African Journal of Hospitality, Tourism and Leisure, Volume 8 (4) - (2019) ISSN: 2223-814X

Assessing the impact of tourism related development on the natural habitant using a Geographical Information System

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Abstract

The growing attraction of tourism to protected areas comes with an increasing need to meet the demands of tourists; this includes building more infrastructure for accommodation and entertainment. Monitoring visitor impacts in protected areas requires a different approach to that taken to monitor impacts on the environment although some techniques could be the same. This study aims to develop a Current Environmental Character (CEC) for the Limpopo National Park (LNP) by using spatial analyses on data and information such as land use, tourist attractions, roads, and railways to identify the most impacted landscapes as well as those where visual and audible intrusion are absent, and which thus offer wilderness experience. The study successfully did CEC for the first time of the LNP in Mozambique. The classification used for the CEC was the ECHOS classification. The classification helped to identify how far the different zones of a CEC should be from an impact. The study found that multiplying the buffer values by two, increased impacted areas. This led to all the other zones of the CEC decreasing (natural undeveloped, wilderness edge and the wilderness area). Reducing the buffer values by half shrinks the impacted areas, increasing the other zones of the CEC. According to the results of the six CECs, it can be concluded that the most impacted areas are along the Limpopo River and near the Massingir dam. The pure wilderness of the park is found in the centre of the park and a small area of the wilderness situated north of the park. GIS can be used to study the impacts that tourism related infrastructure has on a park before any expansion is done

Keywords: Biodiversity, tourism, Geographical Information System, tourism Impact.

Introduction

Land cover change is one of the most important indicators of how humans interact with the environment (Dewan, Yamaguchi & Rahman, 2012). Although, there are natural factors that influence land use and land cover such as temperature, precipitation, elevation, and slope (Lintern *et al.*, 2018; You *et al.*, 2019), human induced changes in land cover play a significant role. Infrastructure development has impacted the four geospheres of the earth (Zeng, Sui & Wu, 2005; Sanderson *et al.*, 2009). The growing attraction of tourism to protected areas comes with an increasing need to meet the demands of tourists; this includes building more infrastructures for accommodation and entertainment. Monitoring visitor impacts in protected areas requires a different approach to that taken to monitor impacts on the environment although some techniques could be the same (Buckley, 2003). Usually park management use environmental indicators in order to see the impacts caused by tourists (Buckley, 2003). Often the increase in tourism activity is celebrated and governments establish ways to increase tourism activity in a country in order to increase income. Different perspectives in whether the increase in tourism is bad or good for the environment in protected areas have been argued over the years. Some scholars argue that the increase in tourism will provide jobs for locals leading to a decrease in use of natural resources in and around protected areas. The other perspective argues that the increase of development can be negative on conservation by increasing the pressure in the zone of interaction (ZOI) due to the increased demand of natural resources (DeFries, Karanth & Pareeth, 2010).

The concept development planning process seeks to combine the character of the environment within the planning process (KAZA IDP, 2008). Concept development also seeks to guide decision making regarding access, use, development and infrastructure within a protected area (KAZA IDP, 2008). The planning constraints come from habitat value, landscape sensitivity, agricultural suitability, cultural value and visual sensitivity (KAZA IDP, 2008). The current study focused on an analysis of the current environmental character (CEC) which reflects audio-visual impacts within the Limpopo National Park (LNP). This provides a standard that can be used when making decisions for planning. This standard shows the impact of proposed development and management interventions on the visual and audio characteristics of the area. Visual and audio impacts not only affect the landscape of a park but also affect the experience of the visitor (KAZA IDP, 2008). National parks are set aside to conserve biodiversity and to provide social and tourism opportunities for people (Dudley, 2008). They also generate income for the country through ecotourism, which requires relatively "undisturbed" natural and cultural resources as a base for sustainable development (KAZA IDP, 2008). The wilderness probably constitutes one of Africa's most valuable resources, yet it is undervalued and not protected enough. International conservation guidelines place tremendous value on wilderness, but most developers see wilderness areas as opportunity for exploitation (KAZA IDP, 2008).

This study aims to develop a CEC for the LNP by using spatial analyses on data and information such as land use, tourist attractions, roads, and railways to identify the most impacted landscapes as well as those where visual and audible intrusion are absent, and which thus offer wilderness experience. Although the LNP has been in existence for the past decade there is a lot of development still taking place in and around the park. The tourism development programme is a good example for current developments. According to the LNP website, the program includes a variety of Cross Border Tourism products, 10 000ha concessions located near the Giriyondo Border post and along the Shingwedzi River and a resort type concession alongside the Massingir Dam near Massingir. It is important that a CEC of the park be defined in order to help the park's management when making decisions with infrastructural developments.

Literature review

The Earth is dominated by humans: although they are supposed to take care of the planet have impacted the four geospheres of the earth (Zeng, Sui & Wu, 2005; Sanderson *et al.*, 2009). Infrastructure and roads built by humans are examples of the things that have the potential to lead to major environmental impacts. Conservationists and environmental planners are concerned wildlife populations may be negatively affected by roads and traffic (Fahrig & Rytwinski, 2009). For instance, with respect to wildlife and roadside plants, roads can contribute to loss and fragmentation of habitat; injury and death of wildlife especially when they are attempting to cross roads; and pollution of air, water, and soil; and finally, they can disturb audio communication especially in areas affected by traffic noise (Basin *et al.*, 2000; Parris & Schneider, 2009). Indeed, in the case of England, the broadleaf forests were divided by roads. Consequently, this led to the common dormouse (*Muscardinus avellanarius*) being endangered due to its inability to cross more than 100m of open country(Auzel *et al.*, 2010).

Roadside vegetation has an abundance of plant species because some plants on the roadside grow fast with plenty light and with moisture from road drainage (Forman & Alexander 1998). The number of road kill has increased such that roads with vehicles contributed to the mortality of animals than hunting (Forman & Alexander, 1998). (Fahrig and Rytwinski, 2009) showed that there were more documented negative effects of roads on animal abundances than the number of positive effects. Species showed clear difference in the way they responded to the presence of roads and traffic (Fahrig & Rytwinski, 2009), for example amphibians and reptiles were likely to show negative effects whereas birds showed mainly negative or no effects with a few positive effects among small birds and vultures. Reasons for the negative effects ranged

from species that are susceptible to disturbances caused by traffic (noise, lights, pollution, traffic motion) and species that are susceptible to road death that are likely to be killed by collusions. Animals are often attracted by roadside resources, those with the intellectual ability and fast speed that allow them to avoid being killed by vehicles showed positive road effects or no effect at all. Most of the animals that showed no effect avoided going to the roads. They are not disturbed by traffic and have small movement ranges paired with high reproductive rate (Fahrig & Rytwinski, 2009).

In protected areas putting up fences along roads, will keep animals away from roads thereby avoiding collisions. This, however, will restrict the movement of animals and this will defeat the ecological purpose of the establishment of the Great Limpopo National Park (GLTP) or any other transfrontier park which is to make more space available for the movement of wildlife. Traffic related disturbances might cause more impacts than the actual roadkill (Forman & Alexander, 1998).

Elephants in the north eastern Gabon prefer to stay in forests that are away from roads and villages (Barber *et al.*, 2010). Traffic also causes noise and according to Barber et al. (2009) for wildlife hearing enables them to be aware of their surroundings. The way anthropogenic noise affects parks has not received much attention. Similar to humans, noise levels above normal can have negative impacts on wildlife (Barber *et al.*, 2010). Although in protected areas it is unlikely that noise levels will cause hearing loss on wildlife, but anthropogenic noise will have a negative impact on wildlife because of the way they respond to human stimuli (Barber *et al.*, 2010). Noise impacts on wild animals can take many forms. For example, masking of bird calls by low frequency traffic noise may explain the observed reductions in bird density near roads, changing habitat use and activity patterns, increasing stress response and reducing reproductive success (Pater, Grubb & Delaney, 2009; Barber *et al.*, 2010).

