A Game Drive Optimisation Strategy for Etosha Heights Game Safaris -Etosha Heights, Namibia

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(Photo of a limestone conglomerate; taken by Gerhard Nortjé)

A report prepared for Etosha Heights Game Safaris

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TERMS OF REFERENCE

Gerhard Nortjé, from the University of South Africa, was requested by Etosha Heights Game Safaris (EHGR) to carry out a soil survey of the Etosha Heights Private Reserve (EHPR), on the southern border of the Etosha National Park (ENP) in Namibia, on the south-western part of the African continent. The aim of the survey was to describe, classify and map the soils occurring in the area, to assess the conservation potential and to make management recommendations concerning road planning, sustainable game drives and erosion- and land degradation control.

CHAPTER 1
Introduction

EHGR manages the EHPR (48,000 ha or 118,610.58 acre) private wildlife concession, comprises a natural area on the south-western border of the ENP. It is in one of the largest private reserves in Namibia, sharing a border of approximately 70 km to the north with the ENP; it offers a robust conservation area of unspoiled wildlife and tranquillity. Just over four hours drive from Windhoek, it has beautiful nature, dramatic skies, vast plains, rich animal diversity and scattered saltpans dotting the landscape.

The purpose of this soil survey was to contribute to the management of the EHPR regarding sustainable soil management; road planning, erosion control and game drive (eco-tourism) activities. It is acknowledged that detailed soil surveys are expensive and time consuming but are indispensable for sustainable land use. However, the costs in terms of yield, crop or vegetation and soil loss if soil survey information is lacking, far outweigh the cost of undertaking the surveys.

Soils are the most important natural resource in any natural area. This is also the case for the EHPR. The different soil forms differ in their natural chemical, physical and biological characteristics and these characteristics reflect in their resilience (recovery potential), stability against erosion, compaction, crusting and fertility for wildlife/livestock grazing. In undertaking the soil survey, the survey area boundaries were identified, landscapes identified, soil geographic points pre-selected and the soils were classified, according to both the South African Soil Classification System (Soil Classification Working Group 1991) and the World Reference Base for Soil Resources Classification System (WRB 1998).

This soil data can contribute to the development of a site specific and scientifically based management plan for the area. The soil survey was conducted during July 2018. This report summarises the findings of this soil survey to provide basic guidelines on soil- and game drive management actions required as believed the be most important at this stage.

1.1 Nature conservation and human impacts

Severe soil degradation (erosion, surface crusting and sub-soil compaction) is often found on game farms, nature reserves and national parks, in southern- western-, as well as eastern Africa (Laker 2004; Nortjé 2014). Mismanagement, like overstocking and off-road driving (ORD), lead to soil crusting and erosion (Laker 2004). ORD is the result of ill-planned game drive activities. Incorrect browser: grazer ratios lead to bush encroachment and/or densification and decreased grass cover and erosion.

In a study on the impacts of ORD on soil compaction in the Kruger National Park (KNP), Nortjé (2014) has shown that eco-tourism activities can sometimes have very negative impacts on the natural environment (soil and vegetation) (Nortjé & Mearns 2017). This, coupled with the low resilience or recovery potential of a large percentage of soils in southern-western-and eastern Africa, make the problem worse. Human impact on degradation of soils and vegetation is strongly linked to the properties and qualities of the different soils (Nortjé 2014).

1.2 Significance of soil studies in Africa

Soil management and research should form an integral part in any conservation efforts in wildlife-protected areas. "*There is an urgent need in developing countries like Namibia for natural resources investigations in order to give a consolidated background for adequate management and future land use planning activities. Soil in particular, as the basis for plant and animal life, needs special attention and protection, both to guarantee human food supply as well as species diversity, especially in protected areas like Etosha National Park (ENP)*" (Beugler-Bell & Buch 1997). Research has shown that severe soil erosion, soil surface crusting and sub-soil compaction (Nortjé 2014) affect large areas in protected areas. This has a very negative impact on the overall biological productivity of the land. Some causes have been proven and partially addressed. However, little is known and/or applied concerning rehabilitation and prevention. My hypothesis (largely proven) is that "*when the soil is degraded, the vegetation dies. This leads to no herbivores, no predators and eventually no tourists*" (Nortjé 2019). This degradation cannot be alleviated naturally due to a lack of soil resilience of a large part of Southern African and some Eastern African soils (Nortjé & Nortjé 2017b).

1.3 Problem statement and objectives

Environmental damage at EHPR, caused by ORD, destroys the soil and vegetation (Fig. 1). Driving on wet roads causes rut formation and erosion (Fig. 2). No drainage on the existing road network causes soil erosion (Figs. 1 and 2). Furthermore, overgrazed areas, which result in soil erosion and surface crusting, and denuded vegetation are predominantly found in low-lying and sodic areas around drinking areas/spots (Figs. 3, 4 and 5). In areas with no water holes, overgrazing and vehicle damage, almost no soil erosion exists and the grass cover is healthy (Fig. 6). The author personally experienced ORD during his visit/soil survey in July 2018. The specific ORD activity happened when numerous game drive vehicles attempted to show their tourists a herd of elephant passing through the concession in search for water, with no official roads available to drive. The existence of a suitable road to drive on would have negated the necessity to drive randomly off-road.

