Spatial planning for off-road driving areas – Pros and cons of environmental regulations

A case study in a semi-arid environment, Namibia

By

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Dedicated to my children and parents

Abstract

Commercial and tourist activities including off-road driving have the potential to cause large scale environmental changes to the fragile ecosystems of the western areas of Namibia. The aim of the study was to develop a generic method to identify activities and areas where off-road driving has been taking place and to assess the environmental sensitivity. The results were used to evaluate the long and short term effects of environmental regulations on spatial planning. Spatial Multi Criteria Evaluation was used as a means to address this complex human-environmental coupled issue by combining spatial information and stakeholder's expertise. Spatial data was collected, processed to vector data and rasterized. The data was grouped by socio-economic and tourist activities, landscape and ecology and integrated in two GIS models. Criteria weighting and group ranking was based on expert knowledge and stakeholder's interest. The first model was used to evaluate activities and environmental sensitivity of the area, while the second model generated off-road driving suitability maps for alternative policy visions. The results reveal that a number of socio-economic and tourist activities were carried out in areas of moderate and high environmental sensitivity, hereby resulting in negative effects on the environment. Priority areas for nature conservation were identified along the coast and in proximity to towns where high, uncontrolled tourist activity was overlapping highly sensitive environmental conditions. In contrast, controlled off-road driving activities within areas of low sensitivity were resulting in minor environmental effects. Using spatial planning and environmental regulations to restrict off-road driving areas leads to avoidance and mitigation of negative effects. The results further showed that spatial planning without strict environmental regulation enhances the negative effects. Planning without environmental regulations is possible and adequate in areas of low environmental sensitivity. However, increasing environmental sensitivity requires a planning approach that incorporates the assistance of environmental regulations to restrict areas for off-road driving to less sensitive areas, hereby channelizing their effects.

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List of acronyms

BaU	Business as Usual
BDC	Biological Diversity Convention
DRFN	Desert Research Foundation of Namibia
EIA	Environmental Impact Assessment
ETM	Enhanced Thematic Mapper
GDP	Gross Domestic Product
GIS	Geographic Information System
IBA	International Bird Area
IUCN	International Union for Conservation of Nature
MEF	Most Environmental Friendly
MET	Ministry of Environment & Tourism
NACOMA	Namibian Coast Conservation and Development Project
NGO	Non Governmental Organisation
NNF	Namibia Nature Foundation
ORD	Off-road driving
ORV	Off-road vehicle
RGB	Red Green Blue
SAIEA	Southern African Institute for Environmental Assessment's
SDSS	Spatial Decision Support System
SMCE	Spatial Multi Criteria Evaluation
UTM	Universal Transverse Mercator
WGS	World geodetic System
WTTC	World Travel & Tourism Council

1. Introduction

1.1. Off-road driving

Off-road driving (ORD) has experienced a rapid growth over the past decades. The trend can be partly attributed to an increase in economic wealth and partly to tourists desire to experience adventurous activities in times of recreation. As tourism has become worldwide a major source of income with a predicted raise of 9.5 % in developing and of 4.5 % in industrialised countries (Abbott, 2006) the use of off-road vehicles (ORV) within this sector will continue to gain significance. Although the growing number of tourists attracted to ORD contributes to economic development, it likewise exerts an increasing pressure on the natural environment. Due to a high population density and over regulation of the do's and don'ts in most of the travellers countries of origin, adventure and remoteness as criteria become more and more essential when choosing a holiday destination. This leads to a susceptibility to environmental changes in areas without or with limited regulations where tourists may experience the freedom and adventure they were looking for.

As North America was a precursor of ORV use for recreation since the beginning of last century (Webb and Wilshire, 1983), it may illustrate how ORV overuse may drive adverse environmental effects. Until the sixties no damage was observed, however this pattern changed in the seventies when numbers of ORV increased dramatically and adverse impacts became so severe that an executive order was issued to control the use of ORV’s (Cloudsley-Thompson, 1984). Although regulations have been in place since, a significant number of ORV’s is registered each year and ORD is still affecting species distribution and abundance (Groom *et al.*, 2007).

Lacking or insufficient environmental legislation worsen the situation in many countries around the globe (Davenport and Davenport, 2006), as it results in ineffective planning and management to confine ORD with the aim to protect vulnerable areas. In countries such as South Africa, the implementation of recreational ORD zones proved to be difficult, as the new legislation has met with criticism from ORV users. Planning and decision making did not consider the socio-economic effects coupled to ORD (Celliers *et al.*, 2004), but primary considered its direct impacts on the environment.

ORD can further be related to socio-economic development and military field exercises in training areas. While the latter decreased in the past, the increasing population and demand for raw materials drive prospecting and exploration activities in often inaccessible areas. Scarcity of minerals and rising values on the stock market has driven mining in areas not considered as profitable only a decade ago. The process of prospecting potential mining sites has in particular related to ORD, as infrastructure development and restoration measures are often prerequisite of development and consequently reduce ORD effects during exploration.

The effects of ORD on biophysical aspects of the environment have been studied extensively. For example: special attention has been given to arid environments and coastal dune areas (Groom *et al.*, 2007, Pickering and Hill, 2007, Priskin, 2003, Rickard *et al.*, 1994), dune erosion caused by vegetation loss in South Africa (Van Der Merwe, 1988), vegetation degradation in Kuwait (Brown and Schoknecht, 2001), soil loss and change in hydrology (Priskin, 2003), and direct destruction of ghost crabs in Australia (Moss and McPhee, 2006). Although this research aims to target the subject in a generic way, the reader's attention will be drawn to Namibia, where the case studies will be carried out.

1.2. Drivers of off road driving

1.2.1. Tourist activities

The rapidly growing attractiveness of Namibia as a tourist destination, relies strongly on adventure based tourism (Buckley, 2007). The national tourist arrival statistic (Namibia Tourism Board, 2008), states an increase between 2005 and 2007 of approximately 20 % travellers annually, from 777,890 to 928,912 in total. ORD as a recreation activity using 4 x 4 vehicles, quad bikes or motor bikes and wildlife watching tours using ORV's as a means of locomotion in otherwise not accessible areas, are activities that can be regarded as adventure tourism. The principle attraction to adventure tourism is related to an outdoor activity in natural terrain, that generally requires specialised equipment and where some excitement is associated to the participant (Buckley, 2007).

