The effect of tourist roads development on road-side vegetation and soils within the Etosha national park

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Abstract

Management of tourism-based protected areas is often faced with a challenge of balancing nature conservation and tourism development. Understanding such interactions is crucial for resources management in tourism-based conservation hotspots such as Etosha National Park (ENP). This study assessed how roads, being part of tourism development, impacts on conservation efforts in ENP, focusing specifically on the road-side landscape, vegetation and soils. Data was collected at at 30 selected sites in major vegetation communities within the park. Herbaceous biomass was assessed using a Disk Pasture Meter based on field calibration from ENP. Soil samples were collected using a soil auger and analyzed. Results show that a substantial network of tourist roads has been developed for Etosha National Park, translating in a road density of 0.2 km/km^2. The development of this road network has left more than 180 unrestored gravel pits, or an average of one gravel pit for every 4 km. Similarly, results demonstrated that roads and related vehicular activities have significant impact on the foliage cover and biomass

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yield of herbaceous species adjacent to the roads, with foliage cover decreasing with increasing proximity to roads. No conclusive evidence emerged to suggest that roads and vehicular emission have a significant impact on roadside soil chemical properties. An exception is made to elevated calcium, carbonate and high cation exchange capacity which is speculated to have been sourced from the Etosha limestone. This study concluded that an unrestricted development of roads and the accompanying quarrying of gravels have a potential to degrade the landscape of Etosha National Park. As a first attempt, this study serves as a baseline for monitoring tourism related ecological disturbances in the park.

Keywords: Etosha, road density, gravel pits, tourism, Namibia

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1 Introduction

Protected areas are ecosystems primarily proclaimed for conservation of biological diversity in efforts to achieve goals of the UN Convention on Biological Diversity (Bastian et al., 2012). In Southern Africa, most protected areas also serve as a major attraction for nature-based tourism due to a rich diversity of plant and animal life they support (Spenceley, 2008). Tourism plays an important role in the sub-region due to its substantial contribution to socio-economic development through employment creation, foreign exchange earnings and tourism related infrastructure development in the host countries (Ashley, 2000; Bushell and Eagles, 2007; Mbaiwa, 2011). Management of tourism-based protected areas however is often presented with challenges to balance conservation efforts and tourism development (Cheng and Zhang, 2005; Ferreira, 2004). Poorly planned tourism developments often results in practices which are in direct conflict with conservation values. If allowed to continue unmonitored, such development may degrade the integrity of the same environment tourism is dependent on (Lacitignola et al., 2010; Lindsay et al., 2008).

The most significant impacts of tourism development in protected areas stem from infrastructure development, such as roads. Road construction may result in a number of effects contrary to conservation. These include landscape fragmentation, roadside edge effects, accelerated soil erosion and modification of roadside vegetation communities (Coffin, 2007; Donaldson and Bennett, 2004; Forman, 1998; Spooner et al., 2004) as well as altered soils properties (Rentch et al., 2005; Spooner et al., 2004; Swaileh Hussein and Abu-Elhaj, 2004; Wang and Qin, 2007), (Forman, 1998, 2003; Hussein and Abu-Elhaj, 2004; Zeng et al., 2011), and the introduction and spreading of weeds. Such impacts have already been observed in many protected areas and other ecosystems worldwide (Ament, Clevenger, Yu & Hardy, 2008; Angold, 1997; Avon, Berges, Dumas & Dupouey, 2010; Coffin, 2007; Donaldson

& Bennett, 2004). The Etosha National Park (ENP) was proclaimed as a nature reserve in 1907 (Berry, 1997). Subsequent changes to the park's land use priorities culminated in tourism being incorporated as a secondary land use in the 1950s.

Despite the long history of coexistence of conservation and tourism in the ENP no study to date investigated the influence of tourism activities in the park. This study explores the impact of infrastructure that support tourism, specifically the road network on roadside vegetation and soils. More specifically the objectives of the study were to (i) determine the density of roads and gravel pits in the Park as this indicates the spatial extent of the impact, (ii) assess the condition of roadside vegetation and soils in relation to the road network. We hypothesized that the development of tourism infrastructure in the Park may have compromised the ecological integrity of the park.

