 2002; Shackleton *et al*., 2007).

2.4.2 Communal lands in contemporary South Africa

In South Africa, communal areas account for almost one quarter of the total savanna surface (Shackleton *et al*., 2001). In South African rural communities, land is divided in two different uses: one for residential, *kraal* (the fenced plot intended for keeping cattle) and household gardening purposes, and the other and larger being the area further from the village and used for grazing and subsistence agriculture (Metcalfe, 1996) and includes the bush area (Anthony and Bellinger, 2007). Savannas provide a variety of goods, services and livelihoods to rural inhabitants and the national economy, such as animals, medicinal plants, fuel wood, edible insects, and edible fruits (Shackleton, 1996). More concretely, savanna tree species are used for fuel wood, edible fruits, construction timber, medicines, or by having cultural significance (Shackleton, 1995). Therefore, savannas and their natural resource base play a central role on the sustenance of rural livelihoods (Lecin and Weimer, 1994; LAPC, 1994), even though a large percentage of any house's income derives from remittances (Cousins, 1996).

In the surroundings of human settlements, natural savannas are experiencing a period of rapid transformation onto subsistence cultivation (Giannecchini *et al.*, 2007). There is a great concern about the over-utilization of these areas and about the possibility that in the near future the ecosystem may not be able to sustain the services on which the rural communities' livelihoods depend (von Maltitz and Scholes, 1995; Banks *et al.*, 1996; Higgins *et al.*, 1999; Els, 2002; Williams and Shackleton, 2002; Shackleton and Shackleton, 2004; Dovie *et al.*, 2002; Wessels *et al.*, 2013)

2.4.3 Economic importance of communal rangelands

Rural livelihoods in southern Africa are "multiple, diverse and dynamic, often aimed at managing risk, reducing vulnerability and enhancing security" (Cousins, 1999), combining wages, remittances and informal sector earnings (May *et al.*, 1995), and involving complex social and economic relationships (Cousins, 1999). Livelihood strategies are institutionally mediated (Cousins, 1999) and the access to resources is regulated by sets of formal and informal rules (Leach *et al.*, 1997). Formal and informal institutions regulate and pattern resource use, although not always meaning the existence of a common property regime (IIED, 1997), and sometimes with conflictive relations between them (Kepe, 1997; Anthony *et al.*, 2011).

Communal rangelands are key pillars of local livelihood strategies, providing food security, nutrition, income, medicine, fertiliser, fuel building material, spiritual health and aesthetic satisfaction (Cousins, 1999). They provide many services to other groups other than livestock owners, called "wild resources" (IIED, 1995), "secondary products" (Shackleton, 1996), "veld products" (Shackleton and Shackleton, 1997), "non-timber forest products" (Grimes et al., 1994), "the uncultivated sector" (Palmer, 1997), and "savanna woodland resources" (Campbell et al., 1997).

Livestock in communal lands is "kept primarily for cultural reasons and as a mechanism of savings and coping with risk, being an asset than can be privately owned and used to harvest natural resources in situations where people generally have limited rights to valorise, manage, or exclude others from "their" resources" (Child *et al.*, 2012). Rural households consider cattle as an insurance policy rather than a commodity production asset (Smet and Ward, 2005; Child *et al.*, 2012). Livestock production in these settings has therefore a multi-purpose behaviour (yielding marketed products, non-marketed products, indirect uses, and non-use values), and its economic return rates per hectare are large when all these functions are taken into account, being up to three times higher than that of commercial ranches (De Ridder and Wagenaar, 1986; Pastoral Development Network, 1992; Scoones, 1995).

The economic value of communal rangelands is socially differentiated, and different actors make use of different resources, at different times of the year, and for different purposes (Clarke *et al.*, 1996; Campbell *et al.*, 1997), which may be a source of conflict between different groups, where power relations determine the outcome (Kepe, 1997). However, these resources are particularly important for the rural poor, for whom they make a key contribution to food security and balanced nutrition (Cousins, 1999).

2.4.4 Evidence for communal rangeland degradation in South Africa

The "top-down" effect of fire and herbivory on savannah dynamics is relatively well understood (Scholes and Archer, 1997; Sankaran et al., 2005; Helm et al., 2011). However, the factors influencing human use are not. The way people use savannahs depends on governance, socioeconomics, and individual and group behaviour, among other aspects

(Scholes, 2009), making the effects on savanna dynamics difficult to quantify and predict. Reid *et al*. (2010) compared studies on rangeland management around the world, concluding that the effect of grazing on biodiversity can be sometimes positive, and sometimes negative.

According to classical rangeland theory, communal rangeland management is an unsustainable and unproductive land use form, blamed to invariably lead to irreversible rangeland degradation (Abel, 1993; Shackleton, 1993, Higgins *et al.*, 1999), including in South African communal rangelands (Smet and Ward, 2005). Dean and MacDonald (1994) studied arid and semi-arid rangelands of the Cape Province, indicating that the stocking rates had diminished significantly during the period 1855-1981 and that this was more due to rangeland deterioration than to government policy and market forces.

It is important to know the extent of this degradation in order to feedback rangeland management, for shifts in plant communities and woody plant abundance have consequences in primary productivity and, hence, in livestock productivity (Burrows *et al*., 1990). A contentious debate has taken place in this regard and, in the last two decades, an abundant body of literature has been written about the effects of overgrazing on plant communities in and across South African biomes.

Thicket

Plant species richness has been found to decline with grazing in thicket vegetation (Hoffman and Cowling, 1991; Lechmere-Oertel *et al*., 2005), especially in communal lands (Hoare, 2003).

Karoo

Some studies found a decline in species richness due to grazing (Beukes and Ellis, 2003; Hendricks *et al*., 2005; Todd, 2006), while others found no effect of grazing (Todd and Hoffman, 1999; Petersen *et al*., 2004; Allsopp *et al*. 2007; Anderson and Hoffman, 2007; Haarmeyer *et al*., 2010).

Savannah

In the Lowveld, heavy grazing has been observed to significantly increase species richness (Shackleton, 2000), decrease woody plant species richness (Shackleton 1993; Higgins *et al*., 1999; Ward *et al*., 2000), increase grass species richness (Shackleton, 2000) and diversity (Tefera *et al*., 2010), reduce plant height and cover (Shackleton, 2000), reduce grass competition (Teague and Smit, 1992; Scholes and Walker, 1993). There have been also negative results: no change in species richness (Prendini *et al*., 1996) or woody and forb species (Shackleton, 2000).

Patterns were found to be dependent on settlement (Shackleton *et al*., 1995; Giannecchini *et al*., 2007), land use system (Parsons *et al*., 1997; Higgins *et al*., In communal lands, plant density and basal cover were higher than in other land uses, and perennial plants had been replaced by annuals, which are often more palatable and have bigger basal areas, preventing soil erosion (Parsons *et al*., 1997). Parsons *et al*. (1997) found also that communal lands had also lower woody plant density and higher proportions of non-palatable species.

In the case of the mopaneveld region, Thomson *et al*. (2013) found no difference species richness between commercial and communal rangelands, although communal lands showed reduced herbaceous cover, high proportions of forbs and annual plants, as well as a reduced woody cover (although this was attributed to direct harvest) and a shift from the original woodland towards a shrubland.

Grassland

Grasslands grazed at twice the recommended rate showed abundant climatic species and high basal cover in Transkei (McKenzie, 1984). Rutherford *et al*. (2012) found a reduction in in plant cover, but no decline in species. Walters *et al*. (2006) and Martindale (2007) found no significant effect of heavy grazing.

Cape region

Communal rangelands showed more bush, lower grazing height, higher basal cover, higher leaf content and lower standing biomass, which however did not imply a reduced productivity, communal grazelands being as productive as more lightly stocked commercial farms (de Bruyn, 1998).

Comparative studies

In studies across South Africa, the management system (Smet and Ward, 2005), geological substrate (Wessels *et al*., 2012), and the rainfall gradient (Rutherford and Powrie, 2013) was found to have a bigger effect than grazing intensity. Heavy grazing was demonstrated not to necessarily lead to reduced plant species richness, which sometimes even increased, while changing species competition and forage quality (Rutherford and Powrie, 2013). Human utilization impact on wood resources differed in type, intensity and frequency amongst the different sampling areas (Louga *et al*., 2002).

However, studies utilising the necessary comprehensive species assessments are not common (O'Connor *et al.*, 2010; Rutherford and Powrie, 2013) which just contributes to the inconclusiveness of the discussion, their outcomes differing across and within regions and biomes. Moreover, does vegetation change necessarily mean land deterioration (Vetter and Bond, 2012)? There is evidence that woodland plant biodiversity is highest at intermediate levels of disturbance, where grazing, trampling and harvesting by humans and livestock create niches by increasing the patchiness of the environment (Grime, 1979; Armest and Pickett, 1985; Huston, 1994). Thomson *et al*. (2013) argued that, at least in the Mopaneveld, plant community composition was not a good indicator of land degradation.

As studied by Dean and MacDonald (1994), deteriorated rangeland ecosystems would undermine the sustainability of high stock rates, which would eventually decline. Despite the concerns, Tapson (1990, 1991) found cattle stock rates in Kwazulu-Natal's communal land to have increased from 1,27 to 1,52 million heads since the 1950's, and stocking rates in the communal rangelands of the Sterkspruit District have shown no decline since the beginning of the register in the 1800s (Vetter and Bond, 2002). De Bruyn (1998) found no decrease in productivity whatsoever in communal lands respect of commercial farms in the Cape Province.

As we can see, the effects of heavy grazing on plant communities in communal lands in South Africa differed across and within different regions and ecosystems, and even from village to village. Even its consequences on productivity and stocking rates varied greatly across the country. Some authors argue that the effects of overgrazing are not that severe as previously thought (Mace, 1991; de Bruys, 1998; Rutherford and Powrie, 2013). Therefore, Walker (1980), Abel and Blaikie (1990), Tapson (1990, 1991), Shackleton (1993), and Cousins

(1996) wondered whether communal rangelands are extremely resilient, or the recommended stocking rates are too conservative. De Bruys (1998) questioned whether the definition of land degradation was correct, what it exactly meant, and whether "deterioration irreversibility" was a fact or not.

2.5. Conclusions

In South Africa degradation is source of major concern, due to the relevance of rangeland ecosystems (savannas and grasslands) for the economy and for the livelihoods of local communities. Despite the scientific concern and the research accomplished so far, the academic debate on this subject is still inconclusive. Many studies have concentrated on the impacts of grazing on plant community composition and structure, but consensus on this has not been achieved. Some authors even doubt of the reliability of these measurements as indicators of land degradation.

On the other side, not many researchers have concentrated on the supposed driver of degradation: livestock. The results of these were as well diverse, from severe declines on stocking rates (Dean & MacDonald, 1994), to long-term stability (Vetter and Bond, 2012) or even increases (Tapson, 1990, 1991). However, none of these studies on stock rates took place in our area of study or its vicinities. A study of livestock population dynamics could help understand these effects better: if degradation is high, it could be expected that livestock populations are stagnant or decreasing, whereas if the carrying capacity has yet not been reached, these could be still growing.

These rural landscapes require continued management to ensure sustained availability of natural resources (Hobbs et al., 2006). Given that rural areas in South Africa are often situated around protected areas, resource use not only affects ecosystem services and function in the immediate area, but also the sustainability of neighbouring protected areas (Joppa et al., 2009). An understanding of local interactions between the biophysical factors, socioeconomics and natural resources is required to manage the resources sustainably (Hobbs et al., 2006; Giannecchini et al., 2007). Therefore, a change in the approach may help achieve a better understanding of this issue.

Chapter 3 - Methods

3.1 Data collection

3.1.1. Livestock data

Data on livestock numbers for the Ba-Phalaborwa municipality was facilitated by the Limpopo Department of Agriculture. Infectious animal diseases (such as anthrax and food-and-mouth disease) are indigenous to many species of herbivores within KNP and neighbouring game reserves, which fosters a continuous monitoring of livestock health all municipalities adjacent to Kruger.

Figure 6. Makushane dip tank. In the image the path leading to the tank can me seen, as well as a young cattle swimming in the veterinary mix.

The monitoring is carried out by the veterinary officers of the Department of Agriculture on a weekly (in the case of communal lands) or monthly basis (in the case of commercial farms).

The inspections take place in the commercial farms or, in the case of communal rangelands, in the dip tanks: a pool with a veterinary chemical mix where the cattle "dip", on a weekly basis, to keep them free of ticks and other parasites that transmit diseases. During the inspections, the officer takes data on stock rates, number of owners, calf and adult mortality, fertility, auctioned animals, and sold and purchased animals. All the data available for the municipality was obtained and captured, covering the period ranging from January 2007 to March 2014.

In commercial farms and communal rangelands, the most common livestock species are cattle and goats. Sheep are seldom present, as well as donkeys (which are common only in the Greater Selwane area), while no mules and horses are common in communal lands.

3.1.2 Balule GR game counts

Annual game counts for the period 2005-13 were provided by the reserve's management. These were aerial full game counts (counting every animal in the reserve) made with fix-winged aircraft in late winter (August-September), when visibility is best (the dry season involves a reduced plant cover). The same team of experts perform the surveys each year, following the same methodology, under request of the reserve's management as independent ecological audits (Child *et al.*, 2013).

3.1.3 Precipitation data

Rainfall data was obtained from KNP weather monitoring stations, available at http://www.sanparks.co.za/parks/kruger/tourism/climate.php. At the monitoring stations, section rangers record monthly precipitation. The two selected weather stations were Mahlangeni and Phalaborwa, both close to KNP's boundary with Ba-Phalaborwa, and chosen to their proximity to both groups of communal lands: northern (Prieska and Greater Selwane) and southern (Greater Namakgale and Greater Lulekani), respectively. The data was used to represent long term (2005-2013) monthly and annual rainfall.

3.1.4 Face-to-face questionnaire

Semi-structured interviews were conducted with livestock owners at various dip tanks to obtain further information on livestock numbers per household, stock trends and their causes, and additional feed and water points. Table 2 summarises the interviews conducted. Unfortunately, no interview was conducted in Prieska due to the difficult accessibility of this location.

Table 2. Interviews summary.

Dip tank	Date	Number of interviews conducted	Total number of cattle owners in the location	% of cattle owners interviewed
Makushane	18 March 2014	16	156	10,25
Mashishimale	19 March 2014	19	253	7,51
Lulekani	8 April 2014	19	134	14,18
Nondweni	9 April 2014	10	14	71,42
Selwane	10 April 2014	23	209	11,00
Maseke	11 April 2014	8	29	27,59
Benfarm	14 April 2014	15	49	30,61
Total: 7 villages		**95**	**844**	**11,25**

At each dip tank, the maximum possible number of interviews was performed, limited by the number of farmers attending that day, and interview duration (given that farmers try to move out from the dip tank as soon as possible to take the cattle to graze or attend to personal affairs). The questionnaires were initially written in English, and the interviews were conducted in the local language (most usually Shangan, although Shoto was also frequent) with the help of an interpreter. The questionnaire covered information on the livestock owned by each farmer, the use and cost of feed, management plans for the livestock, causes of change in livestock numbers, economic transactions involving livestock, and the existence and use of artificial water points (Annex 1).

3.1.5 Geographical data

Administrative and geographic maps of Ba-Phalaborwa and Bushbuckridge municipalities were obtained from www.demarcation.org.za, while vegetation maps are available at the South African National Biodiversity Institute's website (www.sanbi.org). The cadastral information for Ba-Phalaborwa was provided by the Limpopo Department of Agriculture, while KNP-related maps were facilitated by SANParks.

3.2 Data analysis

3.2.1 Stock densities calculation

For the communal lands, the different villages were consolidated into the following four groups according to cattle movement, grouping together all the areas across which cattle moved freely:

- **Prieska**: encompassing only one village, due to its isolation respect of all other settlements.
- **Greater Selwane**: encompassing adjacent communal lands of the Nondweni, Selwane, Mahale villages, as well as the reclaimed lands of Makwena and Loskop, in the northern part of the municipality.
- **Greater Lulekani**: encompassing the Lulekani and Benfarm villages.
- **Greater Namakgale**: grouping the villages of Droebult, Namakgale, Makushane, Maseke and Mashishimale. Despite its proximity with Greater Lulekani, it was decided to keep both groups separated due to 1) the physical separation with a main road (not usually crossed by livestock) and 2) because of the two-year gap in the data that followed the retirement of the officer who used to monitor that area, so that this gap would not distort the continues data series for Greater Lulekani.

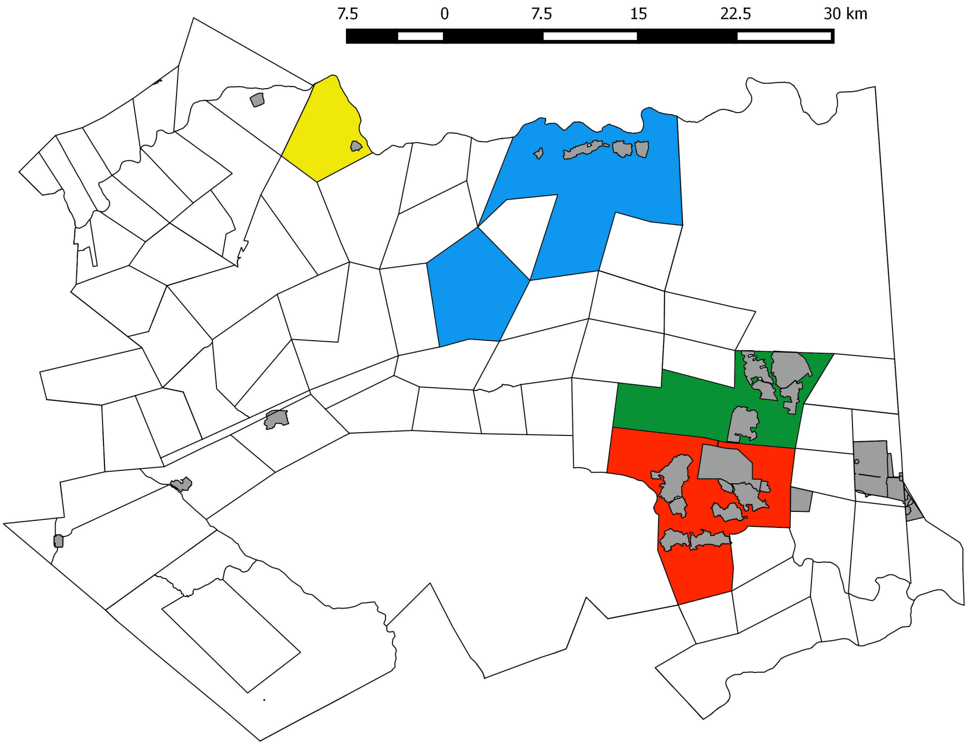

Figure 7. Grouped communal lands. Prieska (yellow), Greater Selwane (blue), Greater Lulekani (green), Greater Namakgale (red).

In the case of commercial farms, these were grouped on two groups: East and West. These were separated according to 1) proximity to the biggest three communal lands (Greater Namakgale, Greater Lulekani and Greater Selwane) and 2) consistency and continuity of the data sets. The Western farms showed more gaps in the data coverage than the Western ones, and were further away from most communal lands.