Among others, duration, skills and remoteness to off-road safaris and wildlife watching has been investigated during a research by Buckley (2007). Off-road safaris tend to be integrated in tours having a period between 1 and 2 weeks and a price range between about 50 and 350 US$ per person per day. In contrast wildlife watching ranged between 2 and 7 to 8 days with a price range between 100 and 700 US$ per person a day. Being medium costly and very specialist tours, this kind of activity has a recognizable commercial signature (Buckley, 2007). Thus it may also be related to consumer behaviour during vacation planning (Kwortnik and Ross, 2007). Tourists described above are likely to undertake their travels in changing environments and are often crossing national boundaries. The goal of such a travel may be a memorable experience, escape, novelty or just a change of scenery (Kwortnik and Ross, 2007). As those tourists are expected to undertake ORD only during their holidays, often once a year and as part of a tour package, ORD impact is not likely to be limited to this group of visitors. In contrast, it may be further associated to more frequent ORD activities and their related interest groups.

Local stakeholders as the recreational fishermen and the ORD community (Celliers et al., 2004) may have different reasons to go off-road. Beach access points may be insufficient of absent, personal interest to specific fishing spots or customized behaviour may influence driving patterns not confined to an existing road network. Spending leisure time in the dunes can be regarded likewise for people living in the area as an activity that supports relaxation and gives time for oneself in a quiet and peaceful environment. To be undisturbed and within the local community, those groups are expected to go to areas not frequented by the tourist community, hereby creating an own area of influence.

1.2.2. Socio-economic activities

Prospecting and mining activities in Namibia are occurring in and close to the Namib Desert (Coakley, 2000). This unique habitat (See Chapter 1.3.) is home to rare and endemic plant and animal species that are vulnerable to ORV. Access to the mining areas mean that the vehicles associated with prospecting and mining need to cross areas previously undisturbed by human activities. Copper, lead, zinc, gold, uranium, diamonds, gemstones and salt are important commodities (Coakley, 2000) and drivers of the countries Gross Domestic Product (GDP). Sand and gravel pits are only of regional importance, as it is not economical to transport those low price materials over a larger distance. As mining in Namibia is diverse and widespread, a simplification was required to illustrate how prospecting of potential mining areas is related to ORD. For the purpose of the study, uranium deposits are used as one natural resource of global importance and a commodity price at the stock market that achieved historically record prices in the past two years (The Chamber of Mines of Namibia, 2008). In addition, Namibia is ranked as the fourth largest uranium producer in the World (Coakley, 2000) highlighting the current and future importance of uranium deposits in the country. However, the overall occurrence of natural resource deposits has to be kept in mind, if the real extent of ORD activity has to be estimated.

Environmental impacts created by movie productions were also investigated by the University of California, Los Angeles. The effect of filming on the location was compared to moving an army (Kamerick, 2008). Observations in Swakopmund confirmed that production crews are often composed of more than 100 people. Those do not only operate in towns but also in environmental sensitive areas as river canyons, gravel plains and dunes. Therefore, the number of people involved in a large scale film production is significant. When sites are located in remote areas, ORD is related to moving equipment and construction materials; or as transportation as part of a film scene. A thriving Namibian film industry is expected in the future, as a public-private sector partnership programme between the German Development Service and four private businesses has just been launched (The Namibia Economist, 2008).

ORD related to event operations as incentives, product launches, concerts or desert dinners was comparable to the impact created when arranging logistics for movie production sites. In addition, ORD safaris are arranged for participants while events that are taking place over various days. As event operations are estimated to generate 60 % (Kolb, van Wyk, pers.com. 2008) of the total tourist revenue in the area, this has to be investigated, as well.

1.2.3. Importance

Disturbance of pristine and intact ecosystems does not only affect fauna and flora, but also human's perspective on the value of scenic areas within a landscape, causing further socio-economic problems. Negative tourism experiences may be communicated through tourism operators, who, in response to consumer satisfaction may shift their operations to comparable less affected destinations in order to keep the companies turnover constant and customers satisfied. In contrast, if the policy of a country supports appropriate recreation activities under environment friendly conditions, it may enhance and drive sustainable tourism in the area, if this would be not only profitable for the area, but also for their businesses.

A Namibian tourism article (tourbrief, 2008) stressed these points, based on observed ORD impacts within the area of Swakopmund and Walvis Bay. This area has particular importance in socio-economic respects, as the two towns are ranked at number 2 and 3 (Ministry of Environment & Tourism, 2005) as the most visited locations by tourists in the country, with 49,9 % for Swakopmund and 36,7 % for Walvis Bay. A decrease in visitor numbers in this area would directly affect the economy and the average household income.

The broader *Travel & Tourism Economy* was estimated to contribute approximately 16.0 % of the country's GDP in 2006, employing around 72.000 people, equivalent to around 17.9 % of the countries total job opportunities (WTTC, 2006). In Erongo 191,433 beds per night were sold in 2007, as part of 765,104 beds in total for the country (Namibia Tourism Board, 2008), representing 25 % in the District. If the forecasted annual growth of 6.9 % for the *Travel & Tourism Economy* should be achieved until 2016, hereby contributing 22.9 % to the GDP (WTTC, 2006), ecologically and touristically important areas have to be preserved and managed in a sustainable way. The World Travel & Tourism Council (2006) states that a lack of co-ordination within ministries is responsible for delaying the approval of the Coastal Zone Management Plan for the Dune Belt area and its following implementation. This would be the requirement for both, the conservation of the unique wilderness that so many people are attracted and the generation of areas where visitors may find adventurous experiences by ensuring a preservation of the physical environment.

1.3. Environmental impacts

The environmental impact of ORD may or may not be severe. This depends on the intensity of ORD, the type of ORV used and the susceptibility of the ecosystem. The impact is further influenced by type and implementation of the legislation in place. In the following section of landscape level studies, flora, fauna and ecosystem services the literature for impacts of ORD on various aspects of the environment is reviewed.