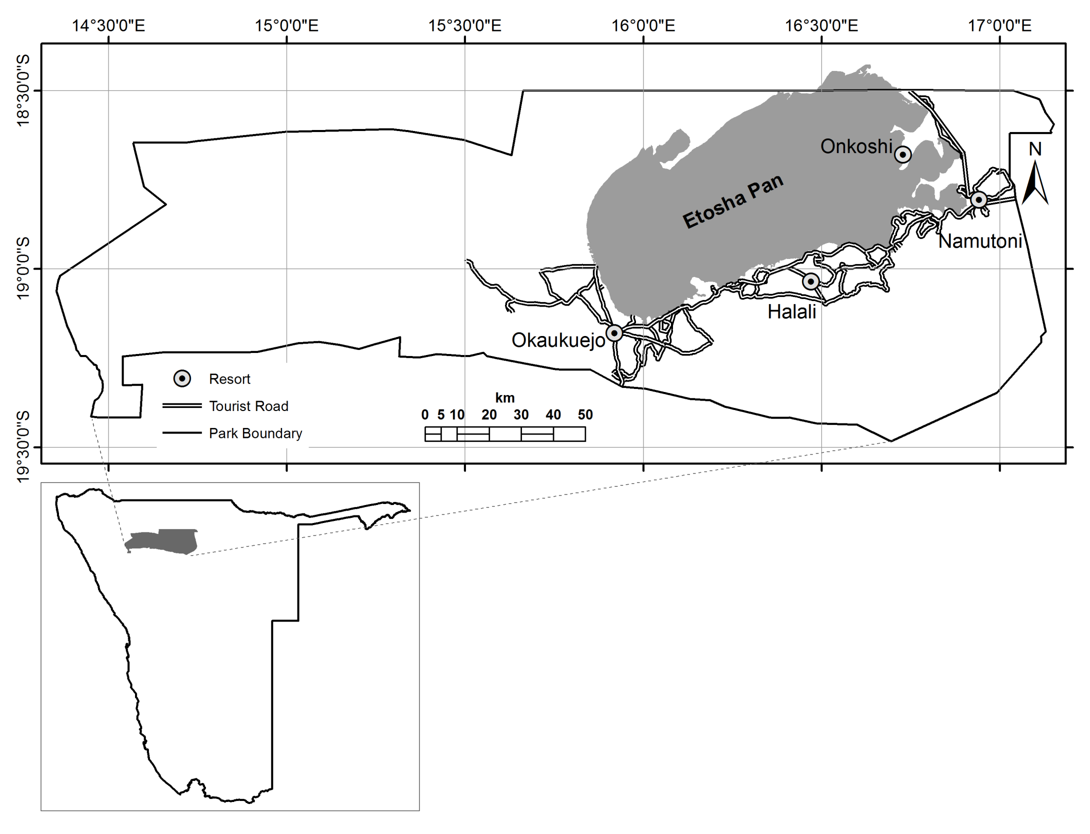

Figure 1: Location of the Study

2 Materials and Methods

2.1 Study area

The Etosha National Park covers an area of approximately 22 270 km^2 and is thus the second largest national park in Namibia (Figure 1). The ENP has nearly five decades history of tourism and recreational infrastructure development (Berry, 1997). The core of the ENP is occupied by a large, saline depression known as Etosha Pan, which occupies nearly 25% of the Park area (Nakanyala, 2012). Located in the semi-arid region of Namibia, the ENP region receives summer rainfall, with an annual average rainfall range of approximately 450 mm/year along the eastern part of the park to 300 mm/year toward the western part of the Park. Rainfall is highly variable in both time and space. The summer temperatures around Okaukuejo (See Figure 1) range between a minimum of around 18°C and a maximum of 35°C while temperatures in winter range between 6°C and 25°C respectively (Du Plessies, Bredenkamp and Trollope, 1998).