Chomitz and Gray (1996) developed a spatially explicit model of land use. The aim of the model was to report effects of roads on forests and address what kind of conversion is induced. To what distance does this conversion effects extend as well as who the construction of the road benefit? The model that they developed showed that the impacts of roads are dependent on the soil quality (Chomitz & Gray, 1996). Some road developments will favour the clearing of forests to make space for commercial crops while others will stimulate the spread of shifting cultivations (Chomitz & Gray, 1996).

When a protected area is being established, restrictions are put in place for local people on how much they can use resources in the area (Wells and Brandon, 1993). When Wells and Brandon (1993) initiated their people and parks study, their aims were to identify local development strategies that can be used to find local incentives that most effectively discourage threats in parks. Traditionally, patrolling parks and penalties were the ways of discouraging violation and illegal activities. More recently however, involving and thus authorising communities in the management of protected areas is widely growing in order to discourage violation and illegal activities (Wells & Brandon, 1993; Neumann, 1997; Mutuso, Charles & Nyambe, 2009). Wells and Brandon (1993) found that many Integrated Conservation Development Projects (ICDPs) struggle balancing conservation with social and economic development.

Wells and Brandon (1993) studied buffer zones and local participation in order to understand the imbalance. Two key concepts are at the centre of this approach: first, designating areas around protected in which both conservation and development related activities are allowed; secondly, finding new ways of management whereby there is greater participation of local people in conservation and development (Wells & Brandon, 1993).They concluded that threats to parks and their neighbours often originate far from park boundaries and that there are broader issues conservationist are not used to dealing with. They also concluded that new developments at sites that are carefully selected and address local people-park relationships

are necessary to the conservation of biodiversity and thus to sustainable development. These projects will be more effective if workable buffer-zones arrangements and effective local participation are implemented (Wells & Brandon, 1993).

There is little agreement in practice about whether zones that are designated for the sustainable use exist to develop conservation areas or to increase the negative impacts that protected areas have on communities (DeFries, Karanth & Pareeth, 2010). For this reason DeFries, Karanth and Pareeth (2010) state that with regards to land use change, the designation of the zone of interaction (ZOI) around protected areas is the first step towards maintaining integrity around protected areas and they proposed that if the ZOI is designated scientifically it may overcome the difficulties faced by the buffer zone concept. The objective of their study was to extend the concept of ZOI and to illustrate the application of the concept using three protected areas that are in settings with different biological and physical environments as well different social and economic settings throughout India (DeFries, Karanth & Pareeth, 2010). Using the ZOI model showed that there is an increase influence of urbanization and expanding middle class on protected areas in India bringing along an increase in tourist bungalows, resorts, associated infrastructure and access roads (DeFries, Karanth & Pareeth, 2010).

The growing attraction of tourism to protected areas comes with an increasing need to meet the demands of tourists; this includes building more infrastructures for accommodation and entertainment. In this section the impacts of tourist in parks is explored. Monitoring visitor impacts in protected areas requires a different approach to that taken to monitor impacts on the environment although some techniques could be the same (Buckley, 2003). Usually park management use environmental indicator in order to see the impacts caused by tourists. To monitor the impact of tourist conservationist, need baseline benchmarks to compare the impacts with (Buckley 2003). It has not been clearly specified whether the increase in tourism is a good thing but there are two perspectives. One that argues that the increase in tourism will provide jobs for locals leading to a decrease in use of natural resources in and around protected areas. The other perspective says that the increase of unplanned development can be negative on conservation by increasing the pressure in the ZOI due to demand for wood and water from tourist establishments (DeFries, Karanth & Pareeth 2010).

Zeng, Sui and Wu (2005) using the Wolong Nature Reserve as a case study, sought to understand the effects of human disturbances on landscape structure in protected areas. Specifically, the research wanted to investigate how several human disturbances show their impacts over landscapes in terms of scale and intensity and eventually how these landscapes structures differ from those areas that are not affected. Based on the thematic mapper (TM) imagery obtained in 1997, eventually, vegetation data for the Wolong nature reserve was extracted (Zeng, Sui & Wu, 2005). The results indicated that human activities and construction of hydropower stations had a great impact on the landscape structure and that the impacts decreased as the distance from the impact increased. The increased impacts lead to the increase of infertile, herbaceous and secondary shrub cover in areas of middle and low altitude alpine forest (Zeng, Sui & Wu, 2005). By comparing landscape structures of areas that were used as buffer zones with the landscapes that were not disturbed but had similar conditions, Zeng and Sui and Wu (2005) learned that activities by humans were adding to deforestation and associated increase of shrub and barren lands.

Literature showed that human utilisation of the environment has many impacts that range from small impacts such as animals avoiding the infrastructure through to habitat and population fragmentation. How the infrastructure and the use there of impacts the environment depends on the type and size of the infrastructure. Understanding these impacts provides guidance to the process of developing the CEC for the LNP.

Study area

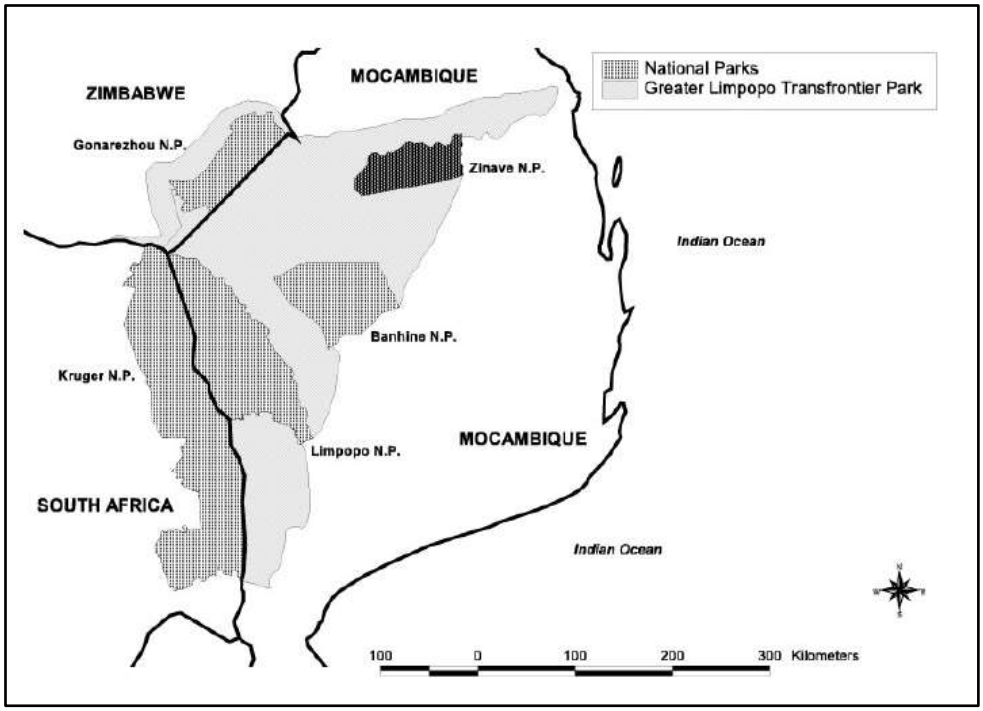

Figure 1. Locality map of the LNP (Adapted from Stalmans & Peel 2010)

The LNP is a 1 123 316-hectare park popularly known by its Portuguese name Parque Nacional do Limpopo (PNL) in Mozambique on the eastern boundary of the Kruger National Park (KNP) and is one of the major components of the Great Limpopo Transfrontier Park (GLTP) (Stalmans, Gertenbach & Carvalho-Serfontein, 2004). The LNP is a contribution made by government of Mozambique towards the creation of the GLTP (Stalmans, Gertenbach & Filipa, 2004; Milgroom & Spierenburg, 2008). A transfrontier Conservation Area is a large piece of land that straddles between two or more international boundaries, containing more than one protected area (Hanks, 2003; Munthali, 2007). Before 2001 the park was formerly used as a hunting zone (PNL website). Since then the park has served as a conservation area.

