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Potential land transformation threats to the distribution range of the Cheetah, *Acinonyx jubatus*, in South Africa.

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Final Report

Declaration

I have read and agree to the guidelines for Higher Degree students and their supervisors issued by the Faculty of Science.

Signed: Date: 13/09/2010

Abstract

Various conservation landscape strategies such as hotspots and ecoregions are directed at ensuring the persistence of a range of species or biodiversity. However some individual species require special attention because of specific threats. The IUCN Red List system has ensured the ensuring the inclusion of a variety of threats in the Red listings and consequently conservation planning. This study evaluated present and future threats on the globally Vulnerable (VU C2a.1) Cheetah *(Acinonyx jubatus,* Shreber, 1775) in South Africa. The following threats were integrated to assess the overall threat to Cheetah in its regional extent of occurrence (EOO) in South Africa; fragmentation, agricultural land use, forestry and human population density. The analysis showed favourable and unfavourable land fractions for cheetah persistence across the EOO. Forestry and agriculture were the major transformation threats in the KwaZulu-Natal (KZN) region. Human population threat was greatest at the edges of the protected areas and in the KZN. This may indicate increased threat for the future with more demand for land by people. This highlights the challenge of integrating cheetah conservation into the land use planning process as a legitimate land use. This can be achieved through community based conservation in the EOO. Such initiatives should also involve other stakeholders such as commercial wildlife farmers, cheetah conservation entities like De Wildt and the Parks Authorities. Fragmentation was measured using the software FRAGSTATS and did not raise any major concern. Using this newly derived information does not seem to alter the placement of the species in the Vulnerable (VU) IUCN Red List category because fragmentation is not a threat.

Acknowledgements & Dedication

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Potential land transformation threats to the habitat and persistence of the Cheetah in South Africa

1.0 INTRODUCTION

1.1 Overview

Conservation is a crisis discipline because of the continuing extinction of the world's biological diversity (Eldredge, 2001, Harris, 2000; Purvis *et al.*, 2000; Soule, 1986). As a result conservation efforts have focused on finding the most effective approaches to avert, or mitigate, the effects of the anthropogenic sixth extinction (Purvis *et al.* 2000). The goal of several systematic multi-criteria conservation approaches is to combine analyses at coarse and fine spatial scales by including data on habitats, processes or individual species (Margules and Pressey, 2000). Different approaches have incorporated these factors to varying degrees with the use of complementarity, minimum sets, iterative algorithms and habitat type uniqueness (Ginsberg, 2001; Margules and Pressey, 2000). These conservation approaches usually cover a regional or landscape scale. Popular examples include the Worldwide Fund for Nature (WWF)'s ecoregions approach, Conservation International (CI)'s hotspots approach (www.biodiversityhotspots.org) as well as the ecosystems' approach used by IUCN (Wikrayamanake *et al.* 2004; Olson *et al.* 2001).

In order to encourage the persistence of species, present and future threats must be incorporated into conservation planning, regardless of whether these species occur inside formal protected areas or in the off-reserve matrix. These threats include overexploitation of natural resources by people and land use changes such as agricultural expansion and urbanisation (Pintea *et al.* 2003). Shifting ecosystem boundaries and changing local conditions as well as habitat fragmentation (Opdam and Wascher, 2004; Noss, 2001; Halpin, 1997) are other threats associated with climate change. Ways to mitigate against these risks in conservation plans have been put forward. They include avoiding fragmentation, enhancing connectivity and protecting functional groups, ecosystem processes and keystone species (Noss, 2001). The strategies applied through landscape approaches have broad biodiversity protection as a main aim and therefore they are often directed at ensuring the persistence of a range of species through habitat management. However, particular species may warrant species-specific action due to their precarious conservation status, for example the rhino and cheetah. The IUCN Red List system has been used to determine species conservation status. This often draws attention to the species concerned and subsequently funding and research (Possingham *et al.* 2002; Lamoureux *et al,* 2003).

The IUCN Red List system seeks to provide an "explicit, objective framework for the classification of the broadest range of species according to their extinction risk". This is done by using 'the best available evidence' in the form of quantitative measures of population size, mature individuals, rarity, rates of decline, population fragmentation, extent of occurrence (EOO), area of occupancy (AOO) and habitat state are used (Willis *et al.* 2003; IUCN, 2001; www.redlist.org). After consideration of these various factors species are listed into relevant categories such as extinct, critically endangered, endangered or vulnerable (Figure 1). This allows the establishment of priorities and comparison among families, guilds and taxa (e.g. Canidae). Because the listings are done at the global scale this raises issues of scale hence the need to apply the system at the regional scale at which conservation action is often planned and executed. This increased awareness of conservation crises of specific species has resulted in positive results such as in the case of the rhinoceros, which has over the years been lifted from near extinction to sustained recovery (Linklater, 2002). Further, Red Lists have ensured that continuing monitoring is done for the species under threat (Willis *et al.* 2003; Possingham *et al.* 2001).

Because humans play an important role in the extinction process factors such as land use change and fragmentation must be better understood (Henle *et al.* 2004; Levin, 1992). Purvis *et al*. (2000) argue that besides the intrinsic factors, e.g. size of body and extrinsic factors e.g. climate change, increasing human population will be the driving force for the next extinction. The link with humans exists because many of the anthropogenic disturbances like habitat alteration are critical in encouraging extinction (Purvis *et al.,* 2000). Directly resulting from increased human populations habitat degradation and fragmentation has led to a decline in the number and size of intact and healthyhabitats. Species with large home ranges, especially carnivores that have more specific prey requirements, are affected by this effect on habitat first (Ginsberg, 2001). The cheetah is one such species that ranges over large tracts of land measuring from 23.6 to 833 km^2 (Marker and Shumann, 1998, Purchase and Du Toit, 2000, Broomhall, Mills and Du Toit, 2003; Friedmann and Daly, 2004). Prey availability, presence of other large predator competitors and the migratory behaviour of prey have been highlighted as key in cheetah home range determination (Broomhall, Mills and Du Toit, 2003, Laver and Kelly, 2004; Friedmann and Daly, 2004; du Bothma & Walker, 1999). Because these factors vary with places there is also spatial variation of the home range size of the cheetah. Therefore conservation biology must now quantify and address this likely threat in the light of the continually declining populations of many species (Loreau *et al.* 2003; Caughley, 1994).

The species is globally classified as Vulnerable (VU C2a.1)by IUCN and is in Appendix 1 under CITES. This indicates a high risk of extinction in the wild (IUCN, 2001; See Figure 1) and restricts any trade in the species (see www.cites.org). Global statistics put the wild cheetah population at about 10 000 mature individuals or less. This reduction in number is attributed to habitat loss, land transformation impacts by increased human population, hunting, persecution by people due to perceived depredation of livestock, edge effects (increased conflicts with people at reserve edges) and reduced available prey among other reasons (see Figure 2; Neke & Du Plessis, 2004; Ogada *et al.* 2003; McKinney, 2001; du Bothma & Walker, 1999; Woodroffe & Ginsberg, 1998).

In South Africa the cheetah has experienced persecution from humans, because it can kill small livestock such as goats, and is perceived to pose a threat to human life. The latter continues to occur despite consensus that cheetah rarely attack humans (Marker-Kraus and Kraus, 1990 in Gros, 1998). Due to concerted efforts by various stakeholders the population numbers of the species have increased in its history in the country. As a result its Red List classification has been reviewed several times. In 1986 it was listed as "out of danger" and in 2004 as vulnerable (Smithers, 1986, Friedmann & Daly, 2004). This new classification means that efforts must be taken to ensure that the cheetah is taken out of this threat category. From the assessment the major threats to the cheetah were defined as exploitation through hunting, persecution, road-kills and habitat fragmentation (Friedmann & Daly, 2004; Neke & DuPlessis, 2004; Ogada *et al.* 2003; Treves & Karanth, 2003; McKinney, 2001) that are directly linked to increasing human population densities.

As in other parts of the world, it is suspected that unsustainable land use and land cover change, habitat degradation and fragmentation and the expanding human population are undermining the conservation efforts applied to date with respect to large carnivores (Neke & DuPlessis, 2004; Ogada et al. 2003; Treves & Karanth, 2003; McKinney, 2001). The habitat threats towards the cheetah become critical because of its large home range and nature of being a landscape species traversing through a variety of habitat types (Evans, 2004). It is known that cheetah occupy savanna habitats that include grasslands, woodlands, open woodlands and semi- desert areas (Table 1; Marker, 2002) both in reserve and off-reserve areas. The viability of the cheetah population in South Africa is therefore dependent on both reserve and off reserve sub-populations (Friedmann & Daly, 2004; Wilson, personal comm.). Any increased competition and stochastic events in the reserves or off–reserves may negatively impact the viability of these populations for future conservation. Therefore determining the potential threat due to prey availability, habitat fragmentation and land transformation factors with some quantitative measures is required (Regan *et al*, 2005). This project sought to specifically address this need using data sets on land cover, human population, land capability, agricultural potential and cheetah occurrence.