Figure 1: Off-road damage (Garmin Virb image)

Figure 2: Ruts due to driving in wet roads (Garmin Virb image)

Figure 3: Denuded vegetation around Wespos (Garmin Virb image)

Figure 4: Denuded vegetation at water hole on sodic soils (Garmin Virb image)

Figure 5: Soil crusting

Figure 6: Wildlife grazers on healthy soil
and dense high quality (nutritious and palatable) grass

The objectives, regarding the method of the soil survey and report, were as follows:

- a semi-detailed soil survey of EHPR to determine the inherent properties, mainly physical and morphological (soil form classification), of the soils;
- compilation of a soil map at a scale large enough to describe the natural distribution of the soils;
- description of the soils in the different map units in terms of their physical, morphological and land use properties;
- evaluation of the general suitability of the soils in terms of land use (eco-tourism, conservation, grazing);
- recommendations regarding roads to be closed and new roads with the objective of preventing ORD, thus optimizing game drives.

The above-mentioned problems of overgrazing and soil erosion are somehow softened by the fact that most of the soils in the EHPR can be classified as 'Coega' soils (Soil Classification Working Group 1991) or Petric calcisols (WRB 1998) (Fig. 7a). The problems are aggravated by the occurrence of unstable "Solonetz" soils, or "sodic soils", on the plains (Fig. 7b). These "sodic soils" are known, in South Africa, as soils of the Estcourt soil form (Soil Classification Working Group 1991). They are highly unstable soils and are extremely vulnerable to erosion when cultivated or overgrazed and have very low resilience (recovery potential) once they have been degraded (Laker 2004). They are only suitable for low intensity extensive grazing due to their low carrying capacity, a result of a low biomass production capacity.

a) b)

Figure 7: The soils in EHPR are characterized by two dominant soils
a) Stable Coega soil forms and b) extremely unstable 'Solonetz' soils on the plains

The limited biomass is highly palatable and nutritious sweet veld, preferred by animals, usually resulting in overgrazing. These soils should be very carefully managed and protected from overgrazing at all costs (Nortjé 2016; Laker 2004). This is difficult in a wildlife ecotourist situation, because areas cannot be fenced off to protect them, mainly from an aesthetic point. Therefore, ingenious management approaches are required.

Nortjé (2014) outlined basic research findings regarding the negative impacts of uncontrolled ORD in protected (wildlife eco-tourism) areas. Nortjé *et al*. (2012, 2016) summarized these findings.

CHAPTER 2
Study Area

2.1 Map of study area

The EHPR lies at the south-western border of the ENP. It covers an area of approximately 48,000 ha (Fig. 8). The area borders the ENP in the North. It is approximately 450 km from the capital city Windhoek and some 150 km to the closest town Outjo. The EHPR can be regarded as a "buffer-zone" to the ENP, acting to absorb environmental pressures from developing communities in the surrounding region (Jokisch 2009).

Figure 8: Location of the study area, at the south-western border of the ENP

2.2 Climate

The climate of the EHPR is largely semi-arid, a hot and relatively dry. Like most semi-desert climates, there is a large variation in temperature between night and day. The wet season coincides with the summer months of November to April. During the dry winter months, from May to October, rainfall is a rarity (Fig. 9).

<u>Winter - May to October</u>
Rainfall is almost completely unheard of during the cool months of the year. Conditions become drier as the winter season progresses. Water sources for wildlife become fewer and vegetation thins out.

- May, June, July and August — most dry and sunny; afternoon temperatures are pleasant, with an average high of 27°C/80°F; cold morning temperatures of 10°C/50°F; the coolest time of year.

- September and October — temperatures rise rapidly during the day to an average of around 33°C/91°F, morning temperatures are normally warmer too, averaging 15°C/60°F; rains usually start in late October or early November.

Wet season - November to April

The wet summer months, yet, rainfall is scant and usually occurs in the afternoon - it is rarely a daily occurrence; days are typically hot and coincides with temperatures of 17°C /63° F at night are common.

- November and December — the rains usually start in November with the occasional thundershower; these are the hottest months and afternoon temperatures are around 33°C/91°F.
- January, February and March — although mostly sunny, these are the wettest months with frequent afternoon showers and the rain ensures average temperatures of around 30°C/86°F.
- April — April sees a dramatic decrease in rainfall with temperatures around 30°C/86°F during the day.