1.3.1. Landscape level studies

A Geographic Information System (GIS) change detection study (Priskin, 2003) was conducted in Western Australia with the aim to measuring the difference in ORD tracks for a 1 km zone between 1965 and 1998. A change from 526.5 km in 1965 to 812.9 km in 1998 was observed, leading on an increase of about 60% of tracks, hereby reducing undisturbed landscape significantly. Similar findings were obtained by Schlacher and Morrison (2008); their findings reveal that up to 90% of the beach area on an Australian barrier island had ORV tracks. The paper suggested that a considerable amount of sand displacement and compaction may be caused by ORV during a single day, hereby resulting in widespread and substantial physical disturbances to sandy beaches. However it did not support the observations from other studies that showed compaction caused by ORD may enhance erosion and hence destabilization of landforms (Pickering and Hill, 2007, Priskin, 2003, Rickard *et al.*, 1994). Compaction and erosion were further regarded as responsible for changes in hydrology and loss of biomass (Pickering and Hill, 2007, Priskin, 2003). The authors highlighted that the ecological impacts caused by ORD, are depending both on the nature and the intensity of the impact and the sensitivity of the species to disturbance. In addition to impacts on the environment, the landscape value and the scenic beauty of an area may be reduced significantly.

1.3.2. Flora

Effects of ORV on plant biodiversity and vegetation have been studied in detail (Groom *et al.*, 2007, Watts, 1998, Yorks *et al.*, 1997, Priskin, 2003). Yorks et al. (1997) compared 1444 individual observations related to human impact by vehicle or trampling. Both effects are considered as comparable; just the impact caused by ORV's is more severe (Priskin, 2003). Based on the observations the authors concluded that a general species and individual plant loss is already caused if ORV's cross vegetations a few times. Four to five times fewer plants were recorded in a dune environment in California open to ORV's, compared to similar sites that were closed for this recreation activity (Groom et al., 2007). Differences in ecosystem productivity were attributed to differences in driving pattern on microphytic crust cover (Watts, 1998); a general reduction in vegetation cover was suggested to result (Jacobs, 2002) in a susceptibility to soil erosion. Impact of vehicle and regeneration time of lichen fields in the Namib Desert were focus of a recent study (Lalley and Viles, 2008). Based on a comparison of lichen cover and community composition, different anthropogenic and mechanical disturbance regimes on soil crust were assessed. Estimation on recovery time ranges from 5 to 530 years, with the slowest recovery rate were made for the study site with the highest impact, in contrast to the site with the lowest impact type having the most rapid recovery rate. Lalley and Viles (2008) further point out that there was a significantly different species composition in recovery areas to those found in non affected areas. A very contrasting finding was made by Brown and Schoknecht (2001) in a severe degraded ecosystem in Kuwait, where a 'positive track effect' (annual vegetation was denser and more species rich in vehicle tracks as on unaffected areas) was noticed in some parts of the country. This noticeable discrepancy was suggested to be caused by very specific soil and climatic factors in the area. The paper stresses that this positive track effect is most likely only relevant for a limited number of desert environments with comparable environmental conditions.

1.3.3. Fauna

ORD may affect animal species *directly* and *indirectly*. Moss and McPhee (2006) assessed the direct impact of ORV's on ghost crabs. Species abundance was measured in areas accessible and confined to recreational ORD on North Stradbroke Island, Australia, to measure the difference in species abundance. Zones open to ORV's had significant lower ghost crab abundance, than areas where no ORD was allowed. The authors reasoned that ghost crabs have a high vulnerability to be crushed by ORV's during night, while feeding at their nestling sites. This observation is similar to results obtained by Boon et al. (1999) in South Africa. ORD might affect many more species in sandy beaches; this however may only be speculated, as little research has been undertaken so far on macrofauna impact by humans.

ORD may also indirectly affect animal populations, while influencing their habitat. Watson and Kerley (1995) investigated the impact of human activity in sensitive dune areas on dune-breeding birds in South Africa. Damara Terns *Sterna balaenarum* was one of the bird species that has been focused on and its conservation status is defined as *Near Threatened* by the International Union for Conservation of Nature (IUCN) red list (IUCN, 2008). No direct evidence has been found that ORD directly affect nesting sites in the area. However, it was recommended that sensitive dune areas are excluded from vehicle traffic and that ORD in sandy areas has to be controlled effectively (Watson and Kerley, 1995).

This links to Namibia, where aerial photographs reveal serious damage to gravel plains indicating that a severe threat to the breeding grounds of *Sterna balaenarum* (ICLEI, 2008, UNEP, 2008) is likely. Similarly at risk is the habitat of many endemic arthropods in the Namib Desert. Lichen morphotypes, overall lichen cover and species richness showed a significant correlation with arthropod species richness and the representation of their subgroups (Lalley *et al.*, 2006). Increasing recreation activities with ORV's in the Namib thus may impact ultimately also on arthropod populations in the area.

1.3.4. Ecosystem services

Indirect benefits to people may be obtained by interactions and feedback processes from ecosystems. Ecosystem services are conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life (WRI and UNEP, 2005). Those ecosystem services are influenced differently by recreational ORD; the services and the intensity of the impacts is depending on the type of environment the activity is carried out. Coastal ecosystems as in Namibia are providing services in form of protection to extreme weather events, species and human habitat, provision of employment, recreation and aesthetic pleasure. Based on the previous review of environmental impacts by ORD, a decrease of ecosystem service can be expected in areas frequently used by ORV. Species habitat through vegetation loss, dune stability and the aesthetic value are directly affected (Celliers *et al.*, 2004, Pickering and Hill, 2007, Priskin, 2003, Schlacher and Morrison, 2008), hereby reducing their services provided. A reduction in carbon sequestration and soil conservation benefits along riverbeds due to a reduction in biomass might occur in areas with a higher vegetation cover in the northern parts of Namibia. In contrast, provision of employment opportunities and recreation services are increasing their value. The trend is expected to change, if the carrying capacity of an area to tourist numbers or to a recreation activity that affects this area is exceeded and parts of the ecosystem including their goods and services are degraded.