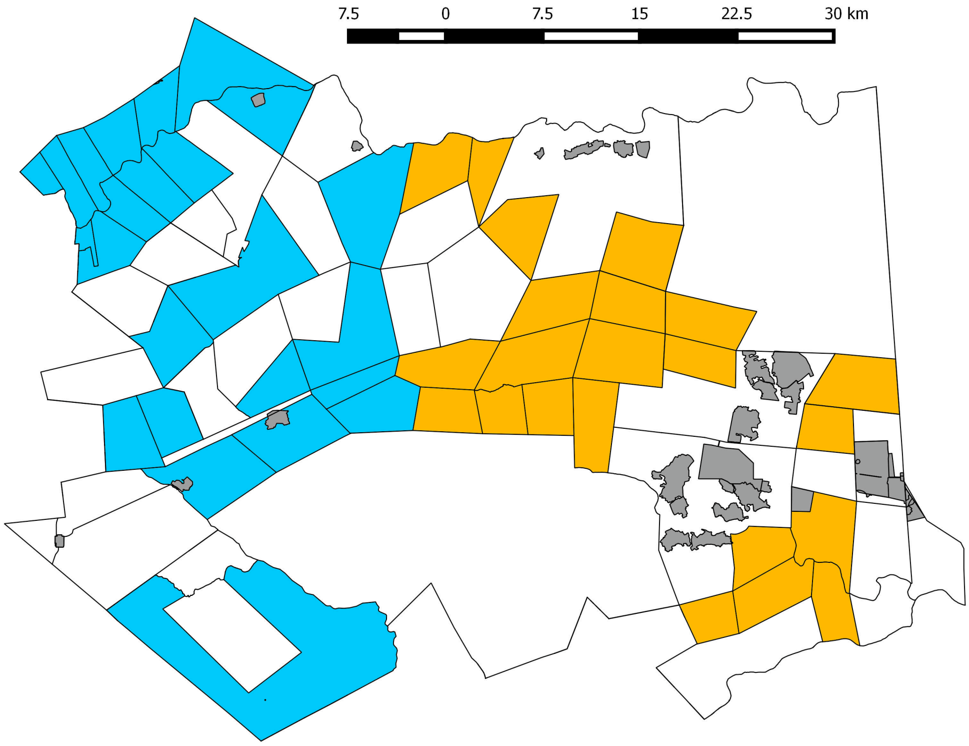

Figure 8. Grouped commercial farms. East (yellow) and West (blue).

Geographic information software (QGIS) was used to map the different farms and communal lands, and calculate their surface area. The obtained areas were used to calculate herbivore population densities in the different locations. In order to compare these with wild herbivores, biomass was calculated assuming an average cattle weight of 400 kg for cattle, and 65 kg for goats, based on field observations during livestock auctions. Biomass and stock rates were calculated for all commercial farms and grouped communal lands, down to kilograms per square kilometre.

In the case of wild herbivores, the same procedure was used. The average mass for the different species were obtained from Stuart and Stuart (2007), and used to calculate biomass for three groups based on feeding habits: elephants, browsers and grazers. Biomass was calculated per square kilometre.

Table 3. **Species categories and average mass.**

Species	**Category**	**Mass (kg) interval (Stuart and Stuart, 2007)**	**Average mass (kg)**
Domestic livestock			
Cattle (*Bos primigenius* Taurus)	Grazer	-	400
Domestic goat (*Capra aegagrus*)	Browser	-	65
Wild herbivores			
African buffalo (*Syncerus caffer*)	Grazer	700 (male) 550 (female)	625
African bush elephant (*Loxodonta africana*)	Grazer/browser	5,000-6,000 (male) 2,800-3,500 (female)	4,400
Black rhinoceros (*Diceros bicornis*)	Browser	800-1,100	950
Blue wildebeest (*Connochaetes taurinus*)	Grazer	250 (male) 180 (female)	215
Bushbuck (*Tragelaphus sylvaticus*)	Browser	45 (male) 30 (female)	37,5
African bushpig (*Potamochoerus larvatus*)	Browser	60	60
Giraffe (*Giraffa camaleopardis*)	Browser	970-1,400 (male) 700-950 (female)	825
Hippopotamus (*Hippopotamus amphibious*)	Grazer	1,000-2,000 (male) 1,000-1,700 (female9	1,425
Greater Kudu (*Tragelaphus strepsiceros*)	Browser	250 (male) 165 (female)	207,5
Impala (*Aepyceros melampus*)	Browser	50 (male) 40 (female)	45
Nyala (*Tragelaphus angasii*)	Browser	108 (male) 62 (female)	85
Plains zebra (*Equus quagga*)	Grazer	290-340	315
Warthog (*Phacochoerus africanus*)	Grazer	60-105 (male) 45-70 (female)	82,5
Waterbuck (*Kobus ellipsiprymnus*)	Grazer	250-270 (male) 210-130 (female)	240
White rhinoceros (*Ceratotherium simum*)	Grazer	2,000-2,300 (male) 1,400-1,700 (female	1,825

3.2.2 Trend assessment and comparison

Biomass linear trends were calculated in order to assess population trends over time for cattle, goats and wild herbivores. A two-tailed analysis correlation coefficient was performed between the following groups: communal-commercial and communal-Balule, in order to study the similarity of the different population trends. In order to compare the monthly livestock values with the annual game counts, the livestock densities for July (end of the climatic year) were used.

The correlation of communal livestock, commercial livestock and wild herbivores with rainfall was also assessed, in order to assess the influence of rainfall in inter-annual variations in population densities. Analysis of variance (ANOVA) was used to compare populations in communal lands with commercial farms and wild herbivores.

3.2.3 Geographic assessment

Geographic information software was used to map herbivore population densities for the different regions in July 2007 and July 2013, as well as population change rates between those two dates.

3.2.4 face-to-face questionnaire

The information obtained during the interviews was used to obtain relevant statistical values on average stock per farmer, stock proportions of different animals, reasons for changes in stock numbers, reasons to want to own more cattle or not, and additional winter feed provision.

3.3 Ethical considerations

This research was performed after the Ethics approval from both Central European University and SANParks. Before the interviews, permission was obtained from the local authorities of the local authorities, which were informed of the nature and purpose of the study. Before conducting interviews, the nature of the study was explained to the interviewees, confidentiality was ensured, as well as the volunteer nature of the participation in the study, and feedback on the results of the study was promised. Upon completion of the study and analysis of the results, a two pages leaflet was produced and distributed at the dip-tanks by a bi-directional approach: through the veterinary technicians of the Department of Agriculture, and through SAEON's environmental monitors.

3.4 Limitations

The following methodological difficulties were encountered during this study:

- Time constrains: the speed of the process was limited by the bureaucratic procedures required to obtain data and the permission to perform the study, already limited by the three month maximum visa period. The data of some conservation areas never arrived, and the data of the Department of Agriculture required of repeated visits to their offices in order to get it.
- Lack of long-term data: in the Department of Agriculture, records older than 2007 were non-existent, lost or in unknown location.
- Language barrier: in the local communities, many livestock owners did not speak English (especially the older ones, who would speak Afrikaans instead). Every time it was possible, the interviews were done in English. Where this was not possible, an interpreter (provided for help by SAEON and who attended all of the field visits) would help in the process.
- Farmers' mistrust: often, the farmers showed reluctance to participate in the study due to fear that the researcher worked for the Government, or by fear that the research was going to give the information to somebody interesting in taking their cattle away. Often, they tried to avoid the approach, or even walk away as soon as they could, even with the interview not finished. This is due to the high crime rates in the area, and the regularity of cattle theft.
- Data quality and reliability: in the case of the livestock data, some considerations must be taken with regard to data quality. The full municipality area is monitored by only

four technicians, which means coverage is lacking in case of a disease outbreak or difficult weather conditions. The best coverage was that provided for communal cattle, the data for goats and commercial farms lands more gaps related with vaccination campaigns, weather complications, and leaves.

- Balule GR's intensive management means that it is not a 100% natural environment. Therefore, a comparison with more conservation areas would have improved the reliability of the results to make comparisons.

Chapter 4 - Results

4.1 Ba-Phalaborwa's livestock data

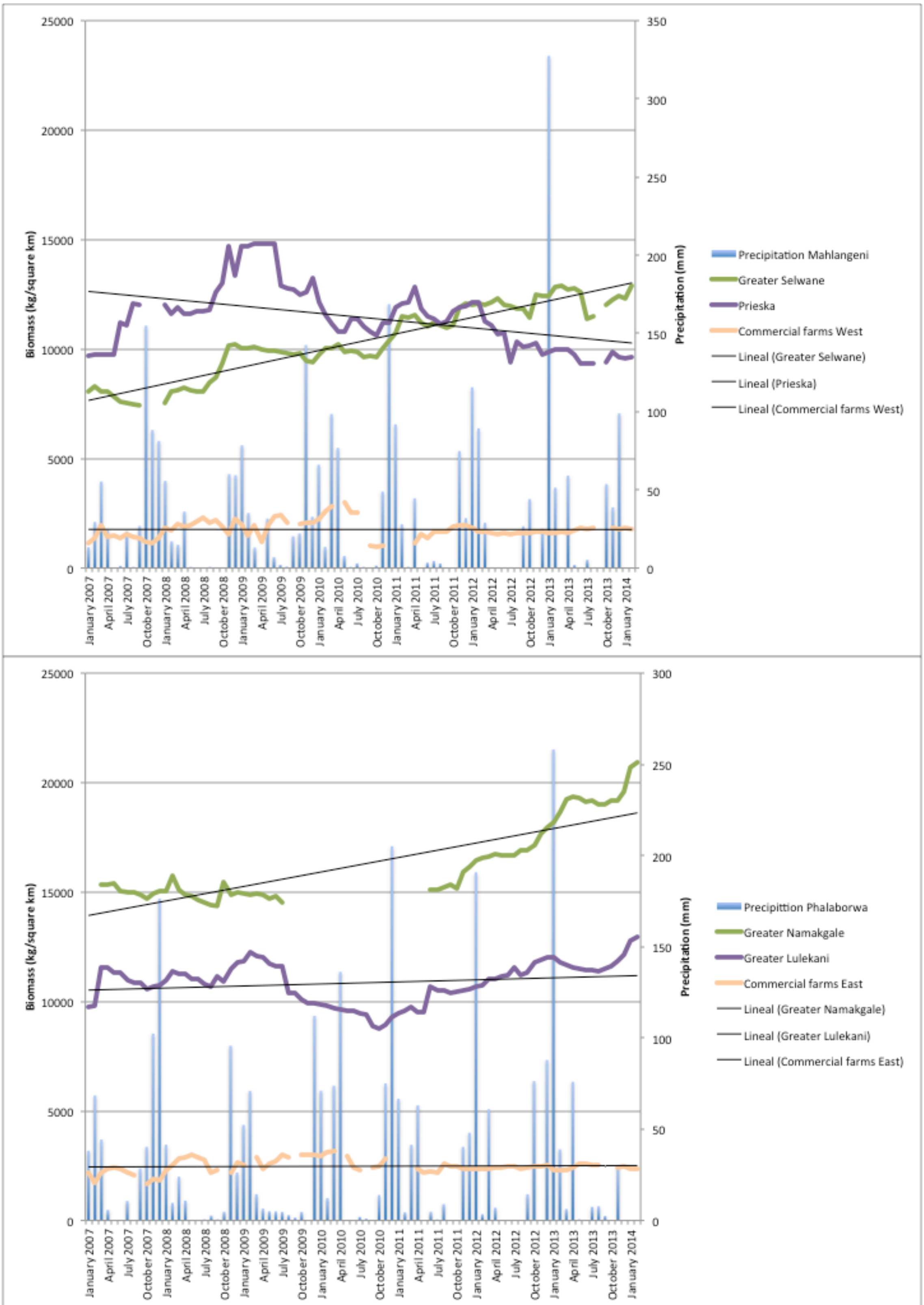

Figure 9. Monthly cattle stock rates and rainfall in Ba-Phalaborwa, Jan 2007- Febr 2014.

Table 4. Cattle population linear trends' slope and R^2 values.

Trend line (cattle)	Slope	R^2
Greater Selwane	63,158	0,89427
Prieska	-27,774	0,21251
Commercial farms West	-0,1407	7,6E-5
Greater Lulekani	7,7667	0,00437
Greater Namakgale	55,096	0,71982
Commercial farms East	0,7155	0,00345

Cattle stock rates in communal lands were 3-9 times higher than those of commercial farms, as seen in Figure 9. The ANOVA resulted in a p=6E-10 for similarity between Greater Selwane, Prieska and the Western commercial farms, and a p=2,6E-15 for Greater Lulekani, Greater Namakgale and the Eastern commercial farms, indicating a lack of similarity in stock rates.

Commercial farms showed not only similarly low stock rates, but also stable growth trends (Table 4). This was not the case for communal lands (Figure 9). Amongst them, only Prieska showed a declining trend, but it seems to have stabilised from 2011. Greater Lulekani's stock rate's trend line indicates a slow growth, but it overlooks the decline in population size for the years 2009-10, from which it started growing again. Greater Namakgale shows the highest stock rates, and an ascending growth trend, but there is a gap in the data for the period 2009-10 (no officer was filling that position after the retirement of the last person). The fastest growth rates were those of Greater Selwane, which had the second highest stock rate in 2014.

A correlation analysis using correlation coefficients was attempted in order to assess the similarity in the long term trends of cattle in communal rangelands and commercial farms. None of the results were significant, indicating a lack of correlation (Table 5).

Table 5. Correlation coefficient analysis for Ba-Phalaborwa's cattle.

Test	Correlation coefficient	Degrees of freedom	0.05 value (two tailed)	Significance (two tailed)
Cattle (G.Namakgale) Vs. annual rainfall (Phalaborwa)	0,615	2	0,95	No
Cattle (G.Lulekani) Vs. annual rainfall (Phalaborwa)	-0129	3	0,878	No
Cattle (G.Selwane) Vs. annual rainfall (Mahlangeni)	0,362	3	0,878	No
Cattle (Prieska) Vs. annual rainfall (Mahlangeni)	-0,474	3	0,878	No
Cattle (G.Namakgale) Vs. biannual rainfall (Phalaborwa)	0,658	2	0,95	No
Cattle (G.Lulekani) Vs. biannual rainfall (Phalaborwa)	0,375	3	0,878	No
Cattle (G.Selwane) Vs. biannual rainfall (Mahlangeni)	0,729	3	0,878	No
Cattle (Prieska) Vs. biannual rainfall (Mahlangeni)	-0,205	3	0,878	No
Annual cattle mortality (North) Vs. annual rainfall (Mahlangeni)	0,314	4	0,811	No
Annual cattle mortality (South) Vs. annual rainfall (Phalaborwa)	-0,498	4	0,811	No
Annual cattle mortality (North) Vs. biannual rainfall (Mahlangeni)	-0,203	4	0,811	No
Annual cattle mortality (South) Vs. biannual rainfall (Phalaborwa)	-0,78	4	0,811	No
Cattle (commercial farms East) Vs. annual rainfall (Phalaborwa)	0,339	5	0,754	No
Cattle (commercial farms West) Vs. annual rainfall (Mahlangeni)	-0,208	5	0,754	No
Cattle (commercial farms East) Vs. biannual rainfall (Phalaborwa)	-0,432	5	0,754	No
Cattle (commercial farms West) Vs. biannual rainfall (Mahlangeni)	-0,061	5	0,754	No
Cattle (G. Namakgale) Vs. cattle (commercial East)	-0,018	54	0,273	No
Cattle (G. Lulekani) Vs. cattle (commercial East)	-0,089	72	0,232	No
Cattle (G. Selwane) Vs. cattle (commercial West)	-0,099	71	0,232	No
Cattle (Prieska) Vs. cattle (commercial West)	0,191	71	0,232	No

The same procedure was used to assess the effect of rainfall on stock rates. The correlation analysis for cattle populations and rainfall (Table 5) was analysed in two different ways. 1) stock rate at the end of the climatic year (June) versus annual rainfall (July-June), and 2) stock rate at the end of the climatic year (June) versus bi-annual rainfall (the two previous climatic years), in order to assess the multi-year effects of variations in precipitation and their delayed effects on herbivore populations. However, no significant correlation was found. The correlation coefficient was also used to compare mortality rates and rainfall, with a negative result. However, Figure 10 suggests that a correlation may exist: the largest peaks in mortality (those bigger than 1%) took place during the dry season (the winter months: July-December), or just at the end of it (January 2010). Mortality data was only available for cattle, so no assessment was performed for goats.

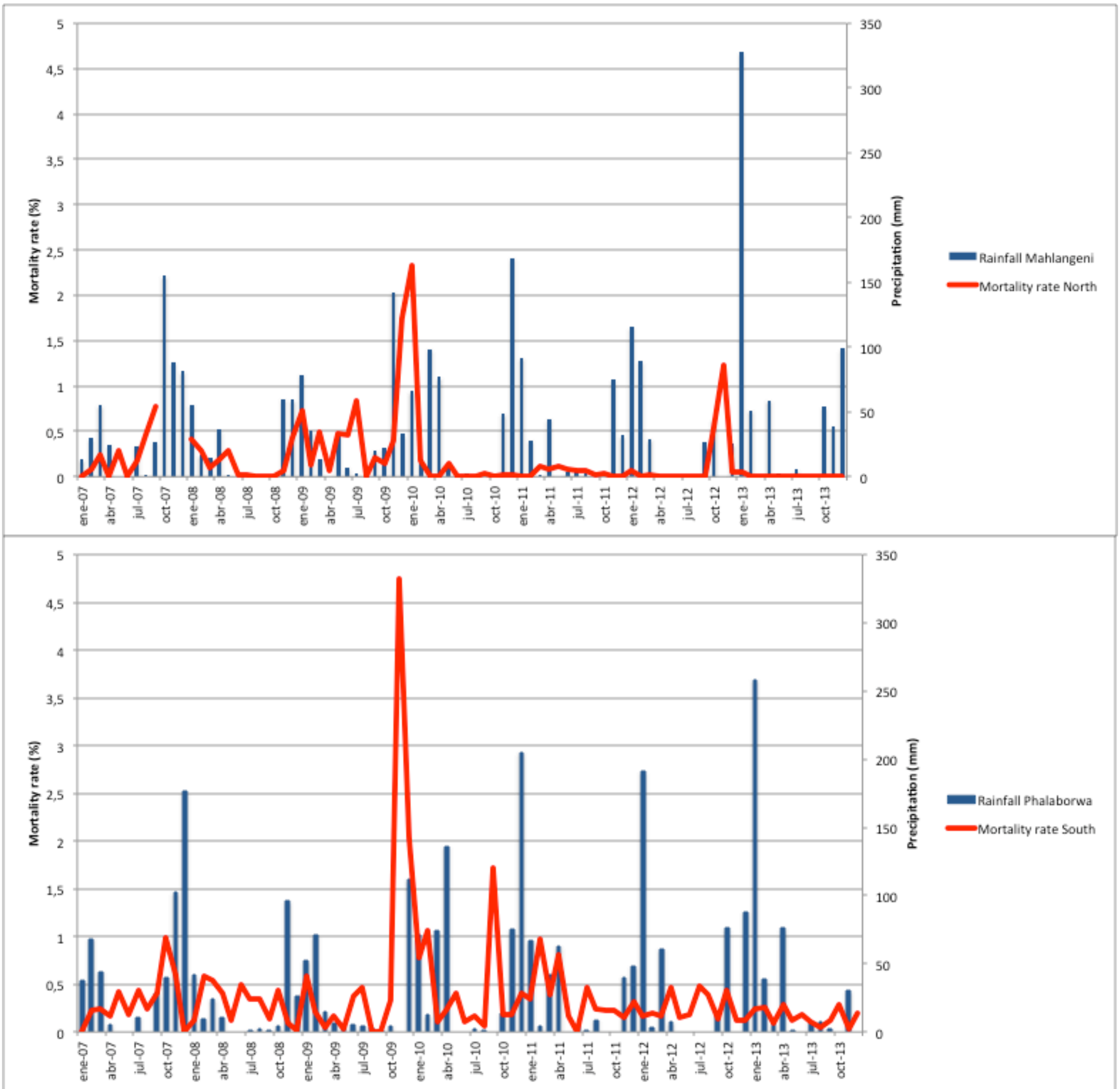

Figure 10. Monthly rainfall and cattle mortality in communal rangelands.

In the case of goats, commercial farms showed ascending trends (Figure 11, Table 6). Figure 11 suggests that these trends have stabilised in the last year. Both groups of farms have shoed substantial increases in their stock rates (from 0 to 200 kg/km^2 in the Eastern group, and from 50 to 150 in the Western one).