1.2 Land transformation and Fragmentation

Land use change is the modification and conversion of landscapes to managed systems like agriculture, forests, pasturelands, urban centres and industry. It is vital for cheetah conservation and carnivore conservation in general as habitat condition is important for these species (Marker, 2002). This has significant consequences for nutrient cycling, biodiversity, soil structure and biology and climate (Balmford *et al.* 2004; Soule and Orians, 2001; Steffen and Tyson, 2001). Despite their importance natural forests in tropical Africa have decreased by 7.2% decrease within the 1980-1990 decade. The underlying drivers for this have been understood to be the more than doubling of the human population, people's responses to economic opportunities and changes and the need for energy and food supply (Lambin and Geist, 2001; Ramankutty *et al,* 2001). Ginsberg (2001) asserts that for carnivores land transformation (conversion and fragmentation) could be regarded as the greatest long-term threat to the persistence of carnivores.

Research on the South African grassland biome by Neke and Du Plessis (2004) and other biomes has confirmed human population pressure as key in the loss of habitat. (van Rensburg *et al.* 2004; Fairbanks & Thompson, 1996). The current population growth rate projection is 2.2% using figures from the 1996 and 2001 censuses (van Rensburg *et al.* 2004). This figure, which is above the world average of 2% coincides with high human population density next to protected areas posing more threat to species like the cheetah in South African reserves (van Rensburg *et al.* 2004; Chown *et al.* 2003). Within the extent of occurrence (EOO) of the cheetah in South Africa, land transformation has occurred (Fairbanks & Thompson, 1996).

Other land transformation threats in South Africathat remain afforestation and urbanisation. These affect cheetah persistence through reduction in prey base and habitat, change in natural cover and actual loss of the species due to persecution (see Table 2).

Land transformation is closely linked to habitat fragmentation. It refers to discontinuities (fragmentation) in an organism's preferred environment (habitat). It may be caused by either natural (e.g. herbivore population explosions) or anthropogenic factors (e.g. fire) (Forman, 1999). The effects of fragmentation are wide ranging, positive and negative (Reed, 2004) and can be classified broadly as being either spatial or species related. The spatial effects are linked to the species effects e.g. increasing patch density, inter-patch distance, reduced patch size and connectivity, increased species isolation, meta-population persistence, extinction rates besides decreasing large home-range species. Fragmentation also causes disruption of species interactions and ecological processes, lowers dispersal success, introducing disease, genetic inbreeding, and decreased habitat heterogeneity (Forman, 1999; Sunquist &Sunquist, 2001; Braschler *et al.* 2003). As a result of these effects many species are unable to maintain viable populations due to disruptions in population movement and breeding leading to extinctions and loss of biodiversity (Reed, 2004). Large mammalian carnivores are even more prone to this kind of local extinction because of their large ranges, low numbers and persecution from humans (Newmark, 1996; Woodroffe &Ginsberg, 1998). Therefore, it has been suggested that connectivity between and among patches through corridors be encouraged although the usefulness of such corridors is yet to be confirmed (Halpin, 1997). For species such as the cheetah that can survive with some level of fragmentation it is therefore important that wide and well-vegetated corridors for dispersal of the metapopulation be available (Mills & Allendorf, 1996; Reed, 2004; Wikramanayake *et al.* 2004; Wilson, personal comm.). The study by Hilty & Merenlender (2004) has thus far been one of the few studies to provide empirical evidence for this proposition. Models based on geographic information systems (GIS) can then be used to identify corridors for use by carnivores in human dominated environments (Reed, 2004, Wikramanayake *et al.,* 2004).

The adverse impacts of habitat fragmentation for carnivores were highlighted by research done by Crooks (2002). Crooks indicated that sensitivity of carnivores to habitat fragmentation is influenced by the area and level of isolation of the fragments. Generally, the species he studied (which included the mountain lion, *Felis concolor,* bobcat, *Felis rufus,* coyote *Canis latrans,* and gray fox *Urocyon cinereoargenteus*) showed trends of disappearing as habitat patches became smaller and more isolated from other patches. Contrastingly the abundance of species such as the domestic cat, which was not native to the area of study, were however enhanced by the fragmentation, indicating its high adaptability to human dominated environments containing the fragments. This species disappearance with decreasing patch size and increasing isolation is a useful indicator of what can be expected in future and mitigated against.

1.3 Predators and people

Since many extinctions and threats to fauna around the world are driven or exacerbated by human impacts it has often been postulated that extinctions are correlated to human population increase (Cardillo *et al.* 2004; Woodroffe, 2000). Research indicates that the tolerance of people towards carnivores has an influence on the species' distribution or area of extent (Lucherini &Lovari, 1996). Clearly the relationship between human density and carnivore presence is not a linear one but an important one to acknowledge.

For the cheetah in South Africa it is critical to understand this relationship because the majority of reserves are too small to provide adequate home range and sustainable prey populations for any large number of cheetah (Woodroffe, 2000). In addition to this, competition with other predators such as lion and hyaena indicate the need to consider conservation outside reserves as a priority for the cheetah (Purchase and du Toit, 2000). Admitting the limitations of the explanatory power of human density due to temporal and regional variation in human impact upon carnivores among other factors, Woodroffe (2000) did a logistic regression of carnivore persistence on human population density and concluded that for the cheetah in Kenya the critical human density (with a 50% probability of extinction) is 16.5 people/km^2. Using data from India where the cheetah has gone extinct Woodroffe (2000) noted that the mean density at the point of extinction was about 120 people/km^2 (range = 88.4-150.8). These differences in the human population densities at extinction indicate particular differences among human communities on the impact of their actions on carnivores. In a paper highlighting the role of population size in raising bird and mammal threat among nations, McKinney (2001) makes note of the pattern that a continental human population–conservation status indicates that *per capita* human impacts are initially high and asymptotically diminish with increasing population size. In comparing the threat levels between birds and mammals he realized that human population seems to affect mammals more rapidly than birds probably due to body size difference. In his analysis for the continental nations human population size explained between 16-33% of the variation in the threat levels among the nations under consideration making a strong case for the usefulness of human population density-threat correlation. This kind of information, although requiring caution in application, could be used as part of the process in classifying species to the IUCN Red list, informing recommendations on the numbers of people to inhabit buffer areas or determining suitability of places for reintroductions (Harcourt & Parks, 2003; Woodroffe, 2000).

The importance of human population density is also highlighted by van Rensburg *et al.* (2004) who indicate that for birds, areas of importance (IBA) and priority areas for conservation coincide with high population density. Although for birds, the accompanying land transformation (van Rensburg *et al.* 2004) by people produces greater species richness, evenness is negatively influenced (Chown *et al.* 2003; Fairbanks *et al.* 2000). This raises a concern when already-threatened species experience a decline in abundance. In an analysis of adding human densities as an index of threat to the IUCN Red List criteria for threatened primates, Harcourt and Parks (2003) concluded that although the match is not perfect adding the human density helps incorporate the threat associated with people into any threat assessment. This can be valuable since human density data is often easily available.

The usefulness of human population density data, potential transformation threats and extent of fragmentationhas not been tested in many studies or Red Listing processes. Thus even the classification of species according to the Red List is often controversial. This study was initiated to consider such land transformation and human population data for the case of the Red Listed Cheetah with the following aims and objectives detailed below.

1.4 Aim and objectives

Aim

To assess potential threats to cheetah distribution range due to expected land transformation.

Objectives

1. Spatially quantify the threat of different potential land transformation activities to cheetah distribution range.
2. Determine the level of habitat fragmentation in the extent of occurrence of cheetah in South Africa.
3. Investigate the relationship between human population density and cheetah extent of occurrence (outside reserves and urban areas).
4. Synthesize outputs to re-evaluate the effects of land-cover and land-use change within the cheetah distribution range in South Africa, and investigate potential implications for the conservation assessment of cheetah*)*.

2.0 STUDY AREA

2.1 Extent of study area

The study used information on the extent of occurrence (EOO) of the cheetah in the whole of South Africa (S.A Mammal CAMP 2002/3). Cheetah have historically occurred in South Africa's savanna, grassland, subtropical /tropical dry and desert regions (Friedmann & Daly, 2004). The species currently occurs in the eastern lowveld of Mpumalanga and Limpopo, Limpopo River valley to Marico River, western North West Province, north Northern Cape and northern KwaZulu-Natal (see Figure 3). According to van der Waal and Dekker (2000), about 26% of the total area in the Northern Province (now Limpopo) is used for game ranching. Rainfall in these areas is around 600mm per year except in the KwaZulu-Natal (KZN) region that receives the highest rainfall (721-1184mm per annum) in the country. The area of occurrence (AOO) is typically savanna with a dry cold season from June to October and a hot wet summer season from November to May.

Cheetah primary populations are thought to exist in Kruger and Kgalagadi National Parks. Other protected areas with cheetah are Hluhluwe-Imfolozi and Pilanesberg. (Friedmann & Daly, 2004). It is estimated that outside of protected areas the cheetah numbers are 325 (Myers (1975) in Gros, 2002). This is in Limpopo, North West and northern Cape Provinces.