Impacts on vegetation and soil substrate are supported by ground observations obtained in the field.

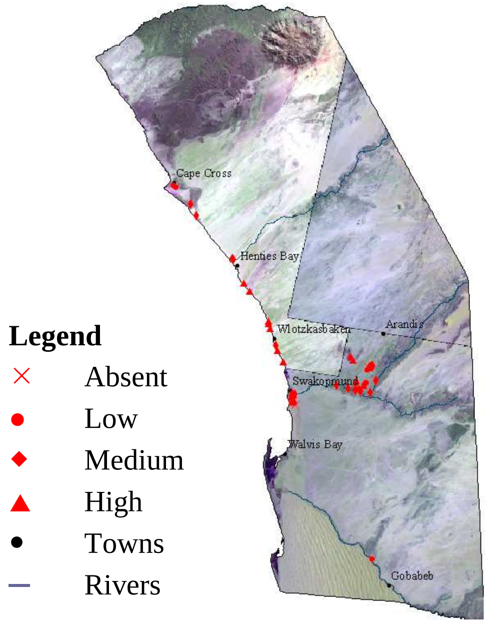


Figure 1: Off-road driving track density (*Primary data*)

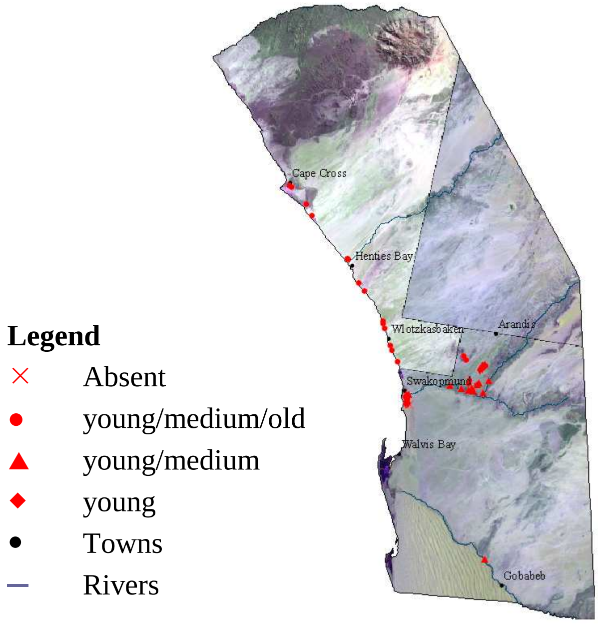


Figure 2: Off-road driving track age (*Primary data*)

Track density and track age (Chapter 2.6.2) is related to tourist and socio-economic activities and ecological and landscape characteristics of the study area. The sample points are captured as vector data and overlaid on a false-colour composite of 3 Landsat Enhanced Thematic Mapper (ETM) images (See Chapter 2.4.1.) shown in Figure 1 and Figure 2. High track density was found along the coast where fishing was taking place and in the wider Khan area where prospecting of potential mining sites was carried out. Low track density was observed in the Dune belt, while the river beds showed a medium track density. The observations were further showing old track age in gravel plains, while medium in riverbeds and low in the Dune Belt. These differences are suggested to be caused by variations in soil, precipitation and weathering processes.

1.4. Schematic representation

Landscape and ecological criteria of an area, together with tourist and socio-economical activities are defining zones with variations of ORD impact. This complex coupled system (Figure 1) required a most reliable and efficient tool to analyse the related problems in a spatial-temporal context, in order to generate transparent and useable information for management and decision making. Spatial Decision Support Systems (SDSS) were suggested to fulfil these requirements (Hill *et al.*, 2005, Malczewski, 2004), by trying to capture the system and its dynamics in a simplified way.

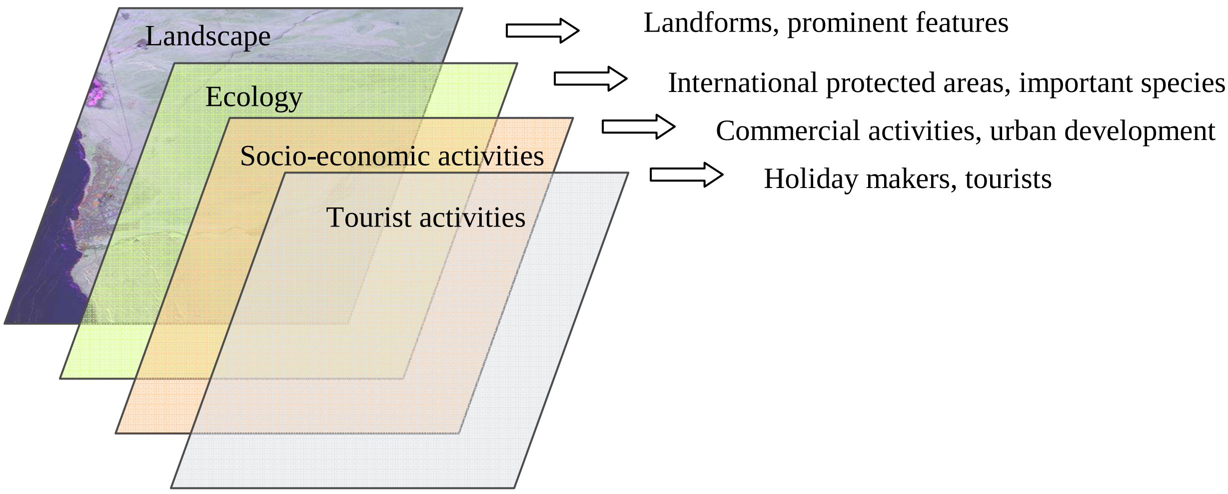


Figure 3: Schematic diagram showing the various components influencing the socio-economic and environmental impact caused by off-road driving

Within a deterministic model, spatial data can be used to combine bio-physical and socio-economic constraints and criteria to generate new data (Celliers *et al.*, 2004, Hill *et al.*, 2005, Malczewski, 2004, Store and Kangas, 2001). One aim of system modelling using a SDSS is to generate alternatives that are predefined and reflect decision options (Linkov *et al.*, 2006, Malczewski, 2004, Salgado *et al.*), with varying weightings on the decision variables within the system. The differences between the alternatives may be major and hence may result in significant variations of data output. Therefore a constant revision throughout the modelling process was required that incorporated expert and stakeholder knowledge, in order to optimize the required output.