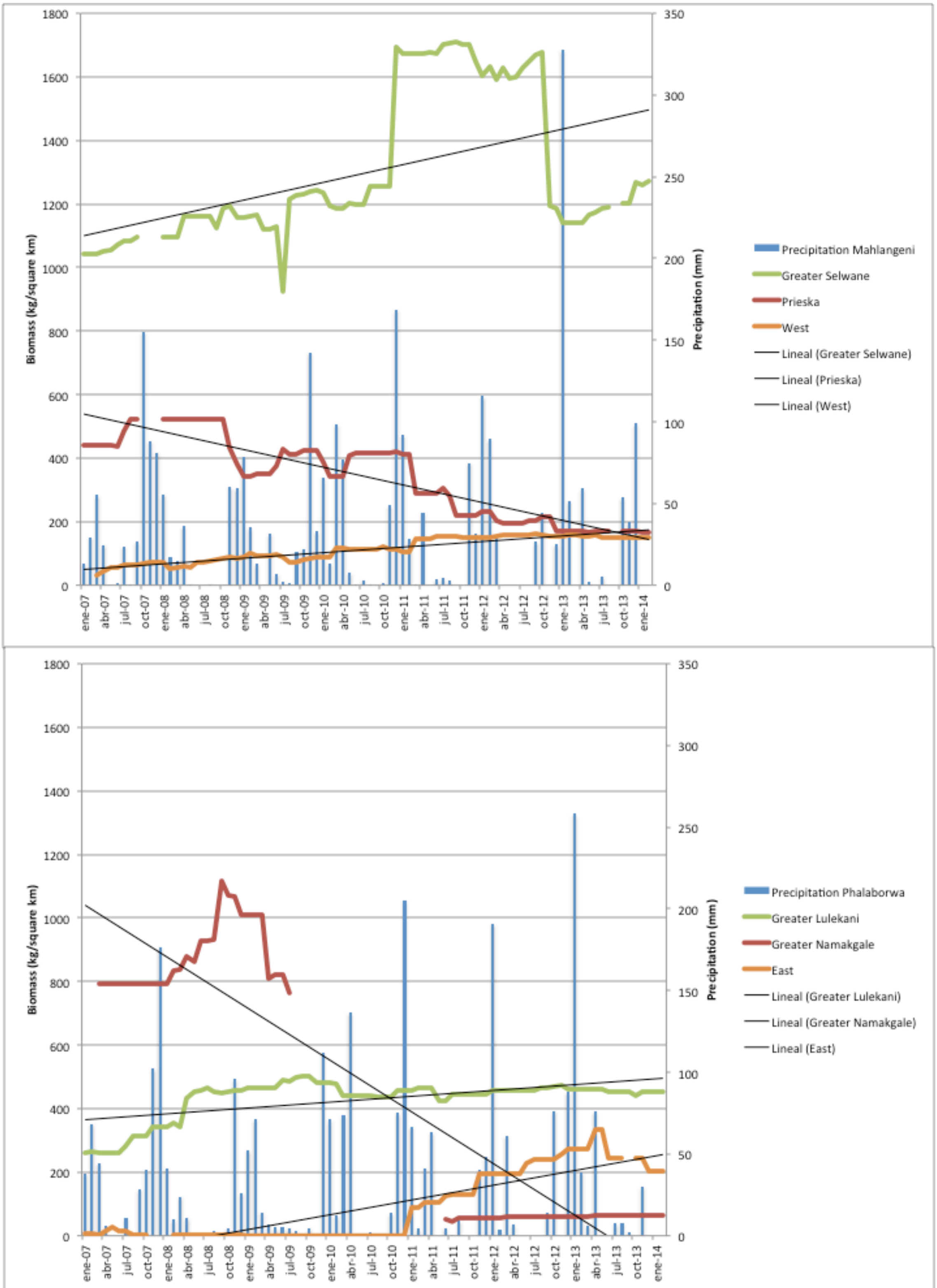

Figure 11. Monthly goat stock rates and rainfall in Ba-Phalaborwa, January 2007-February 2014.

Table 6. Goat population linear trends' slope and R^2 values.

Trend line (goats)	Slope	R^2
Greater Selwane	0,1531	0,23789
Prieska	-0,1527	0,82185
Commercial farms West	0,0482	0,97941
Greater Lulekani	0,0504	0,36527
Greater Namakgale	-0,4448	0,83488
Commercial farms East	0,127	0,74877

In communal lands, Prieska and Greater Namakgale showed substantial declines in goat stocks, being particularly severe that of Greater Namakgale (from 1100 kg/km^2 in 2008, to bellow 100 in 2010). Greater Lulekani showed an ascending trend line, but the graph suggests that this growth was mostly concentrated in 2007 and 2008, having remained stable ever since. However, the most striking case was Greater Selwane: it showed and overall ascending trend, but in late 2012 it experienced a 30% increase, only to drop again to below the original level in late 2012.

Table 7. Correlation coefficient analysis for Ba-Phalaborwa's goats.

Test	Correlation coefficient	Degrees of freedom	0.05 value (two tailed)	Significance (two tailed)
Goats (G.Namakgale) Vs. annual rainfall (Phalaborwa)	-0,548	2	0,95	No
Goats (G.Lulekani) Vs. annual rainfall (Phalaborwa)	0,322	3	0,878	No
Goats (G.Selwane) Vs. annual rainfall (Mahlangeni)	0,108	3	0,878	No
Goats (Prieska) Vs. annual rainfall (Mahlangeni)	-0,256	3	0,878	No
Goats (G.Namakgale) Vs. biannual rainfall (Phalaborwa)	-0,799	2	0,95	No
Goats (G.Lulekani) Vs. biannual rainfall (Phalaborwa)	-0,237	3	0,878	No
Goats (G.Selwane) Vs. biannual rainfall (Mahlangeni)	0,317	3	0,878	No
Goats (Prieska) Vs. biannual rainfall (Mahlangeni)	0,628	3	0,878	No
Goats (Commercial West) Vs. annual rainfall (Phalaborwa)	0,365	5	0,754	No
Goats (Commercial East) Vs. annual rainfall (Mahlangeni)	0,502	5	0,754	No
Goats (Commercial West) Vs. biannual rainfall (Phalaborwa)	0,704	5	0,754	No
Goats (Commercial East) Vs. biannual rainfall (Mahlangeni)	0,764	5	0,754	**Yes**
Goats (G. Namakgale) Vs. goats (commercial East)	-0,923	55	0,273	**Yes**
Goats (G. Lulekani) Vs. goats (commercial East)	0,274	79	0,232	**Yes**
Goats (G. Selwane) Vs. goats (commercial West)	0,613	77	0,232	**Yes**
Goats (Prieska) Vs. goats (commercial West)	-0,90	77	0,232	**Yes**

As with the case of cattle, correlation coefficients and their significances were calculated to assess the similarity of the stocks in communal lands and those of commercial farms, and to correlate goat populations with yearly rainfall, using the same procedures. Greater Namakgale and Prieska were found to have goat stocks negatively correlated with those of their nearby commercial farms (East and West, respectively), whereas stocks in Greater Lulekani and Greater Selwane were found to be positively correlated with the Eastern and the Western commercial farms, respectively. With regard to the relationship between goat stocks and rainfall, only the Easter commercial farms showed a significant correlation with biannual rainfall. All the other communal lands, as well as the Western commercial farms had stock rates that were not correlated with neither annual nor biannual rainfall.

An ANOVA was done in order to assess the similarity between commercial and communal goat stocks. Both the analysis for Prieska, Greater Selwane and Western commercial farms (p=1,8E-9) and for Greater Lulekani, Greater Namakgale and Eastern commercial farms (p=4,8E-8) suggested no similarity between the populations.

4.2 Balule GR

As Figure 12 shows, herbivore populations in Balule showed overall rising trends for all the groups analysed (total herbivore biomass, browsers, and grazers; and elephants, buffaloes and impalas as most representative species). Elephants where the group that accounted for the largest biomass, and hence the one that influenced the total count the most. They showed the greatest fluctuations, showing declines in and after the driest years (2006-07, 2008-09 and 2011-12), when rainfall felt below 350 mm. As seen in figure 13, impalas also showed declines after the driest years (which can also be observed in the case of grazers, for impala was the species that accounted for the greatest biomass in this group), but only when rainfall felt below 310 mm. Buffaloes only declined after the driest season. Correlation coefficients were calculated in order to test these trends (Table 9), and elephants were found to be positively correlated with bi-annual rainfall.

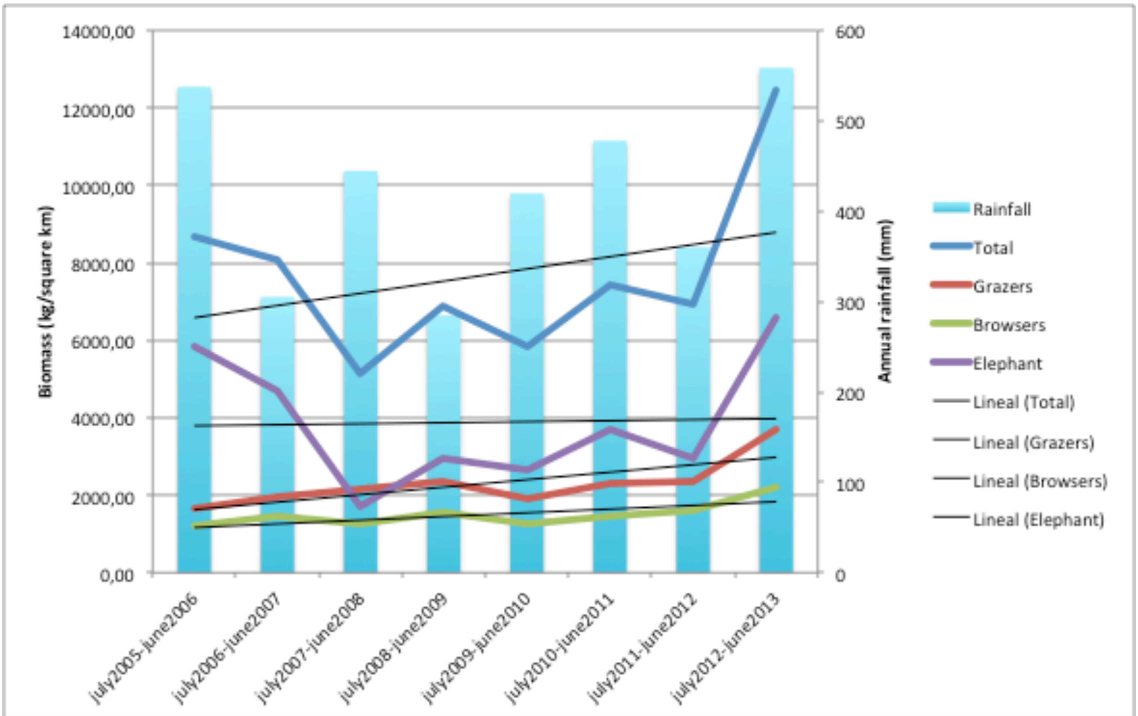

Figure 12. Herbivore biomass and annual rainfall by the end of the climatic year in Balule GR.

Table 8. Wild herbivore population linear trends' slope and R^2 value.

Trend line (Balule)	**Slope**	**R^2**
Total herbivore biomass	314,67	0,11774
Elephants	26,099	0,00145
Grazers	193,1	0,59739
Browsers	95,464	0,53033
Buffaloes	129,61	0,5777
Impalas	69,242	0,64703

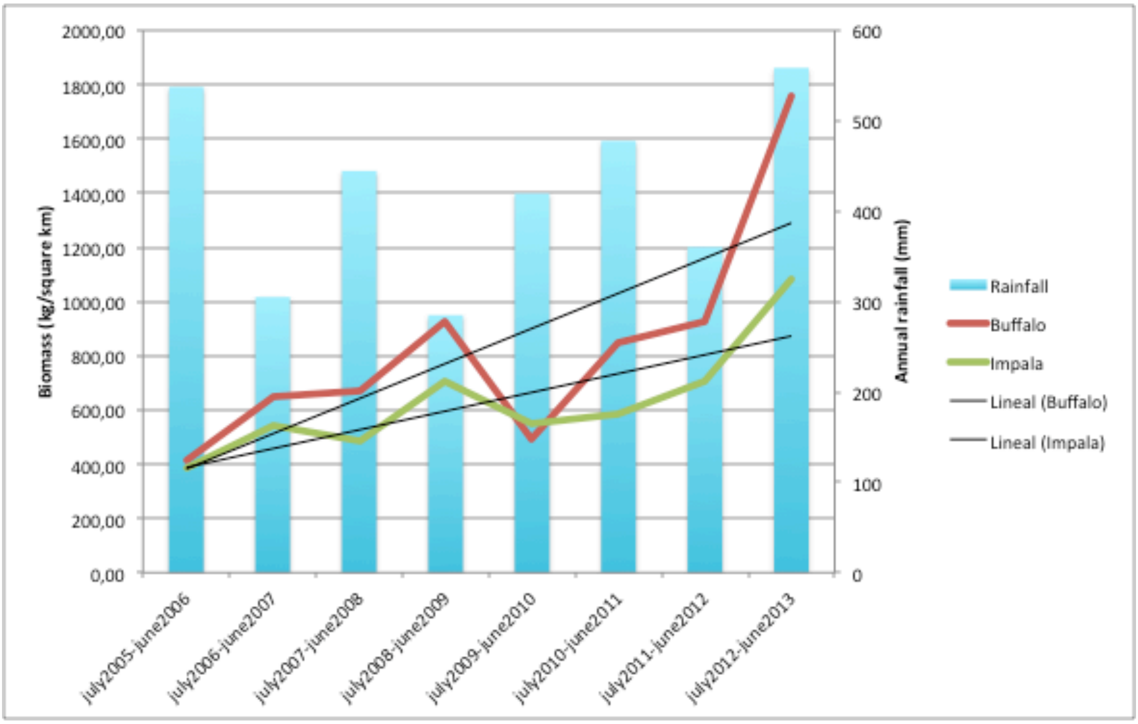

Figure 13. Buffalo and impala biomass and annual rainfall at the end of the climatic year in Balule GR.

Table 9. Correlation coefficient analysis for Balule GR's herbivores.

Test	Correlation coefficient	Degrees of freedom	0.05 value (two tailed)	Significance (two tailed)
Balule herbivores Vs. annual rainfall (Phalaborwa)	0,509	6	0,707	No
Balule elephants Vs. annual rainfall (Phalaborwa)	0,529	6	0,707	No
Balule grazers Vs. annual rainfall (Phalaborwa)	0,317	6	0,707	No
Balule browsers Vs. annual rainfall (Phalaborwa)	0,191	6	0,707	No
Balule buffaloes Vs. annual rainfall (Phalaborwa)	0,264	6	0,707	No
Balule impalas Vs. annual rainfall (Phalaborwa)	0,148	6	0,707	No
Balule herbivores Vs. biannual rainfall (Phalaborwa)	0,753	5	0,754	No
Balule elephants Vs. biannual rainfall (Phalaborwa)	0,758	5	0,754	Yes
Balule grazers Vs. biannual rainfall (Phalaborwa)	0,618	5	0,754	No
Balule browsers Vs. biannual rainfall (Phalaborwa)	0,663	5	0,754	No
Balule buffaloes Vs. biannual rainfall (Phalaborwa)	0,553	5	0,754	No
Balule impalas Vs. biannual rainfall (Phalaborwa)	0,541	5	0,754	No

4.3 Comparison between wild and domestic herbivores

In Figure 15 we can see that total herbivore biomass in communal lands (cattle and goats) has been systematically larger than that of Balule GR (all herbivore species) until 2013, when a sharp rise in elephant biomass took place.

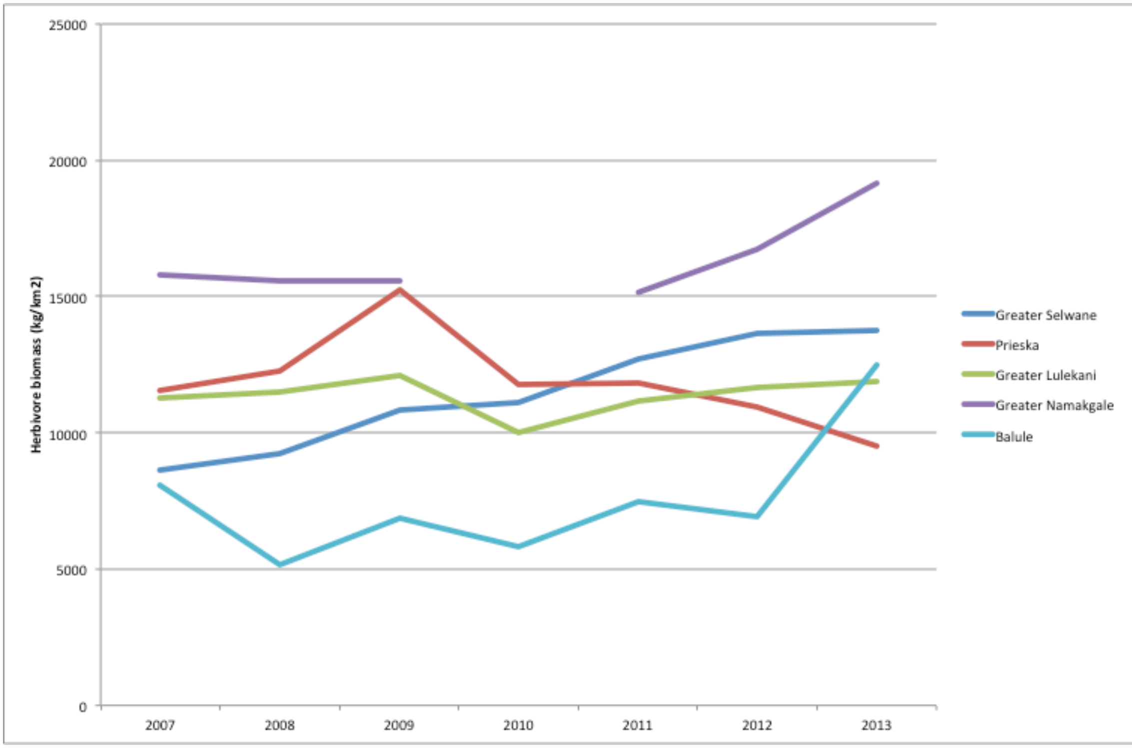

Figure 14. Total herbivore biomass in communal lands and Balule GR, 2005-13.

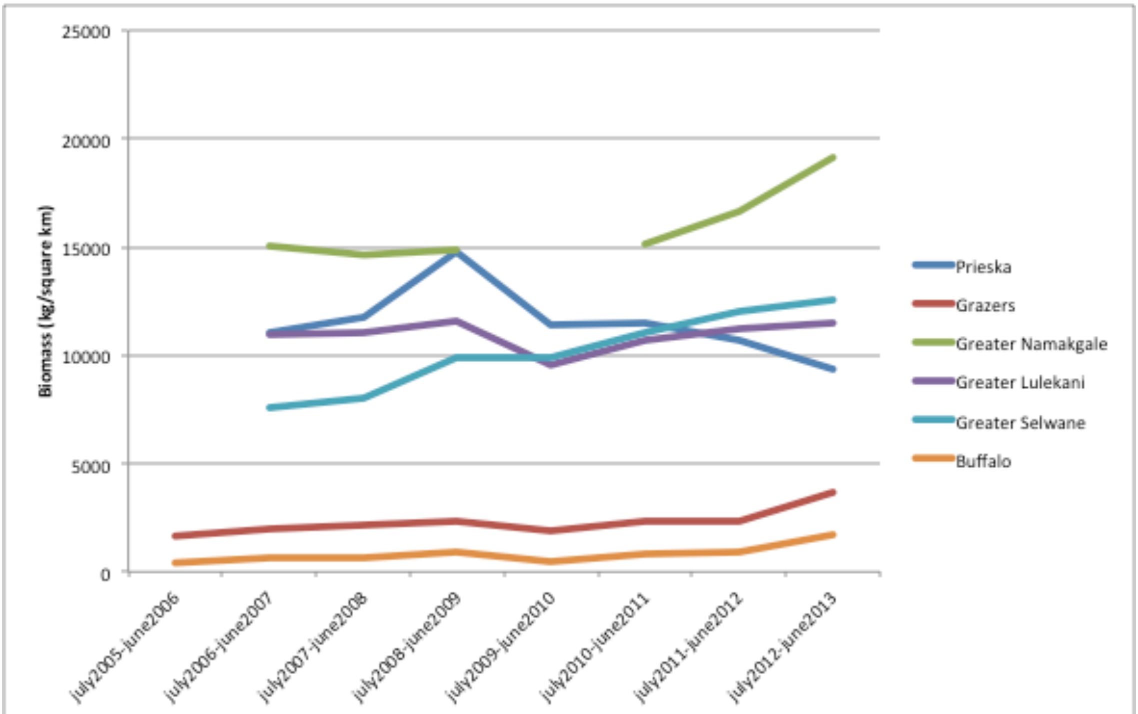

Figure 15. Communal cattle, buffalo and total grazer biomass, 2005-13.