3.0 METHODS

3.1 Data

The project used the following data sets**:**

3.1.1 Land use and land cover data (Fairbanks *et al.* 2000)

The Land Cover database (NLC) produced by Fairbanks *et al* (2000) for South Africa (including Swaziland and Lesotho) was used in the study. Fairbanks *et* al (2000) produced this database by stratifying natural land cover and human land use using Landsat Thematic Mapper imagery from 1994 to 1996. Using the 31 land cover descriptions, literature like Thompson, 1996 and expert knowledge major land uses were asigned to each of the classes. The major land uses were classified as favourable or unfavourable land cover for cheetah (see Table 3)Some key unfavourable aspects of land use were mining, cropping, residence or communal livestock grazing. Protected areas, game farms and areas possessing natural cover such as woodlands and natural forest were classified as favourable for the cheetah.

3.1.2 Cheetah occurrence data (S.A. Mammal CAMP 2002/3)

Cheetah occurrence data used in this study was based on data from various natural history museums in the country that were collated to locate areas of cheetah occurence(AOO) and extent of occurrence (EOO) by the South African Integrated Spatial Information System (SA-ISIS; www.sa-isis.co.za). The EOO was a refinement of the AOO data by experts using research data and designated by polygons. As a result, Conservation Assessment and Management Plan (CAMP) produced a distribution map for the Mammals of South Africa. The CAMP meeting was sponsored by the Carnivore Breeding Specialist Group and the Endangered Wildlife Trust in 2002 (Friedmann & Daly, 2004). Data used for without the reserves occurrence was supplied by Kelly Wilson of De Wildt Cheetah and Wildlife Centre.

3.1.3 Protected Areas data (SANPARKS)

Data in the form of a map layer showing the protected areas of South Africa was also used during the course of the study in conjunction with the other sets of data. This was obtained from the South Africa National Parks (SANPARKS), the protected areas authority in the country.

3.1.4 Population census data (Census 2001)

Population census data, from the 2001 census count, was used in the study. The data was obtained from Statistics South Africa, a department mandated by an Act of Parliament to collect and analyse population data in South Africa (www.statssa.gov.za). The census results were generalised to quarter degree squares (QDS) from the enumeration areas.

3.1.5 Land capability data (ARC, 2000)

Land capability data indicates the suitability of land for cultivation. The data was obtained from The ARC –Institute for Soil, Climate and Water. Land suitability in the data were cultivation, grazing and wildlife. Accordingly the following suitability classes are recommended using the data: (Classes I-IV), grazing (Classes V-VII) or wildlife (Class VIII). These seven (7) classes indicate land units with similar potentials and continuing limitations or hazards (Table 4). The data set is parametric, GIS–compatible with maps at (1:250 000) scale and had climate imposed on it to give unique capability classes. For the purposes of the analysis Classes I-IV (suitable for cultivation) and Classes V-VII (suitable for grazing) were deemed unfavourable and Classes VIII (ideal for wildlife) favourable for cheetah persistence.

3.1.6 Potential agricultural expansion data (ARC, 2000)

Agriculture, being one of the major land transformation drivers (Fairbanks *et al.* 2000) data indicating potential commercial cropping activity was used in conjunction with the cheetah distribution data.. Specifically the crops and forestry tree species examined in the study were maize, wheat, sorghum, sugar, *Eucalyptus* and *Pinus*.
The data was classified as favourable or unfavourable as shown in the Table 5.

3.2 Analysis

Spatial data analysis was done using ArcGIS 8.3 GIS software (ESRI Inc., 2003) while FRAGSTATS ver 3.3 software (McGarigal *et al.,* 2002) was used to calculate the fragmentation metrics. The data was projected to an Albers projection (WGS84 datum) with appropriate parameters for regional South African data. The Albers projection is conformal, which means that the scale at any point is the same and areas and angles are preserved (ESRI, 2004). This projection was best suited for the analysis since it is ideal for land masses that extend more in the east-to-west orientation than those lying north to south and can be used for mapping areas that extend beyond the limits of State Plane and UTM zones which was the case with our study area (www.gis.state.ga.us).

First, the National Land Cover dara was clipped using the EOO polygons. Using criteria mentioned under section 3.1.1 the EOO was delineated into favourable and unfavourable fractions. Fragmentation metrics were then calculated using FRAGSTAS software at patch, class and landscape levels. A patch was defined using the 8-neighbourhood rule. This rule considers both the orthogonal and diagonal cells in the image when calculating the fragmentation statistics as no directional-specific trends were expected. Several indices were measured using this software although the following indices were critical in the analysis: (1) total area (ha); (2) number of patches; and (3) mean patch size (ha) (McGarigal, 2002; Saura, 2004). The class metrics were also calculated for comparison between and among the different classes. Similarly landscape metrics (cohesion, aggregation index) were calculated to give a more comprehensive picture of the current threat potential of fragmentation.

Secondly to investigate potential the National Land Cover data in the EOO were further overlaid with the following data layers: potential agriculture (crops and forest tree species), land capability and human density. The land capability and potential agriculture overlays were used to calculate the potential losses of favourable and unfavourable land fractions within the EOO in case these threats become reality. Both sets of data were used since land capability data included area coverage that was not as specific as contained within the potential agriculture expansion data. The human population density data was used to show the areas where the cheetah could persist without human interference using 16 people per km² as the threshold population density (Woodroffe & Ginsberg, 1998).

All the results from these processes were mapped and integrated to assess the overall threat to the cheetah in its extent of occurrence. Data on the prey availability in the EOO was not available at the time to be used since prey is an important factor for cheetah survival.

4.0 RESULTS

4.1. Extent of occurrence in relation to land use

The total area of the EOO for the cheetah in South Africa is 205 580 km² (Fig 3). The two major protected areas, Kruger National Park and the Kgalagadi Transfrontier Park (on the South African side), contributed 19 599.10 km² and 8 444.28 km² respectively, totalling 13% of the total area. Other protected areas in the EOO were about 3% of the total area. Most of the small protected areas (54 of 74) were of an average size of 21.92 km2 while the rest had a mean size of 243.16 km² (SD +/-110.28). (Table 6, Figure 5).

Furthermore 77% of the land in the EOO was favourable by virtue of being forest, indigenous woodland, thicket, bush clamps and unimproved grassland. Notably thickets contributed the most to followed by forest and woodland class (NLC Class 1) Unfavourable land cover was less than the favourable land cover by 54% with 9% of the land (20 288 km²) under cultivation. Development in the form of urban buildings, exotic forests, improved grasslands was 6.4%.

4.2. Extent of occurrence in relation to potential agricultural use and forestry

The suitability, extent and abundance of the cheetah favourable and unfavourable land differed with the varying species and land capabilities (Table 7). Areas where potential productivity were regarded as favourable varied with species. The range for suitability of land ranged from 0 to 49339.2 km². *Eucalyptus* posed the largest threat with potential for productivity in 24% of the EOO. Sugar only showed potential in the areas around KZN while wheat showed no potential within the EOO.

An overlay of all the crop and plant potential data indicated that 81.7% of total EOO holds potential for one form of crop or plant. Seventy-seven percent (129 681.69km²) of this is found in favourable land (Table 8) leaving 23% favourable land cover under no threat. However 39 280.96km² (32%) in unfavourable land cover is under threat to cropping or forestry.

4.3. Extent of occurrence in relation to land capability

Land capability Classes II to IV, where agricultural cultivation can be done, covered 76 074.06 km² while classes V-VIII, ideal for livestock grazing, covered 129 197.4 km². Class VIII, ideal for wildlife, covered 12 132.99 km² (Table 9).

The land capability data was overlaid with the land cover data so that we could see the classes that coincided with the favourable land cover classes. About 62% of the area is fit for grazing and therefore capable of supporting wildlife herbivores and subsequently cheetah was in already favourable land.

4.5. Extent of occurrence in relation to human population outside Protected Areas

The total human population in the extent of occurrence is 9 508 293 with about 53% of this being females (CSO, 2001). The average human population density across the EOO was 16.93 km² and varied from 0 to 32.19 km² for the different land cover classes within the extent of occurrence (Figure. 4).

Fifty eight percent (58%) of the EOO has a population density of less than 16 people per km². Close examination of the data revealed 18 Quarter Degree Square (QDS) densities that were extremely high. They represented populations in urban environments of cities and towns in Gauteng, KwaZulu-Natal, and Polokwane..Exclusion of the 18 urban QDS densities reduced the density to 117 people per km².

Protected areas with area of less than 100km² had population densities over 72 people per km² around them. The Tuli block, where South Africa borders with Zimbabwe and Botswana and the location of the Kgalagadi Transboundary Park , had the lowest human population density of 3 people per km² or less.

4.6. Extent of occurrence and fragmentation metrics

4.6.1 Patch Metrics

In the EOO the majority of the patches were favourable land making about 77% of the EOO. Land Cover Class 3 made up of Thicket, bushland and bush clumps had the widest coverage of favourable patches of 38%. The mean size of the favourable patches was 166km² from 617 patches while for unfavourable parts had a mean patch size of 23km² and had patches totalling 1207 (Table 6). This represents a core area of 158 375 km² for favourable land for the cheetah in the EOO. The largest patch index, which is the ratio of the largest patch against the total land area, was 13.31. Cultivation in the extent of occurrence had the most number of patches of 583 with a mean size of 34.8 km².