The surrounding area of the ENP area is relatively flat, with the exception of dolomite hills to the south west of the park. This Park lies within the geological formation of the Damara sub-group (Le Roux et al., 1988), and located at the southern edge of the Owambo basin. The study area is dominated by soil type such as *calcaric Regosols, lithic Arenosols, mollic Leptesols*, which are largely influenced by the underlying geology, aeolian and fluvial processes (Beugler-Bell and Buch, 1997). Vegetation types found in the area constitute a variety of woody species such as *Acacia newbrownii, Acacia reficiens, Acacia erioloba, Acacia mellifera, Albizia anthelmentica, Catophractes alexandri, Colophospermum mopane, Boscia foetida, Combretum apiculatum, Commiphora spp., Grewia spp., Terminalia prunioides, Terminalia sericea, Ziziphus mucronata* and others (Berry, Loutit and Muller, 2006). Whereas, grassy species dominating the park's vast grasslands such as Andoni plain and Okondeka Grassland are such as *Sporobolus spicatus, Eragostic biflora, Mariscus squarosa* (Cunningham and Jankowitz, 2011; Le Roux et al., 1988). Rainfall pattern and soil type are the main determinant for vegetation distribution in the Park (Beugler-Bell and Buch, 1997; Engert, 1997; Le Roux et al., 1988). As one of the tourist hotspot in the country, the ENP hosted six resorts and a designated road network for recreational activities.

2.2 Vegetation assessment

A total of 30 sampling sites covering the major vegetation communities of ENP were randomly selected using (Quantum Development Core-team, 2012). The vegetation community classes used was those developed by Le Roux et al. (1988). Fieldwork was carried out during

February 2010. At each sample site, herbaceous foliage cover was assessed using 1 m×1 m frame, while woody plants cover was assessed using a 10×10 m plot. Sampling was done at a distance of 5 m, 50 m, 100 m and 200 m from the roadside edge. This assessment was replicated on both sides of the roads. Herbaceous foliage biomass was estimated using disc pasture meter, after Brasbay and Tainton (1977); Dorgeloh (2002); Sharrow (1984); Zambatis and Zacharias (2006). Biomass yield from the disc pasture meter field measurements was calibrated using model developed by Du Plessis (1997) for the park. The model had been based on extensive field measurements in the park.

2.3 Spatial data

As per the study design, fieldwork was supplemented by the integration and analysis of spatial data. Spatial data such as vegetation vegetation communities and park tourism roads were acquired from the Etosha Ecological Institutes. In addition, gravel pits were mapped using handheld Global Positioning System Receiver with an accuracy of ±3 m (Garmin eTrex, USA). A Universe Transverse Mercator (UTM) georeferencing system was used. Those spatial data were integrated and analyzed under a GIS environment using ArcGIS version 10 (ESRI, USA).

2.4 Soil sampling

Soils were sampled at 0-30 cm depth using a handheld soil auger (Agrisearch, Netherland). Sampling was done at a distance of 5 m, 50 m, 100 m, and 200 m away from roads. Thereafter, soils samples were air-dried and sieved using a 2 mm mesh to retain the fine earth fraction of 2 mm in diameter. For chemical extraction, plant available phosphorus was extracted using the Olsen method (Kovor, 2009) and measured spectrophotometrically using the phosphomolybdate blue method. Exchangeable cations were extracted using 1 M ammonium acetate at pH 7 and atomic absorption spectroscopy was used to measure K, Ca, Mg, and Na concentrations in the extracted samples. Soil pH was determined in distilled water (HO2) using a 1:2.5, soil:water ratio. Electrical conductivity was measured in the supernatant of the 1:2:5 soil:water suspension prior to measurement of soil pH. Carbonate was determined by the reaction of soil with hydrochloric acid and estimation of acid consumed by titration with sodium hydroxide. All soil analyses were carried out at the soil laboratory of the Ministry of Agriculture, Water and Forestry (MAWF), Namibia.