In Figure 15, cattle biomass in communal rangelands is systematically higher than grazer biomass in Balule (ANOVA result p=8,9E-14). This is not the case for goats: only Prieska reached a goat biomass greater than that of browsers in Balule, and it was the only one whose biomass was systematically higher than that of impalas. The other three communities' biomass was considerably smaller. However, goat populations and grazers were found to be distinct under ANOVA (p=1,8E-10).

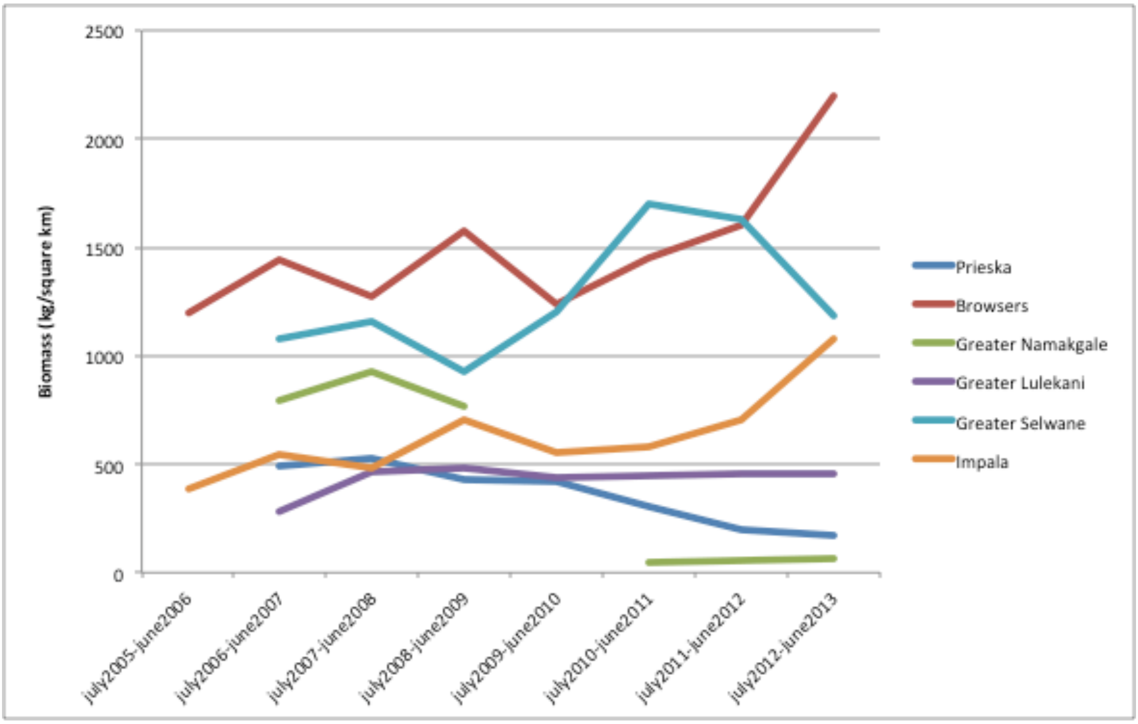

Figure 16. Communal goat, impala and total browser biomass, 2005-13.

A correlation coefficient analysis was performed to test the relationships between communal and commercial cattle and grazers and buffaloes, and between goats and browsers and impalas (Table 10). The results indicate significant positive correlation between buffaloes and grazers in Balule and cattle in Greater Namakgale, and a significant negative correlation between impalas and grazers in Balule and goats in Prieska. A 10% tolerance interval also hinted a positive correlation between buffaloes and grazers in Balule and cattle in Greater Selwane.

Table 10. Correlation coefficient analysis for communal livestock and Balule GR's herbivores.

Test	Correlation coefficient	Degrees of freedom	0.05 value (two tailed)	Significance
Balule buffaloes Vs. cattle (G. Lulekani)	0,599	5	0,754	No
Balule buffaloes Vs. cattle (G. Namakgale)	0,932	4	0,811	**Yes**
Balule buffaloes Vs. cattle (G. Selwane)	0,710	5	0,754	Yes
Balule buffaloes Vs. cattle (Prieska)	-0,415	5	0,754	No
Balule impalas Vs. goats (G. Lulekani)	0,261	5	0,754	No
Balule impalas Vs. goats (G. Namakgale)	-0,567	4	0,811	No
Balule impalas Vs. goats (G. Selwane)	-0,053	5	0,754	No
Balule impalas Vs. goats (Prieska)	-0,770	5	0,754	**Yes**
Balule grazers Vs. cattle (G. Lulekani)	0,522	5	0,754	No
Balule grazers Vs. cattle (G. Namakgale)	0,922	4	0,811	**Yes**
Balule grazers Vs. cattle (G. Selwane)	0,700	5	0,754	No
Balule grazers Vs. cattle (Prieska)	-0,55	5	0,754	No
Balule browsers Vs. goats (G. Lulekani)	0,139	5	0,754	No
Balule browsers Vs. goats (G. Namakgale)	-0,574	4	0,811	No
Balule browsers Vs. goats (G. Selwane)	-0,024	5	0,754	No
Balule browsers Vs. goats (Prieska)	-0,749	5	0,754	**Yes**
Balule grazers Vs. cattle (Commercial East)	0,211	5	0,754	No
Balule grazers Vs. cattle (Commercial West)	-0,253	5	0,754	No
Balule browsers Vs. goats (Commercial East)	0,739	5	0,754	No
Balule browsers Vs. goats (Commercial West)	0,510	5	0,754	No
Balule buffaloes Vs. cattle (Commercial East)	0,218	5	0,754	No
Balule buffaloes Vs. cattle (Commercial West)	-0,324	5	0,754	No
Balule impalas Vs. goats (Commercial East)	0,716	5	0,754	No
Balule impalas Vs. goats (Commercial West)	0,528	5	0,754	No

4.4 Geographic assessment

Figures 20 and 21 show biomass in our study area in July 2007 and July 2013, respectively. The cattle biomass for the different commercial farms and communal lands was represented whereas, for Balule, the total grazers biomass was used. We can observe, in both cases, that the highest densities of cattle take place in the communal lands and in a group of three plots in the Western part of the municipality: the darkest spot corresponds to Josephine Farm, where the feedlot is. Two nearby farms show as well high densities of cattle.

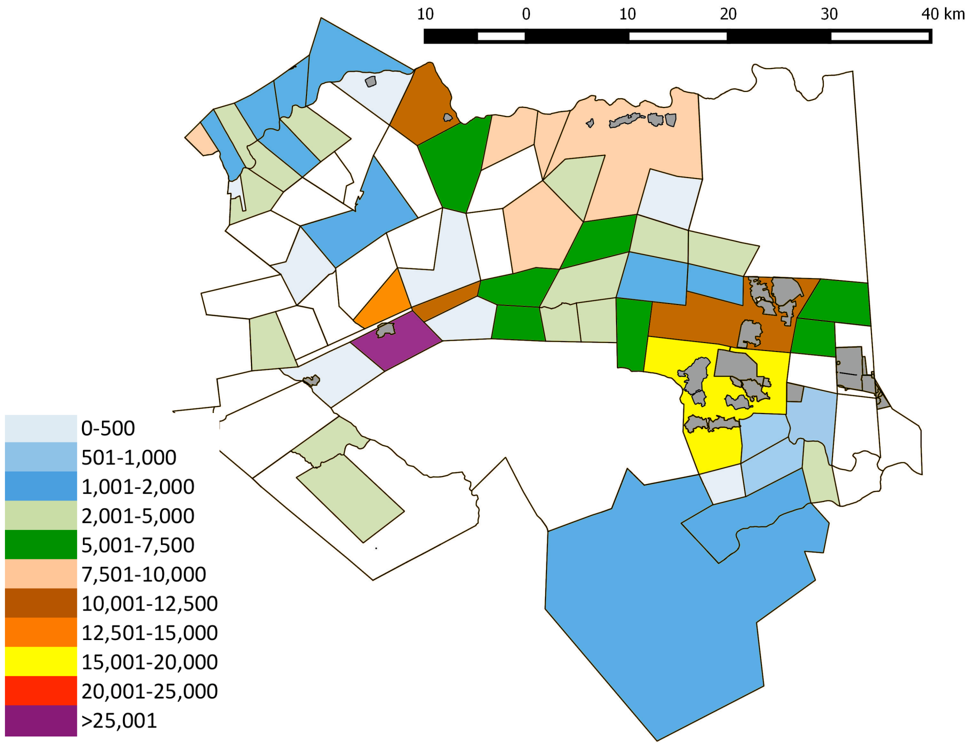

Figure 17. Cattle and grazer biomass (in kg/km^2), July 2007.

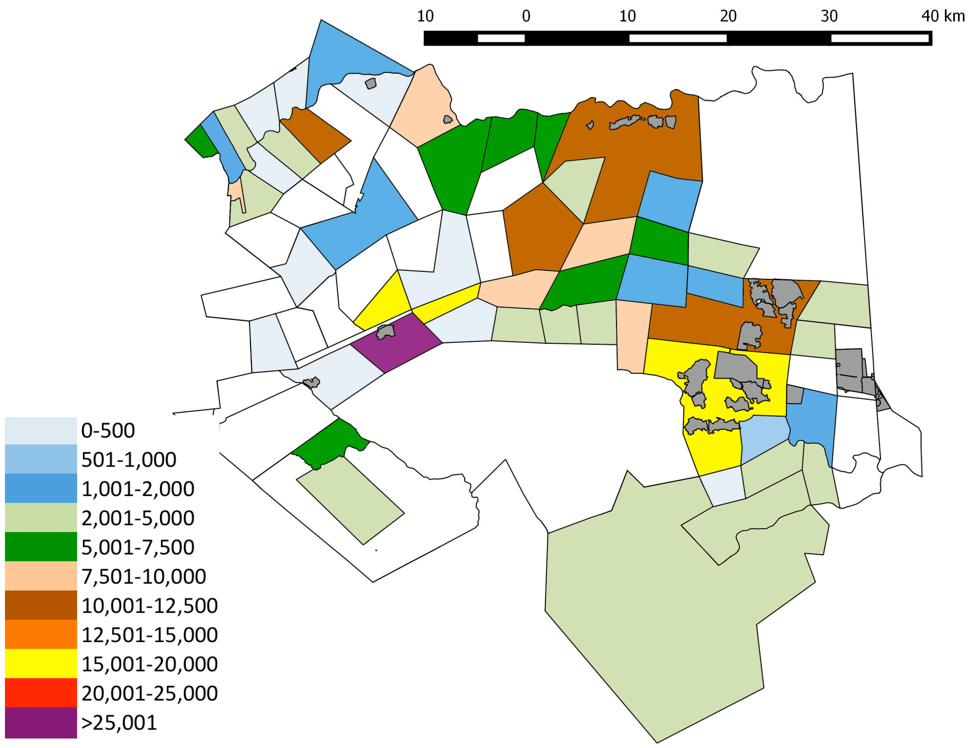

Figure 18. Cattle and grazer biomass (in kg/km^2), July 2013.

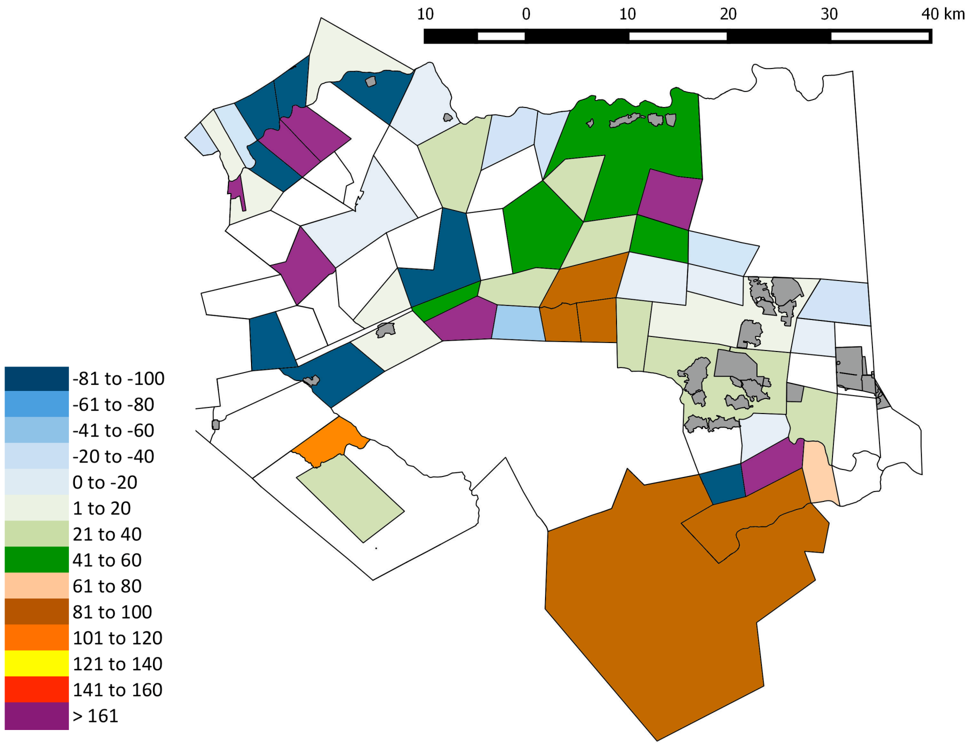

Figure 19. Change in cattle and grazer biomass for the period July 2007-July 2013 (as %).

Figure 19 shows the percentage of change for cattle and grazer biomass during the same period. We can observe the increases of grazer biomass in Balule, Greater Selwane and Greater Namakgale. 8 commercial farms have stopped their operations (dark blue plots), whereas some have dramatically increased their stock rates (purple).

On the contrary, Figures 20 and 21 show goat and grazer biomass in July 2007 and 2013, respectively. In 2007, we can observe the highest browser biomass in the communal lands and Balule, with low densities in commercial farms. By 2013, the highest densities take place in Balule, and decreases in most of the Eastern farms, with increases in the Eastern ones. We can observe as well the decline in goat numbers in Prieska and Greater Namakgale.

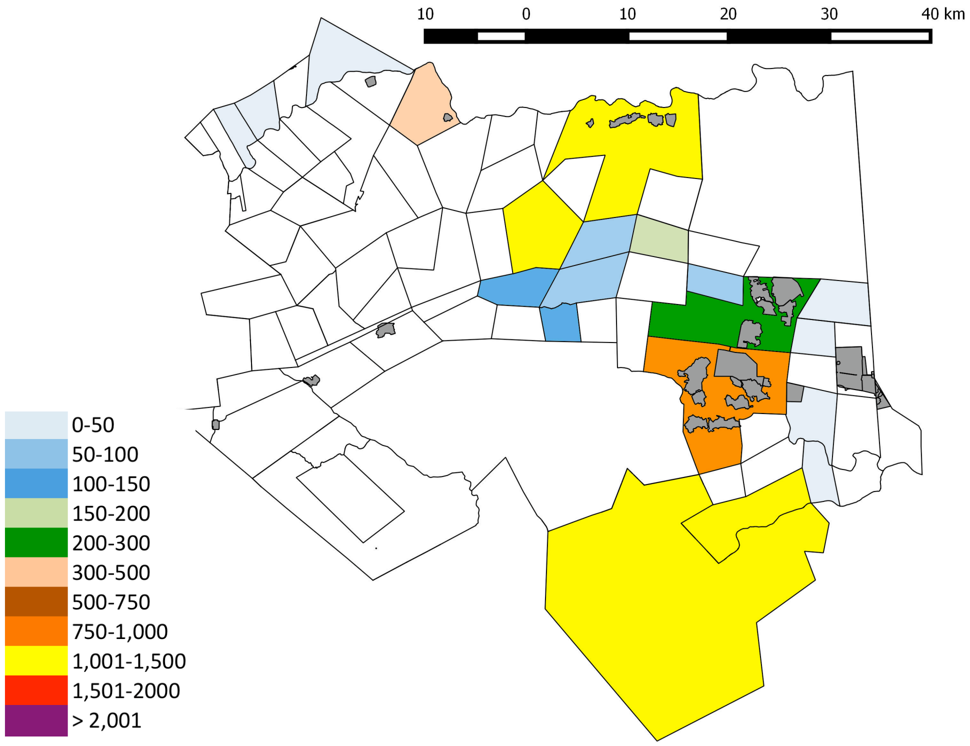

Figure 20. Goat and browser biomass (in kg/km^2), July 2007.

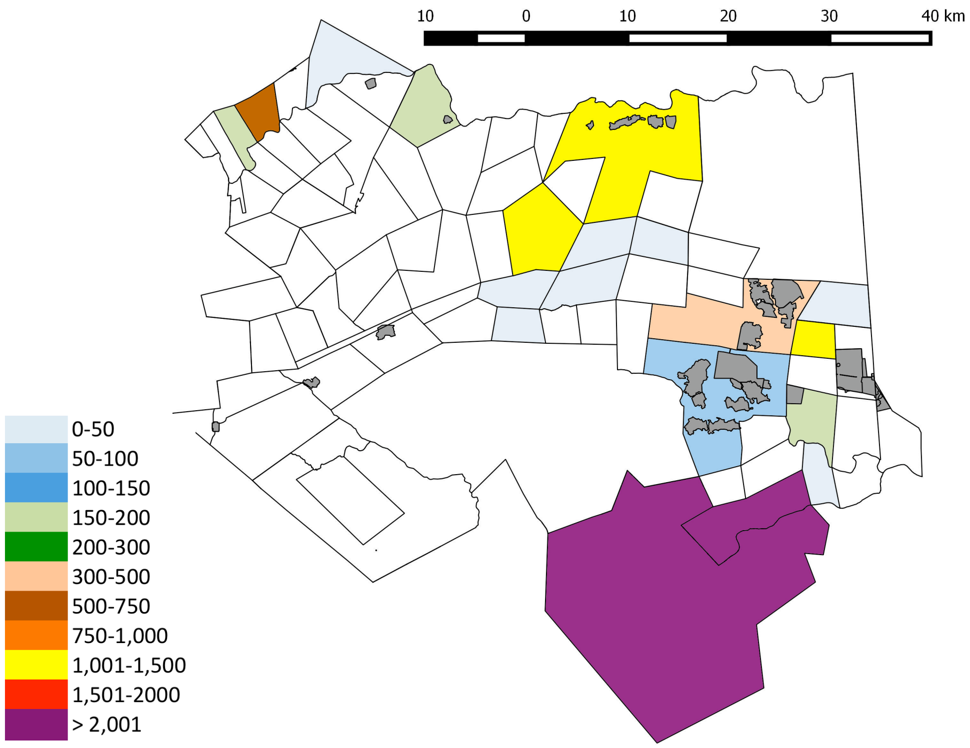

Figure 21. Goat and browser biomass (in kg/km^2), July 2013.