4.6.2 Class & Landscape Metrics

Class and Landscape metrics cannot be interpreted in isolation and are presented together .The favourable patches were less fragmented compared to the unfavourable patches with a cohesion value of 94.68. The aggregation index for patches was high (68%). This is a measure of the closeness of the patches (See Table 12). The Modified

Simpson's diversity evenness index was 0.4259. These patches reflected 0 connectance at a threshold value of 10 m and were isolated at a search radius of at least 100m although there was some level of aggregation for similar type of patches as shown by the aggregation index of 69%.

5.0 DISCUSSION

The Study indicated that the favourable land for cheetah existence (Classes 3,1 and 6) is 77% of the total land area in the extent of occurrence. The protected areas within the EOO contributed about 15% (24 091.34 km²) of this. Therefore without protected areas favourable land is 57% which emphasises the importance of areas outside of formal protected area network for cheetah conservation in South Africa (Deguise & Kerr, 2006). This requires that all future land use planning and development within the EOO incorporates the conservation needs of the species (Cardillo *et al.* 2004; Primm & Clark, 1996). Monitoring of land use and land cover changes in the EOO would be useful in this regard so that timely action taken where required (Reyers, 2004). This study used the year 2000 land cover data which can be used as a yardstick for comparison with newer or more recent land use data. Such an exercise together with ground truthing would have a combined effect of giving quantitative measure of land transformation and the intensity of human actions where they are occurring.

Class 3, made up of thickets and bush land, requires further examination as it may arguably be indicative of human transformation due to invasive woody species (Neke & du Plessis, 2004). If this is correct (and prey assumed to be low for the cheetah in such an environment) then the level of human transformation in the EOO will be 49.9% (102 583.792 km²).

5.1 Crops & Land Capability

The importance of water availability was evident in explaining the threat of the different crops in the EOO. Sorghum had the widest potential in the EOO since its water requirements are the least among the crops considered. The KZN region had the greatest threat from agricultural transformation probably because of the higher rainfall in that region compared to the northern parts of the country. However maize potential may be greater than indicated by the analysis because of its status as the staple crop for the majority of rural farmers (Twine *et* al, 2004; www.info.gov.za). Farmers would still farm maize even in marginal land. This is especially because the population in the country has been steadily increasing and requires food and economic development offered by agriculture compared to conservation.

About 69% of the EOO is considered favourable land (grazing and wildlife) using the land capability data. This strengthens the argument for convincing farmers and land planners to seriously consider cheetah friendly activities such as game ranching as the prime activity in the EOO (Bulte & Damania, 2005; Muir Leresche & Nelson, 2000). This is a viable option for both for conservation and tourism (Marker, 2002). Preliminary findings from the DeWildt Wild Cheetah Project report success with farmers in the north of the EOO with such activities (Wilson-personal comm.).

5.2 Human Population

The results showed that the human population density around the protected areas in the EOO is relatively high with some places recording over 1000 people per km^2 (van Rensburg *et al.* 2004). This is likely to result in conflict between people and cheetah (Woodroffe & Ginsberg, 1998) as people view cheetah as a nuisance (when it kills livestock), and limited dispersal opportunities from reserves (Sunquist & Sunquist, 2001; Chown *et al.* 2003; Treves & Karanth, 2003). To mitigate against this Cheetah-Human Conflict an education programme is suggested. This could tackle the myths around cheetah, benefits of the species and possibilities of reducing off-take of livestock by them (Sillero-Zubiri *et al,* 2004). Building predator proof fences around the protected areas may also be ideal to deter some of the cheetah movement before attitudes of people have changed towards the species. (Friedmann & Daly, 2004). Work by the cheetah Conservation Fund in Namibia provides a good example to follow on how to involve communities in cheetah conservation.

Using the population density of 16 per km² as the acceptable threshold population density for cheetah extinction (Woodroffe & Ginsberg, 1998) designated all the EOO as unfavourable (Fig. 7). A better threshold value for use in South Africa must be sought. In coming up with such a human population density threshold value for the cheetah consideration must be given direct persecution and the attitudes of people living with the cheetah to the species (Clark *et al*, 1996). Work by De Wildt wild Cheetah project has aspects that cover this although this is limited in terms of geographic scope. Another factor that needs to be included in such a threshold value is the differential sensitivity of the different age classes of cheetah to the presence of people (Crooks, 2002). This is important since cheetah cubs are more prone to being killed than the adult cheetah.

5.3 Fragmentation

The fragmentation statistics in the EOO indicated that the favourable patches were large and coherent; their number low and the mean size relatively larger in the favourable portion of the EOO. Further the largest patch index was low. This is good for the Cheetah since the number of patches (NP) can be used as a fragmentation index with higher NP indicating greater fragmentation. The mean patch size also indicates greater fragmentation when it is lower while higher patch cohesion values show lower fragmentation. (Opdam *et al,* 2003; Saura, 2004; Tischendorf, 2001; Tischendorf & Fahrig, 2000; Schumaker, 1996; Forman, 1999). Their size (of the favourable patches) was also generally larger (mean 166 km² ranging from 352 to 143 km²) compared to the unfavourable patches that were small (mean size<100 km²). This mean patch size of the favourable land cover is able to accommodate the HR size from studies on the cheetah (Marker and Shumann, 1998, Purchase and Du Toit, 2000, Broomhall, Mills and Du Toit, 2003). At a landscape level similar patches (PLADJ) that are adjacent to each other made up a proportion of 68%. The similar patches clumped together showed physical connection hence the Cohesion value of 94.68.

Edge metrics were not so useful because cheetahs are landscape species and are not confined to a single habitat type (Evans, 2004). They readily move between land covers and exploit multiple habitat types. Put together this means that Cheetah-Friendly Farms and conservancies can be created by joining adjacent farms. This would add value to the conservation effort as it will create corridors for the movement of the cheetah and other species (Bulte & Damania, 2005; Rouget *et al*, 2006). Incentives for such action by landowners such as reduced taxes may be important (Berger, 2006; Newburn *et al*, 2005).

5.4 Relation of the threats to Red Listing

The amount of land favourable for the cheetah within the EOO was found to be 23% (158 296km²) less than the original estimate. Integrating the other threats reduced this to further about 54 000km² (Figure 8). This is above the threshold value for the Vulnerable (VU) category of 20 000km² and can therefore not facilitate a Red Listing change (IUCN, 2001). Furthermore the level of fragmentation found does not warrant undue concern. Therefore using this newly derived information does not seem to alter the placement of the species in the Vulnerable Category. Chances of a more favourable categorisation are likely in the future if the increasing number of game farms (with more available prey) continues and the efforts to encourage cheetah - friendly farms in the EOO are successful (Berger, 2006; Muir-Leresche & Nelson, 2000; Wilson & Cilliers–personal comm.; Linklater, 2002).

6.0 CONCLUSIONS AND RECOMMENDATIONS

The inclusion of current and potential (direct and indirect) threat data as determined by land cover in the EOO area into the Red Listing process is important. Agriculture- and other human population derived threats should be used to refine the listing as well as to inform conservation and land use planning (Deguise & Kerr, 2006). Doing this, for the case of the cheetah revealed that the actual land available for the cheetah is almost half of the original EOO. Since the EOO was delineated through the creation of polygons around the areas of occupancy this must be regarded as only the best approximation.

The use of quantitative measurements to indicate severity of fragmentation is a positive development that must be continued as it reduces subjectivity. The threshold land area before fragmentation is regarded as adverse must be investigated (Rasker & Hackman, 1996).

Although the NLC data used in this study proved helpful in the analysis of the current state and potential threat it had some limitations. The data set used was 1994 and later data could have been used. Also the geographic scope of the data was limited to South Africa yet the cheetah ranges into neighbouring Botswana and Zimbabwe. Therefore the importance of a large percentage of favourable habitat in the South African cheetah EOO may have to be re-evaluated using land cover data with wider spatial scale.