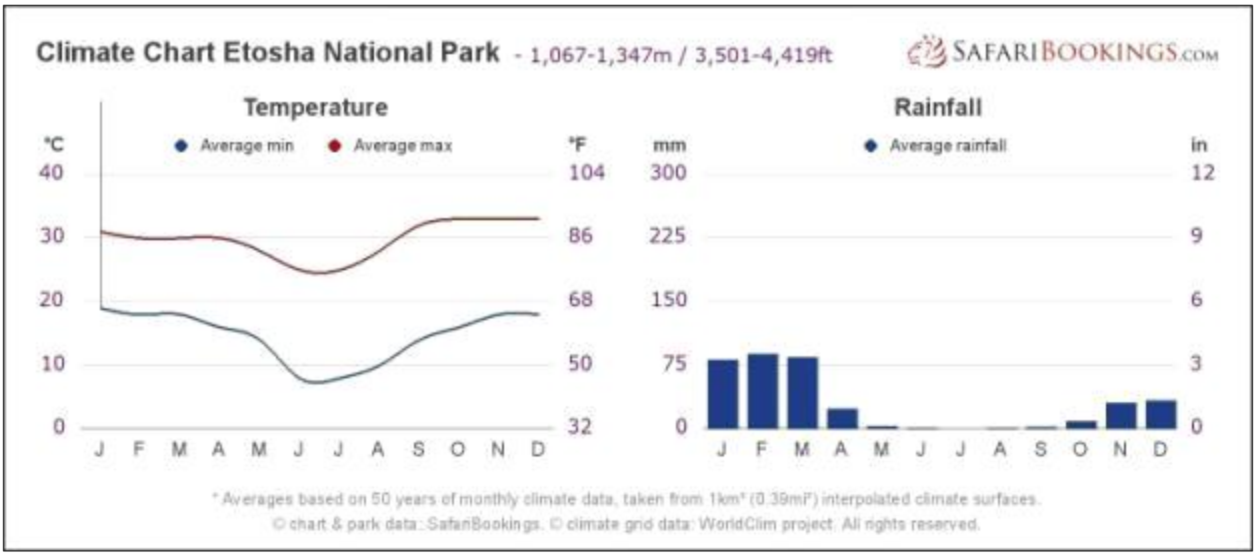

Figure 9: Climate (long-term average rainfall and temperatures) for the EHPR

2.3 Geology

The major soils at EHPR have their origin from the underlain geology in the area. The EHPR consists of carbonate-rich rock. These rocks are typical of warm, arid climates. Limestone and dolomite form the mountains and hills of EHPR and the plains and pans originate from sands and calcrete (unconsolidated sediments).

2.4 Soils of Etosha Heights Private Reserve area

The soils of the EHPR are described in Tables 1 and 2, below. Table 1 divides the soils into 1) soils with special sub-soil characteristics and 2) young soils. The soils of major concern, for the impact of human (ORD by game-drive vehicles) and animals (wildlife), are the duplex soils, namely Estcourt ('Solonetz') and Valsrivier ('calcic luvisols'). A small percentage of the soils in the concession are Estcourt ('Solonetz'). Fortunately, there are not many roads in this area (Fig. 11). 'Solonetz' soils are highly unstable clayey soils and should under no circumstances be disturbed, whether by overgrazing or ORD. Most soils in EHPR are of the relatively stable Coega or Petric calcisol forms. This is also where most of the road network exists.

Table 1: Major soil forms in the EHPR

Soil division	Soil characteristic	Major soil forms	
		Soil Classification Working Group (1991)	**WRB** (1998)
Soils with special subsoil characteristics relating to pedogenic accu-mulation and with an orthic topsoil	**Duplex soils** (marked textural contrast through clay enrichment)	Valsrivier	Calcic luvisols
		Estcourt	Solonetz
	Calcic soils (carbonate or gypsum enriched; arid climate)	Coega	Petric calcisols
Young soils with an orthic topsoil but weakly developed subsoil	**Lithic soils** (developing soil formation on weathering rock or saprolite)	Glenrosa	Leptosols
		Mispah	Leptosols

Table 2: Soil form characteristics and land use implications

Soil Form	Terrain morphological unit	Properties	Land Use
Coega	Mid slope to foot slope	**Medium stability** against erosion and soil crusting.	Bare soil prone to water runoff and erosion. Extensive grazing. Well suited for permanent roads. Sweet veld.
Valsrivier	Valley bottom	**Highly unstable and erodible** when disturbed under both dry and wet conditions.	Easily disturbed by overgrazing, off-road traffic or cultivation. Sweet veld.
Estcourt	Mid slope to foot slope	A large percentage of soils in EHPR concession are characterized by extremely unstable 'Solonetz' or 'Estcourt' soils. **Highly erodible and unstable when disturbed in any way.**	Extremely susceptible to degradation due to human activities, such as overgrazing by wildlife or ORD. **No artificial waterpoints**. Sweet veld.
Glenrosa	Scarp	The Glenrosa soil form with its red Litho-cutanic B-horizon (soil within loose stone matrix) stores water and nutrients. Highly drained soils. **Low to medium stability against erosion.**	The topsoil determines the quality of the soil for various purposes. At EHPR, they are shallow. Not suitable for grazing. Sour veld.
Mispah	Crest	The Mispah soil form is normally shallow with a solid stony layer (impermeable) below the shallow topsoil. Highly drained soils. **Low stability against erosion.**	Not suitable for grazing. Sour veld

2.5 Soil form characteristics and land use implications

Table 2 classifies and describes the soils in relation to their landscape position (terrain morphological unit) (explained in detail under section 2.6), and their land use utilization and limitations. Again, as with Table 1, the two soils of major concern are the Estcourt ('Solonetz') and Valsrivier ('calcic luvisols') soil forms. They are naturally highly erodible and unstable when disturbed in any way. They are also extremely susceptible to degradation due to human activities, such as overgrazing or ORD. This does not mean that the other soils forms are not vulnerable to overgrazing and degradation.

2.6 Soil forms in relation to landscape or geomorphological unit

A very good relationship exists between soils and landscapes on both concave and convex slopes in Africa and in general the 'catena concept' (Fig. 10). Hill slopes were separated as concave or convex depending on the slope form and position. Landscape positions that were sampled on each hill slope included crest, scarp, valley bottom, mid-slope and mid-slope to foot slope (Table 2). The soils' characteristics differ according to their landscape position. The tendency of soil property variations depends partly on the hill-slope and form (convex or concave). The concave and convex hill slopes are usually also different concerning most soil properties.

The soil catena (terrain morphological unit) of the EHPR is showed in figures 10, at five different geographical positions. The sequence of soils (catena) of about the same age and derived from similar parent material from west to east in the south-eastern part of EHPR is indicated by Fig. 10a. The catena from west to east, in the western part of EHPR, is indicated by Fig. 10b. The catena for the centre-west, centre, centre-east and eastern parts of the EHPR are shown in Figs. 10c, 10d, 10e and 10f.