The LNP falls under the Miombo Woodlands Ecoregion (Timberlake & Chidumayo, 2011). The Miombo woodlands are dominated by trees in the legume subfamily *Caesalpinioideae* cover an estimated 3.6 million km^2 in central and southern Africa (Byers, 2001). The dominant species in tall, closed woodland (Stalmans & Peel, 2010), is known as the *Colophospermum Mopane or Chanate* is mostly confined to lower lying areas with clay and are nutrient rich (Chidumayo & Gumbo, 2010). This kind of vegetation is low in endemism. This ecoregion can however support large wildlife populations in Africa for example the vulnerable (Blanc, 2008) African elephant (*Loxodanta Africana*). There are around 1000 plant species in the Miombo ecoregion which is high species richness for an arid area. In Mozambique the main threat to the Mopane woodland vegetation is cutting of *Androstachys* and Mopane wood for charcoal production (Byers, 2001; Timberlake & Chidumayo, 2011). Recent years have seen wildlife in the LNP being recovered, after being annihilated during the Mozambique civil war. In 2010 there were over a thousand elephants spotted in the park. Other examples of animals that have crossed the border from Kruger National Park are kudu, gazelles, lions, sable, giraffes, zebras, and impalas. The Miombo Ecoregion supports a range of different birdlife, reptiles, amphibians and fish, most of which are endangered and endemic to the ecoregion (Timberlake & Chidumayo, 2011).

The LNP is home to about 27 000 people, who belong to seven communities who depend on natural resources in the park. Approximately 20 000 of whom reside in the eastern and southern borders of the park whereas the other 7 000 are distributed among eight villages alone the Shingwedzi River (Milgroom & Spierenburg, 2008). These communities' practice subsistence farming through cattle and goats as well as seasonal crops. The animals tend to shy away from these habitats, and they have been recurring conflicts among livestock, communities and wildlife. The resettlement of these villages to areas outside the park was put on hold due to lack of funds, however, this are set to resume in October 2019. The villages will be relocated to areas that will provide sustainable improvement to their livelihoods (Scoones, 2009). Wildlife is expected to move into the areas currently occupied by the communities once the relocation is completed.

Methodology

The simplest way to explain what a CEC entails is by answering two questions:

1. Is the area formally protected or not?

If the area is protected, it is categorised as Natural and if not, it is categorised as Rural.

The definition of a protected area given by the International Union for Conservation of Nature (IUCN) is "a clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values" (Dudley, 2008: 19). The LNP was proclaimed in 2001 as a national protected park therefore it is classified as natural. Since the whole study area is a national protected park, there is no area classified as rural.

2. Is the area impacted or not?

If the area is impacted upon/developed, it is considered **developed and i**f there are no impacts/developments, it is categorised as **undeveloped**

Impacted areas

Several audio-visual impacts (intrusions) such as roads, power- lines, buildings, infrastructure, villages, towns etc. occur within and around the LNP. These composed together represent the factors that impact on the environmental character of the area and thus are classified as the impacted areas. The impacts in the landscape are derived through buffering infrastructure data. For example, a picnic site could be buffered by 2000m due to the amount of people it attracts, so it has a large audio impact, but a camp could have a buffer of only 300m due to its small size and insignificant visual intrusion. If a lodge was placed between trees and/or behind a hill, it may have an impact of 1000 m (it might not be seen but be heard), but if it was on top of a hill with no vegetation cover, it could have an impact of 3km or more, for as far as it could be seen in the landscape.

Buffer zone

Linear buffers were used around roads and power lines then circular buffers around infrastructure, tourist attractions and populated places. These areas were buffered according to the visual and audible impacts that they have on the landscape. Table one below shows the buffer values used to define the impacted areas. The impacted area buffers were also used to identify those areas where visual and audible disturbances are absent offering landscape wilderness edge, natural undeveloped and wilderness area. In the natural undeveloped areas, there is still an opportunity to experience some natural aspects of the park.

Table 1. Buffer values

TYPE	BUFFER 1(m)	BUFFER 2(m)	BUFFER 3(m)
		(buffer 1)*2	(buffer 1)/2
Populated Places			
Village (Rural)	1000	2000	500
Rural settlement	1000	2000	500
Tourism			
Camp	500	1000	250
Lodge	1000	2000	500
Tourism Activity	2000	4000	1000
Airstrip	1500	3000	750
Gate	500	1000	250
Viewpoint	750	1500	375
4x4 operator camp	300	600	150
4x4 camp	300	600	150
4x4 camp	300	600	150
canoe trail	100	200	50
Hiking trail	100	200	50
Hiking trail camp	300	600	150
ranger camps	250	500	125
rest camps	500	1000	250
Infrastructure			
Boat launch	2000	4000	1000
Irrigation project	1000	2000	500
PNL official	500	1000	250
Ranger picket	250	500	125
Registration office	500	1000	250
Tower	1000	2000	500
Roads			
Main (Untarred)	850	1700	425
Tracks (Management)	250	500	125
Trail	100	200	50
unknown	250	500	125
Other			
Power lines	200	400	100

The first buffer values are those that were prescribed by the Peace Parks Foundation. They are based on how far the impacts of a development extend to that is how far it can be seen or heard.

Sensitivity analysis

Two extra buffers were added to the study. This was done to define the extent of the impacts in the LNP. The two buffers will act as a sensitivity analysis to see how decreasing or increasing the buffer values affect the CEC, whether the visual and audio impacts of developed or impacted areas intensify or decrease at these values. If there are any changes, the percentage of difference noted and whether the wilderness area increase or decrease with the increase or decrease of the defined buffer values. The second buffer will be accomplished by multiplying the Peace Parks Foundation buffer values by two and the third set of buffer values will be a result of dividing the Peace Parks Foundation buffer values by two.

Using ArcGIS buffers around the developments were made according to the buffer field. The buffers for the different themes were union together into one polygon, that shows the impacted areas as full area unlike before with the buffers where different areas where represented individually. This union reduces the number of polygons to work making things easier for analysis purposes.

Classification

To create a CEC, a move from impacted areas, to undeveloped areas, to wilderness edge and finally to wilderness is made if applicable. To do the classifications, query builder was used to identify the types of landscapes in the LNP. Table two below shows the classifications that were used.

Table 2. ECHOS classification

	Protected	Impacts	Buffer (km)	Notes
Wilderness	Yes	No	15	Wilderness can only start 15 km from an impact zone
Wilderness edge	Yes	No	5	Wilderness edge only allowed to start 5 km from an impact zone
Natural undeveloped	Yes	No	-	Areas that still offer undisturbed natural experience
Natural developed	Yes	Yes	extent	Subsistence farming used as main indicator
Rural undeveloped	No	No	Extent	This status could change to natural or wilderness depending on the protection status afforded to it
Rural developed	No	Yes	Extent	Subsistence farming used as main indicator

The World Conservation Union (IUCN) Framework for Protected Areas defines a wilderness area as ‘‘a large area of unmodified or slightly modified land and or sea, retaining its natural character and influence, which is protected and managed so as to preserve its natural condition’’ (Mittermeier *et al.*, 2003). This means wilderness areas are supposed to be without any development. Wilderness areas provide an environment in which biodiversity and ecosystem processes that were previously disturbed by human activity be restored. Human use is limited, often allowing only those who are willing to travel of their own accord rather than via established touristic activities. Two different sets of CECs each with the three buffer values discussed above were done. The first was named the classic CEC, was done using the vector data that showed the several audio-visual impacts (intrusions) such as roads, power lines, buildings, infrastructure, villages, towns etc. The second set of CEC was done using the same vector layers from the classic CEC together with a land cover raster image.