2.5 Statistical analysis

A general linear model (glm) in R (R development Core Team 2012) was used to analyze the relationship between distance from roads and the concentration of major soil chemical properties. Those data were checked for normality and homogeneity using Shapiro test and F test respectively. On the other hand, herbaceous foliage cover and biomass was analyzed using Kruskal-Wallis test because they did not assume the normal distribution, a prerequisite for `glm`. Results were considered statistical significant at 0.05 alpha level.

Table 1: Tourist roads density (km/km^2) in the major vegetation communities of Etosha National Park.

Vegetation Structure	Vegetation Cover (km^2)	Vegetation Cover (%)	Tourist Road length (km)	Tourist Road length (%)	Tourist Road density) (km/km^2
Bushveld	2375.24	10.67	103.5	13.5	0.04
Grassland	2465.76	11.07	402.61	52.51	0.16
Saline and Pan	5085.37	22.84	8.68	1.13	0.00
Scrubland	192.97	0.87	0.00	0.00	0.00
Shrubland	6226.84	27.96	38.04	4.96	0.00
Woodland	5923.81	26.60	213.92	27.9	0.03
Total	22 270	100	766.75	100	0.25

3 Results

3.1 Road density in the ENP

A tourist road network of around 766 km has been developed in the park. The width of roads is estimated at 8.56±3.36 m (Table 1). This translated into approximately 0.25 km per km2 for the entire Park. Over 50% of such roads are found on the Etosha grassland, a vegetation community which occupies merely 11% of the entire park area. Within the grassland, tourist roads are more concentrated on the south east grassveld as well as the Duneveld covering mostly the Okondeka grassland and Andoniveld. Road infrastructure are further extended to other vegetation communities particularly the woodland found between Namutoni and Halali resort as well as those found to the west of Okaukuejo resort. The shrubland vegetation community which covers nearly a quarter of the Park area size constitute among the lowest road density in the Park. The Etosha Pan, a wilderness zone within the park, a road length of approximately 8.6 km.

Figure 2: Some of the unrehabilitated gravel pits created during roads construction in ENP. (a) a pile of unrestored pit, (b) solid waste dumped at gravel pit, (c) vegetation reclamation around abandoned pit, and (d) a newly created gravel pit.

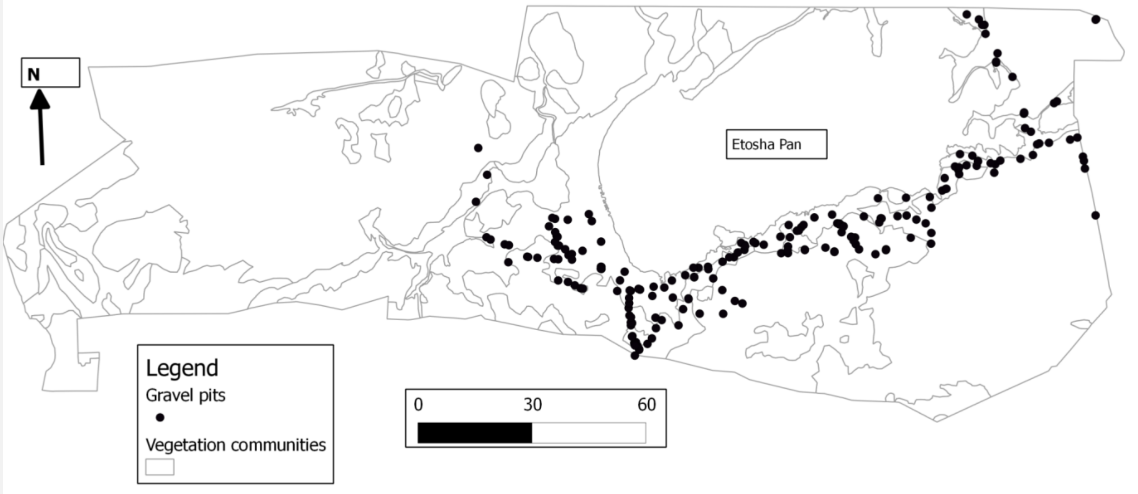

Figure 3: The distribution of gravel pits around the active tourism development area in Etosha National Park