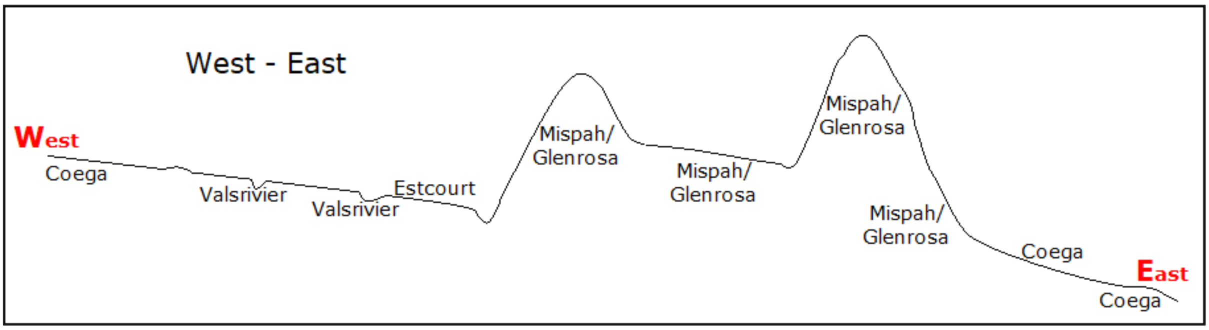

Figure 10a: Soil catena from west to east of the EHPR

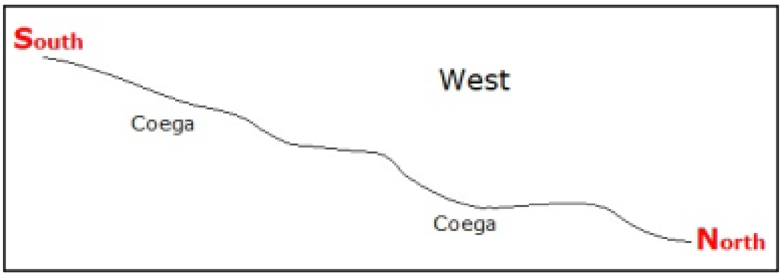

Figure 10b: Soil catena in the western part of the EHPR

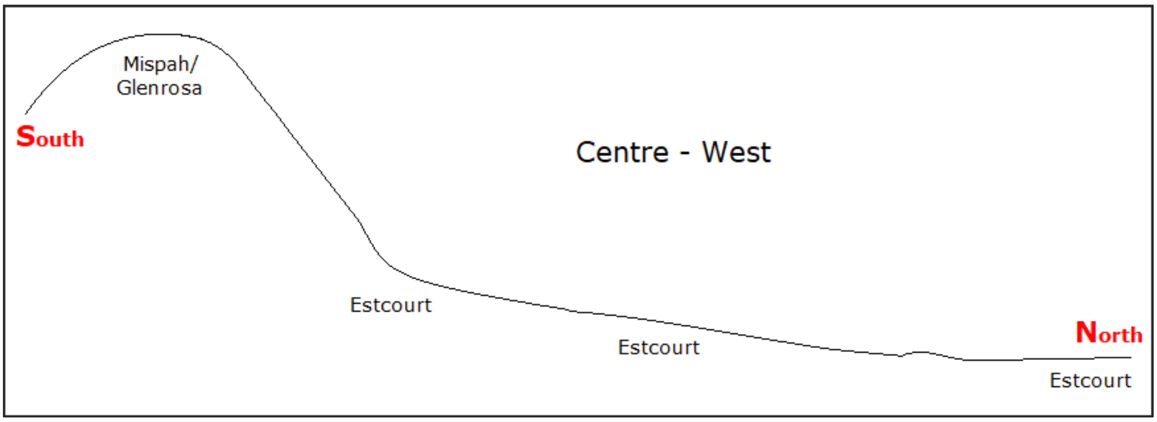

Figure 10c: Soil catena in the centre-western part of the EHPR

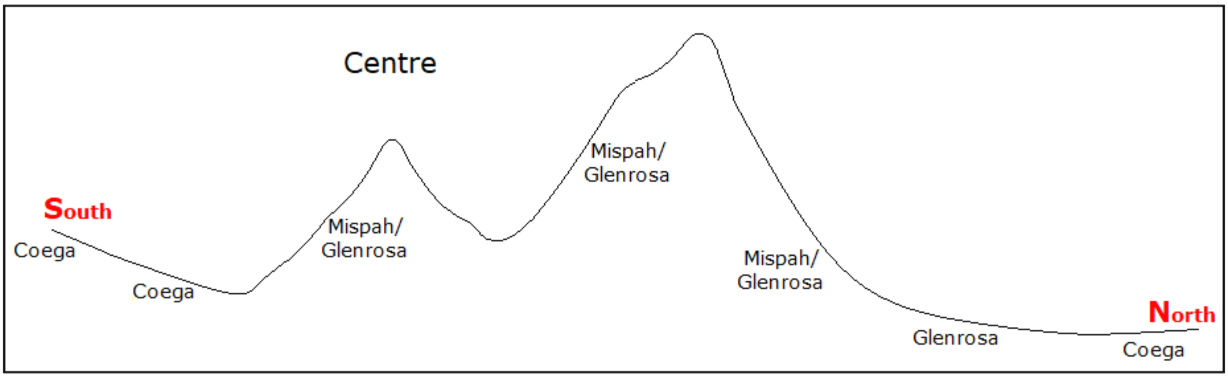

Figure 10d: Soil catena in the central part of the EHPR

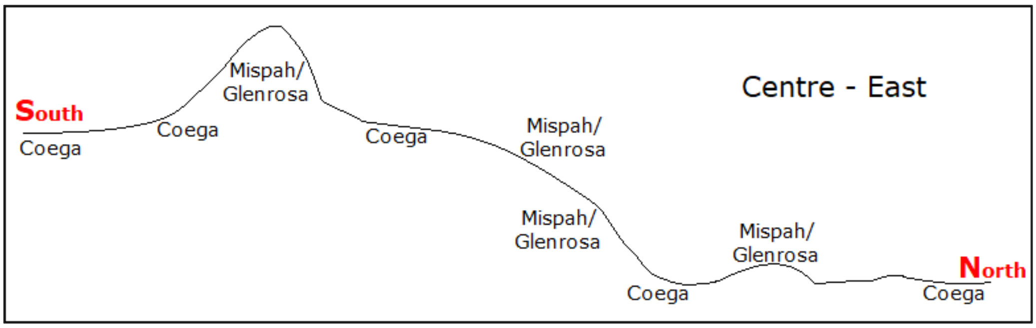

Figure 10e: Soil catena in the centre-eastern part of the EHPR

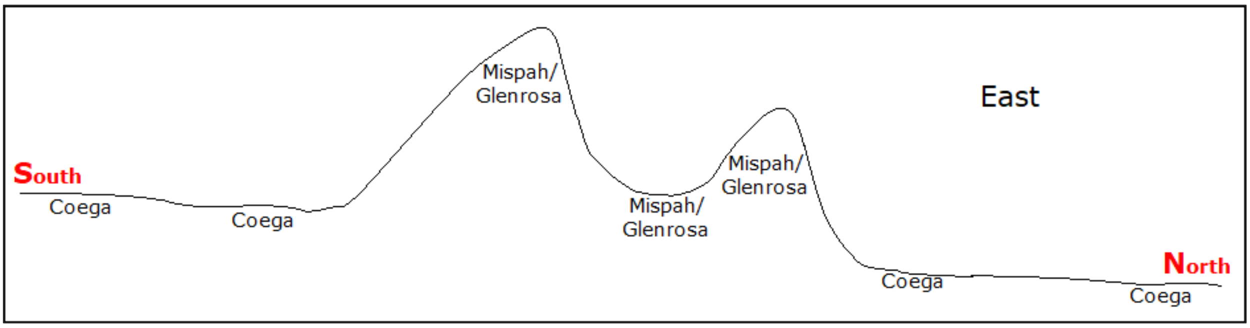

Figure 10f: Soil catena in the eastern part of the EHPR

2.7 Soil map of Etosha Heights Private Reserve

The semi-detailed soil map of the EHPR was completed during February 2019 (Fig. 11). The map was completed with the use of satellite imagery from Google Earth Pro, delineation of the survey area (data supplied by EHGS). The roads network coordinates were determined by GPS after all the roads were driven by vehicle. The map in Fig. 11 indicate the most important soil forms in both classification systems, the South African and the WRB for Soil Resources. The road network supplied was overlaid on this soil map.

CHAPTER 3
Methods

3.1 Data collection and analysis

3.1.1 Soil survey and mapping

The scientific information used in this report is mostly from data and research by Nortjé (2014). Any other related information can be found in publications by Nortjé *et al.* (2012, 2016), as well as in the review paper of Laker (2004) and the excellent paper by Snyman (1999) on rangeland degradation. These served as background for the soil survey in the Etosha Heights in 2018 (Nortjé 2016).

Google Earth images were used and a DEM (digital elevation model) was created to generate a base map for the semi-detailed soil survey.

A total of 70 soil profiles and auger samples were sampled, identified and classified. The latitude and longitude of these samples were determined by GPS during the field soil survey (Fig. 11).