1.5. Spatial Decision Support Systems

Recently, considerable efforts has been undertaken to develop techniques that environmental scientist may use to provide more usable information to support well balanced spatial decision making (Jacobs, 2002, Liu *et al.*, 2008). They may integrate an environmental science problem, expert and local knowledge, stakeholder's interests and concerns, as well as spatial information for ecosystem properties into their problem analysis. Although SDSS has been suggested to meet their functional specifications that were set at the beginning of a project, they are still rarely used (Uran and Janssen, 2003). This research provided a link to this discussion by undertaking a case study on ORD in central-western Namibia using a SDSS. Spatial-temporal information for different policy visions was generated related to ORD activities by using a Spatial Multi Criteria Evaluation (SMCE) approach. SMCE allowed the integration of stakeholder knowledge and decision makers' preferences in order to manipulate spatial and non-spatial data according to defined decision variables referred to as criteria and problem constraints. Based on expert knowledge, criteria were assigned a specific weight within the SMCE. To maintain transparency during the analysis, the criteria are grouped together in terms of themes. The definition of alternatives regarding decision variables (Malczewski, 2004) was linked to preferences expressed by decision makers and their own goals and objectives. The method assisted to understand the relationship between the different defined themes and constrains to optimize spatial planning including ecological and socio-economic factors.

1.5.1. Stakeholders

The identified stakeholders that are suggested as most relevant to ORD in the area are grouped according to their interests and function (Table 1).

Table 1: Relevant stakeholders to off-road driving, their interests and functions

National and Provincial Government	Ministry of Environment & Tourism	**Decision makers**
	Ministry of Land & Resettlement	
	Regional Councils	
	Municipalities	
NGO's	NACOMA	**Experts**
	DRFN	
	NNF	
	SAIEA	
Business	Quad bike rental	**Local actors**
	Tour operators and guides	
	Other related businesses	
	Mining	
Public	Fishing community (recreational)	
	ORD community	
	Public not involved in off-road	
Tourists	International and national tourists	**Consumers**

1.5.2. Spatial Multi Criteria Evaluation

Attempting to representing complex real-world systems with GIS models is difficult and next to impossible as the models at best only reflects a sub-set of the possible parameters of the possible situation (Munda, 2004). A wide range of different and conflicting opinions has to be integrated (Munda, 2004) in the evaluation process of public plans or projects. The same is valid when assessing human caused environmental impacts, as ORD. Objective and subjective data and information has to be combined in a correct way (Malczewski, 2004) to achieve the most accurate representation of the problem in a spatial-temporal way. Munda (2004) suggests multi criteria evaluation as an appropriate framework to address such complex issues. As a consequence, SMCE is suggested as a suitable tool, when spatial information is to be generated. Various authors (Celliers *et al.*, 2004, Hill *et al.*, 2005, Jacobs, 2002, Makropoulos and Butler, 2006, Paterson *et al.*, 2008) have used his method for a variety of different applications and have described its benefits and limitations in detail.

1.5.3. Why Spatial Multi Criteria Evaluation seems a suitable tool

When assessing a human-environmental associated problem, a number of factors need to be taken into account, not the least of there is human interests and concerns (Linkov *et al.*, 2006, Munda, Munda, 2004, Salgado *et al.*). In the framework of sustainable development, stakeholder participation is essential and local knowledge and interests may well be incorporated in SMCE. The method aims to link expert knowledge and decision making in a way that appears more suitable for this study than other ecosystem models. Ignoring the importance of local stakeholder and tourists' interest would only partly analyse the problem of ORD and is expected to cause less accurate final results, through the omission of essential spatial information required for the analysis.

It may further lead to substantial opposition of the public (Davenport and Davenport, 2006) as recently observed in South Africa. Due to a lack of scientific and social research it was suggested as nearly impossible to motivate (Celliers et al., 2004) why certain areas were included or excluded as recreational use areas for ORV. Celliers et al. (2004) emphasised the need to combine socio-economic considerations with appropriate scientific and conservation expertise for an effective coastal use strategy. This research tried to include the recreational and fishing community, to reduce the opposition and criticism of ORV users in the area. Transparency through the process can be regarded as another strong point of the SMCE approach. The model's ability to analyse large data sets related to complex human-environmental questions, to join spatial and non-spatial criteria and to combine environmental and socio-economic aspects in one analysis is of additional importance.

In seeking to formulate decision options for planning and development, the most common denominator between the interest groups becomes the focus. However, what may be lost in the development of these plans are considerations for the sensitivity of the environment. On the other hand, what maybe required is the need for a single vision that takes into account environmental and socio-economic aspirations of the interest groups, and the Convention on Biological Diversity. In an attempt to answer these questions, SMCE was used for a spatial planning approach with and without strict environmental regulations.

1.5.4. Spatial planning under Stakeholder Visions

Areas suitable for off-road driving were identified in line with decision maker's preferences for various policy visions. Those were integrated in the final model stage to determine the importance of the different groups through weight assignment for each decision option. Key interests of decision makers and hence of government policies are unduly influenced the decision-making process. The model parameters can be adjusted at the final stage, if the generated spatial alternatives do not conform to future development plans at a higher hierarchical policy level. If additional areas are required for new socio-economic developments, these need to incorporated into management plans and zoning requirements. The integration of stakeholders at the final stage aims to produce an optimal spatial planning solution for developments in an area by combining socio-economic and environmental interest. However, this procedure may hinder strategic environmental decision as it seeks to compromise environmental and consumer concerns.