3.2 Gravel mining in the ENP

The unpaved tourist roads have been constructed using gravel quarried within the ENP. This has left around 187 abandoned gravel pits (Figure 2) distributed primarily along the most active tourism development area in ENP (Figure 3). These pits cover an average area of approximately 7260 m^2. No depth measurements were taken owing to lack of appropriate. About 45% of those gravel pits are located in the grassland vegetation, while 34% were created within the woodlands. The reminders are found in the bushveld (16%) while 2.5% are found in each of the shrubland and saline pans communities. In open vegetation communities such as grassy patches and savanna the gravels pits are on average situated at approximately 6 km from the roads. Gravel pits in thicket vegetation are located within an average distance of 40 m from roads. The different distances may affect the visibility of the pits to the road users. No evidence of restoration/rehabilitation was observed at any of the gravel pits assessed.

3.3 Grass cover and biomass yield

Grass and herb foliage cover did not significantly differ between 5 m, 50 m, 100 and 200 m distance from roads ($p > 0.05$), but were significantly different between the vegetation communities ($p < 0.05$). Grass foliage cover was approximately 28% at a distance of 5 m from roads. It then increased gradually to 38% at 50 m and 43% at 100 m, before dropping to just above 30% at 200 m. Herb foliage cover was lowest at a distance of 5 m at approximately 10% but increased to approximately 13% and gradually to 15% at 50 m and 100 m respectively. Herb foliage cover then decreased to approximately 11% at a distance of 200 m (Figure 4). In comparison to herb foliage cover, grass foliage cover was significantly higher at all localities from roads ($p < 0.05$).

Herbaceous biomass yield including both grass and herb significantly different ($p < 0.05$) between the four main localities, but it did not consistently increase or decrease with distance from roads. Herbaceous biomass yield seems to have been determined mainly by vegetation type rather than proximity to roads. For instance, in the bushveld and the grassland, biomass yield was lowest at a distance of 5 m from roads and highest at 200 m, while a reverse trend was observed in the shrubland and the woodland.

3.4 Roadside soil properties

Soil analysis shows that the sampled sites are mainly dominated by sandy soils, covering more than half of the soil grain size distribution at all localities surveyed. Table 3 present the