During the field soil survey, the individual soil profiles were investigated and the important soil properties were described following standard procedures as prescribed by the *Institute for Soil, Climate and Water*, in Pretoria. Based on recognisable, as well as inferred properties, the soils were classified according to both classification systems mentioned in the 'Introduction' section.

These systems are based on the recognition of diagnostic soil horizons and materials. Soil forms are defined in terms of the type and vertical sequence of diagnostic horizons or materials. The soil map was created with the application of Predictive Soil Mapping (PSM) or Digital Soil Mapping (DSM). Figure 12 is a Google Earth image of the EHPR indicating the existing and proposed new roads.

3.1.2 Road network planning and predator sightings

One of the main goals of eco-tourism in an area like EHPR, is to show tourists the wildlife (environment and animals). Eco-tourists have a preference for the Big 5 (elephant, rhino, buffalo, lion and leopard) (Nortjé & Mearns 2017), and to be able to see these animals, game guides sometimes choose to drive off-road. A dual approach was used in this survey in order to achieve the main objectives of this report. Firstly, predator, or carnivore, sighting information was collected over a 9-month period (13 February 2018 to 19 November 2018) (Fig. 13) and, secondly, the soil map (Fig. 11) and the soil form characteristics for specific land uses (Table 2), were used to determine and plan the new roads.

The approach therefore, was to determine where (**geographical position** and **soil form**) and when (wet and dry seasons), these animals roam during the year. Then, to plan and adapt the road network to allow game drive vehicles to see these animals, without driving off-road.

3.2 Limitations of the report

The purpose of the study was mainly soil surveying and mapping according to soil forms/types and their land use implications, and the application of these data for better road planning for optimal game drive activities. The only possible limitation to this study is the large size of the area and the limited time in which to complete the study.