The way forward for cheetah conservation must therefore involve the farmers and communities to create a positive attitude towards the species (Johnson *et al*, 2001; Marker, 2002; van der Waal and Dekker, 2000; Pimm & Clark, 1996). Doing this also benefit other diverse flora and fauna (Rouget *et al*, 2006)

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Figures

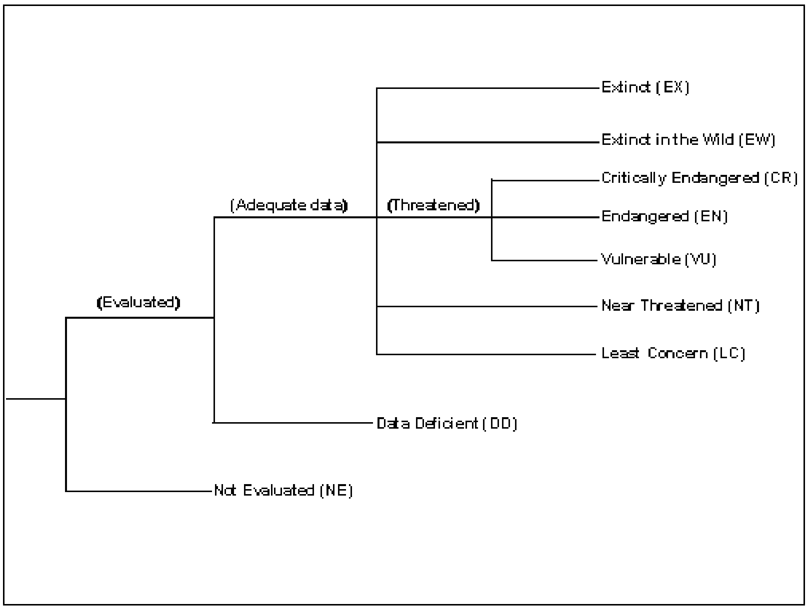

Figure 1. Structure of the categories (taken from www.redlist.org)

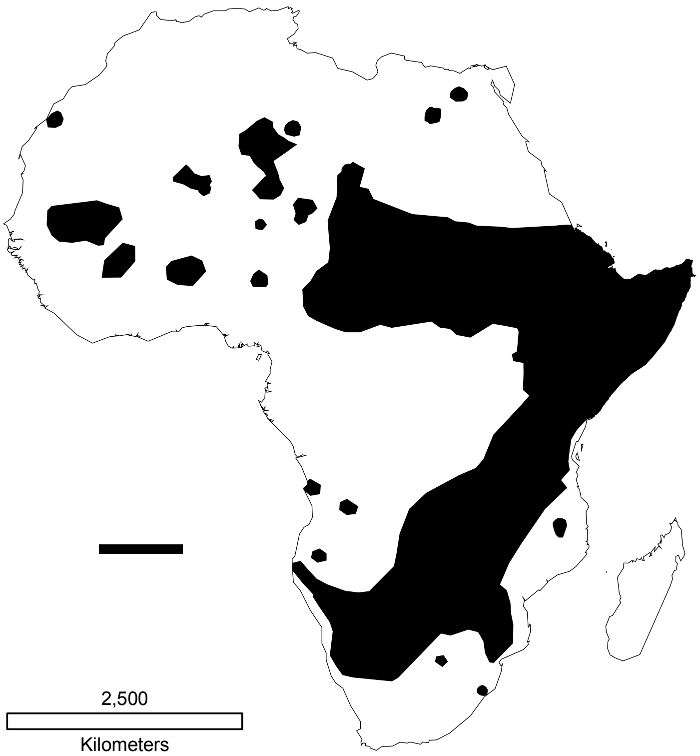

Figure 2. Present range of cheetah in Africa

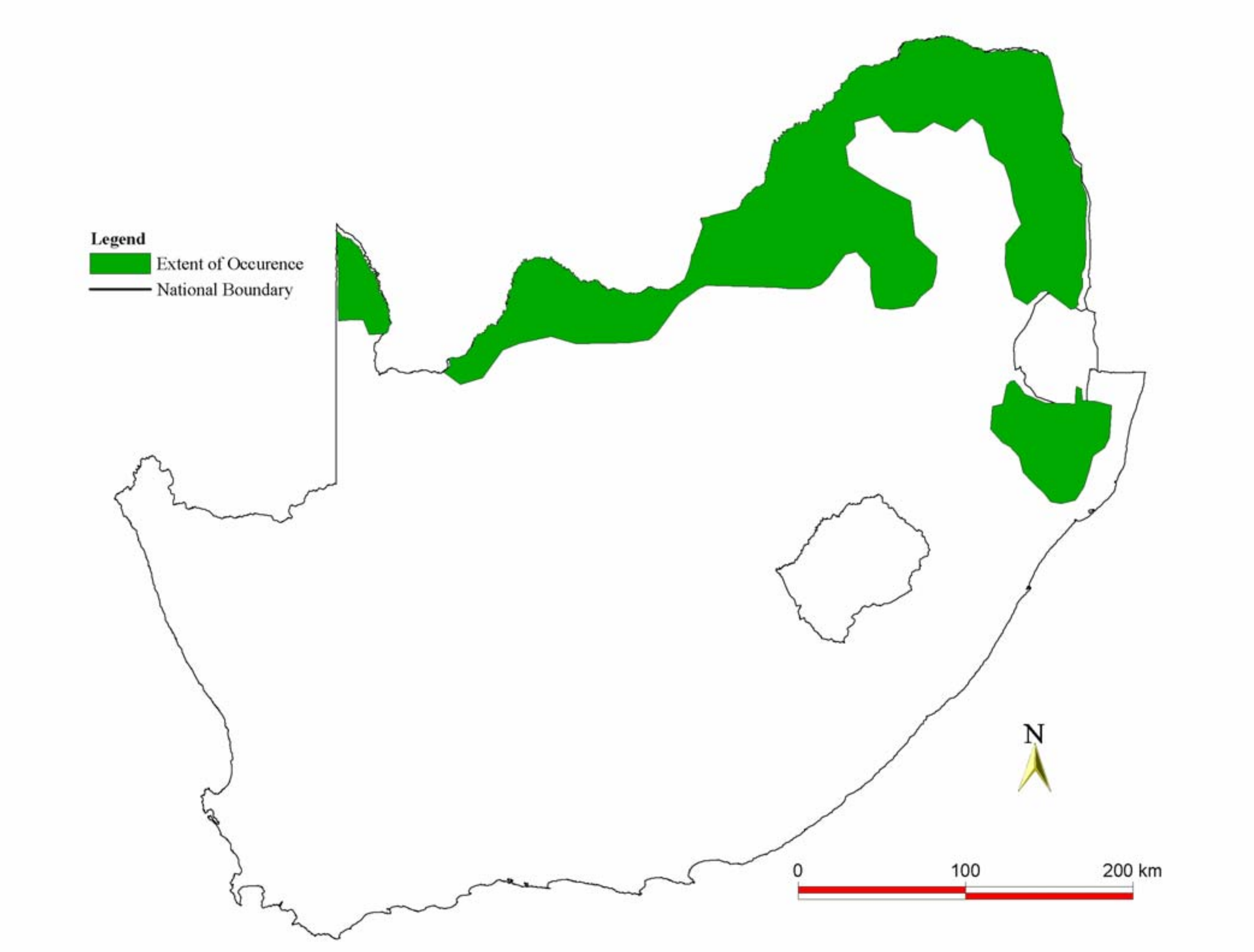

Figure 3. Map of the extent of occurrence (EOO) of the cheetah *(Acinonyx jubatus*), in South Africa.

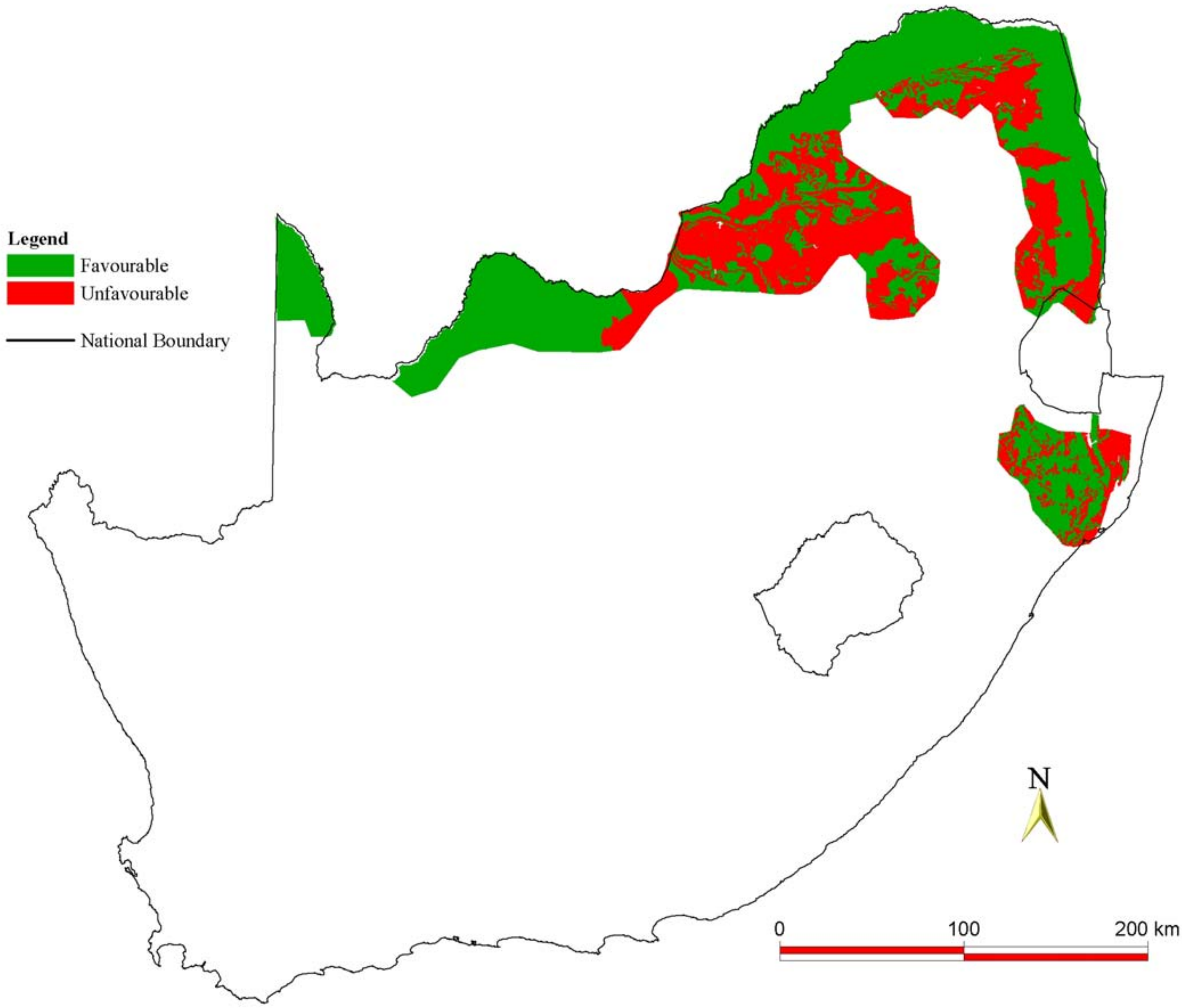

Figure 4. Map showing the favourable and unfavourable fractions within the extent of occurrence of the cheetah according to land capability and agriculture data