Classic CEC

After identitifying the natural developed area, the remaining parts of the park are natural undeveloped areas. A buffer of -5000m of the natural undeveloped areas (negative number used so that the buffer can start inside the polygon) was made, to indentify that wilderness edge. The wilderness edge according to the ECHOS classification starts 5000m from the impacted zones. The wilderness areas on the other starts 15 000m from the impacted zone. In order to indentify the wilderness area a buffer of -15 000m was made around the natural undeveloped, this giving use the wilderness areas.

To make a final CEC map a union that is combine selected features into one new feature of the wilderness edge, wilderness, natural developed and natural undeveloped is made.

Amended CEC

In the amended CEC a 2005 land cover image of the GLTP was used. The land cover descriptions can be found in appendix A. Before using the land cover image in the analysis, it was converted into a vector (shape file) using ArcGIS. The reason for the conversion is that all the other data is in vector and in order to union the land cover with the natural developed, they should be in the same data type. For the purpose of this study the land cover vector layer was clipped to the extent of the study area, the LNP. The two land cover types found in the LNP are urban or settlement areas and dry land or subsistence cultivation. Settlement areas

refers to those areas with concentrated urban or settlement patterns and dry land/subsistence cultivation refers to rain fed subsistence/semi-commercial cultivation\ activities (predominately field mosaics but may include scattered dwellings).

The land cover was union with the layer that shows the impacted areas together with the undeveloepd areas. The different types of land cover were classified as natural developed areas as they have been altered by humans. A buffer of -5000m of the natural undeveloped areas was made, to indentify that wilderness edge. The wilderness edge according to the ECHOS classification starts 5000m from the impacted zones. The wilderness areas on the other hand starts 15 000m from the impacted zone. In order to indentify the wilderness area a buffer of -15 000m was made around the natural undeveloped. To make a final CEC map a union that combines wilderness edge, wilderness, natural developed and natural undeveloped into one new feature was made.

Results

Figure three shows natural developed and natural undeveloped for both the classic and amended CECs. Natural developed showing impacted areas. As mentioned in the methodology these areas were obtained by buffering the developments such as roads, infrastructure, villages, rural settlements and tourist attractions (picnic sites, viewpoints etc.). The different buffered areas were union into one to make on area that is impacted. The inverse is natural undeveloped areas that still have a high quality of natural experience. From the natural undeveloped further classification will identify wilderness and wilderness edge. From figure three shows that the amended CEC has a slight increase in the developed areas, (the areas that appear black) this is the result of the land cover that was added.

The impacted areas

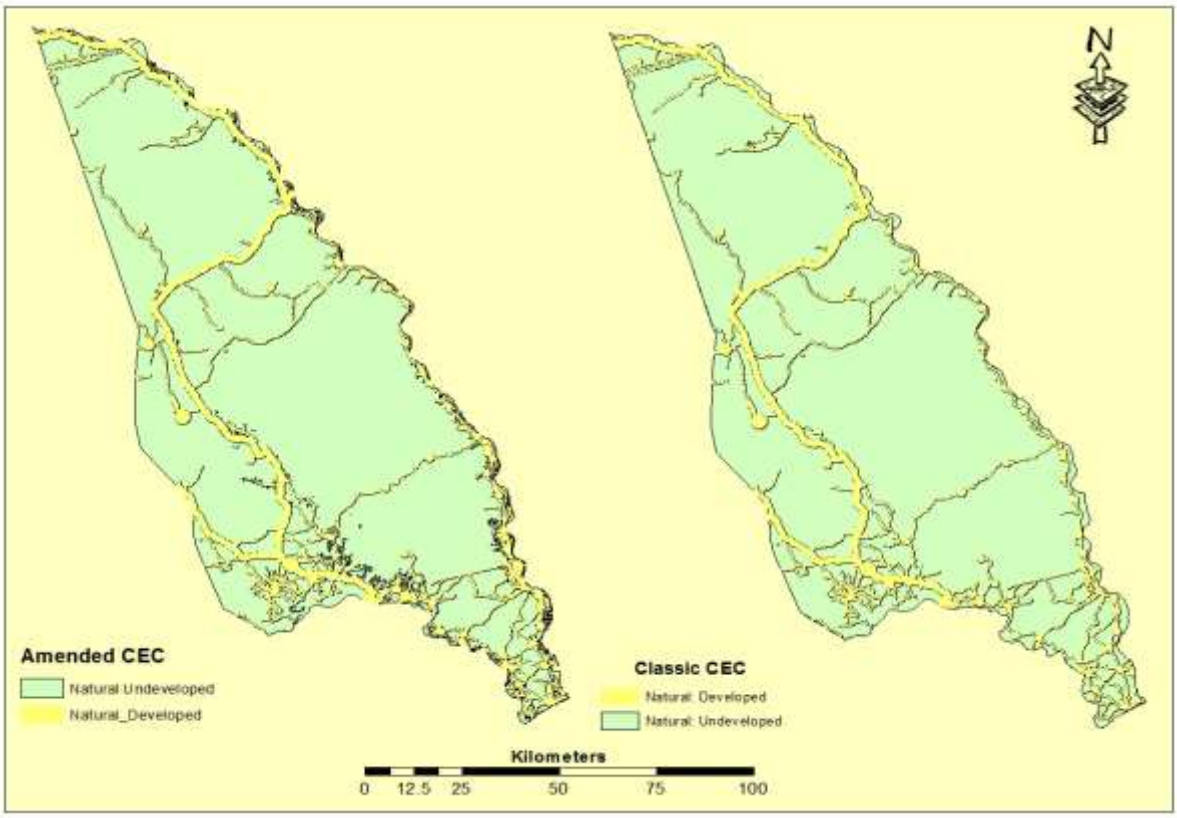

Figure 2. Natural developed and Undeveloped

The Natural developed areas line that seems to be dividing the park into two east and west parts and runs from the North West part of the park to the south eastern part, is the main road buffer. The main road was given a large buffer when identifying the extent of its impact because of the audio and visual impacts roads have on biodiversity, some of which were discussed in the literature review. This area stands out as the most impacted emphasizing that roads do have a large impact. The southern part of the park and the eastern border appears to be the most impacted areas (contains the most developments). The eastern part of the park is bordered by the Limpopo River. Most of the developments along the river are villages and rural settlements and they presumed to be located there because of the water source. The land cover shows that along the river there a lot of subsistence cultivation and urban settlements, which makes sense because it is easy to farm where there is easy access to water.

Classic Current environmental character

Classic CEC one

Using the ECHOS classification the wilderness edge and wilderness area were selected. These then combined into CEC of the area.