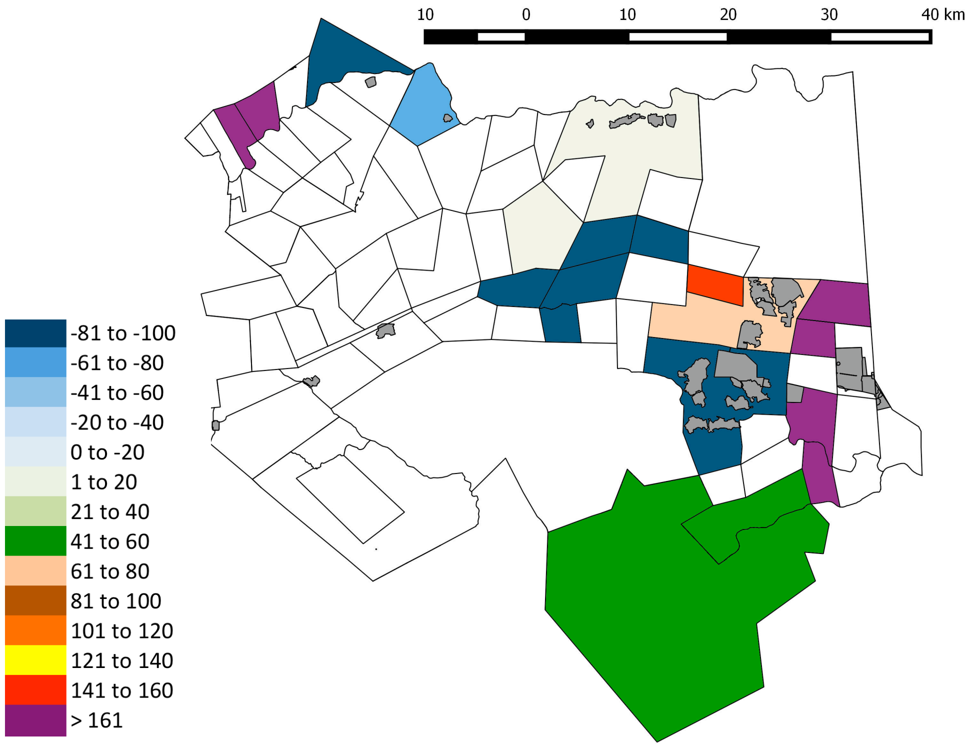

Figure 22. Change in goat and browser biomass for the period July 2007-July 2013 (as %).

However, Figure 22 shows the percentages of change in goat/browser rates. Some farms, despite small changes in the rates, experienced huge relative increases (as seen in violet), whereas many other suffered severe reductions in their stocks, or directly stopped raising goats (dark blue). The increase in Greater Lulekani and Balule can be observed, as well as the decreases in Prieska and Greater Namakgale.

4.5 Face-to-face questionnaire

As seen in Table 11, the average number of heads of cattle per farmer was 4,68, being the lowest in Makushane (3,76) and the highest in Selwane (5,51).

Table 11. Average heads of cattle per farmer.

	Average head of cattle/farmer
Makushane (Greater Namakgale)	3,77
Mashishimale (Greater Namakgale)	4,88
Lulekani (Greater Lulekani)	4,32
Nondweni (Greater Selwane)	4,75
Selwane (Greater Selwane)	5,51
Maseke (Greater Namakgale)	4,72
Benfarm (Greater Lulekani)	4,74
Total	4,68

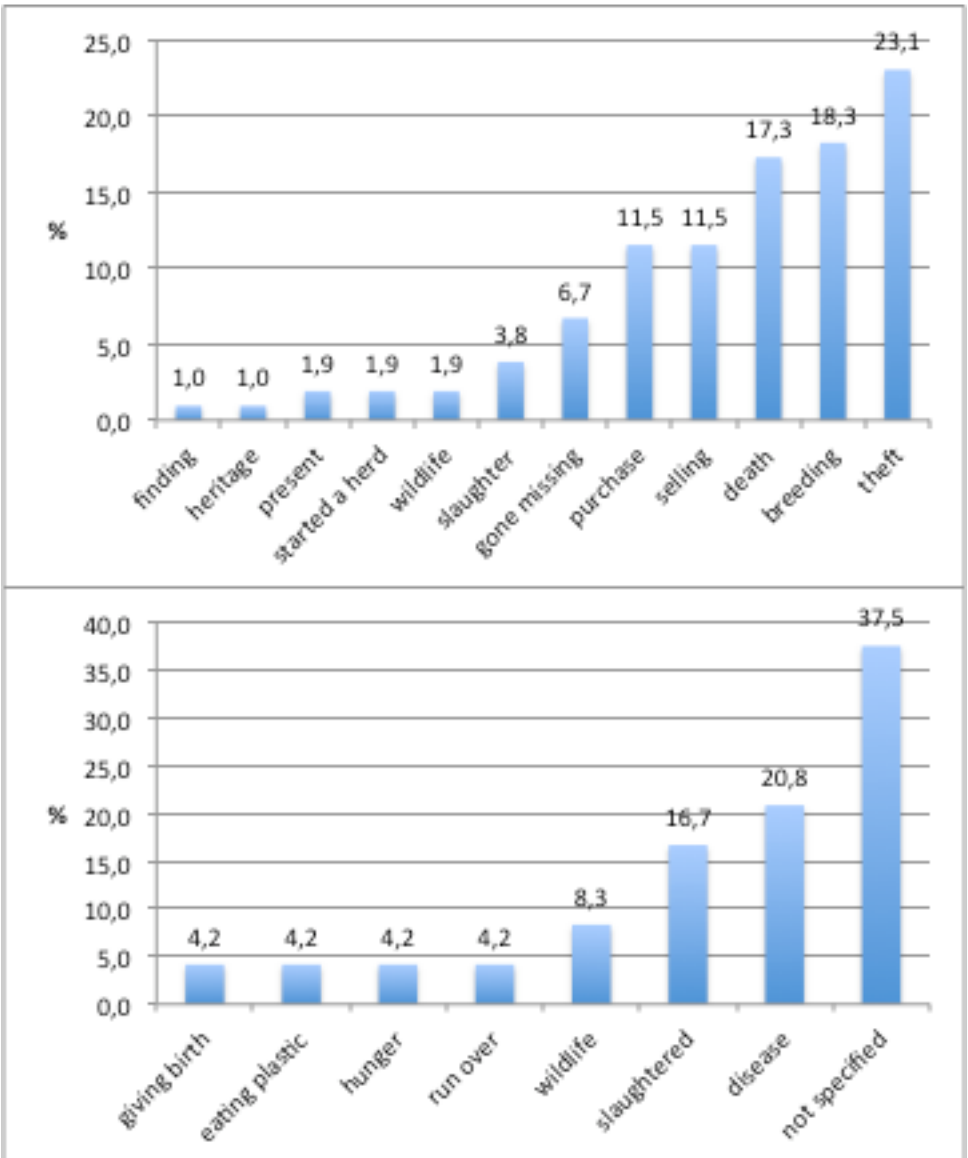

Figure 23. **Reasons for change in cattle numbers**. General reasons (above) and causes of death (below).

The most mentioned reason for change in cattle number was theft (23,1%), which was mentioned more often than breeding (18,3%), death (17,3%) or commercial transactions (23%). A farmer affirmed to have found a cow in the bush, another one to have received them as heritage, and two to have received cattle as a present. Slaughtering the cattle was not a desirable option, and was reserved for special occasions such as funerals. Within the reasons for cattle death, disease was the one mentioned most often (20,8%), followed by slaughter (16,7%) and death by wild animals such as lions (8,3%, which only happened in Greater Selwane, due to its proximity with Letaba Ranch GR).

78,5% of the farmers affirmed that they would like to own more cattle, which was perceived as a very good investment option according to 40,3% of them (Figure 23, above). Another 35,5% said they wanted to have more cattle because they depended on it for their livelihoods. Other reasons included love for animal husbandry (4,8%) and the fact that owning cattle is an indicator of personal, economic, and social success (4,8%). Only 4,8% of the farmers owned cattle in order to make business with it, and only 1,6% as a source of food.

Only 21,5% of the farmers said they did not want to own more cattle. As seen in Figure 24 (below), the reason mentioned most often for this was uncertainty and lack of safety, (35,7%) following by not being able to afford cattle maintenance/looking after costs (28,6%). People who already had a job were not so interested in owning cattle either (14,3%), whereas 7,1% mentioned the lack of grazing as a concern and a limitation. 14,3% believed they had as much cattle as they wanted already.

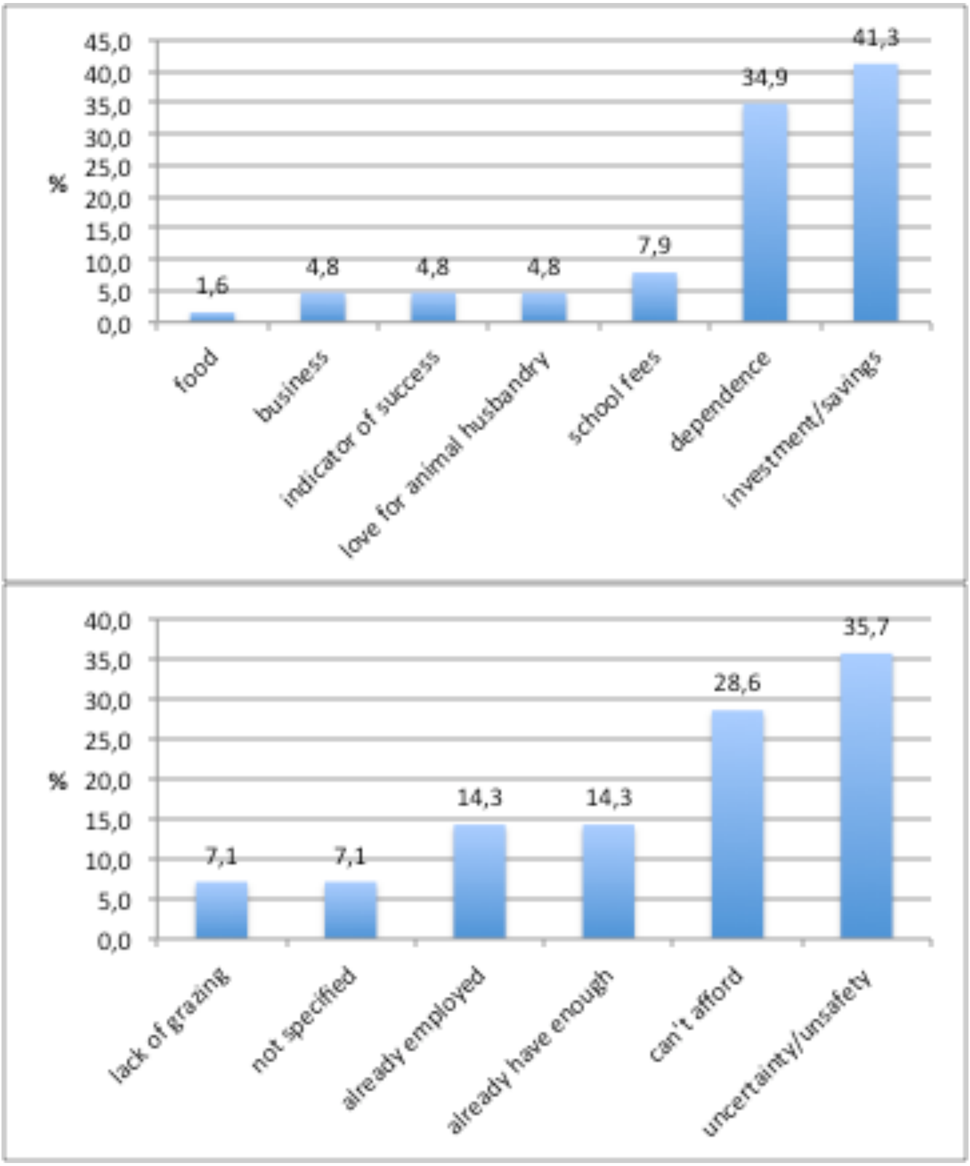

Figure 24. Reasons to own (above) or not to own more cattle (below).

An average 58,7% of farmers affirmed to provide their cattle with additional winter feed. However, the differences between villages were great, from the 100% in Makushane to the only 20% in Benfarm, as shown in Figure 25. The only village with artificial water points for livestock was Selwane, with 8 wells. In the other villages, livestock just gets the water from naturally occurring sources.

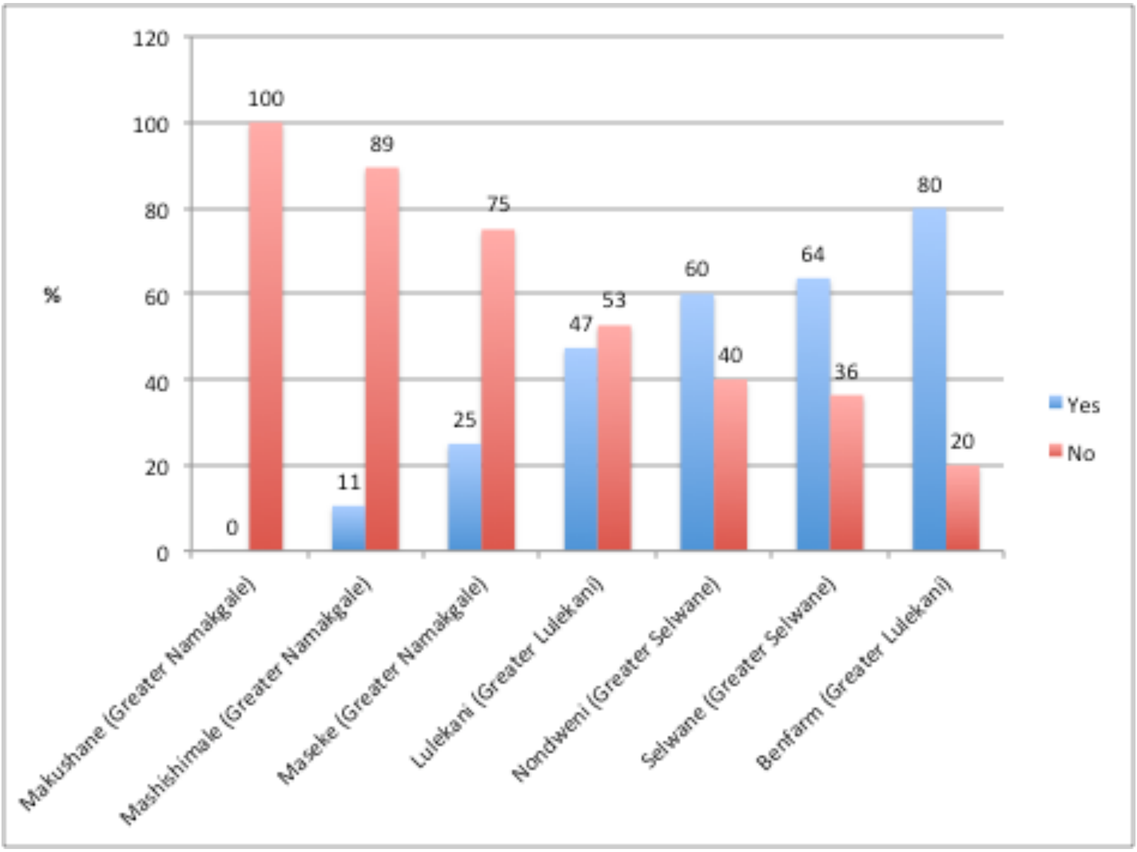

Figure 25. Winter feed provision.

During the interviews, a surprising fact arose. Many formerly white-owned commercial farms have undergone land-claims in order to return the land to the communities. In the case of the Makwena and Loskop territories this was a fact, and the livestock owner of Selwane begun to bring their cattle to those territories in 2010, enlarging the communal rangeland significantly. However, these were not the only territories claimed by these communities: the Nondweni B and Waterbok farms were told to have undergone the claim as well, but they have experienced an "spontaneous privatisation" (Behnke, 1995; Graham, 1988) or capture (Lawry, 1990; White, 1992), for some members of the community squatted the land before the legal procedures were over and begun doing commercial cattle farming there.

Chapter 5 - Discussion

5.1 Ba-Phalaborwa's livestock

5.1.1 Cattle

The data showed ascending trends for three of the communal rangelands (Greater Namakgale, Greater Lulekani and Greater Selwane). The highest stock rates (above 20,000 kg/km^2) were those of Greater Namakgale, where the trend had not stabilised yet. However, this was not the case for nearby Greater Lulekani where, despite some oscillations, the stocking rate had not grown that rapidly and seemed to have oscillated around the 11,000 kg/km^2. The second highest stock rate was that of Greater Selwane, which seems to keep on rising and had already achieved 12,000 kg/km^2.

But this has not always been this way: Prieska had the highest stock rates in 2009, reaching 15,000 kg/km^2 after a fast rise from 10,000 kg/km^2 in two years. However, this did not last for long, and in late 2009 the numbers started declining, and seem to have stabilised finally around the original stock rate (10,000 kg/km^2) since 2013. This is remarkably similar to the stock rate of Greater Lulekani, which, as already mentioned, showed a long lasting stability around that level. This may indicate that the land was indeed over-stocked, and the stock rates declined back to the ecosystem's carrying capacity.

So how do the other two communities manage to keep on rising their stock rates? One plausible answer could be the land quality, as mentioned often by farmers in Greater Selwane during the interviews, who blamed their soil to be very good and productive. Other explication could be the provision of winter-feed. However, the stock rate in Greater Selwane is still not that high (just above 12,000 kg/km^2), and it could be stabilizing around that level during the last couple of years. Moreover, the use of winter-feed in Greater Selwane was not widespread (Figure 25), although, opposite to other villages, they had eight artificial water points. The most remarkable case would therefore be Greater Namakgale, with its very high and rising stock rates, and where most farmers provided winter feed to their animals (Figure 25).

In any case, the stock rates of commercial ranches were much lower and constant than those of communal lands, and both seemed to follow a stable trend around the 2,000 kg/km^2. This could be due to the application of strict stock rates on private properties, and adherence to them, which is not the case in communal land. However, as seen in Figures 20 and 21, the stock rates may differ greatly across farms, and, while some farms stop their operations, some other intensify them. This could indicate a transfer of stock from some farms to the others, hence the stability of their overall stocking rate over the 8-year study period.

The fact that neither communal mortality rates, commercial farm stock rates or communal rangeland stock rates seemed to be correlated with rainfall, hints towards an intensive management of the stock. However, all peaks in mortality rates higher than 1% happened during the dry season or just at the end of it (Figure 10), suggesting a weaker correlation that may have not been detected by the correlation coefficient analysis.

5.1.2 Goats

In the case of goats, the situation was clearly different to that of cattle. Figure 11 shows how Prieska's goat stock rate converges with that of the Western Commercial farms, which followed descending and ascending trends, respectively. Both seemed to stabilize at the same level, close to 200 kg/km^2. The Eastern commercial stock followed as well an ascending trend and seemed to stabilize at the same level. Therefore, we have only two cases that diverge from these "convergence to 200" situation: Greater Selwane and Greater Namakgale.

Greater Selwane had the highest stock rates and an overall ascending trend, but it also showed and the most striking situation: the *plateau* in the graph during the years 2011 and 2012, when the stock rate first rose sharply from 1,200 kg/km^2 to a new stable level around 1,700 kg/km^2, and the sudden reduction back to 1,200 kg/km^2. Since that population crash, the trend seemed to slowly go upwards once more. In the case of Greater Namakgale, it had a high and rising stock rate in 2007 and 2008, moment in which the population seemed to crash. Unfortunately, the register stops at that moment, and the next available data corresponds to July 2011, moment from which the stock rate seemed to have stabilized below 100 kg/km^2.

The correlation coefficient analysis confirmed these results: the goats of Greater Namakgale were negatively correlated with those of the Eastern commercial farms, and those of Prieska with the Western ones, whit which they converged. On the other hand, Greater Lulekani was positively correlated with the Easterb commercial farms, even if with higher stock rates, and Greater Selwane was positively correlated with the Western farms, following similar overall ascending trends. These convergent trends may indicate a transfer of stock from some territories to others, as in the case of cattle.

Goats differed as well from cattle in that the stock rates of one group (the Eastern commercial farms) were positively correlated with bi-annual rainfall. A possible explanation is that goats are not as intensively managed as cattle, and consequently resemble more a "natural population", and are therefore more dependent on natural resources and environmental constrains.