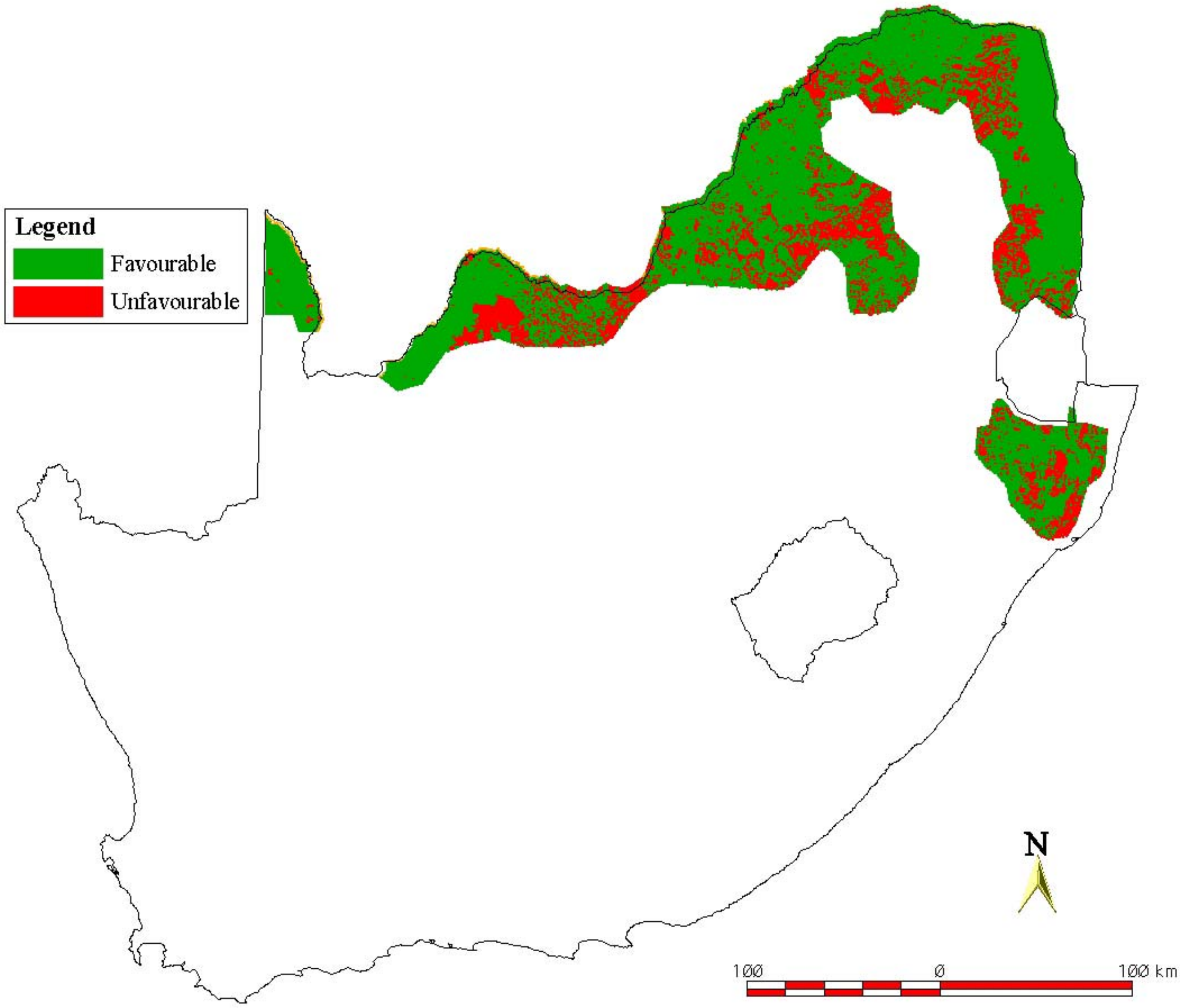

Figure 5. Map showing the favourable and unfavourable fractions of the extent of occurrence of the cheetah according to land cover

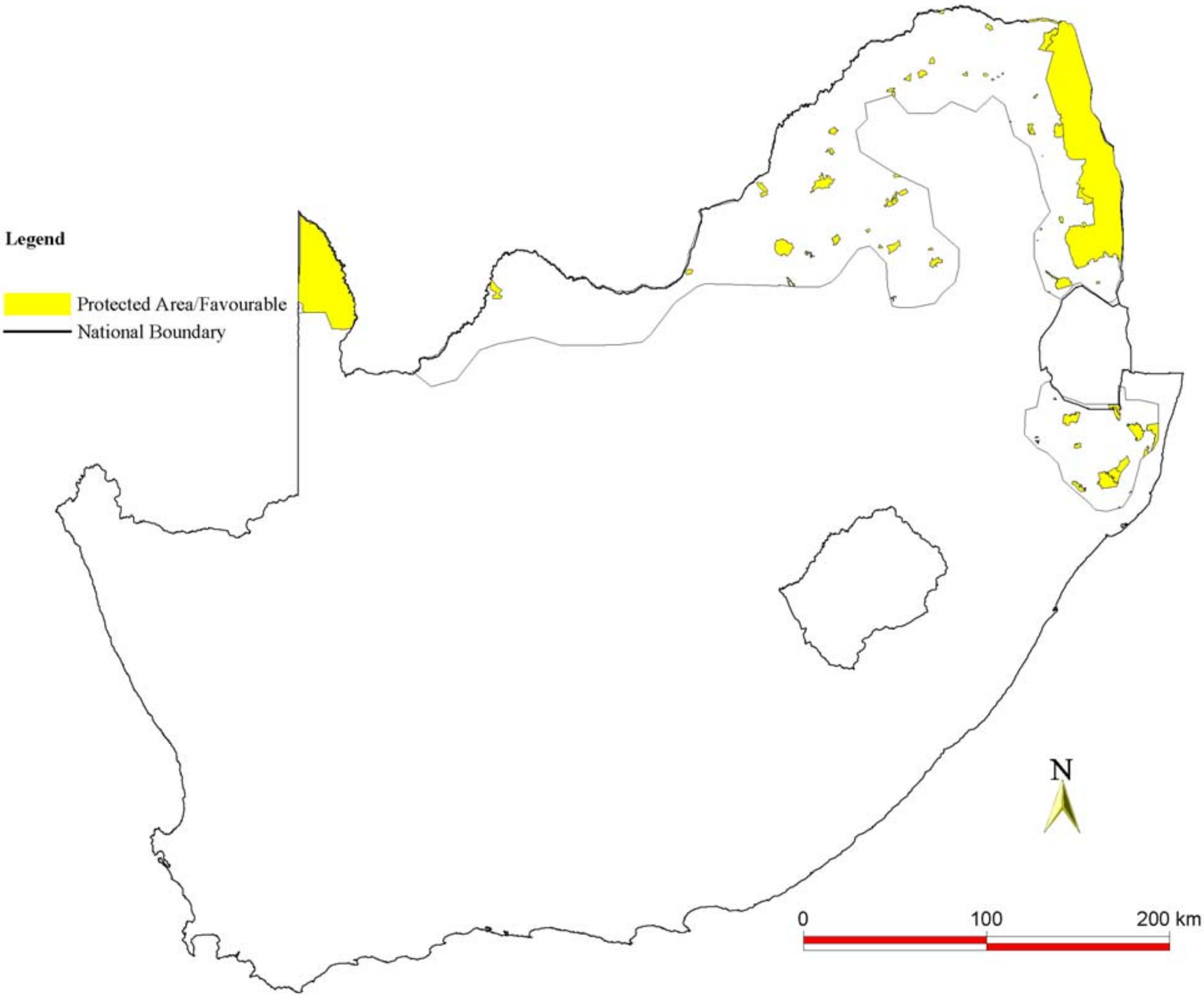

Figure 6. Map showing the favourable fractions of the extent of occurrence of the cheetah, as a result of the protected area coverage