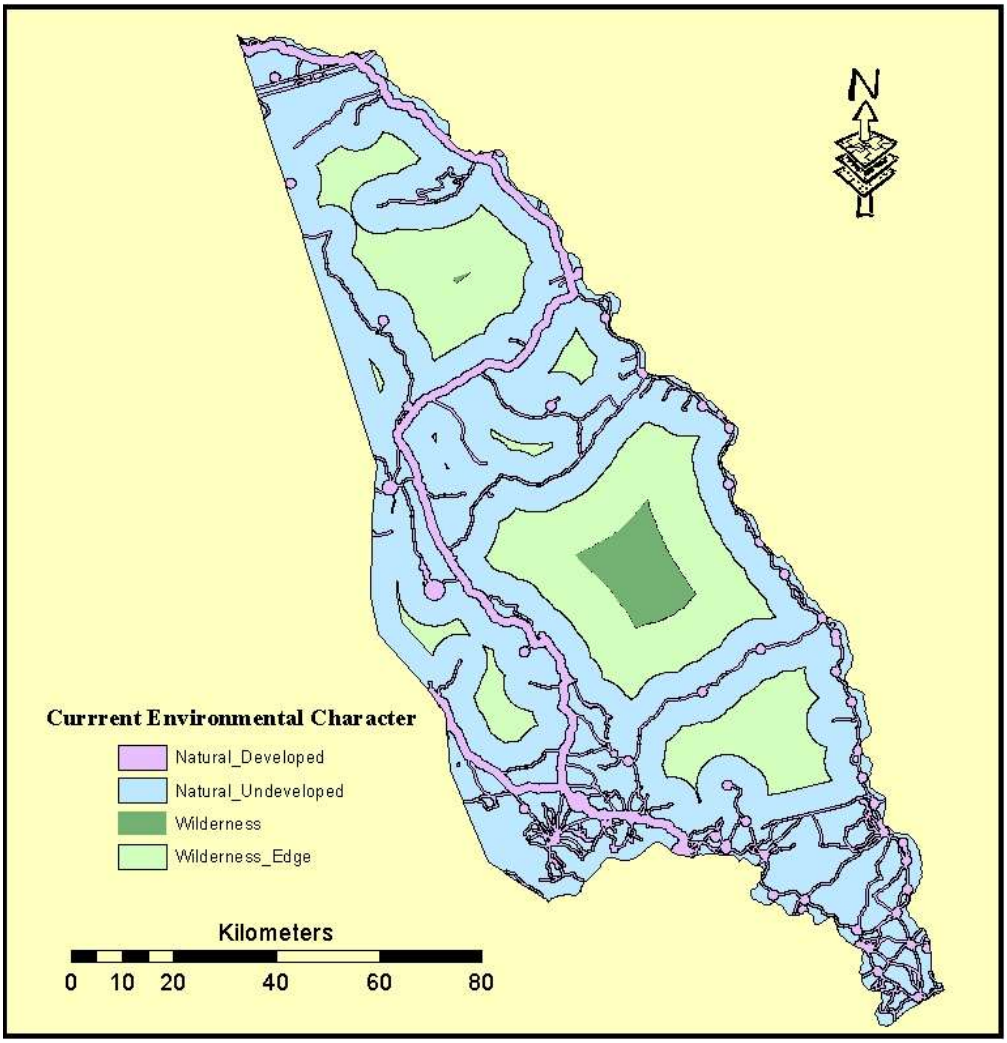

Figure 3. Classic CEC one

Table 3. Area of the different CEC one zones

CEC	AREA (ha)	PERCENTAGE
Natural Developed	133 885.33	12.17
Natural Undeveloped	678 170.65	61.62
Wilderness Edge	260 863.89	23.70
Wilderness	27 606.03	2.51
TOTAL AREA	1 100 525.90	100.00

Figure four shows the classic CEC. Natural undeveloped area appears to be the majority zone in the park. This is further supported by table three which shows that natural undeveloped covers a total area of 61.62%. Natural undeveloped areas have no human-induced impacts and still offer undisturbed natural experience (KAZA IDP 2008). Wilderness edge is about a quarter of the park, covering 23.70% of the total area. 12.17% of the area is impacted by development and only 2.51% is classified as the wilderness area which is the smallest zone.

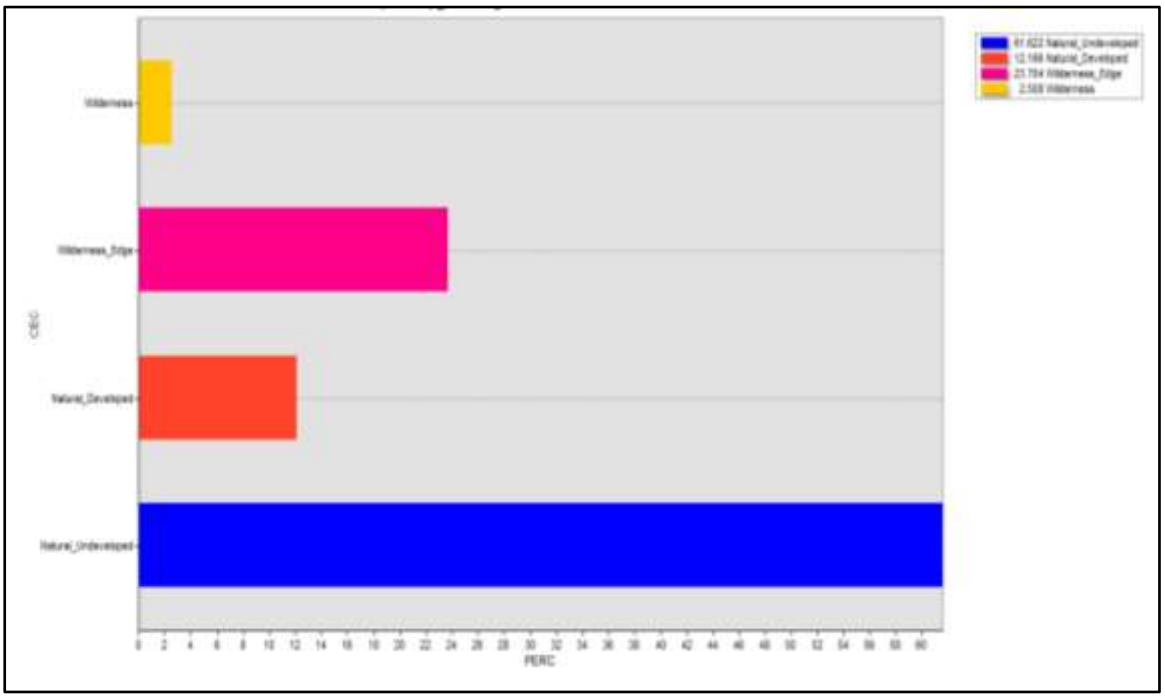

Figure 4b. Graph depicting the percentage difference of the different zones

In figure five the difference of the various zones is depicted in percentage. One can clearly see the difference between the zones for instance the huge difference between wilderness and natural undeveloped.

Classic CEC two

For the second CEC the original buffer values were multiplied by two.

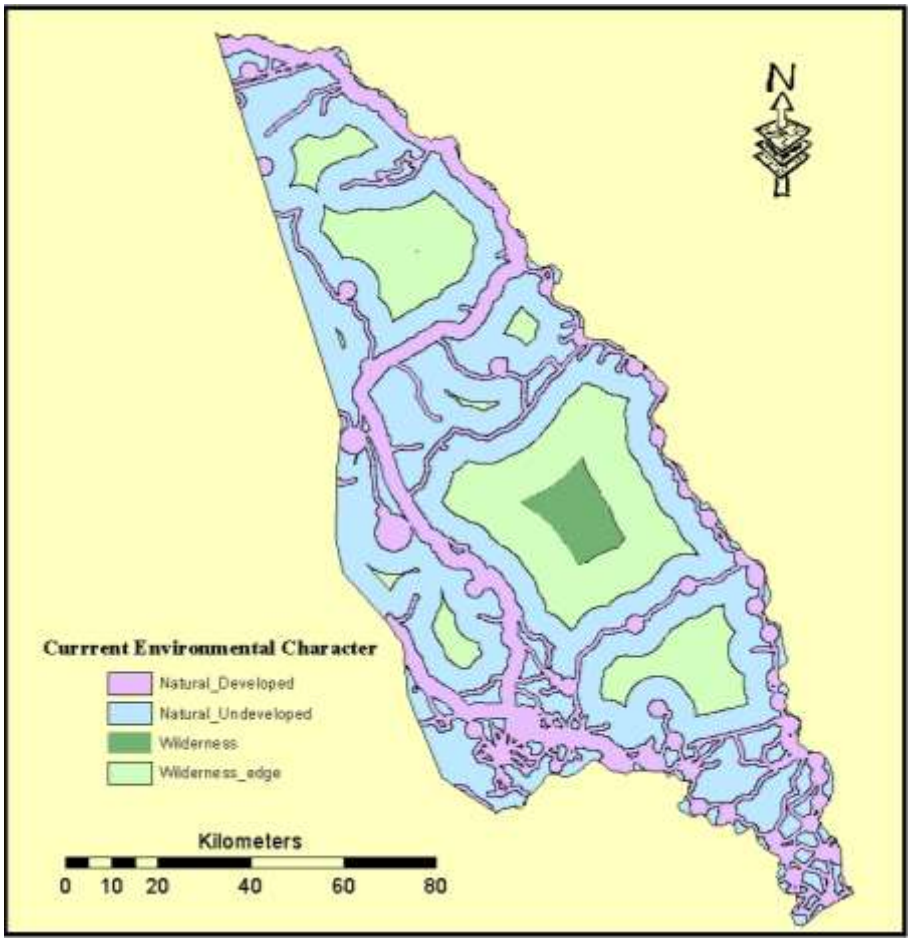

Figure 4. Classic CEC two

Table 4. Area of the different second CEC zones

CEC	AREA (ha)	PERCENTAGE
Natural Developed	259 462.81	23.58
Natural Undeveloped	582 202.94	52.90
Wilderness edge	235 285.51	21.38
Wilderness	23 574.64	2.14
TOTAL AREA	1 100 525.90	100.00