5.2 Balule GR wild herbivores

The herbivore populations were found to be growing since 2006 (Figure 12). Elephant biomass was found positively correlated with bi-annual rainfall. Impalas and buffaloes (Figure 13) were not significantly correlated, but they showed small declines after the driest years (rainfall of 310 mm or lower). This may indicate 1) a weak correlation, that the test was not able to detect, or 2) a lower dependence on rainfall influx of water. This option seems opportune to Balule, where artificial water points are relatively abundant (4,7//km^2). This abundance of water points suggests that these are small. Therefore, they may be sufficient to supply water during the dry season for smaller ungulates, and even buffaloes, but not that much for elephants, given their large biomass and water and food needs. The same may apply to winter feed, which is know to be used in Balule at times during the dry season.

5.3 Comparison between wild and domestic herbivores

Communal cattle were compared to the total grazer biomass, and to total buffalo biomass (being buffaloes the closest equivalent to cattle amongst the wild herbivores). Cattle biomass in communal lands was between 3 and 8 times higher than that of grazers. Cattle and grazer biomass was found to be positively correlated with Greater Namakgale's cattle with 5% confidence interval, and with Greater Selwane's cattle with a 10%. This suggests that some factor is driving both populations, even if with very different population size. This may be the provision of winter feed, similar dependences on rainfall, or even disease outbreaks, for buffaloes and cattle share many infectious diseases.

However, goat stock rates were not higher than browser biomass but in one single occasion for one single community (Greater Selwane, which showed the highest stock rate). Only Greater Selwane showed a continued greater biomass than that of impalas. The only significant correlation was that of impalas and browsers with Prieska's goats, that turned out to be negative. This can be attributed to the different vegetation types between both locations and the slightly different rain regime in both areas.

5.4 Face to face questionnaire

78,5% of the cattle owners in the communal lands stated that they would like to own more cattle, due to different reasons, being money the main limiting factor in the size of their herd. This is due to the perception of cattle as a great investment option, with much higher return rates than keeping money in a bank (3% return rate or lower), for cattle grows and breeds, generating large returns in only one year. From this, it can be inferred that cattle numbers are likely to keep on increasing in these communities. In many cases, people also stated their dependence on livestock for their livelihoods, due to unemployment, or to pay the school fees and equipment for their sons and daughters.

It is remarkable the level of insecurity found in the villages, being theft the most mentioned reason for both change in cattle numbers and reasons not to want to own more cattle (Figures 23 and 24). Stolen cattle are not sold for cash to some other owner, but rather it is rapidly slaughtered in order to sell the meat. Therefore, stolen cattle can be considered as removed from the stock, theft acting in an equivalent manner to top predators in conservation areas. It can be deducted that, shall the security improve, stock rates would grow faster than now. Theft and insecurity damaged the herds of many owners, and during a field visit in Maseke, the case of a farmer who got all of his 50 cows stolen was reported during the interview as an example of this problem, which was widespread through all the communities.

The survey covered winter feed as well. In the villages within the Greater Namakgale group, most of the farmers (even all of them, such as in Makushane) had to provide winter feed. In Greater Selwane, more people could pass the winter without extra feed for the animals than the ones that provided it, and in Greater Lulekani winter-feed was used more often in Lulekani than in Benfarm.

This is consistent with the stock rates. Greater Namakgale showed the highest stock rates, and consequently winter-feed was widespread. From this, we can infer rangeland deterioration and overstocking of the communal rangeland. Conversely, in Greater Lulekani, where the growth trend remained more or less stable, fewer people needed the winter feed, from which we can infer that the stock rates are adequate to the location. In Greater Selwane, where the stock rate keeps on growing, most cattle owners did not provide additional winter-feed to their animals. They affirmed that, despite the dry weather, the soil was very rich. All these hints towards the fact that the carrying capacity of the local ecosystem may habe not been reached yet.

5.5 Further implications

5.5.1 Rangeland degradation and stock rate sustainability

We have discussed the different trends followed by cattle and goats in the different villages, as well as possible explanations for these. Also, we saw that these are several times higher than commercial stock rates and naturally occurring herbivores, the formers showing stable trends, and the later showing ascending ones. What are the implications of these results? Several non-excluding options arise:

- Considering that naturally occurring herbivore populations keep on growing in Balule, this may indicate the carrying capacity of that ecosystem has not been achieved yet.

- The stock rates of the commercial farms may be too conservative, such as in the case of communal rangelands in Kwazulu-Natal described by Tapson (1990, 1991).
- The stock rates in communal rangelands may be too high, and may be kept at that level by the provision of supplementary feed. This seems to be the case particularly in Greater Namakgale, where feed use was widespread. This is similar to the case in the Sterkspruit District, as studied by Vetter and Bond (2102).
- Prieska's cattle population may have crashed after rising to an unsustainable level, being now stable at a low level. This would follow a pattern similar to what Dean and MacDonad (1990) described in the Cape province.
- The differences in soil and vegetation characteristics in the different communal rangelands provide for different carrying capacities, therefore the ascending trends in some communities (particularly Greater Selwane, where feed provision was not widespread yet).
- The local ecosystems are very resilient, and even though livestock can foster changes in the plant community and composition, this does not necessarily mean reduced productivity, as described by de Bruyn (1998).

So, are the concerns for rangeland deterioration in communal rangelands (Hoffman and Ashwell, 2001; Vetter *et al.,* 2006) applicable in the Ba-Phalaborwa province? Our results indicate that this depends on the community. Greater Namakgale seems to be an example of rangeland degradation and over stocking, whereas Prieska could be of stock collapse, and Lulekani of long-term sustainable stock rates. This would also depend on vegetation and soil types, as seen with the case of Greater Selwane. However, further research would be needed to estimate the extent of rangeland deterioration in these communities, covering as well soil and plant community qualities.

5.5.2 Equilibrium or non-equilibrium systems?

There is a debate over whether arid and semi-arid rangelands, such as those in our study area, are equilibrium (Clements, 1916) or non-equilibrium systems (Noy-Meir, 1973; Ellis and Swift, 1988). As discussed above, it seems that the stock rates in communal rangelands in Ba-Phalaborwa are several times higher than those of naturally occurring herbivores and that, in some cases, this are kept at a high level by the means of winter feed and water provision. This supports the non-equilibrium systems theory, which states minimum or non-existent effects of herbivory in vegetation typical of equilibrium systems (Ellis and Swift, 1988; Behnke and Scoones, 1993), for herbivore populations cannot track vegetation due to the stochastic nature of the system (Smet and Ward, 2005), which we can observe through elephant population fluctuations in Balule GR. This theory also states that herbivores cannot cause land degradation (Ellis and Swift, 1988). But, if this was the case, why would the more highly stocked villages need more winter feed?

The most recent theory is the generalized dynamic equilibrium model/grazing reversal hypothesis (Milchumas *et al*., 1988; May *et al*., 2009; Oesterheld and Semmartin, 2011), which states a direct correlation between tolerance towards grazing in the ecosystem and the evolutionary history shared between grazing and the plant community. Given that human impacts on Southern African ecosystems have been present for thousands of years, this could explain the sustainability of high stocking rates, particularly where livestock has no competence of wild herbivores, such as in the communal rangelands of our study. However, this is just a theoretical hypothesis.

Illius and O'Connor (1999) stated that, in arid and semi-arid ecosystems, the population of herbivores is coupled to some key resources, such as water and vegetation, which limit the population size (especially during the dry season), and around which the effects of herbivory intensify. This model fits the best our study area, for the higher the stock rate, the higher it was the need for extra provisions of key resources (winter feed, or water).

5.5.3 A common pool resource, or a common property regime?

In Chapter 2.3.4, we discussed the discussion about whether South African communal lands are common pool resources (Ostrom, 1986) or common property regimes, with two different definitions: an extended one by Swallow (1990) and a reduced/minimum one by Lawry (1990). Do the communities in our study area fulfil the requirements for any of these two definitions?

In order to match Lawry's definition, defined membership rules ad exclusion on non-members are in place. However, we have seen that insecurity is widespread, and theft is a major problem with regard to the livestock resource. Therefore this definition is not fulfilled. Out of the five discussed requirements of Swallow's definition (Chapter 2,3.4), we can state that in these communal lands 1) members certainty on having access in the future to the resource is undermined by theft and insecurity, 2) in the case of the existence on communally-defined guidelines for resource use, these are not enforced, and 3) there is no punishing mechanism to combat deviant behaviour.

Therefore, we can say that communal rangelands in Ba-Phalaborwa either are or are becoming a common-pool resource, which has been previously reported to lead to increasing resource degradation (Veveld, 1992). As we have seen, 34,9% of livestock owners affirmed to depend on livestock for their livelihoods, and 7,9% needed it in order to pay for school costs.

Therefore, the swift towards a common pool resource undermines the livelihoods of livestock owners in the area in the long term.

Spontaneous capture (Lawry, 1990; White, 1992) privatisation of communal resources (Behnke, 1985; Graham, 1988) was also recorded in the area, with re-claimed lands being squatted and which should be benefitting all community members. All these corroborates the claims for the loss of power of traditional institutions over communal resources (Kaschula *et al*., 2005; Twine, 2005), which poses a threat to sustainability, for individuals get discouraged to self-control their use of the common pool resources (Scholes, 2009).

5.5.4 Uses and value of cattle

Cousins (1996) stated that, in village economies, are multi-purpose. Child *et al*. (2012), however, described them as having a cultural value, and as mechanism of savings and insurance form. Our findings agree with Child more than with Cousins, for most people mentioned “investment/savings” (41,4%) and “dependence” (34,9) as the main reasons to own livestock. The third most mentioned reason was “school fees” (7,9%, being all the other reasons secondary mentioned less that 5% of the times. he cultural component was reflected in those answers that stated “success in life” as a reason to own cattle (4,8%). The slaughter for meat was mentioned only 1,6 %. Therefore, we can guess that these herds are not that multi-purpose: the main three reasons (accounting for a total of 84,1% of the answers) were related with the generation of income. In Ba-Phalaborwa, the main and most important purpose of the cattle to grow, breed and, when big enough, be sold. Summarizing, to bring money to the household.

Chapter 6 - Conclusion

6.1 Research problem and questions: discussion

In South Africa, rangeland degradation is a source of main concern, especially in the heavily stocked communal lands (Hoffman and Ashwell, 2001; Vetter *et al*., 2006), although now study has yet analysed cattle populations in the Mopaneveld bioregion. Through this project, we analysed livestock population densities over time in communal lands in Ba-Phalaborwa, and we compared them with livestock population densities in commercial farms, with wild herbivores in a nearby conservation area (Balule GR) and with rainfall data. The objective was to study how these population densities were changing over time, and which were the driving forces for these changes. Were the research questions answered?

RQ1: How does the current density of livestock in rural areas compare with the density of herbivores in conservation areas?

Considering the biomass of all herbivores in Balule, the total biomass per square kilometre did not differ greatly from the stock rates in the communities: Greater Lulekani and Prieska were actually lower, but Greater Namakgale was over 50% higher. However, it is remarkable that this is due to the sharp rise in elephant numbers in Balule GR in 2013, and in previous years biomass in the communities has consistently been 2-3 times higher.

If we exclude elephants (due to their high mobility and their mixed feeding habits), and we take onto consideration only the comparison between similar groups of herbivores (cattle and grazers on the one side, and goats and browsers on the other) the results are different. Cattle biomass in the communities is and has been systematically 3-7 times higher than that of grazers in Balule GR whereas, in the case of goats, their biomass rarely exceeded that of browsers.

RQ2: How have these densities changed over time?

The evolution of livestock population differed between both kinds of livestock, and across communities. With regard to cattle:

- in Prieska the population reached a maximum in 2009 and then had declined to find stability at a lower level,
- Greater Lulekani showed a stable/slowly ascending trend, and
- Greater Selwane and Greater Namakgale showed rapidly growing trends, albeit stock rates were higher in the former than in the later.

With respect to goats,

- in Prieska the population rose to a peak in 2011 and then declined again,
- in Greater Lulekani they showed a stable trend,
- in Greater Selwane, the goat population is growing,
- in Greater Namakgale, the original population reached a peak in 2008, and then declined drastically to the current stable level.

In Balule GR:

- Herbivore populations showed an ascending trend.
- The most fluctuant population was that of elephants, which was moreover positively correlated with rainfall.

RQ3: What are the driving forces behind the observed results?

The strong correlation of cattle in Greater Namakgale and the weak correlation in Greater Selwane with the buffaloes and other grazers in Balule GR indicate common factors influencing population size. The absence of correlation with rainfall raises two possibilities:

- Human stock management, for rainfall did not exert a significant influence, and because the existence of artificial water provision in Balule GR and occasional winter feed, as in the villages.
- Disease, due to the same infectious diseases shared by cattle and buffaloes and that may me driving mortality for both.

6.2 Final remarks

The findings of this study indicate a trend towards higher cattle populations in the communal rangelands in Ba-Phalaborwa (with the exception of Prieska), given the observed population trends and the farmers' willingness and desire to enlarge their herds. However, some of these communal rangelands may be approaching dangerous stock rates and experiencing degradation, as deduction from the statistics on winter-feed. The fact that stock rates in all of the villages are higher than naturally occurring ones indicates that the communal rangelands may be already hosting livestock densities above a sustainable carrying capacity. The non-equilibrium nature of the local ecosystem provides it with the resilience to tolerate these high pressures, provided that winter-feed and water are provided to the animals during the dry season. However, the results obtained should be treated carefully, due to the data gaps and the limitations and constrains under which the study was conducted. A further study analysing vegetation and soil would be adequate to make a more complete assessment of rangeland conservation status in the area.

Another interesting finding is the insecurity in the communal lands, which severely affects the livelihoods of cattle owners. It may be one of main the forces preventing stock rates from growing unsustainably, but it is an important issue that needs to be rapidly addressed, due to their implications for rural households' income. The loss of power of the local authorities has undermined the common property regime, which is likely to lead to rangeland deterioration in the long term, if not in the short term.

References

Abel, N.O.J. 1993. Reducing cattle numbers on southern African communal range: is it worth it? In: *Range Ecology at Disequilibrium*, eds. R.H. Behnke, I. Scoones, and C. Kerven, 173-195. London: Overseas Development Agency (ODA), International Institute for Environment and Development (IIED) and Commonwealth Secretariat.

Abel, N.O.J. , and Blaikie, P.M. 1990. Land degradation, stocking rates and conservation policies in the communal rangelands of Botswana and Zimbabwe. In: *Pastoral Development Network Set 29*, paper 29a.

Adler, P.B., Raff, D.A., and Lauenroth, W.K. 2001. The effect of grazing on the spatial heterogeneity of vegetation. *Oecologia* 128: 465-479.

Agritrade. 2012. *Executive brief update: beef sector*. Available online at: http://agritrade.cta.int/Agriculture/Commodities/Beef/Executive-Brief-Update-2012-Beef-sector [consulted 7 March 2014].

Allred, B.W., Fuhlendorf, S.D., and Hamilton, R.G. 2011. The role of herbivores in Great Plains conservation: comparative ecology of bison and cattle. *Ecosphere* 2, art26.

Allred, B.W., Fuhlendorf, S.D., Smeins, F.E., and Taylor, C.A. 2012. Herbivore species and grazing intensity regulate community composition and an encroaching woody plant in semi-arid rangeland. *Basic and Applied Ecology*, 13: 149-158.

Allsopp, N., Gaika, L., Knight, R., monakisi, C., and Hoffman, M.T. 2007. The impact of heavy grazing on an ephemeral river system in the Succulent Karoo, South Africa. *Journal of Arid Environments* 71: 82-96.

Anderson, P.M.L., and Hoffman, M.T. 2007. The impacts of sustained heavy grazing on plant diversity and composition in lowland and upland habitats across the Kamiesber mountain range in the Succulent Karoo, South Africa. *Journal of Arid Environments* 70: 686-700.

Anthony, B., and Bellinger, E.G. 2007. Use and value of landscapes, flora and fauna by Tsonga communities in the rural areas of Limpopo Province, South Africa. *South African Journal of Science* 103 (3-4): 148-154.

Anthony, B., Abonyi, S., Terblanche, P., and Watt, A. 2011. Towards bringing worldviews in biodiversity conservation: exploring the Tsonga concept of *Ntumboloko* in South Africa. In: *Research in biodiversity – Models and applications*, Ed.: Igor Ya. Pavlinov, pp. 3-24. Rijeka, Croatia: InTech Open Acces Publishing.

Armest, J.J., and Pickett, S.T. 1985. Experiments of disturbance in old-field plant communities: impact on species richness and abundance. *Ecology* 66: 230-240.

Asner, G.P., Levick, S.R., Kennedy-Bowdoin, T., Knapp, D.E., Emerson, R., Jacobson, J, Colgan, M.S., and Martin, R.E. 2009. Large-scale impacts of herbivores on the structural diversity of African savannas. *Proceedings of the National Academy of Sciences of the United States of America* 106: 4947-4952.

Augustine, D.J., and McNaughton, S.J. 1998. Ungulate effects on the functional species composition of plant communities: herbivore selectivity and plant tolerance. *Journal of Wildlife Management*, 62: 1165-1183.

Banks, D.I., Griffin, N.J., Shackleton, C.M., and Shackleton, S.E. 1996. Wood supply and demand around two rural settlements in a semi-arid savanna, South Africa. *Biomass Bioenergy* 11: 319-31.

Bartels, G.B., Norton, B.E., and Perrier, G.K. 1993. An examination of the carrying capacity concept. In: *Range ecology at disequilibrium: new modes of natural variability and pastoral adaptation in African savannas,* eds. R.H. Behnke, I. Scoones, and C. Kerven, 89-103. London: Overseas Development Institute (ODI).

Behnke, R.H. 1985. Open-range management and property rights in pastoral Africa: a case of spontaneous range enclosure in South Darfur, Sudan. *Pastoral Development Network*, paper 20f, London: Overseas Development Institute (ODI).

Behnke, R.H., and Scoones, H.I. 1993. Rethinking range ecology: implications for range management in Africa. In: *Range ecology at disequilibrium: new modes of natural variability and pastoral adaptation in African savannas,* eds. R.H. Behnke, I. Scoones, and C. Kerven,. London: Overseas Development Institute (ODI).

Behnke, R.H., Scoones, H.I., and Kerven. C. 1993. *Range ecology and disequilibrium*. *New models of natural variability and pastoral adaptation in African savannas*. London: Overseas Development Institute (ODI) & International Institute for Environment and Development (IIED).

Beinart, W. 1984. Soil erosion, conservation and ideas about development: a southern African exploration 1900-1960. *Journal of Southern African studies* 11: 52-84.

Beinart, W. 2003. *The rise of conservation in South Africa. Settlers, livestock, and the environment*. *1770-1950*. Oxford: Oxford University Press.

Belsky, A.J., Mwonga, S.M., Amundson, R.G., Duxbury, J.M., and Ali, A.R. 1992. Comparative effects of isolated trees on their undercanopy environments in high- and low-rainfall savannas. *Journal of Applied Ecology* 30: 143-155.

Bengis, R.G., Kock, R.A., Thomson, G.R., and Bigalke, R.D. 2004. Infectious diseases of animals in sub-Saharan Africa: the livestock/wildlife interface. In: *Infectious Diseases of Livestock,* eds- J.A.W. Goetzer, and R.C. Tustin, 225-238. Cape Town: Oxford University Press.

Benjaminsen, T.A., Rohde, R., Sjaastad, E., Wisborg, P., and Lembert, T. 2006. Land reform, range ecology, and carrying capacities in Namaqualand, South Africa. *Annals of the Association of America Geographers* 96 (3): 524-540.

Beukes, P.C., and Ellis, F. 2003. Soil and vegetation changes across a Succulent Karoo grazing gradient. *African Journal of Range and Forage Science* 20: 11-19.

Bond, W.J., Woodward, F.I., and Midgley, G.F. 2005. The global distribution of ecosystems in a world without fire. *New Phytologist* 165: 525-538.

Breman, E., Gillson, L., and Willis, K. 2011. How fire and climate shaped grass-dominated vegetation and forest mosaics in northern South Africa during past millennia. *The Holocene* 22 (12): 1427-1439.