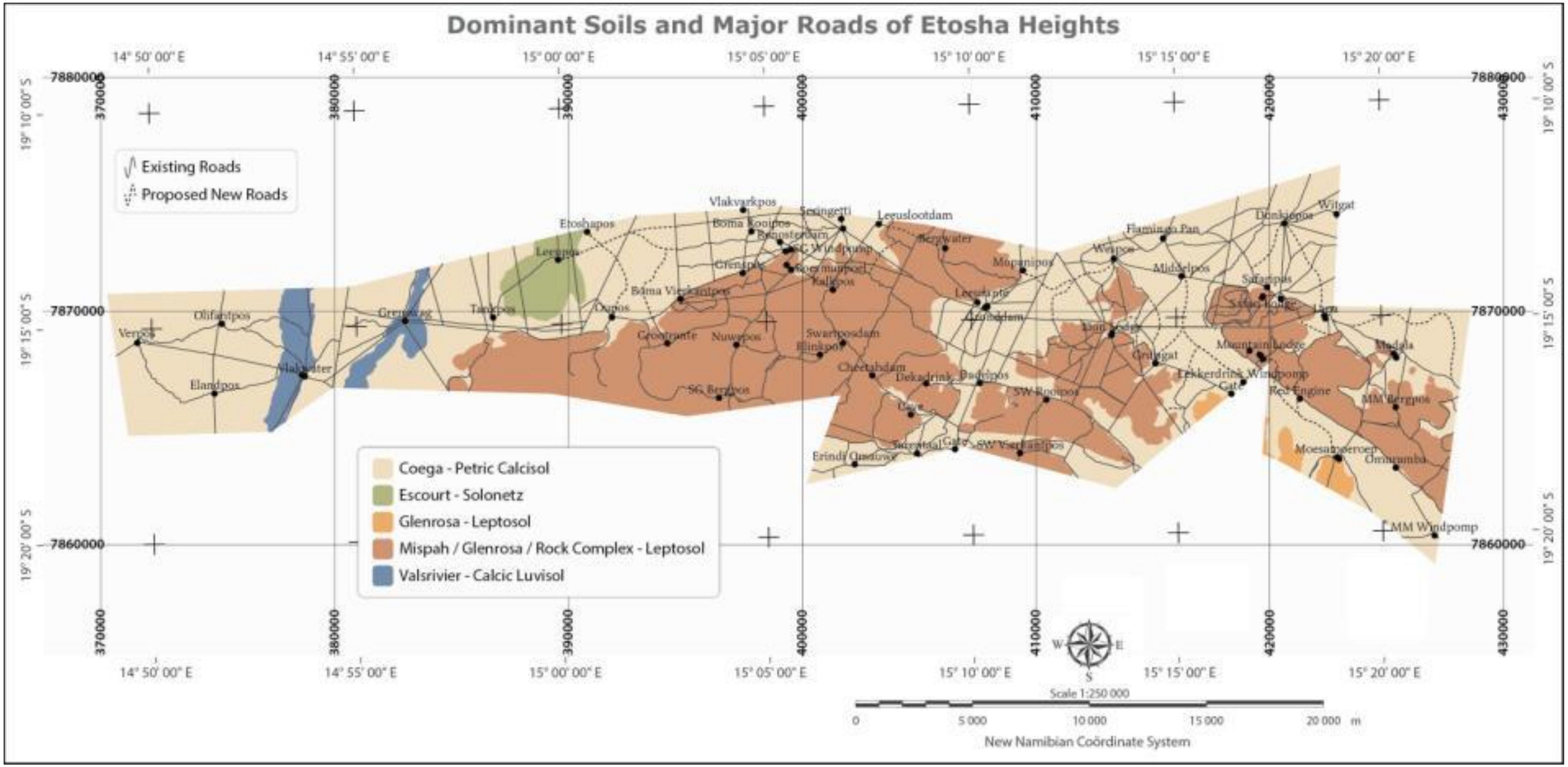

Figure 11: Map of dominant soils and major roads of the EHPR
(map by TerraGis)

Figure 12: Satellite image of the EHPR indicating current and new roads
(map by TerraGis)