Figure six shows the second classic CEC and table four has the areas in hectares of the different zones. The natural developed area in figure six still appear to be the dominant zone; however, it has decreased only now taking up 52.90% of the total area unlike 61.62% from the first CEC. The decrease is the result of multiplying the buffer values used to identify the impacted areas by two. The natural developed however increased by almost half when compared with the original CEC classification, now covering 23.58% of the area. The wilderness edge and wilderness both had a slight decrease. Wilderness edge is about a quarter of the park, covering 21.38% of the total area and only 2.51% is classified as the wilderness area which is the smallest zone.

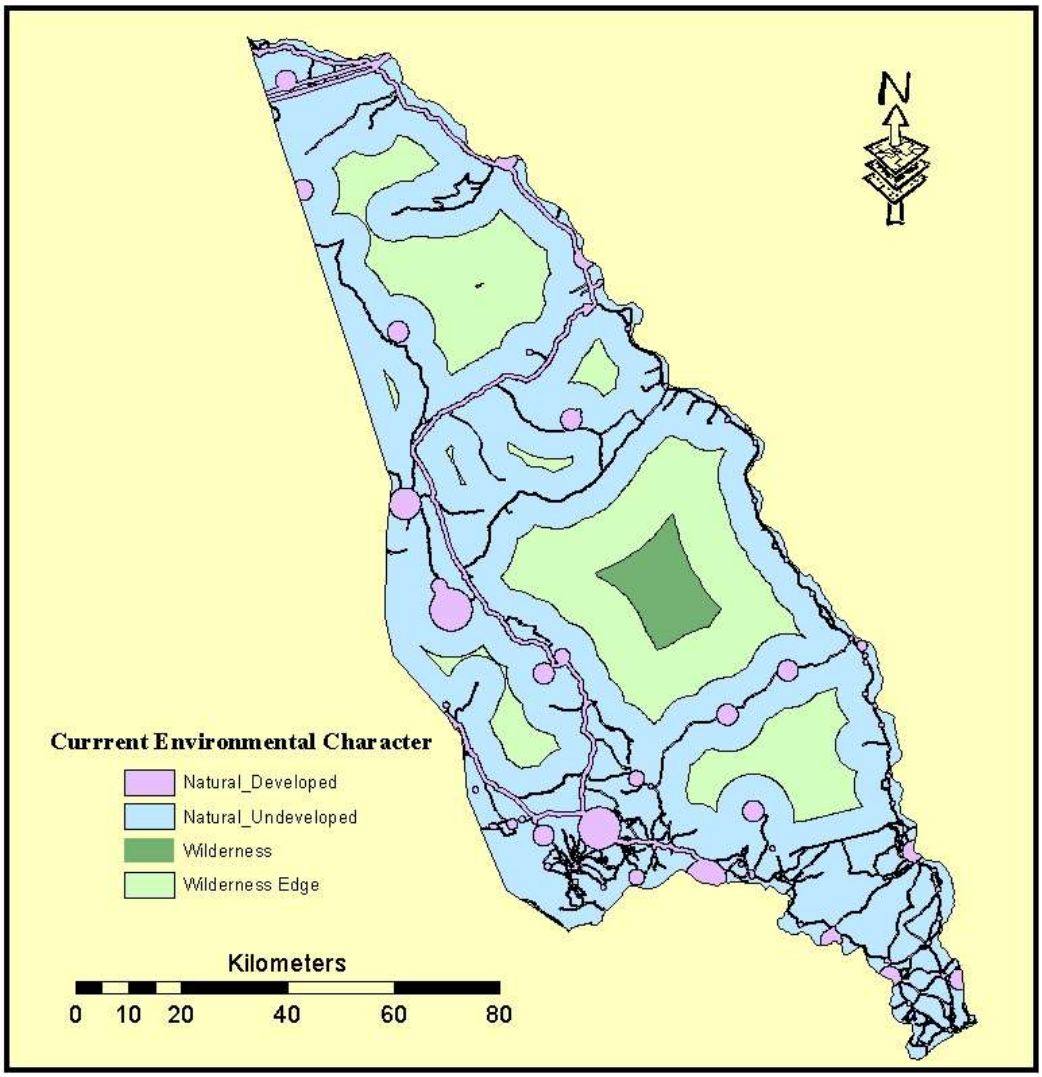

Figure 5. Classic CEC three

Table 5. Area of the different third CEC zones

CEC	AREA	PERCENTAGE
Natural Developed	98 661.67	8.96
Natural Undeveloped	715 199.94	64.99
Wilderness Edge	259 577.47	23.59
Wilderness	27 086.82	2.46
TOTAL AREA	1 100 525.90	100.00

Figure four shows the third classic CEC, with the wilderness area still appearing to be the smallest and at the centre of the park. Table five shows that dividing the original buffer values by two results in a 5.18% increase of the natural undeveloped areas. This zone although has decrease remains dominant in the park. The natural developed area decreases by 26.38%. The wilderness edge decreases by a mere 0.46% and the wilderness decreases 1.88%.

Amended CEC

The amended CEC included the shapefiles showing the impacted areas, the following results were obtained.

Amended CEC one

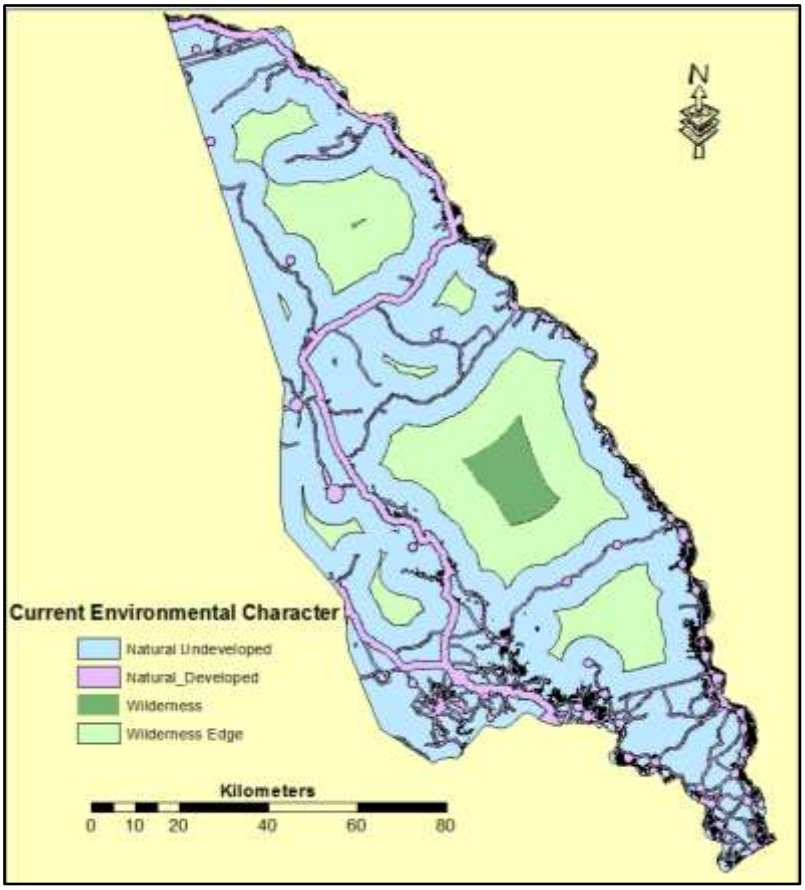

Figure 6. first amended Current Environmental Character

Table 6. Amended CEC one

CEC	AREA	PERCENTAGE
Natural Undeveloped	680 521.73	61.84
Natural Developed	149 041.75	13.54
Wilderness Edge	245 473.44	22.31
Wilderness	25 488.98	2.32
TOTAL AREA	1 100 525.90	100.00

Natural developed areas in figure eight appear to be concentrated in the east and south part of the park. The natural undeveloped areas take up the largest area of the park, table six shows that this area is almost a third of the total area taking up 61.84% of the total area. The wilderness edge takes up the second largest area of the park which is almost a quarter of the total area. The natural developed area only takes up 10.52%. The wilderness area is the smallest area in the park, only taking up 2.32%. The wilderness area is divided into two pieces by the main road. The piece that is north of the park is very small and can be easily missed.