Bruner, A.G., Gullison, R.E., Rice, R.E., and Fonseca, G.A.B. 2001. The effectiveness of parks in protecting biological diversity. *Science* 291 (5501): 125-128.

Burrows, W.H., Carter, J.O., Scanlan, J.C., and Anderson, E.R. 1990. Management of savannas for livestock production in north-east Australia: contrast across the tree-grass continuum. *Journal of Biogeography* 17: 503-512.

Callimanopoulos, D. 1984. Relocating blacks in South Africa. *Cultural Survival Quarterly* 8 (1): available online at http://www.culturalsurvival.org/newpage/publications/csq/back_issues.cfm.

Campbell, B.M., Luckert, M., and Scoones, I. 1997. Local-level valuation of savanna resources: a case study from Zimbabwe. *Economic Botany* 51 (1): 59-77.

Child, B.A., Musengezi, J., Parent, G.D., and Child, G.F.T. 2012. The economics and institutional economics of wildlife on private land in Africa. *Pastoralism: Research, Policy and Practice* 2012: 2-18. In: *Oryx* 47(1): 29-40.

Child, M.F., Peerl, M.J.S., Smit, I.P.J., and Sutherland, W.J. 2013. Quantifying the effects of diverse private protected area management systems on ecosystem properties in a savannah biome, South Africa.

Clarke, J., Cavendish, W., and Coote, C. 1996. Rural households and *miombo* woodlands: use, value and management. In: *The miombo in transition: woodlands and welfare in Africa,* ed. B.M. Campbell. Bogor: Centre for International Forestry Research.

Clements, F.E. 1916. *Plant succession: an analysis of the development of vegetation*. Washington: Carnegie Institution of Washington.

Constanza, R., d'Arge, R., de Groots, S., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R., Paruelo, J., Raskins, R., Sutton, P., and van den Belt, M. 1997. The value of the world's ecosystem services and natural capital. *Nature* 187: 253-260.

Cousins, B. 1992. *Room for dancing on: grazing schemes in communal lands of Zimbabwe*. Harare: Centre for Applied Social Sciences, University of Zimbabwe.

Cousins, B. 1996. Livestock production and common property struggles in South Africa's agrarian reform. *The Journal of Peasant Studies* 23 (2-3): 166-208.

Cousins, B. 1999. Invisible capital: the contribution of communal rangelands to rural livelihoods in South Africa. *Development Southern Africa* 16 (2).

Cowling, R.M., Gibbs-Russell, G.E., Hoffman, M.T., and Hilton-Taylor, C. 1989. Patterns of plant species in southern Africa. In: *Biotic diversity in southern Africa: concepts and conservation,* ed. B.J. Huntley, 19-50. Cape Town: Oxford University Press.

Coughermour, M.B., and Ellis, J.E. 1993. Landscape and climatic control of woody vegetation in a dry tropical ecosystem: Turkana District, Kenya. *Journal of Biogeography* 20: 383-398.

Cumming, D.H.M. 2008. *Large scale conservation planning and priorities for the Kavango-Zambezi transfrontier conservation area*. Available at: http://www.fitzpatrick.uct.ac.za/publications/Cumming_2008.pdf [Visited 7 March 2014].

Cumming, D.H.M. 2011. *Constrains to conservation and development success in the wildlife-livestock-human interface in Southern African Transfrontier Conservation Areas: a preliminary review*. Report to the Wildlife Conservation Society's (WCS) AHEAD Program. Available at http://www.wcs-ahead.org/kaza/rpt_constraints_to_cons_&_dev_cumming_ltr_final.pdf [Visited 7 March 2014].

Cumming, D.H.M., and Atkinson, M.W. 2012. Land use paradigms, wildlife and livestock: southern African challenges, choices and potential ways forward. In: *Animal health and biodiversity: preparing for the future: Compendium of the OIE Global Conference on Wildlife, 23-25 February 2011,* eds. W.Karesh, and C. Machalaba, 101-112. Paris: World Organisation for Animal Health-

Cumming, D.H.M., and Bond, I. 1991. Animal production in southern Africa: present practices and opportunities for peasant farmers in arid lands. *Multispecies animal production systems* project paper no. 22. Harare: WWF Multispecies Project.

Danckwerts, J.E., and King, P.G. 1984. Conservative stocking or maximum profit: a grazing management dilemma. *Journal of the Grassland Society of Southern Africa* 1: 25-28.

Darkoh, M.B.K. 1979. *Man and desertification in Tropical Africa*. Dar es Salaam: University of Dar es Salaam Press, Dar es Salaam.

Darkoh, M.B.K. 2003. Regional perspectives on agriculture and biodiversity in the drylands of Africa. *Journal of Arid Environments* 54: 261-279.

Darkoh, M.B.K. 2009. An overview of environmental issues in southern Africa. *African Journal of Ecology* 48 (suppl. 1): 93-98.

Department of Environmental Affairs and Tourism (DEAT). 1997. *White paper on the conservation and sustainable use of South Africa's biological diversity: draft for discussion. Notice 1095 of 1997.* Pretoria: Department of Environmental Affairs and Tourism, Government Printer.

Department of Environmental Affairs and Tourism (DEAT). 1998. *Convention on Biological Diversity: South African report to the Fourth Conference of the Parties*. Pretoria: Department of Environmental Affairs and Tourism (DEAT).

Department of Environmental Affairs and Tourism (DEAT). 2009. *Fourth report to the Convention on Biological Diversity*. Pretoria: Department of Environmental Affairs and Tourism (DEAT).

Department of Environmental Affairs and Tourism (DEAT). 2013. *Rhino issue management report.* Pretoria: Department of Environmental Affairs and Tourism (DEAT).

De Bruyn, T.D. 1998. The condition, productivity and sustainability of communally grazed rangelands in the central Eastern Cape Province. In: *Proceedings of a woorkshop on research and training strategies for goat production systems in South Africa, 22-26 November 1998,* Hogsback, South Africa.

De Groot, R.S., Wilson, M.A., and Boumans, R.M.J. 2002. A typology for the classification, description, and valuation of ecosystem functions, goods and services. *Ecological Economics* 41: 393:408.

De Ridder, N., and Wagenaar, K.T. 1996. Energy and protein balances in traditional livestock systems and ranching in eastern Botswana. *Agricultural Systems* 20: 1-16.

Dean, W.R.J., and MacDonald, I.A.W. 1994. Historical changes in stocking rates of domestic livestock as a measure of semi-arid and arid rangeland degradation in the Cape Province, South Africa. In: *Journal of Arid Environments* 26: 281-298.

Dovie, D.B.K., Shackleton, C.M., and Witkowski, E.T.F. 2002. Direct-use values consumed and traded in a South African village. *International Journal of Sustainable Development and World Ecology* 9: 269-83.

Dublin, H.T., Sinclair, A.R.E., and McGlade, J. 1990. Elephants and fire as causes of multiple stable states in the Serengeti-Mara woodlands. *Journal of Animal Ecology* 59: 1147-1164.

Dyksterhuis, E.J. 1949. Condition and management of range land based on quantitative ecology. *Journal of Range Management* 2: 104-115.

Ebrahimi, A., Milotic, T., and Hoffman, M. 2010. A herbivore specific grazing capacity model accounting for spatio-temporal variation: a tool for a more sustainable nature conservation and rangeland management. *Ecological Modelling* 221: 900-910.

Edwards, V., and Steins, N.A. 1996. *Developing and analytical framework for multiple-use commons.* Paper presented to the 6th Annual Conference of the International Association for the Study of Common Property. Berkeley (USA), 5-8 June.

Ehrlich, P.R., and Ehrlich, A.H. 1992. The value of biodiversity. *Ambio* 21 (3): 219-226.

Ellis, J.E., and Swift, D.M. 1988. Stability of African pastoral systems: alternate paradigms and implications for development. *Journal of Range Management* 41: 450-459.

Els, H. 2002. The role of African people within their environment. In *Game Ranch management. Fourth edition*, ed. J. du P. Bothma, 645-661. Pretoria: Van Schaik.

Erasmus, B.F.N., van Jaarsveld, A.S., Chown, S.L., Kshatriya, M., and Wessels, K.J. 2002. Vulnerability of South African mammal taxa to climate change. *Global Change Biology* 8: 679-693.

Fairbanks, D.H.K., Thompson M.W., Vink, D.E., Newby, T.S., van Den Berg, H.M., and Everard, D.A. 2000. The South African land-cover characteristics database: a synopsis of the landscape. *South African Journal of Science* 96: 69-82.

FAOSTAT. 2012. *Livestock primary*: http://data.fao.org/dataset?entryId=857d1a1d-103c-4ceb-8c72-9a034785b3f3 [Visited 7 March 2014].

Fleischner, T.L. 1994. Ecological costs of livestock grazing in western North America. *Conservation Biology* 8: 629-644.

Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., and Holling, C.S. 2004. Regime shifts, resilience, and biodiversity in ecosystem management. *Annual Review of Ecology, Evolution and Systematics* 35: 557-581.

Frank, D.A., and Groffman, P.M. 1998. Ungulate vs. landscape control of soil C and N processes in grasslands of Yellowstone National Park. *Ecology* 79: 2229-2241.

Friedel, M.H. 1991. Range condition assessment and the concept of thresholds: a viewpoint. *Journal of Range Management* 44: 422-426.

Giannecchini, M., Twine, W., and Vogel, C. 2007. Land-cover change and human-environment interactions in a rural cultural landscape in South Africa. *The Geographical Journal* 173: 26-42.

Grace, J., San Jose, J., Meir, P., Miranda, H.S., and Montes, R.A. 2006 productivity and carbon fluxes of tropical savannas. *Journal of Biogeography* 33: 387-400

Graham, O. 1988. *Enclosure of the East African rangelands: recent trends and their impact. Pastoral Development Network*, No.25a, London: Overseas Development Institute (ODI).

Grime, J.P. 1979. *Plant strategies and vegetation processes.* New York: Wiley, New Yor.

Grimes, A., Loomis, S., Jahnige, P., Burnham, M., Onthank, K., Alarcón, R., Palacios Cuenca, W., Cerón, Martínez, C., Neill, D., Balick, M., Bennett, B., and Mendelsohn, R. 1994. Valuing the rain forest: the economic value of non-timber forest products in Ecuador. *Ambio* 23 (7): 403-410.

Grossman, D., and Gandar, D. 1989. Land transformation in South African savanna regions. *South African Geography Journal* 71: 38-45.

Haarmeyer, D.H., Schmiedel, U., Dengler, J., and Bösinng, B.M. 2010. How does grazing intensity affect vegetation types in arid Succulent Karoo, South Africa? Implications for conservation management. *Biological Conservation* 143: 588-596.

Hardin, G.J. 1971. The tragedy of the commons. *Science* 162: 1243-1248.

Helm, C.V., Wilson, G., Midgley, J., Kruger, L., and Witowski, E.T.F. 2011. Investigating the vulnerability of an African savanna tree (*Sclerocarya birrea* spp. *caffra*) to fire and herbivory. *Austral Ecology* 36 (8): 964-973.

Hendricks, H.H., Bond, W.J., Midgley, J.J, and Novellie, P.A. 2005. Plant species richness and composition along livestock grazing intensity gradients in a Namaqualand (South Africa) protected area. *Plant Ecology* 176, 19-33.

Hickman, K.R., Hartnett, D.C., Cochran, R.C., and Owensby, C.E. 2004. Grazing management effect on plant species diversity in tallgrass prairie. *Journal of Range Management* 57: 58-65.

Hiernaux, P. 1982. Méthodes d'évaluation du potentiel fourager des parcours sahéliens proposés par les chercheurs di CIPEA. In *La capacité de charge des paturâges sahéliens pour les systèmes d'élevage de la region,* ed. H. Berman. Compte rendu de la table ronde, CABO, Wagenigen, 1e 26 et 27 Janvier 1982. Wagenigen: Centrum voor agrobioogisch onderzoek. [Methods of evaluating feed potential of Sahelian rangelands proposed by researchers from the International Livestock Centre for Africa. In *Carrying capacity of Sahelian rangelands for the pastoral systems of the region*. Proceedings of the round table. Wagenigen: Centre for Agrobiological Studies].

Higgins, S.I., Shackleton, C.M., and Robinson, E.R. 1999. Changes in woody community structure and composition under contrasting land use systems in semi-arid savannah, South Africa. *Journal of Biogeography* 26: 610-627.

Hoare, D. 2003. Biodiversity and performance of grassland ecosystems in communal and commercial farming systems in South Africa. In: *Biodiversity and the ecosystem approach in agriculture, forestry and fisheries*, 10-27. Rome: Food and Agriculture Organization (FAO).

Hobbs, R.J., Arico, S., Aronson, J., Baron, J.S., Bridgewater, P., Cramer, V.A., Epstein, P.R., Ewel, J.J., Klink, C.A., Lugo, A.E., Norton, D., Ojima, D., Richardson, D.M., Sanderson, E.W., Valladares, F., Vila, M., Zamora, R., and Zobel, M. 2006. Novel ecosystems: theoretical and management aspects of the new ecological world order. *Global Ecology and Biogeography* 15: 1-7.

Hoffman, M.T., and Ashwell, A. 2001. *Nature divided - Land degradation in South Africa*. Cape Town: University of Cape Town Press.

Hoffman, M.T., and Cowling, R.M. 1991. Phytochronology and endemism along aridity and grazing gradients in the lower Sundays River Valley, South Africa: implications for vegetation history. *Journal of Biogeography* 18: 189-201.

Hoffman, M.T., Todd, S., Ntshona, Z., and Turner, S. 1999. *Land degradation in South Africa*. Unpublished report. Cape Town: National Botanical Institute, Kirstenbosch.

Holecheck, J.L., Pieper, R.D., and Herbel, C.H. 2004. *Range management, principle and practice*. 5th edn. New York: Pearson Education Inc.

Homer-Dixon, T., and Percival, V. 1998. Environmental scarcity and violent conflict: the case of South Africa. *Journal of Peace Research* 35 (3): 279-298.

Hulme, M., Doherty, R., Ngara, T., New. M., and Lister, D. 2001. African climate change: 1900-2100. *Climate Resources* 17 (2): 1856-1857.

Huston, M.A. 1994. *Biological diversity: the coexistence of species on changing landscapes*. Cambridge: Cambridge University Press.

Illius, A.W., and O'Connor, T.G. 1999. On the relevance of non-equilibrium concepts to arid and semi-arid grazing systems. *Ecological applications* 9: 798-813.

International Institute for Environment and Development (IIED). 1995. *The hidden harvest: the value of wild resources in agricultural systems – a summary*. London: International Institute for Environment and Development (IIED).

International Institute for Environment and Development (IIED). 1997. *Valuing the hidden harvest: methodological approaches for local-level economic analysis of wild resources.* Research Series, 3(4). London: International Institute for Environment and Development (IIED).

International Union for the Conservation of Nature (IUCN). 2008. *Guidelines for applying protected area management categories*. Gland: International Union for the Conservation of Nature.

Jacobs, N.J. 2003. *Environment, power, and injustice – A South African history*. Cambridge: Cambridge University Press.

Joppa, L.N., Loarie, S.R., and Pimm, S.L. 2009. On population growth near protected areas. *PLoS ONE* 4: e4279.

Kaschula, S.A., Twine, W.E. & Scholes M.C. 2005. Coppice harvesting of fuelwood species on a South African common: utilizing scientific and indigenous knowledge in community based natural resource management. *Human Ecology* 33. 387-418.

Kelly, R.D., and Walker, B.H. 1976. The effects of different forms of land use on the ecology of a semi-arid region in south-eastern Rhodesia. *Journal of Ecology* 64: 553-576.

Kepe, T. 1997. *Environmental entitlements in Mkambati: livelihoods, social institutions and environmental change on the Wild Coast of the Eastern Cape, South Africa*. Research Report No.1, Programme for Land and Agrarian Studies. Cape Town: University of the Western Cape.

Lawry, S.W. 1990. Tenure policy toward common property natural resources in sub-Saharan Africa. *Natural Resources journal* 30: 403-422.

Leach, M., Mearns, R., and Scoones, I. 1997. *Environmental entitlements: a framework for understanding the institutional dynamics of environmental change.* Discussion paper no.359, Sussex: Institute for Development Studies.

Lechmere-Oertel, R.G., Kerley, G.I.H., and Cowling, R.M. 2005. Patterns and implications of transformation in semi-arid succulent thicket, South Africa. *Journal of Arid Environments* 62: 459-474.

Levick, S.R., Asner, G.P., Kennedy-Bowdoin, T., and Knapp, D.E. 2009. The relative influence of fire and herbivory on savanna three-dimensional vegetation structure. *Biological Conservation* 142: 1693-1700.

Loveland, T.R., Reed, B.C., Brown, J.F., Ohlen, D.O., Zhu, Z., Yang, L., and Merchant, J.W. 2000. Development of a global land cover characteristics database and IGBP DIS cover from 1 km AVHRR data. *International journal of remote sensing* 21: 1303-1330.

Low, A.B., and Rebelo, A.G. 1996. *Vegetation of South Africa, Lesotho and Swaziland*. Pretoria: DEAT.

MacDonald, I.A.W. 1984. Man's role in changing the face of southern Africa. In: *Biotic diversity in southern Africa: concepts and conservation,* ed. B.J. Huntley. Cape Town: Oxford University Press,.

Mace, R. 1991. Overgrazing overstated. *Nature* 349: 280-281.

Makhado, R.A., von Maltitz, G.P., Potgieter, M.J., and Wessels, D.C.J. 2009. Contribution of woodland products to rural livelihoods in the northeast of Limpopo province, South Africa. *South African Geographical Journal* 91: 46-53.

Margules, C.R., and Pressey, R.L. 2000. Review article: systematic conservation planning. *Nature* 405: 243-253.

Martindale, G. 2007. Influence of livestock grazing on plant diversity on Highveld Sourveld grassland in Kwazulu-Natal. Unpublished MSc thesis, School of Animal, Plant and Environmental Sciences, University of Witwatersrand, Johannesburg.

Mckenzie, B. 1984. *Historical, political and sociological factors affecting land use in the Transkei today: an ecological interpretation*. Carnegie Conference Paper No.307, Second Carnegie Inquiry Into Poverty and Development in Southern Africa. Cape Town: SALDRU.

McNaughton, S.J. 1984. Grazing lawns: animals in herds, plant form, and coevolution. *American Naturalist* 124: 863-886.

McNaughton, S.J., Banyikwa, F.F., and McNaughton, M.M. 2001. Promotion of cycling of diet enhancing nutrients by African grazers. *Science* 278: 1798-1800.

Metcalfe, S. 1996. Whose resources at stake? Community based conservation and community self-governance. *The Rural Extension Bulletin* 10: 14-18.

Milchumas, D.G., Sala, O.E., and Lauenroth, W.K. 1988. A generalized model of the effects of grazing by large herbivores on grassland community structure. *American Naturalist* 132: 87-106.

Milton, S.J., and Hoffman, M.T. 1994. The application of state-and-transition models to rangeland research and management in arid succulent and semi-arid grassy Karoo, South Africa. *African Journal of Range and Forage Science* 11: 18-26.

Mitchell, P. 2002. *The archaeology of Southern Africa*. Cambridge (United Kingdom): Cambridge Academic Press.

Mucina, L., and Rutherford, M.C. 2006. *The vegetation of South Africa, Lesotho and Swaziland*. Pretoria: South African National Biodiversity Institute.

Murphy, B.P., and Bowman, D.M.J.S. 2012. What controls the distribution of tropical forest and savanna? *Ecology Letters* 15: 748-758.

Mwavu, E.N., and Witowski, E.T.F. 2008. Land-use and cover changes (1988-2002) around Budongo Forest Reserve, NW Uganda: implications for forest and woodland sustainability. *Land Degradation and Development* 19: 606-622.

Noy-meir, I. 1973. Desert ecosystems: environments and producers. *Annual Review of Ecology and Systematics* 4: 25-51.

O'Connor, T.G. 1985. A synthesis of field experiments concerning the grass layer in the savanna regions of southern Africa. *South African National Scientific Programme Report* 114: 1-125.