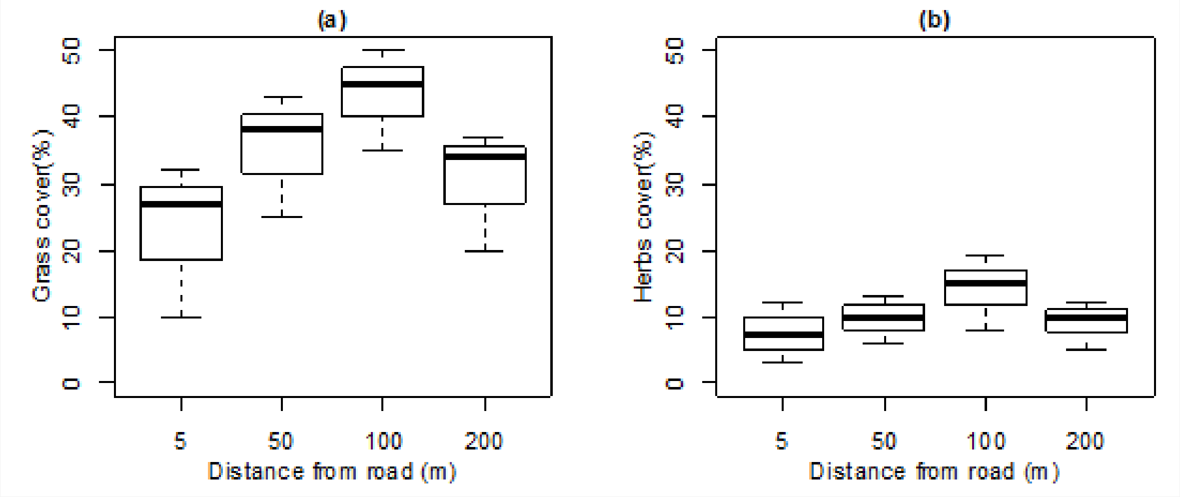

Figure 4: Grass (a) and (b) herbs foliage cover at various localities from tourist roads

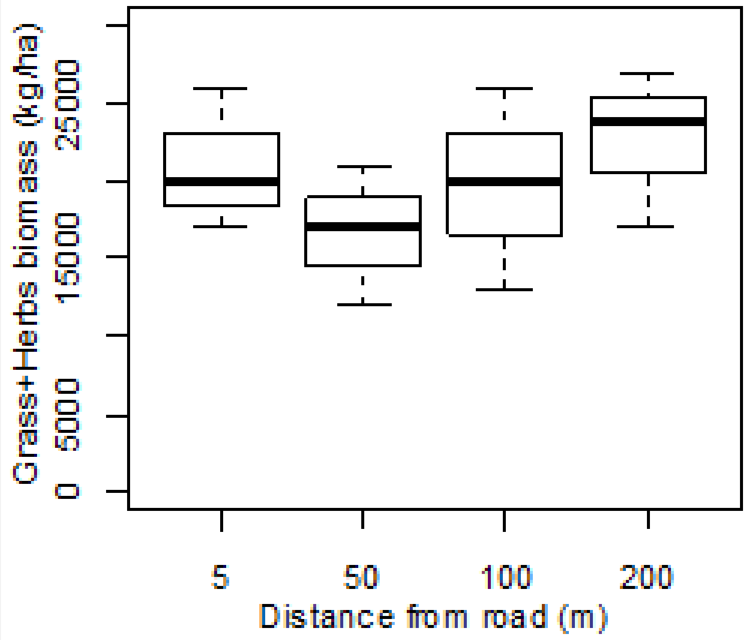

Figure 5: Aggregated grass and herbs biomass yield at various localities from roads

descriptive statistics and linear model analysis results on the concentration of various soil properties at varying proximity to roads. Soil properties showed various distinctive patterns with distance form roads. Soil carbonate was highly concentrated at a distance of 5 m, but significantly declined with increasing distance from roads ($p < 0.05$). Soil CEC and exchange Ca were significantly higher at a distance of 50 m ($p < 0.05$) compared to other sub-sites. No statistical significant results were found for the reminder of the soil physico-chemical properties. Results also indicate that distance from roads did not significantly explain much of the percentage variance in the soil properties presented as shown by the R^2 value in Table 2. Instead, those were mainly explained by soil texture type found in different parts of the Etosha National Park (Table 3).