Amended CEC two

The buffer values used to identify the impacted area or developed area in similar method to that followed when classifying the original CEC that is the original buffer values multiplied by two.

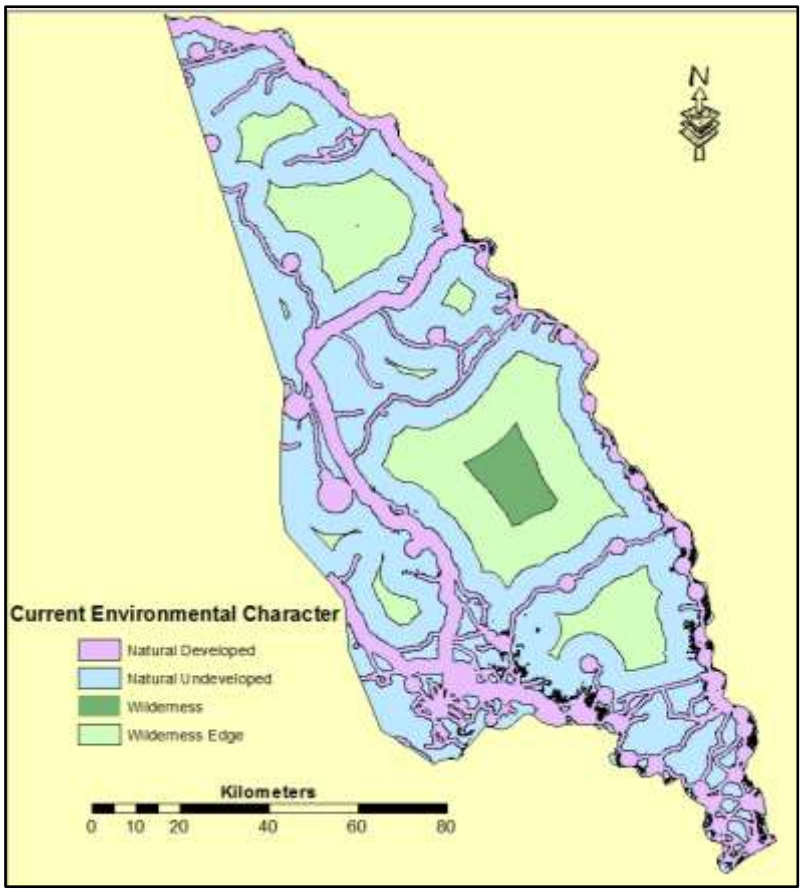

Figure 7. Second amended Current Environmental Character

Table 7. Amended CEC two

CEC	AREA	PERCENTAGE
Natural Developed	265 478.60	24.12
Natural Undeveloped	586 400.59	53.28
Wilderness Edge	225 665.92	20.51
Wilderness	22 980.79	2.09
TOTAL AREA	1 100 525.90	100.00

Increasing the buffer values lead to a significant increase in the natural developed areas and a decrease in the natural undeveloped areas. The increase in buffer values means that the impacted area that is identified also increase, decreasing the undeveloped areas. The largest area is the natural undeveloped followed by the developed areas. The developed areas show an increase of almost 10% from the first amended CEC with the original buffer values. The wilderness still is the smallest area of the park only occupying 2.09% of the total area meaning that multiplying the buffer values by two lead to a decrease of the wilderness area by a fraction. The significance decrease of the wilderness shows in the north piece of the wilderness in figure eight. The wilderness edge has decreased by almost 2%. Increasing the impacted area led to a decrease of all the other zones in the park.

Amended CEC three

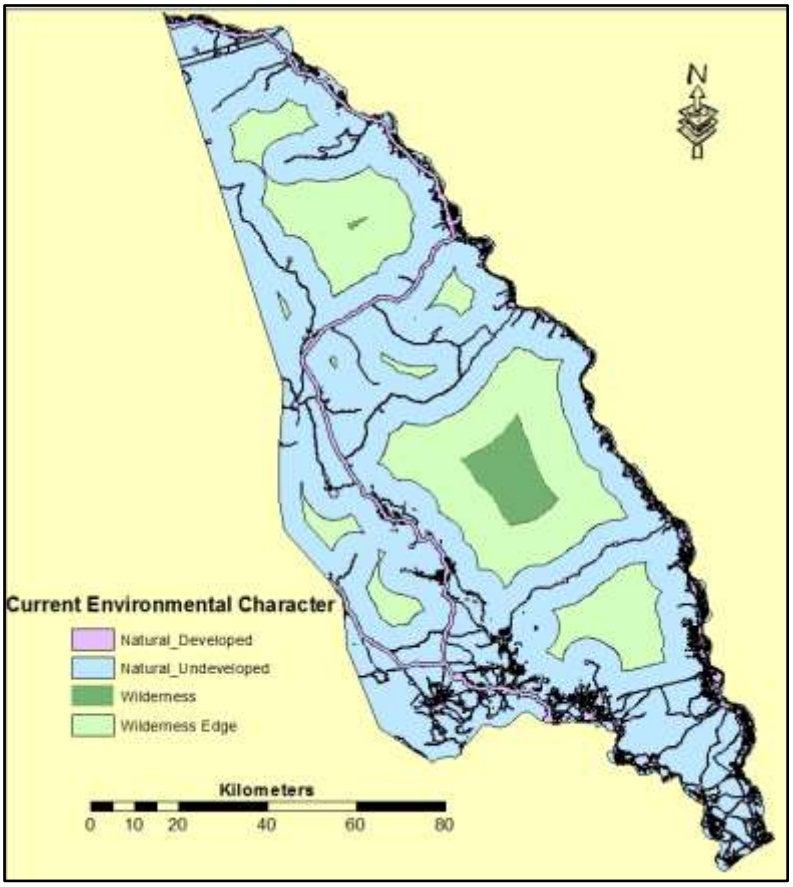

Figure 8. Third amended Current Environmental Character

Table 8. Amended CEC 3

CEC	AREA	PERCENTAGE
Natural Developed	90 090.14	8.19
Natural Undeveloped	729 942.59	66.33
Wilderness Edge	254 369.01	23.11
Wilderness	26 124.16	2.37
TOTAL AREA	1 100 525.90	100.00

Decreasing the impacted area by halving the original buffer values led to a decrease of the developed areas by 39.16%, which is expected since the impacted area is now reduced. The undeveloped areas increase by 4.49%, from taking up 61.84 in the first CEC to taking up 66.33% in the third CEC. Wilderness edge got increased by almost 1% and the wilderness area increased by 0.05%. Reducing the buffer values therefore decreasing the developed or impacted area, leads to an increase all the other zones.

Classic CEC and Amended CEC

Comparing Figure eight amended CEC one with the original buffer values CEC in Figure 3 one cannot immediately spot the difference in the zonation of the area. The different zones still occupy the same areas in the park. Below a comparison of the changes in areas of the

different zones in the classic and amended is made. The comparison will clearly show, how adding the land cover impacted on the results of the CEC.