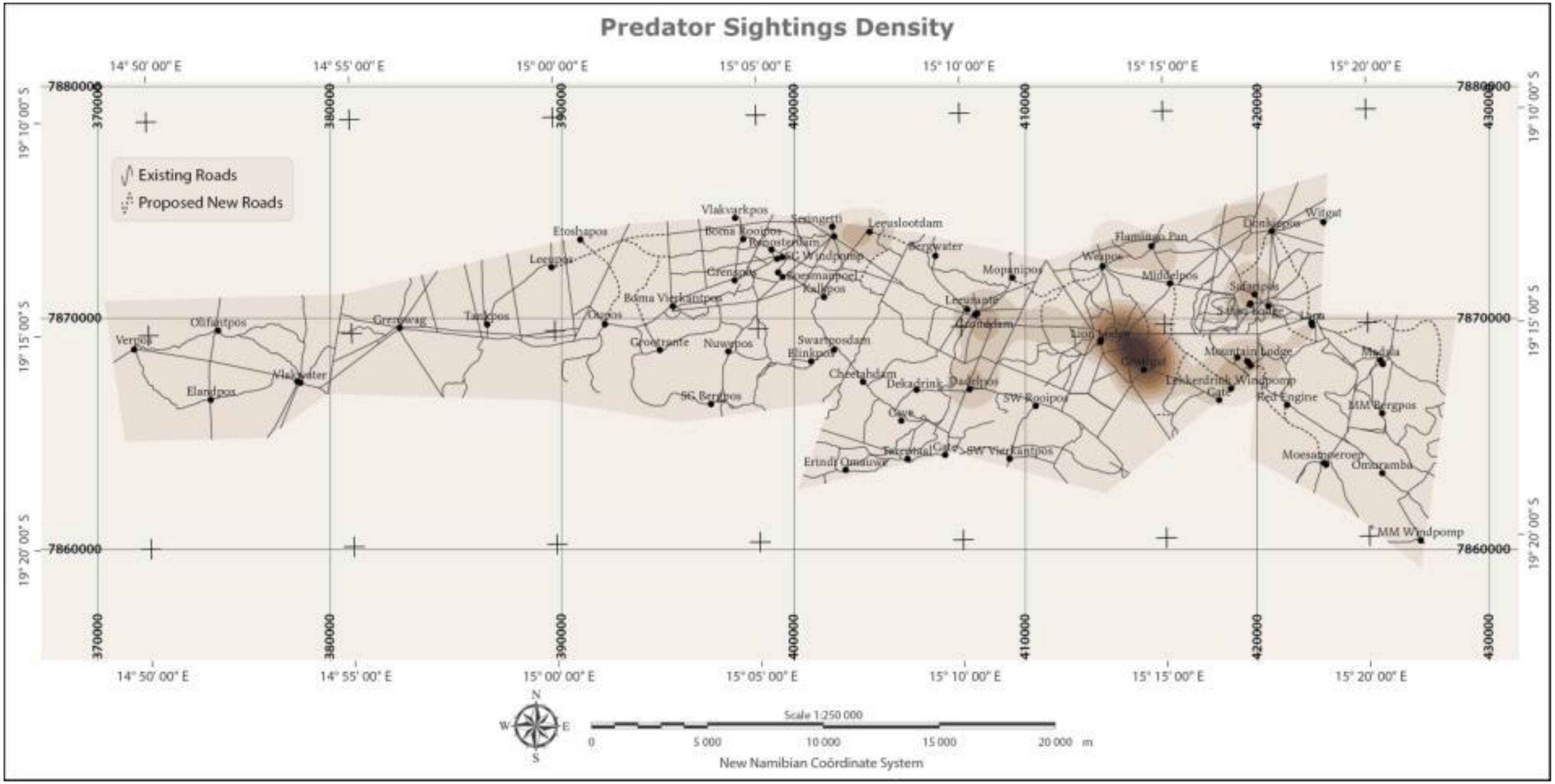

Figure 13: Map of predator sightings density of the EHPR (data used over an 11-month period) (map by TerraGis)

CHAPTER 4
Conclusions, interpretations and problems

Road network densities should be as optimal as possible to minimize impacts on the environment. Wildlife protected areas like the KNP and Sabi Sands, in South Africa has road densities of 1.54 m/ha (calculated from 3,000 km of road from 19,485 km^2) and Sabi Sands = 15-30 m/ha (20x the density of KNP). The trend is the smaller the area, the higher the densities. The road density in EHPR = 14.58 m/ha and well within the norm; 700 km /48,000 ha (9.5x density of KNP).

The estimated road distribution per soil form is currently as a percentage/soil form, including the new proposed road (dotted lines in Fig. 11,) as follows: Coega (35-45%), Mispah /Glenrosa rock complex (40-45%), Valsrivier (5%), and 'Solonetz' (5%).

In order to eliminate ORD, it is necessary to establish a road network that is ecologically sustainable, but also eco-tourism sustainable. The soil map and the proposed roads map (Fig. 11) suggests that only permanent roads should be established and they be managed as such (Class A, B and C roads) (Table 3). Permanent roads (Class A, B and C), in the right areas (planned according to predator sightings and soil type), can limit the need for ORD.

Table 3: Definition of the road categories in the EHPR

	Road Category			
	A	**B**	**C**	**D**
Description	Surfaced link road between other areas in the park or the access road to the tourist lodges	All-weather gravel roads, access road to game lodge	Lightly trafficked all-weather two track roads, ring roads	Lightly trafficked two track roads, link roads
Importance service level	Very important. High level of service.	Important. High level of service.	Less important. Moderate level of service.	Less important. Moderate to low level of service.

CHAPTER 5
Management Recommendations

The management recommendations focus on land degradation, erosion prevention and road network planning. The recommendations and suggestions concerning soil and vegetation management should seriously be considered, investigated and implemented in order to ensure the long-term survival and sustainability of the area (Nortjé & Nortjé 2017a). The following are highly recommended:

- prevent further bare soil development by not allowing overgrazing or unnecessary ORD;
- design/re-design road networks according to the soil map (Fig. 11) such as to minimize soil and vegetation degradation due to runoff and erosion from roads, while at the same time enabling excellent animal sightings without the need for ORD;
- prohibit ORD in the following areas: Ramsar pans, vleis and soils with Prismacutanic B-horizons (so-called 'sodic' sites, silt-loam soils and soils with high (fine sand + silt) contents, sandy soils with less than 15% clay content, barren areas with no grass cover - 'Solonetz' soils (Fig.11);
- further research regarding soil, game sightings and the road network utilization, should be initiated;
- rehabilitation of damaged areas. Non-expensive ways are available;
- investigate possible ways to promote packages for walking safaris in wilderness areas, with temporary camps in the western part of the EHPR;
- no water points on the 'Estcourt' (Solonetz) soil (Fig. 11) or on steep slopes;

Regarding ORD, the following recommendations should apply: **No ORD**. But if ORD necessary (exceptional circumstances), follow the following rules:

- no ORD to be allowed from Class A roads;
- ORD may only be undertaken in the event of a confirmed sighting of elephant, leopard, lion, rhino, buffalo, wild dog and cheetah;
- ORD should not be permitted in areas where Red Data Plant species are known to exist or in any other areas that EHPR are using for conservation or other management purposes;
- vehicles driving off-road must under all circumstances follow in the tracks of another vehicle;
- NO ORD should be permitted at river crossings;
- ORD is not permitted in wet conditions, on sodic patches ('Solonetz' soils) or duplex soils (Valsrivier) (Fig. 11); and
- any off-road damage to be repaired immediately (compaction reversed, ruts erased).