1.5.5. Spatial planning using strict environmental regulations

In contrast, the research proposed a Biological Diversity Convention Vision that takes into account only one policy vision where suitability for ORD is subject to restrictions. Common goal is sustainable development in the area under strict environmental regulations, following the Convention on Biological Diversity. The approach may facilitate discussions on one hand, as no alternative comes into question and prioritisation of interest groups becomes less important. On the other hand, one solution without alternative is likely to result in substantial criticism of stakeholders, if the need for nature conservation is not emphasised in-depth and most important no direct layout is suggested, how socio-economic and tourist activities may take place.

1.5.6. Aims, objectives and research questions

1.5.6.1. Aims

Target of this research was consequently; to develop a generic method to identify areas susceptible to environmental changes caused by ORD and further to compare a spatial planning approach with and without strict environmental regulations. In the light of observed ORD impacts in the past, such a research seemed valuable and may assist future planning and management processes in comparable environments, to promote sustainable development in those areas.

1.5.6.2. Objectives

- Identifying areas where ORD takes place (spatial)
- Identifying activities that cause ORD (spatial)
- Assessing the ecological and landscape sensitivity to ORD (spatial)
- Assessing the ORD suitability of the area under different policy visions (spatial/temporal)
- Assessing possible ways for ORD to avoid or mitigate negative environmental effect (spatial)
- Comparing short and long term effects between spatial planning for ORD with and without strict environmental regulations (spatial/temporal)

1.5.6.3. Research questions

- What are the current impacts of ORD?
- To what extent could negative impacts be avoided and mitigated by spatial planning?
- To what extent could negative impacts be avoided and mitigated by regulations?
- What are the short and long term effects of these two approaches?

Based on this a number of hypothesis were developed which were scrutinized and where possible proved in the research.

Hypothesis 1: ORD caused by socio-economic activities lead to negative effects on the environment.

Hypothesis 2: ORD caused by tourist activities lead to negative effects on the environment

Hypothesis 3: Restricting ORD areas using strict environmental regulations leads to avoidance and mitigation of negative effects on the environment.

Hypothesis 4: Managing ORD without strict regulations leads to unsustainable social, economic, cultural and environmental development.

Hypothesis 5: Managing ORD using strict environmental regulations lead to social, economic, cultural and environmental sustainable development.

The hypotheses were supported by the following claims:

Claim 1: A number of socio-economic activities inducing ORD lead to negative effects on the environment.

Claim 2: A number of tourist activities inducing ORD lead to negative effects on the environment.

Claim 3: Restricting ORD areas using strict environmental regulations lead to avoidance and mitigation of negative effects on the environment.

Claim 4: Spatial planning for ORD without strict environmental regulations leads long term to social, economic, cultural and environmental unsustainable development.

Claim 5: Spatial planning for ORD with strict environmental regulations leads long term to social, economic, cultural and environmental sustainable development.

2. Methodology

2.1. Study area

The study area was the central Namib Desert that is characterized by a hyper-arid climate and great landscape character (Goudie and Eckardt, 1999). The area was formed over the historical past where plate tectonics and chancing climatic conditions created a landscape of complex geological pattern. The Namib Desert dunes, some exceeding 300 m, are among the highest in the World. They are bounded in the west by the Atlantic Ocean and are stretching more than 150 km inland. The annual rainfall in this area ranges from about 10 mm at the coast and increases towards the east, where it may exceed 200 mm (Goudie and Eckardt, 1999). Extensive ephemeral river catchments with gravel plains transverse the Namib westwards (Botes et al., 2003) where their estuaries open out into the ocean. Sand dunes, as well as river beds and estuaries are susceptible for ORD as highlighted in the previous chapter. There are concerns that the aesthetic and environmental value of the area may become degraded (UNEP, 2008) by the extent of off-road driving caused during recreation activities.

2.1.1. Study area selection

The study area is the Erongo District in western Namibia, with a virtual boundary in the eastern part, defined at around 100 km inland. This limit was set to concentrate on the coastal, sensitive areas, where most of the ORD is occurring, without omitting the Messum Crater and Brandberg area. Those two locations are recognized as important locations for biological diversity, cultural heritage and tourism activities. The fieldwork was carried out in the area between latitude 20° and 22° S, including the towns of Walvis Bay in the south and Swakopmund in the north. This site was chosen for its importance to tourism industry at a national and international level. Considering its richness in biodiversity and its already observed impact of off-road vehicles on the fragile dune ecosystem (UNEP, 2008), this area seemed very suitable for a study on ORD impacts. In addition, the results may be integrated in the current assessment and development for a zoning plan within the dune belt area, which is targeted within the Dune Belt Management Plan and Regulations (ICLEI, 2008) and therefore of use for the regional planning process.