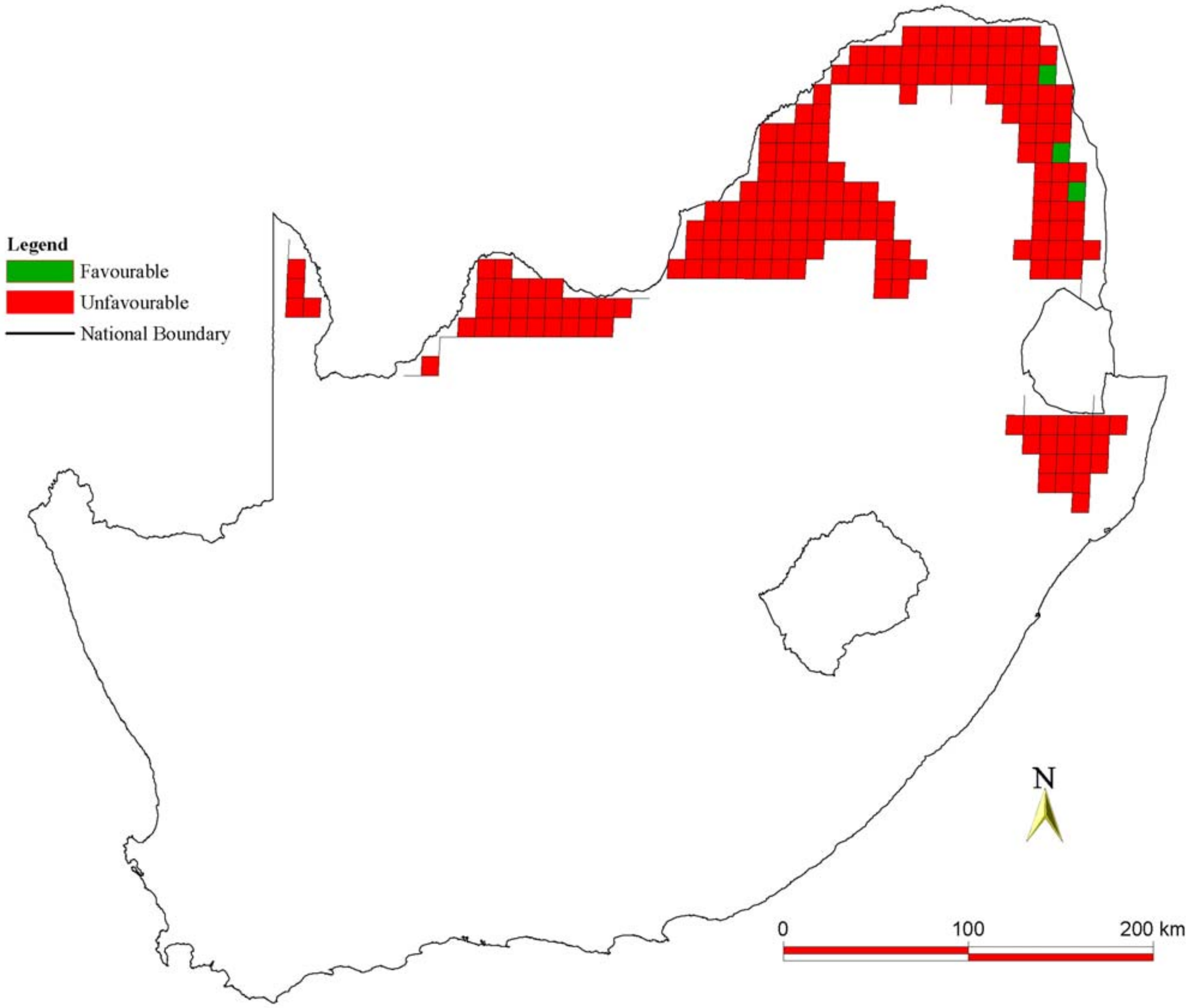

Fig 7. Map showing the favourable and unfavourable fractions of the extent of occurrence of the cheetah according to human population density above 16 people per km²

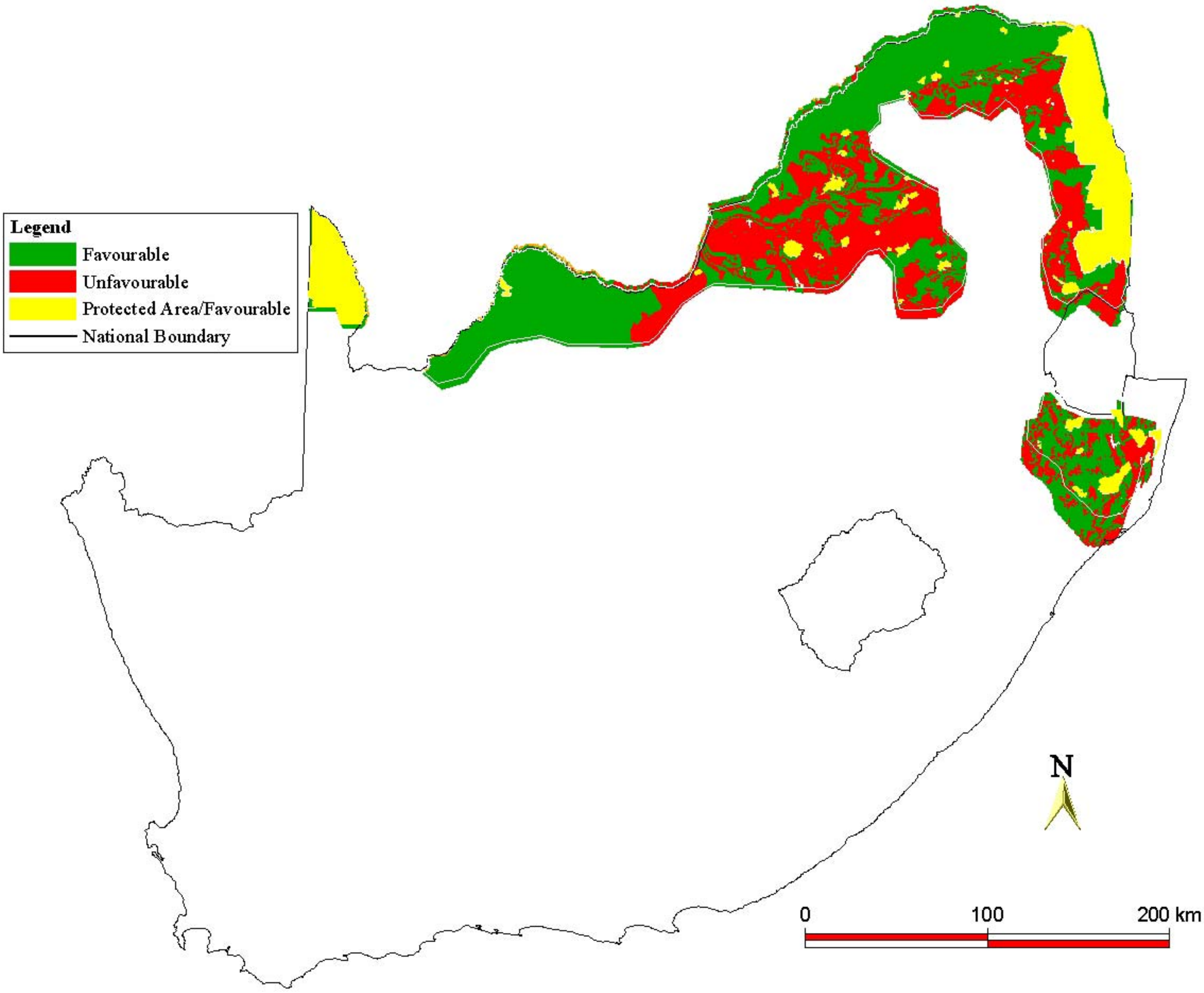

Figure 8. Integrated threat map for the cheetah within the extent of occurrence in South Africa

Tables

Table 1. Scored habitat preferences for the cheetah in Africa (from Friedmann & Daly, 2004)

Preference Score	Type of habitat
1	Open woodland and woodland mosaics and transitions; grasslands; semi-desert vegetation; shrubland, bushland and thicket and their mosaics
2	Dense woodlands; coastal desert; Saharo-montane vegetation; savanna/cropland mosaics
3	Forests; absolute desert

Table 2. Land uses and their likely threats to and effects on the cheetah

Land use	Perceived threat	Effect on the cheetah
Afforestation (pines and eucalyptus)	Altered fire regimes, nutrient and hydrological cycles, disrupted dispersal of plant and animal species, monoculture with no grass, habitat fragmentation into smaller patches Habitat change?	Reduction in the prey base, unable to locate prey
Agriculture (maize, sorghum, sugar, wheat)	Loss and degradation of natural cover, dispersal of prey species, loss of topsoil and natural nutrient processes, habitat fragmentation into smaller patches	Change of natural cover for the cheetah, reduction in the prey base as food and habitat for prey is taken away
Urbanisation	Change in microclimate & natural cover, invasions, increased prey species predation, persecution, disconnections through roads, degradation of natural habitat	Elimination or reduction of prey, reduction in the density of the cheetah due to persecution