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ADDENDA

ADDENDUM 1
Glossary of Terms

All-weather road
A road that is trafficable in all weather conditions. Typically, this means a road that is constructed in such a way that excessive rain does not cause it to be flooded or sodden to such an extent that vehicles travelling over it are likely to become bogged.

Calcrete
Soil saturated by lime/an indurated layer cemented by calcium carbonate.

Carbonate-rich rock
A class of sedimentary rocks composed primarily of carbonate minerals. The two major types are limestone, which is composed of calcite or aragonite (different crystal forms of $CaCO_3$) and dolostone, which is composed of the mineral dolomite ($CaMg(CO_3)_2$).

Catena
The term 'catena' refers to the sequence of soils of about the same age and derived from similar parent material. These soils occur under similar macroclimatic conditions, but have different characteristics due only to variation in topography and drainage.

Dolomite
The mineral $CaMg(CO_3)_2$; also, the rock which consists mainly of this mineral.

Limestone
A sedimentary rock consisting mainly of calcium carbonate, deposited as the calcareous remains of marine animals or chemically precipitated from the sea; used as a building stone, for the manufacture of cement, lime, agricultural lime, etc.

Predictive soil mapping (PSM)
Can be defined as the development of a numerical or statistical model of the relationship among environmental variables and soil properties, which is then applied to a geographic data base to create a predictive map / Digital Soil Mapping (DSM) in soil science, also referred to as predictive soil mapping or pedometric mapping, is the computer-assisted production of digital maps of soil types and soil properties. Soil mapping, in general, involves the creation and population of spatial soil information by the use of field and laboratory observational methods coupled with spatial and non-spatial soil inference systems.

Sand
A loose granular substance, typically pale yellowish brown, resulting from the erosion of siliceous and other rocks and forming a major constituent of beaches, river beds, the seabed and deserts; sand is a granular material composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. Sand can also refer to a textural class of soil or soil type, i.e., a soil containing more than 85% sand-sized particles by mass.

Soil degradation

Soil degradation affects the physical, chemical or biological deterioration of soil. Soil erosion, soil salinization and loss of biological life, respectively, are examples.

Soil erosion

(1) The wearing away of the land surface by running water, wind, ice or other geological agents, including such processes as gravitational creep.

(2) Detachment and movement of soil or rock fragments by water, wind, ice or gravity. The following terms are used to describe different types of water erosion: accelerated erosion, donga erosion, geological erosion, gully erosion, natural erosion, normal erosion, rill erosion, sheet erosion, splash erosion, raindrop erosion, tunnel erosion.

Soil resilience

Soil resilience (recovery potential) is the ability of a soil to approach its original state following utilization thereof and which resulted in loss of productivity due to chemical, physical and/or biological degradation.

Soil survey

Soil survey is a process of systematic examination, description, classification and mapping of soils in an area for a specific purpose. Soil surveys are classified according to the purpose of, kind and intensity of field examination. The soil survey consists of four parts:

a) the selection of sites for, and preparation of, soil pits;
b) the description of the soil profile and identification of the soil form and/or series;
c) the selection of samples for the determination of the physical and chemical properties of the profile; and
d) the mapping of the soils. Cf. reconnaissance survey; soil classification; soil map.

ADDENDUM 2

Soil classification

Soil classification is the ordering of soils into a hierarchy of classes. The product is an arrangement or system of classification designed to express interrelationships of soils and to serve as a filing system. Broad groupings are made based on general characteristics; subdivisions based on more detailed differences in specific properties. Various soil classification systems exist. The Taxonomic System for South Africa, the international World Reference Base for Soil Resources and the Soil Taxonomy from USA, are outlined below.

(1) Soil Classification - A Taxonomic System for South Africa

(Soil Classification Working Group 1991)

The system is a very simple one, which employs two main categories or levels of classes - an upper or general level containing SOIL FORMS and a lower, more specific one containing SOIL FAMILIES. Each soil form is a class at the upper level, defined by a unique vertical sequence of diagnostic horizons and/or materials. Although some forms contain only one family, most are divided into a number of families which have in common the properties of the form (that is, the prescribed sequence of horizons and/or materials), but are differentiated within the form based on other defined properties. The range of variation at the family level is thus narrower than at the form level.

To date, 73 soil forms and 400 soil families have been defined.

(2) World Reference Base for Soil Resources

(WRB 1998)

The World Reference Base (WRB) is the international standard for soil classification system endorsed by the International Union of Soil Sciences. It was developed by an international collaboration coordinated by the IUSS Working Group. It replaced the FAO/UNESCO Legend for the Soil Map of the World as international standard. The WRB borrows heavily from modern soil classification concepts, including Soil Taxonomy, the legend for the FAO Soil Map of the World 1988 and the *Référentiel Pédologique* and Russian concepts. The classification is based mainly on soil morphology as an expression of pedogenesis. As far as possible, diagnostic criteria match those of existing systems, so that correlation with national and previous international systems is as straightforward as possible.

(3) Soil Taxonomy

(USDA 1975; Soil survey staff 1994)

In this system, the category at the highest level of generalization is the soil order. The lower categories of classification are suborder, great group, subgroup, family and series. The properties selected to distinguish the orders are reflections of the degree of horizon development and the kinds of horizons present. Eleven orders are defined.

This system was not used in this soil survey.

ADDENDUM 3
Photos of the soil forms of Etosha Heights Private Reserve

Mispah soil form (Leptosols)

Glenrosa soil form (Leptosols)

Estcourt soil form (Solonetz)

Valsrivier soil form (Calcic luvisols)

Coega soil form (Petric calcisols)