Table 9. A comparison of all the zones of both the Classic and Amended CEC

	ONE (original)		**TWO (Multiply by 2)**		**THREE (divide by 2)**	
Area	Classic	Amended	Classic	Amended	Classic	Amended
Natural Developed	12.17	13.54	23.58	24.12	8.96	8.19
Natural Undeveloped	61.62	61.84	52.90	53.28	64.99	66.33
Wilderness Edge	23.70	22.31	21.38	20.51	23.59	23.11
Wilderness	2.51	2.32	2.14	2.09	2.46	2.37

Original buffer values

The difference in areas of the different zones between the classic and amended CEC is not a large one. Table nine above compares the difference between the classic and amended CEC using percentage of the total area each zone takes up. In the wilderness area, using the original buffer values in the classic CEC the wilderness is 2.51% of the total area and in the amended CEC it is 2.32%. Adding the land use from the land cover image increased the natural developed area from 12.17% in the classic CEC to 13.54% in the amended. The increase of the developed areas in the amended CEC means that the original points from the shape files do not cover the whole developed areas, for example a point cannot represent the whole areas of an urban settlement whereas the land cover image covers it all. The natural undeveloped increased by 0.22% in the amended. The wilderness edge and wilderness areas both decreased by 1.39% and 0.19% respectively.

Multiplying buffer values by two

Doubling the buffer values increases the natural developed by 0.54% in the amended from the classic CEC. The natural undeveloped is smaller in the classic CEC taking up 52.90% of the total area whereas in the amended it takes up 53.28%. The wilderness edge is smaller by 0.87% in the amended. The wilderness area decreased from 2.14% in the classic to 2.09 in the amended CEC.

Dividing the buffer values by two

The original buffer values halved decreases the impacted area (the natural developed area). In the classic CEC the natural developed takes up 8.96% which decrease in the amended CEC to 8.19%. The natural undeveloped area increased from 64.99% in the classic CEC to 66.33% in the amended CEC. The wilderness edge is 0.48% smaller in the amended CEC than it was in the classic CEC. In the halved CECs, the natural developed decreased when it was union with the land cover, it was expected that the developed area will increase instead.

The common trend in both CECs is that an increase in the buffer values increases the developed areas, decreasing the natural undeveloped areas, wilderness edge and the wilderness area.

Discussion and conclusion

The CEC done using peace parks foundation buffer values shows a wilderness area of 27606.03 ha. The proposed zone planned a wilderness area or zone of 58784 ha. There is a 53.04% difference. The proposed zonation and what the park is currently are quite different.

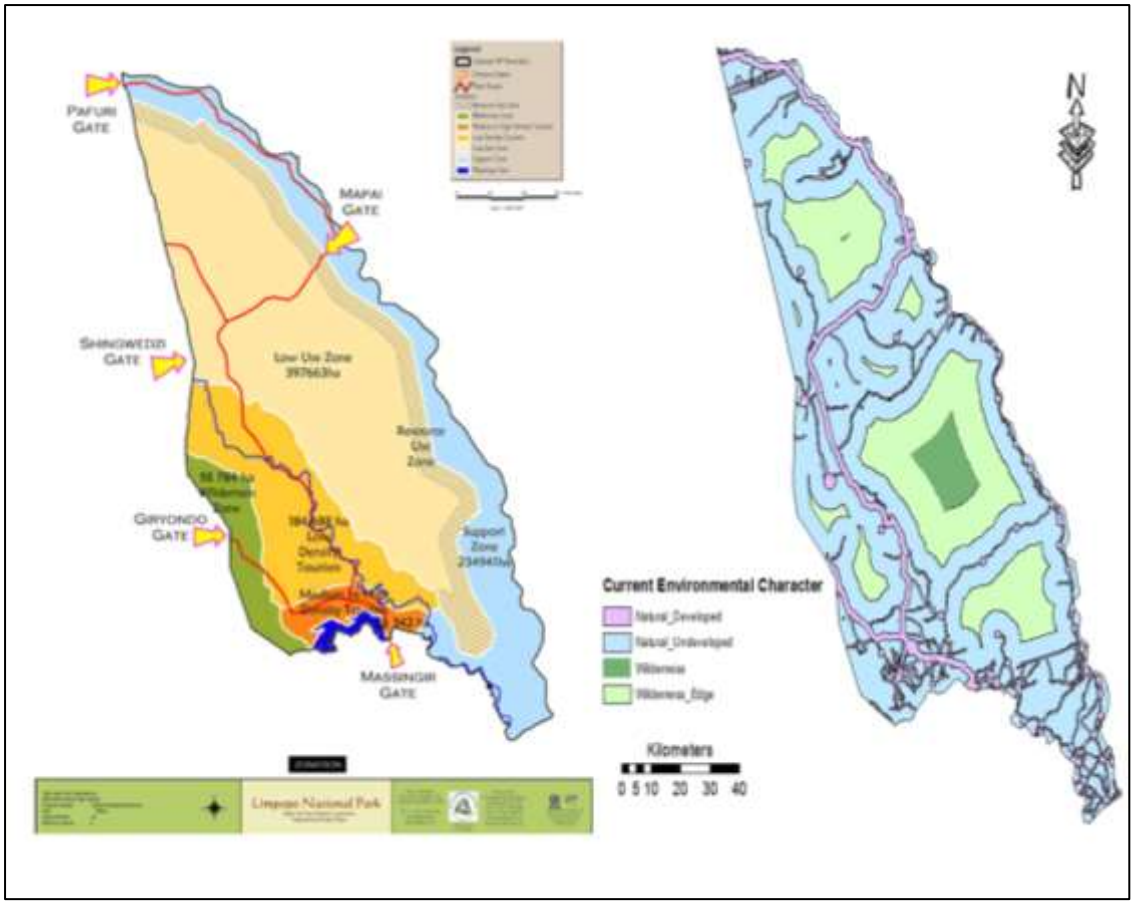

Figure 9. comparison of a CEC and the proposed zoning

The current study has successfully met the main aim, which was to identify, for the first time, the current environmental character of the Limpopo National Park using development meant to increase tourism activity. The extent to which developed areas impact on the park was identified by buffering the developed areas using ArcGIS. It was found that increasing the buffer values also increase impacted areas, decreasing all the other zones of the CEC (natural undeveloped, wilderness edge and the wilderness area). Decreasing the buffer values by half reduces the impacted areas, increasing the other zones of the CEC (natural undeveloped, wilderness edge and the wilderness area).

From all six CECs done using different buffer values and three including the land cover data, the presence of the main road in the park has an impact on the area. The main road stands out in all CECs as one of the areas with most impacts, and the road divides the wilderness areas in two pieces. Perhaps without the presence of the road it would have been one big wilderness area. It was also observed that most of the impacted areas are clustered along the border that is close to the Limpopo River and the south of the park where there is the Massingir dam. In 2004 a lodge near the Massingir dam (the Covane Community Lodge) was opened (Spenceley, 2006). The lodge offers accommodation as well as traditional dances, traditional food, hiking trails, village visits and viewing by boat, and the opportunity to purchase local crafts (Spenceley, 2006). The presence of a lodge and its related tourist's activities explains why that of the park appears to be most impacted. Along the Limpopo River there is mostly cultivated land, the main attraction for their location is water. The cultivation lands are mostly accompanied by settlements, villages with 20 000 people estimated to be staying there (Spenceley, 2006) and some tourist activities, increasing the human impact on the park. There is a small area in the LNP that is classified as wilderness. Further development in the park might reduce this area. Mozambique part of the GLTP has minimal infrastructure and there is

still planning to go on for tourism development (Spenceley, 2006). It is recommended that when planning the appropriate development in the LNP, management should consider the wilderness and that there should not be further development in areas that already have high human impact, for example, all the Limpopo River boundary.

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