Table 3: Favourable and unfavourable land classes for the cheetah according to the National Land Cover (NLC) map (adapted from Thompson, 1996 and from Fairbanks *et al.* 2000)

NLC Code	Land cover class	Land use
Favourable		
1	Forest and woodland	*Conservation, wood collection, communal grazing
2	Indigenous forest	Conservation, wood collection, communal grazing
3	Thicket, bushland, bush clumps	Conservation, wood collection, communal grazing-
4	Low shrubland and Fynbos	Conservation, wood collection, communal grazing-
5	Herbland	Conservation, wood collection, communal grazing
6	Unimproved grassland	Conservation, wood collection, communal grazing, managed as fire break
Unfavourable		
7	Improved grassland (pasture, recreational fields)	Communal grazing, residential area
8	Forest plantation(exotic tree species)	Managed exotic forest
9	Waterbodies	River, farm dam, lagoon
10	Wetlands	Conservation, within individual property
11	Bare rock and soil (natural)	Abandoned/ fallow fields
12	Bare rock and soil (erosion surfaces)	Abandoned/ fallow fields
13-17	Degraded vegetation, by classes 1, 3, 4, 5, 6	Cropping (subsistence, commercial, irrigated or non irrigated)
18-23	Cultivated lands, variations of permanent/ temporary crop, irrigated /dryland and commercial/subsistence/ sugarcane	
24-30	Urban / built-up land (residential)	Residential (formal or non formal)
31	Mines and quarries	Open cast or sub surface activities

*Conservation- game farms, protected areas (PAs), Communal Forest,

Table 4. Classification of land into classes using capability and intensity of use (wildlife (W), Forestry (F), light grazing (LG), moderate grazing (MG), intensive grazing (IG), poorly adapted cultivation (LC), moderately well adapted cultivation (MC), intensive well adapted cultivation (IC) and very intensive, well adapted cultivation (VIC)) (Taken Schoeman *et al.* 2002).

Class	Land use options	Land capability
I	W F LG MG IG LC MC IC VIC	
II	W F LG MG IG LC MC IC	Arable land
III	W F LG MG IG LC	
IV	W F LG MG IG	
V	W F LG MG	
VI	W F LG MG	Grazing
VII	W F LG	
VIII	W	Wildlife

Table 5: Favourable and unfavourable classification of the crops and forest tree species according to productivity levels

Crop/ Tree species	Class/es & Productivity level	Favourable	Unfavourable
Maize	1&2: 2-6 ton/ha	X	
	3&4: 6-10 ton/ha		X
Wheat	1&2: 80-130 ton/ha	X	
	3&4: 130-170 ton/ha		X
Sugar	1&2:	X	
	3&4		X
Pine	1&2: 20-40%	X	
	3-5: 40-100%		X
Eucalyptus	1 &2: 0-40%	X	
	3-5: 40-100%		X

Table 6: Proportions of the different land use classes within the extent of occurrence of the Cheetah in South Africa

NLC Code	Level 1 land-cover class	Area (km²)	Area in Protected Areas	% age of total
1	Forest and woodland	58 178.63	19 128.95	28.30
2	Indigenous forest	351.10	87.60	0.17
3	Thicket, bushland, bush clumps	78 507.04	4 919.45	38.19
4	Low shrubland and Fynbos	327.49	291.36	0.16
5	Herbland	-	-	-
6	Unimproved grassland	21 239.20	8 230.17	10.33
7	Improved grassland (pasture, recreational fields)	26.47??	186.86	?
8	Forest plantation (exotic tree species)	3 016.98	20.43	1.47
9	Waterbodies	278.24	186.86	0.14
10	Wetlands	250.33	112.92	0.05
11	Bare rock and soil (natural)	107.33	100.05	0.05
12	Bare rock and soil (erosion surfaces)	25.69	1.35	-
13-17	Degraded vegetation, by classes 1, 3, 4, 5, 6	16 427.74	139.95	7.99
18-23	*Cultivated lands,	23 819.15	121.88	11.59
24	Urban/ built-up (residential)	1 921.53	8.00	0.93
25-28	^Urban/ built-up	98.27	1.78	0.04
29	Urban/ built-up land (commercial)	12.26	-	-
30	Urban/ built-up land (industrial/ transport)	39.01	-	-
31	Mines and quarries	209.64	2.05	0.10

*Cultivated lands, variations of permanent/ temporary crop, irrigated /dry land and commercial/subsistence/ sugarcane

^Urban/ built up (residential small holdings subdivided by vegetation classes 1, 3, 4,5,6)

Table 7. Key fragmentation indices for the favourable and unfavourable land fractions within the cheetah extent of occurrence area

Land Type	Fragmentation Indices		
	Total Core Area (km^2)	Mean patch Area (km^2)	No. of patches
Favourable	158375	166	617
Unfavourable	46 786	23	1207

Table 8. Area proportions of high crop and plant threats to extent of occurrence of cheetah (outside of the protected areas)

Crop/ Plant species	Percentages area of EOO (outside PAs)
Eucalyptus	24
Pinus	11
Maize	3
Sorghum	9
Sugar	<<1 (0.01%)

Table 9. Different land type uses in the combined potential cropping and forestry areas

Land use type/ Grid code	Area (km²)
Favourable	
1	56711.07
2	351.10
3	58869.80
4	30.64
6	12719.08
Unfavourable	
7	7.59
8	3016.98
9	277.69
10	228.06
11	12.12
12	25.69
13-17	10868.14
18-23	22611.76
24-30	2023.29
31	209.64

Table 10. Areas covered by the different land capability classes within the Cheetah EOO

Capability Class	**Land Capability**	**Area covered (km²)**
2	Arable land	2797.97
3		33858.40
4		39418.25
5	Grazing	42718.63
6		35432.92
7		38912.90
8	Wildlife	12132.99

Table 11. Land use capability in the EOO and for the favourable land use classes

Capability class	Land capability	Total land area in EOO	Area of favourable land covered
I-IV	Arable land	76 074.62	42 378.86
V-VII	Grazing	117 064.45	84 864.06
VIII	Wildlife	12 132.99	10 014.54

Table 12. Landscape pattern within the extent of occurrence of the cheetah

Land Metric	**Value**
Total area	205160
Number of patches	1824
Largest patch index	13.3168
Mean patch area	112.47
PLADJ	68.0171
Cohesion	94.68

Table 13. Extent of occurrence class fragmentation indices at class level

Land Cover Type	**NLC Code**	**Fragmentation Indices**				
		Total Core Area (km²)	Mean Patch Area (km²)	No. of Patches	% of landscape	Landscape Patch Index (%)
Thicket, bushland, bush clumps	3	78056.77	282.81	276	38.05	12.13
Forest and woodland	1	58439.80	352.05	166	28.48	13.32
Cultivated lands	21	2189.59	26.70	82	1.07	0.17
Degraded vegetation	14	11528.88	52.17	221	5.62	1.97
Mines and quarries	31	223.43	14.90	15	0.11	0.03
Degraded vegetation	13	4718.80	39.99	118	2.30	0.31
Cultivated lands	23	10885.41	53.10	205	5.31	1.10
Cultivated lands	22	9437.59	38.52	245	4.60	1.33
Waterbodies	9	321.74	18.93	17	0.16	0.06
Urban/ built-up (residential	24	1912.54	13.19	145	0.93	0.02
Forest plantation (exotic tree species)	8	2931.37	56.37	52	1.43	0.55
Unimproved grassland	6	21243.52	143.54	148	10.35	3.76
Cultivated lands	19	384.30	21.35	18	0.19	0.05
Indigenous forest	2	375.36	18.77	20	0.18	0.03
Low shrubland and Fynbos	4	259.18	37.03	7	0.13	0.07
Urban/ built-up land	30	53.62	8.94	6	0.03	0.00
*Cultivated lands	18	348.55	23.24	15	0.17	0.05
^Urban/ built up	25	71.50	23.83	3	0.03	0.02
Wetlands	10	223.43	17.19	13	0.11	0.05
Bare rock and soil (erosion surfaces	12	26.81	8.94	3	0.01	0.00
Cultivated lands	20	831.15	46.18	18	0.41	0.09
Urban/ built-up land (commercial)	29	26.81	8.94	3	0.01	0.00
Bare rock and soil (natural)	11	98.31	19.66	5	0.05	0.02
Urban/ built-up	26	35.75	11.92	3	0.02	0.01
Urban/ built-up	28	8.94	8.94	1	0.00	0.00
~Improved grassland	7	8.94	8.94	1	0.00	0.00
#Degraded vegetation	15	518.35	28.80	18	0.25	0.08

*Cultivated lands, variations of permanent/ temporary crop, irrigated /dry land and commercial/subsistence/ sugarcane
^Urban/ built up (residential small holdings subdivided by vegetation classes 1, 3, 4, 5, 6)
#Degraded vegetation, by classes 1, 3, 4, 5, 6
~Improved grassland (pasture, recreational fields