O'Connor, T.G. 1999. Patterns of plant selection by grazing cattle in two savanna grasslands: a plant's eye view. *Journal of the Grassland Society of South Africa* 9: 97-104.

O'Kane, C.A.J., Duffy, K.J., Page, B.R., and MacDonald, D.W. 2012. Heavy impacts on seedlings by the impala suggest a central role in woodland dynamics. *Journal of Tropical Ecology* 28: 291-297.

Oba, G., Vetaas, O.R.m and Stenseth, N.C. 2001. Relationships between biomass and plant species richness in arid-zone grazing lands. *Journal of Applied Ecology* 38: 836-845.

Oesterheld, M., and Semmartin, M. 2011. Impact of grazing on species composition: adding complexity to a generalized model. *Austral Ecology* 36: 881-890.

Olff, H., and Ritchie, M.E. 1998. Effects of herbivores on grassland plant diversity. *Trends in Ecology and Evolution* 13: 261-265.

Ostrom, E. 1986. Issues of definition and theory: some conclusions and hypotheses. In: *Proceedings of the conference on common property resource management*. Washington: National Academic Press.

Osofsky, S.A., Cleaveland, S., Karesh, W.B., Kock, M.D., Nyhus, P.J., Starr, L., and Yang, A. 2005. *Conservation and development interventions at the wildlife/livestock* *interface: implications for wildlife, livestock, and human health*. Gland and Cambridge: International Union for the Conservation of Nature (IUCN).

Osofsky, S.A., Cumming, D.H.M., and Kock, M.D. 2008. Transboundary management of natural resources and the importance of a "one health" approach: perspectives on southern Africa. In *State of the Wild 2008-09: a global portrait of wildlife, wildlands, and ocean,* eds. E. Fearn and K.H. Redford, 89-98. Washington: Island Press.

Palmer, R. 1997. *Rural adaptations in the Eastern Cape, South Africa*. Working Paper No.11, Rome: Institute for Southern African Studies and National University of Lesotho.

Parsons, D.A.B., Shackleton, C.M., and Scholes, R.J. 1997. Changes in herbaceous layer condition under contrasting land use systems in the semi-arid lowveld. South Africa. *Journal of Arid Environments* 37: 319-329.

Pastoral Development Network. 1992. Newsletter No. 32. London: Overseas Development Institute (ODI).

Perrings, C. 2000. The Biodiversity Convention and biodiversity loss in Sub-Saharan Africa. In: *The economics of biodiversity conservation in Sub-Saharan Africa: mending the Ark,* ed. C. Perrings, 1-43. Cheltenham: Edward Elgar.

Petersen, A., Young, E.M., Hoffman, M.T., and Musil, C.F. 2004. The impact of livestock grazing on landscape biophysical attributes in privately and communally managed rangelands in Namaqualand. *South African Journal of Botany* 70: 770-783.

Prendini, L., Theron, L-J., van der Merwe, K., Owen-Smith, N. 1996. Abundance and guild structure of grasshoppers (Orthoptera: Acridoidea) in communally grazed and protected savanna. *South African Journal of Zoology* 31: 120-130.

Ratnam, J, Bond, W.J., Fensham, R.J., Hoffman, W.A., Archibald, S., Lehmann, C.E.R., Anderson, M.T., Higgins, S.I., and Sankaran, M. 2011. When is a "forest" a savanna, and why does it matter? *Global Ecology and Biogeography* 20: 653-660.

Reid, R.S., Bedelian, C. Said, M.Y., Kruska, R.L., Mauricio, R.M., Castel, V., Olson, J., and Thornton, P.K. 2010. Global livestock impacts on biodiversity. In: *Livestock in a changing landscape*, *vol. 1: drivers, consequences and response,* eds. H. Steinfield, H.A. Mooney, F. Schneider and L.E. Neville, 11-137. Washington: Island Press, Washington.

Riginos, C, and Hoffman, M.T. 2003. Changes in population biology of two succulent shrubs along a grazing gradient. *Journal of Applied Ecology* 40: 615-625.

Rutherford, M.C., Powrie, L.W., and Thompson, D.I. 2012. Impacts of high utilizaiton pressure on biodiversity components in Colospherum mopane savannah. *African Journal of Range & Forage Science* 29 (1): 1-11.

Southern Africa Development Community (SADC). 2014. *SADC Statistics Yearbook*: http://www.sadc.int/information-services/sadc-statistics/sadc-statiyearbook/ [Visited: 13 March 2014].

Southern Africa Development Community (SADC), European Union (EU) and United States of America (USA). 2008. *Achieving compatibility between the transfrontier conservation area (TFCA) concept and international standards for the management of transboundary animal diseases (TADs)*. Report of the workshop held at the Chobe Marina Lodge, Kasane (Botswana), 11-14 November 2008.

Sandford, S. 1983. *Management of pastoral development in the third world*. New York (USA): Wiley.

Sankaran, M., Ratnam, J., and Hanan, H.P. 2004. Tree-grass coexistence in savannas revisited – insights from an examination of assumptions and mechanisms invoked in existing models. *Ecology Letters* 7: 480-490.

Sankaran, M., Hanan, N.P., Scholes, R.J., Ratman, J., Augustine, D.J., Cade, B.S., Gignoux, J., Higgins, S.I., Le Roux, X., Ludwig, F., Ardo, J., Banyikwa, F., Bronn, A., Buccini, G., Caylor, K.K., Coughenour, M.B., Diouf, A., Ekaya, W., Feral, C.J., February, E.C., Frost, P.G.H., Hiernaux, P., Hrabr, H., Metzger, K.L., Prins, H.H.T., Ringrose, S., Sea, W., Tews, J., Worden, J., and Zambatis, N. 2005. Determinants of woody cover in African savannas. *Nature* 438: 846-849.

Sankaran, M., Ratman, J., and Hanan, N. 2008. Woody cover in African savannas: the role of resources, fire and herbivory. *Global Ecology and Biogeography* 17: 236-245.

Sansom, A.L. 1999. Upland vegetation management: the impacts of overstocking. *Water Science and Technology* 39: 85-92.

Scholes, R.K. 2009. Syndromes of dryland degradation in southern Africa. *African Journal of Range and Forest Science* 26: 113-125.

Scholes, R.J., and Archer, S.R. 1997. Tree-grass interactions in savannas. *Annual Review of Ecology and Systematics* 28: 517-544.

Scholes, R.J., and Briggs, R. 2004. *Ecosystem services in southern Africa: a regional assessment. A contribution to the Millennium Ecosystem Assessment*. Pretoria: Department of Environmental Affairs and Tourism (DEAT).

Scholes, R.J., and Walker, B.H. 1993. *An African savanna: synthesis of the Nylsvley Study*. Cambridge: Cambridge Academic Press.

Scoones, I. 1995. *Living with uncertainty: new directions in pastoral development in Africa*. London: Intermediate Technology Publications.

Shackleton, C.M. 1993. Are the communal grazing lands in need of saving? *Development Southern Africa* 10: 65-78.

Shackleton, C.M. 1996. Potential stimulation of local rural economies by harvesting secondary products: a case study of the central Transvaal lowveld, South Africa. *Ambio* 25: 33-38.

Shackleton, C.M. 2000. Comparison of plant diversity in protected and communal lands in the Bushbuckridge lowveld savannah, South Africa. *Biological Conservation* 94: 273-285.

Shackleton, C.M., and Shackleton, S.E. 1997. *The use and potential for commercialization of veld products in the Bushbuckridge area*. Nelspruit: Department of Water Affairs and Forestry.

Shackleton, C.M., and Shackleton, S.E. 2004. The importance of non-timber forest products in rural livelihood security and as safety nets: a review of evidence from South Africa. *South African journal of Science* 100: 658-64.

Shackleton, C.M., Griffen, N.J., Banks, D.I., Mavrandonis, J.M., and Shackleton, S.E. 1994. Community structure and species composition along a disturbance gradient in a communal managed South Africa savanna. *Vegetatio* 115: 157-167.

Shackleton, C.M., Shackleton, S.E., Buiten, E., and Bird, N. 2007. The importance of dry woodlands and forests in rural livelihoods and poverty alleviation in South Africa. *Forest Policy and Economics* 9: 558-565.

Shackleton, C.M., Willis, C.B., and Scholes, R.J. 2001. Woodlands or wastelands: examining the value of South Africa's woodlands. *The Southern African Forestry Journal* 192 (1): 65-72.

Shackleton, S.E., Shackleton, C.M., Mathabela, F.R., Dzeferos, C. Shabangu, M., and Mdaka, S.B. 1995. *Local names and uses of common trees in the Bushbuckridge region of the Eastern Transvaal Lowveld*. Acornhoedk: Wits. Rural Facility, Acornhoek.

Siebert, F., Bredenkamp, G.D., and Siebert, S.J. 2003. A comparison of mopaneveld vegetation in South Africa, Namibia and Zimbabwe. *Bothalia* 33: 121-134.

Siegfried, W.R. 1989. Preservation of species in southern Africa nature reserves. In: *Biotic diversity in southern Africa: concepts and conservation,* ed. B.J. Huntley, 186-201. Cape Town: Oxford University Press.

Skarpe, C. 1991. Impact of grazing in savanna ecosystems. *Ambio* 20: 351-356.

Smet, M., and Ward, D. 2005. A comparison of the effects of different rangeland management systems on plant species composition, diversity and vegetation structure in a semi-arid savannah. *African Journal of Range & Forage Science* 22 (1): 59-71.

Statistics South Africa. 2013. Ba-Phalaborwa municipality: (http://beta2.statssa.gov.za/?page_id=993&id=ba-phalaborwa-municipality) [Last visit: 25 May 2014]

Steenkamp, C., and Uhr, J. 2000. Discovering power relations in South African CBNRM case study: the Makulele community of the Northern Province. In *Empowering communities to manage natural resources: case studies of Southern Africa*, eds. S. Shackleton and B. Campbell, 125-155. Pretoria: CSIR.

Stuart, C., and Stuart, T. 2007. *Field guide to the mammals of southern Africa*. Cape Town: Struik Nature.

Sullivan, S., and Rohde, R.F. 2002. On non-equilibrium in arid and semi-arid grazing systems. *Journal of Biogeography* 29: 1-26.

Swallow, B.M. 1990. *Strategies and tenure in African livestock development.* LTC paper 140. Madison, WI: Land Tenure Centre, University of Wisconsin-Madison.

Tainton, N.M. 1999. The ecology of the main grazing lands of South Africa. In: *Veld management in South Africa,* ed. N.M. Tainton, 23-53. Pietermaritzburg: University of Natal Press.

Tapson, D.R. 1990. *A socio-economic analysis of small-holder cattle producers in Kwazulu*. Unpublished PhD dissertation, Vista University, South Africa.

Tapson, D.R: 1991. *The overstocking and offtake controversy re-examined for the case of Kwazulu*. Pastoral Development Network, Paper No.31a- London: Overseas Development Institute (ODI).

Tapson, D.R. 1993. Biological sustainability in pastoral systems: the Kwazulu cause. In: *Range ecology at disequilibrium: new models of natural variability and pastoral adaptation in African savannas,* eds. R.H. Behnke, I. Scoones and C. Kerven, 118-135. London: Overseas Development Institute (ODI).

Teague, W.R., and Smit, G.N. 1992. Relationships between woody and herbaceous components and the effects of bushclearing in Southern African savannas. *Jounal of the Grassland Society of South Africa* 9: 60-71.

Tefera, S., Dlamini, B.J., and Dlamini, A.M. 2010. Changes in soil characteristics and grass layer condition in relation to land management systems in the semi-arid savannas of Swaziland. *Journal of Arid Environments* 74: 675-684.

Thomson, D., Rutherford, M., and Powrie, L. 2012. Are communal grazing lands necessarily degraded? Unexpected answers from the Mopane and other Bioregions of South Africa. Presentation at SANBI.

Thomson, G.R., Penrith, M.-L., Atkinson, M.W., Cassidy, J., and Osofsky, S.A. 2013a. Balancing livestock production and wildlife conservation in and around Southern Africa's transfrontier conservation areas. *Transboundary and emerging diseases* 60: 492-506.

Thomson. G.R., Penrith, M.-L., Atkinson, M.W., Thalwitzer, A., Mancuso, A., Atkinson, S.J., and Osofsky, S.A. 2013b. International trade standards for commodities and products derived from animals: the need for a system that integrates food safety and animal disease risk management. *Transboundary and Emerging Diseases* 60: 507-515.

Thornton, P.K., Kruska, R.L., Henninger, N., Kristjanson, P.M., Reid, R.S., Atieno, F., Odero, A.N., and Ndegwa, T. 2002. *Mapping poverty and livestock in the developing world*. Nairobi: International Livestock Research Institute.

Todd, S. 2006. Gradients in vegetation cover, structure and species richness of Nama-Karoo shrubland in relation to distance from livestock watering points. *Journal of Applied Ecology* 43, 293-403.

Todd, S, and Hoffman, M.T. 1999. A fence-line contrast reveals effects of heavy livestock grazing on plant diversity and community composition in Namaqualand, South Africa. *Plant Ecology* 142: 169-178.

Twine, W. 2005. Socio-economic transitions influence vegetation change in the communal rangelands of the South African lowveld. *African Journal of Range & Forage Science* 22: 93-99.

Twine, W., Moshe, D., Netshiluvhi, T., and Siphugu, V. 2003. Consumption and direct-use values of savannah bio-resources used by rural households in Mametja, a semi-arid area of Limpopo province, South Africa. *South African Journal of Science* 99: 467-473.

United Nations Environment Proram (UNEP). 2012. *Global Environment Outlook 5*. Nairobi: United Nations Environment Program (UNEP).

University of Pretoria/Agricultural Research Council. 2012. *Southern Africa foot and mouth disease bulletin*, edition 3. Unpublished report. Pretoria: University of Pretoria and Agricultural Research Council.

van Langevelde, F., van van de Vijver, C., Kumar, L., van de Koppel, J., de Ridder, N., van Andel, J., Skidmore, A.K., Hearne, J.W., Stroosnijder, L., Bond, W.J., Prins, H.H.T., and Rietkerk, M. 2003. Effects of fire an herbivory on the stability of savanna ecosystems. *Ecology* 84: 337-350.

van Oene, H., van Deursen, E.J.M., and Berendse, F. 1999. Plant-herbivore interaction and its consequences for succession in wetland ecosystems: a modelling approach. *Ecosystems* 2: 122-138.

Venter, J., Liggit, B., Tainton, N.M., and Clarke, G.P.Y. 1989. The influence of different land-use practices on soil erosion, herbage production and on grass species richness and diversity. *Journal of the Grassland Society of South Africa* 6: 89-98.

Venter, J., Scholes, R.J., and Eckhardt, H.C. 2003. The abiotic template and its associated vegetation pattern. In: *The Kruger Experience: ecology and management of savanna heterogeneity,* eds. J. du Toit, K.H. Rogers and H.C. Biggs, 83-129. London: Island Press.

Vedeld, T. 1992. Local institution-building and resource management in the West African Sahel. *Pastoral Development Network*, paper No.33c, London: Overseas Development Institute (ODI).

Vetter, S. and Bond, W.L. 2012. Changing predictors of spatial and temporal variability in stocking rates in a severely degraded communal rangeland. *Land Degradation and Development* 23: 190-199.

Vetter, S., Goqwana, W.M., Bond, W.L., and Trollope, M.M. 2006. Effects of land tenure, geology and topography on vegetation and soils of two grassland types in South Africa. *African Journal of Range and Forage Science* 23: 13-27.

von Maltiz, G.E., and Scholes, R.J. 2005. The burning of fuelwood in South Africa: when is it sustainable? *Environmental Monitoring and Assessment* 38: 243-51.

Walker, B.H. 1980. Stable production versus resilience: a grazing management conflict. *Proceedings of the Grasslands Society of Southern Africa* 15: 79-83.

Walpole, M.J., Nabaala, M., and Matankory, C. 2004. Status of the Mara Woodlands in Kenya. *African Journal of Ecology* 42: 180-188.

Walters, D.J.J., Kotze, D.C., and O'Connor, T.G. 2006. Impact of land use on vegetation composition, diversity, and selected soil properties of wetlands in the southern Drakensberg mountains, South Africa. *Wetlands Ecology and Management* 14: 329-348.

Ward, D., Ngaigorue, B.T., Karamata, J., Kapofi, I., Samuels, R., and Ofran, Y. 2000. *Effects of communal pastoralism on vegetation and soil in a semi-arid and in an arid region of Namibia*. Proceedings of the IAVS Symposium 1998: 344-347.

Wessels, K.J., Colgan, M.S., Erasmus, B.F.N, Asner, G.P., Twine, W.C., Mathieu, R., van Aardt, J., Fisher, J.T., and Smit, I.P.J. 2013. Unsustainable fuelwood extraction from South African savannas. *Environmental Research Letters* 8: 014007

Wessels, K.J., Mathieu, R., Erasmus, B.F.N., Asner, G.P., Smit, I.P.J., van Aardt, J.A.N., Main, R., Fisher, J., Marais, W., Kennedy-Bowdoin, T., Knapp, D.E., Emerson, R., and Jacobson, J. (2012) Impact of communal land use and conservation on woody vegetation structure in the Lowveld savannas of South Africa. *Forest Ecology and Management* 261: 19-29.

Western, D. 2007. A half a century change in Amboseli National Park, Kenya. *African Journal of Ecology* 45: 302-310.

Western, D., and Maitumo, D. 2004. Woodland lose and restoration in a savannah park: a 20-year experiment. *African Journal of Ecology* 42: 11-121.

Westoby, M., Walker, B., and Noy-meir, I. 1989. Range management on the basis of a model which does not seek to establish equilibrium. *Journal of Arid Environments* 17: 235-239.

Westoby, M., Walker, B., and Noy.meir, I. 1989. Opportunistic management for rangelands not at equilibrium. *Journal of Range Management* 42: 266-274.

White, R. 1992. *Livestock development and pastoral production on communal rangeland in Botswana*. London: Commonwealth Secretariat.

Williams, A., and Shackleton, C.M. 2002. Fuelwood use in South Africa: where to in the 21 century? *South African Forestry Journal* 196: 1-6.

World Organisation for Animal Health (OIE). 2012. *Terrestrial Animal Health Code On-line*. Available online at: http://www.oie.int/es/normas-internacionales/codigo-terrestre/acceso-en-linea/ [Last visit: 25 May 2014]

World Trade Organisation (WTO). 2012. *Agreement on the application of sanitary and phitosanitary measures* (SPS Agreement). Available online at: http://www.oie.int/es/normas-internacionales/codigo-terrestre/acceso-en-linea/ [Last visit: 25 May 2014]

Appendix: interview form, page 1

Informed consent **(read to participant and tick the box)**

I hereby confirm that that:

- I have been told by the researcher about the purpose of the research and what I need to do to participate.
- I understand that:
  - I don't have to participate and I can stop participating at any time.
  - Any information I share with the research will be confidential and my name will not be used.
  - Appropriate feedback on the results will be given to me and my community.

Location				**Name**				
Date				**Persons in the household**				
	Number of animals	**Do you feed them supplementary? (Y/N)**	**When/ Which months?**	**How much do you spend in feed? (PER MONTH)**	**Have you bought or sold animals in the last 3-5 years? (Y/N)**	**What prices did you pay/get per animal?**	**Additional notes**	
Cattle								
Sheep								
Goats								
Horses								
Donkeys								
Mules								
Pigs								
Ostriches								
Ducks/geese								
Chicken								
Pigeons								
Dogs								
Cats								

Appendix: interview form, page 2

▫

Location	
Date	
Name (optional)	

EXTRA QUESTIONS

Has the number of livestock you owned changed in the last 5 years? YES / NO

If yes, how have your livestock numbers changed?

Would you like to own more livestock? YES / NO

Why?

Are there water holes in the area? YES / NO

If yes, how many?

Does your livestock use them? YES / NO

If yes, how often?

Final question:
Do you know about the KNP compensation scheme for human-wildlife conflict that is in preparation? YES / NO

If yes, how did you get to know about it?

If you lost a cow, what do you understand abut the process you need to follow in order to claim compensation?