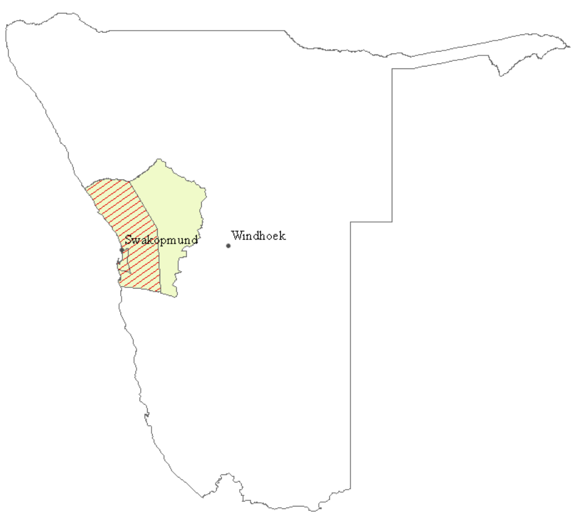


Figure 4.1: Study area in western Namibia

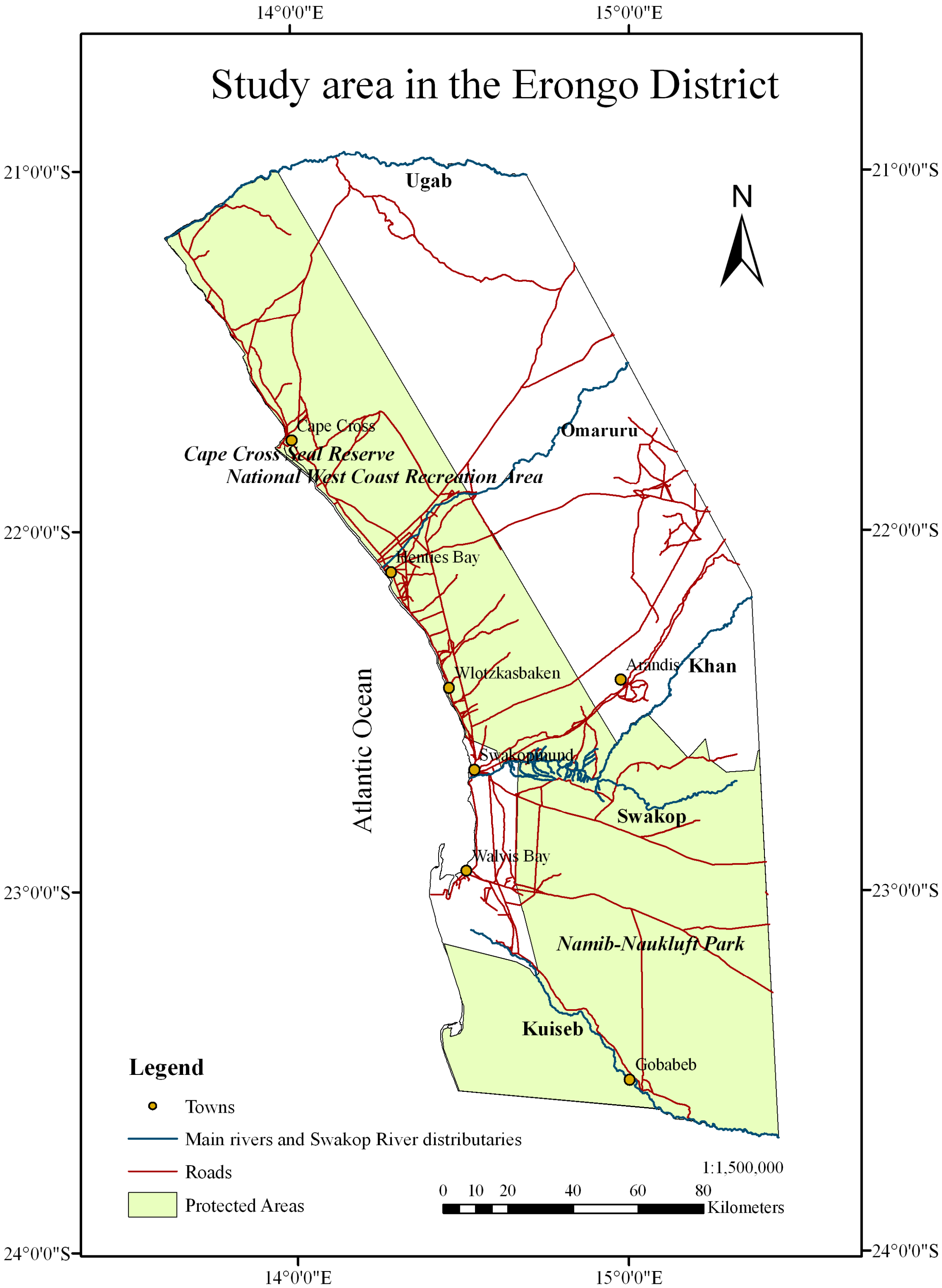


Figure 4.2: Detailed view of the study area and general map information

Projection Information:

Projection: Transverse Mercator	False Easting: 500000.000000
Geographic Coordinate System: WGS 1984	False Northing: 0.000000
UTM Zone 33 S	Central Meridian: 15.000000
Datum: WGS1984	Scale Factor: 0.999600
Linear Unit: Meter	Latitude of Origin: 0.000000