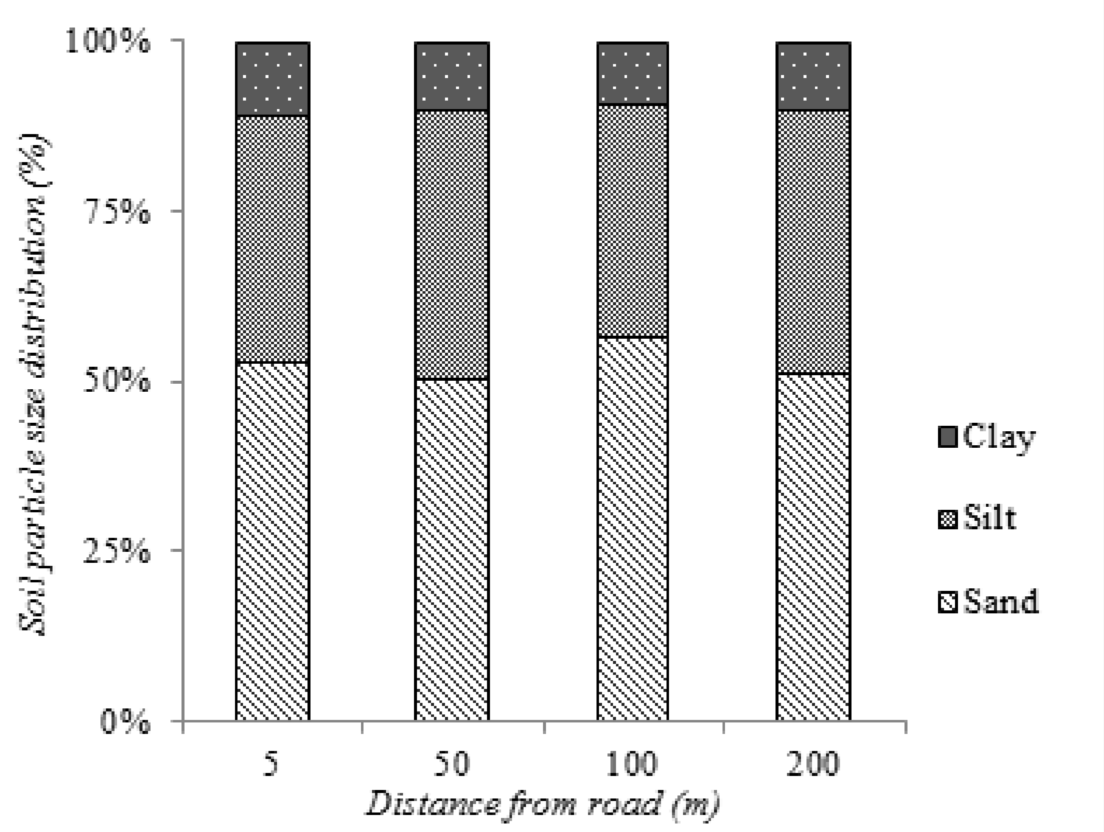

Figure 6: Soil samples grain size distribution

Table 2: Relationship between distance from roads and the concentration of soil physico-chemical properties ($n = 30$).

Soil properties	Adj R^2	F	$p - value$
Carbonate %	0.048	3.62	< 0.05
[‡]CEC (me/100g)	0.082	5.56	< 0.05
exch Ca (me/100g)	0.058	4.18	< 0.05
P ppm	0.004	0.8	> 0.05
Soil pH	0.002	0.85	> 0.05
EC 2.5 (uS/cm)	0.002	0.89	> 0.05
SOM %	0.017	0.1	> 0.05
Exch Mg (me/100g)	0.005	1.29	> 0.05
Exch K (me/100g)	0.006	1.33	> 0.05
Exch Na (me/100g)	0.019	2.00	> 0.05

[‡]CEC = Cation Exchange Capacity;
Exch Ca=Exchange Calcium;
P ppm=Phosphorus;
EC=Electrical conductivity;
SOM= Soil organic matter;
Exc Mg= Exchange Magnesium;
Exchange K= Exchange Potassium;
Exch Na= Exchange Nitrogen.

Table 3: Relationship between soil texture and the concentration of soil physico-chemical properties ($n = 30$).

Soil elements	Adj R^2	F	$p - value$
[‡]CEC (Me/100g)	0.27	8.05	< 0.001
Exch Na (Me/100g)	0.24	7.07	< 0.000
Soil pH	0.17	4.82	< 0.001
Exch Ca (me/100g)	0.15	4.35	< 0.001
Exch Mag (me/ 100g)	0.13	3.87	< 0.001
EC 2.5 (uS/cm)	0.13	3.83	< 0.001
SOM%	0.11	3.37	< 0.001
Exch K (me/100g)	0.10	3.08	< 0.001
Carbonate%	0.19	3.48	<0.01
P ppm	0.04	1.79	>0.05
Exch N (me/100g)	0.07	2.02	>0.05

[‡]Abbreviations as in Table 2.

4 Discussions

The objectives of this study were mainly to understand how roads development for tourism and recreational activities in protected areas, specifically ENP may compromise the integrity of ecological systems. Evidence suggests that a substantial road network has been constructed within sections of the ENP to facilitate tourism related activities. The development and maintenance of such infrastructure, however, has a considerable long term affect on the development of the vegetation and soils. The distribution of such road infrastructures is particularly concentrated on the Etosha grasslands. Grasslands are favorable habitats for various and large number of plain ungulate species, and thus because of the good prospect for game viewing, as a result they serve as a major target for road development. A plethora of gravel pits along roads in ENP provides alarming evidence that the continuous development of such infrastructure could compromise the ecological integrity of the park such as fragmentation of habitats if allowed to continue unhindered. Field observation revealed that most of such gravel pits are left to reclaim themselves as no evidence of restoration surfaced. Concern of the continuous creating of gravels pits in ENP has existed since the 80s and 90s. At that time, it was hypothesized that anthrax (*Bacillus anthracis*) an endemic animal disease in ENP, which decimates plain ungulates and elephants in their numbers each year, tends to breed in those gravel pits (Ebedes, 1976; Turnbull, Hofmeyr, McGetrick & Oppenheim, 1986). Although this idea was later discredited by studies that followed such as Lindeque & Turnbull (1994), it has left a controversy around the ecological consequences of gravel mining in the ENP. In addition, Beugler-Bell and Buch (1997) observed that the creation of gravel pits in the ENP is among the main factors responsible for accelerating soil erosion in the Park.

The vegetation data did not reveal significant evidence to suggest that roadside herbaceous foliage cover was under stress from roadside vehicular activities. However, herbaceous biomass indeed showed a significant decline with increasing proximity to roads, suggestion that road usage and vehicular activities have impacts on roadside vegetation biomass productivity. This may be attributed to changes in soil texture, resulting in less favourable soil conditions along roads. For example, Makineci et al. (2007) as well as Takahashi and Miyajima (2010) whose studies indicated that an increase in gravels and rocks along road edges may have contributed to the inability of herbaceous plants to grow well along roads. Result on soils chemical properties revealed no conclusive evidence to suggest that roads and vehicular usage have affected adjacent soil properties. An exception is made to soil properties such as CEC, exch Ca and Carbonate. Results showed that there was a significant increase in soil cation exchange capacity, exchange calcium and carbonate content with distance to roads. This suggests that the gravel materials used for construction of roads were quarried from soils rich in calcium carbonate. This pattern is speculated here to have its origin from the Etosha limestone, which then accumulated in roadside soil. Indeed, calcrete that is usually sought after for roads construction in ENP and elsewhere in Namibia is an accumulation of calcium carbonate and other alkaline minerals in the soils. This is consistent with Barbosa, Feunandes, Carneiro, Junior (2010) who found that uses of limestone gravel, rich in calcium was responsible for increased calcium and carbonate rich soil along unpaved roads in Serra do Cipo Grassland, Brazil. It is not certain as to what impact a high carbonate will have on roadside ecosystems.

5 Conclusion

This study demonstrated that unmonitored tourism infrastructure developments may indeed culminate in direct conflict with conservation efforts. For ENP, an unrestricted increase in road density has led to an increase in anthropogenic disturbance on protected ecosystems such as gravel quarrying. Quarrying gravels for road construction without being accompanied by restoration measures will increase degradation of the landscape that was once an attractive nature for tourists, thereby compromising the attainment of a sustainable ecotourism development in tourism in Etosha National Park. This study serve a baseline for monitoring roadside vegetation conditions, soils as well as any other tourism related ecological disturbances in ENP.

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