2.2. Generic Framework

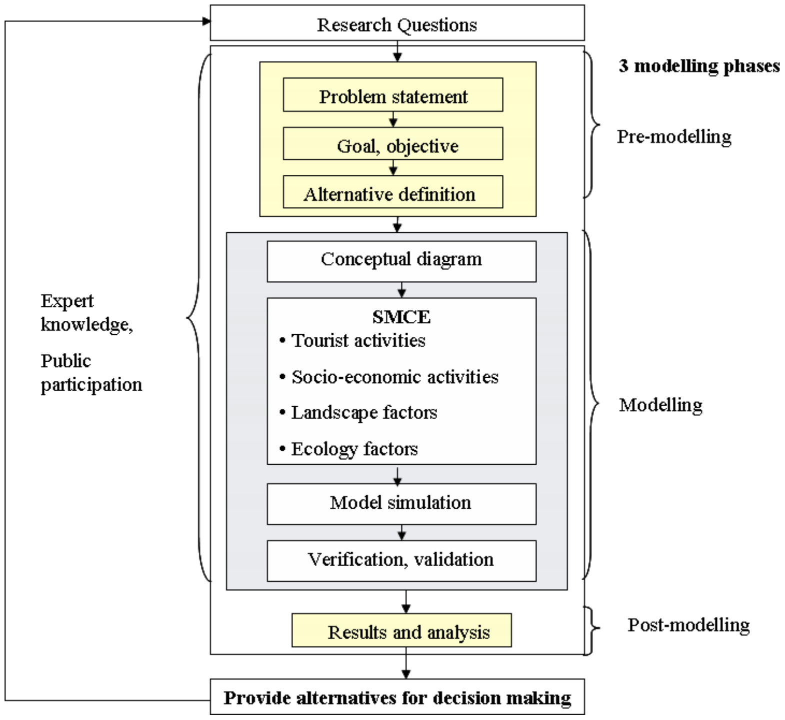


Figure 5: Generic Modelling Framework

2.3. Conceptual diagram

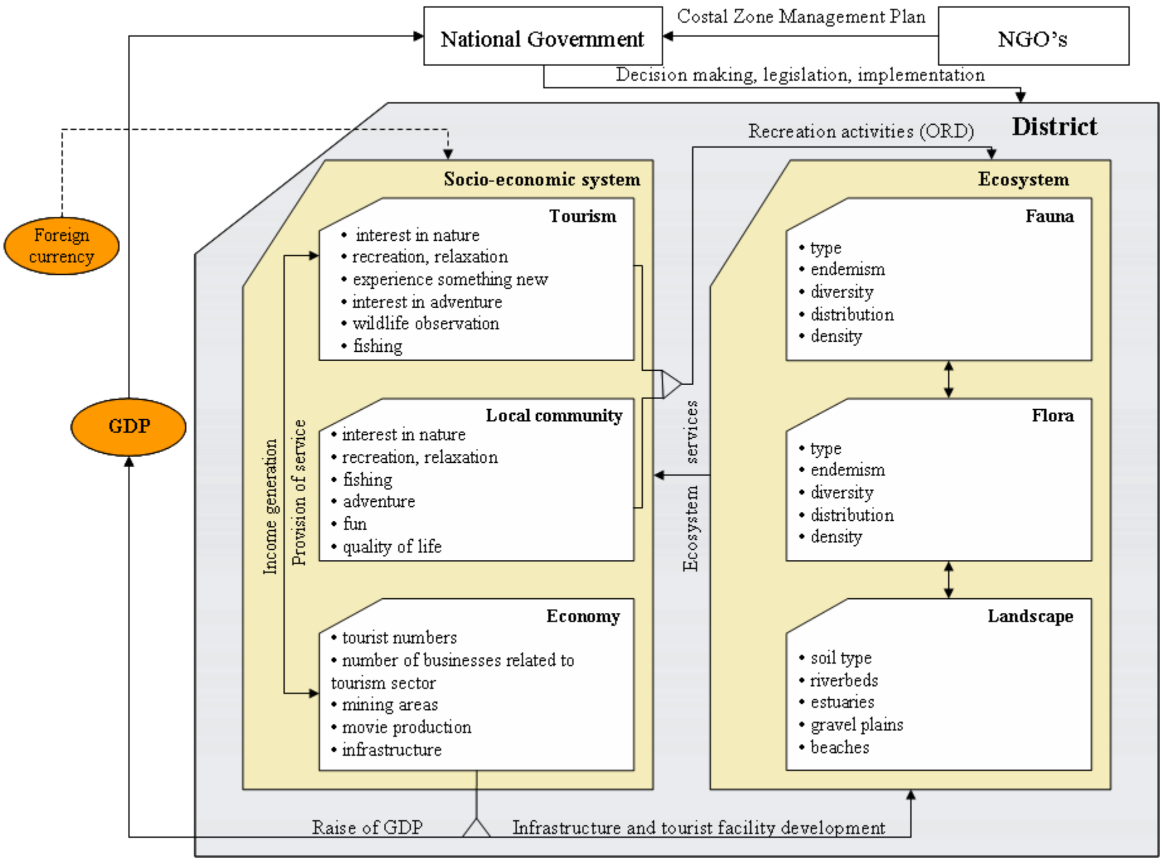


Figure 6: Conceptual diagram showing the dynamics related to ORD within the district system

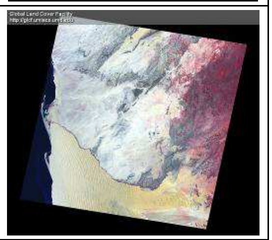
The conceptual diagram (Figure 4) focuses on ORD and omits irrelevant factors. It tries to explain the dynamics within the district system that is driven in part by foreign currency generated through the tourism industry. ORD and the development of infrastructure and new tourist facilities are affecting the ecosystem. Drivers are socio-economic and tourist activities and governmental policies that aim to achieve their set goals during one legislative period. Social, economic, cultural and environmental sustainability would result in an equilibrium between socio-economic and ecosystem requirements. However, unsustainable use driven by socio-economic aspects would automatically result in a negative feedback loop, as the services provided by the ecosystem would decrease. Hence, fewer services would be gained form tourist site, less foreign currency would flow into the system, leading to less GDP generated and an unstable situation within the system. Such feedback loop would therefore result in decreasing services not only for humans, but also for the coupled subsystems fauna, flora and landscape. Based on the systems dynamics, specific attention were given during the fieldwork period on the socio-economic factors related to ORD.

2.4. Data Description

2.4.1. Landsat ETM images

Since the year 2000, there were no more than 3 Landsat ETM GeoCover images (Global Land Cover Facility, 2008) available that combined covered the study area. GeoCover images provide multi-temporal high resolution images that are corrected for terrain distortions and errors in image geometry; they are resampled using a nearest-neighbour method. All images have a pixel size of 28.5 m and are projected in UTM/WGS84. The scenes are cloud free. Table 2 shows the details of the selected images:

Table 2: ETM + image characteristics and acquisition date

Satelitte	Sensor	World Reference System	Path	Row	Aquisition date	Image
Landsat 7	ETM+	WRS-2	180	75	02.07.2000	
Landsat 7	ETM+	WRS-2	179	76	06.04.2000	
Landsat 7	ETM+	WRS-2	179	75	20.02.2001	

2.4.2. GIS data

Appendix 1 shows the essential primary and secondary vector data (Chapter 6.2.) that was integrated in the SMCE. The data required was revised during the research period based on new insights and expert knowledge.

2.4.3. Pre-processing of data

Landsat ETM+ layers, representing the bands 1 to 5, were stacked for each image and grouped together to cover the study area. Raster and vector data was projected to WGS84 UTM Zone 33S. Bands displayed for on-screen digitizing were band 4, 5 and 2 in Red Green Blue (RGB). Primary data was generated using various techniques and sources that are shown in Table 3 and Figure 7.

Table 3: Techniques and sources used for the generation of primary data

Technique	Data Generation
On-screen digitizing using Landsat ETM+	Dune Belt, Brandberg, Messum Crater, roads, rivers, ocean boundary, estuaries
Mobile GIS	Tour route, Living Desert route, sand boarding, beach access, ground control points (GCP)
Participatory mapping (Appendix 6)	Damara Tern breeding sites, Yamaha route, event sites, event access, recreation community, movie production, fenced areas, sand mining
Literature / printed source (Appendix 5)	IBA, lichen distribution, fishing, uranium deposits

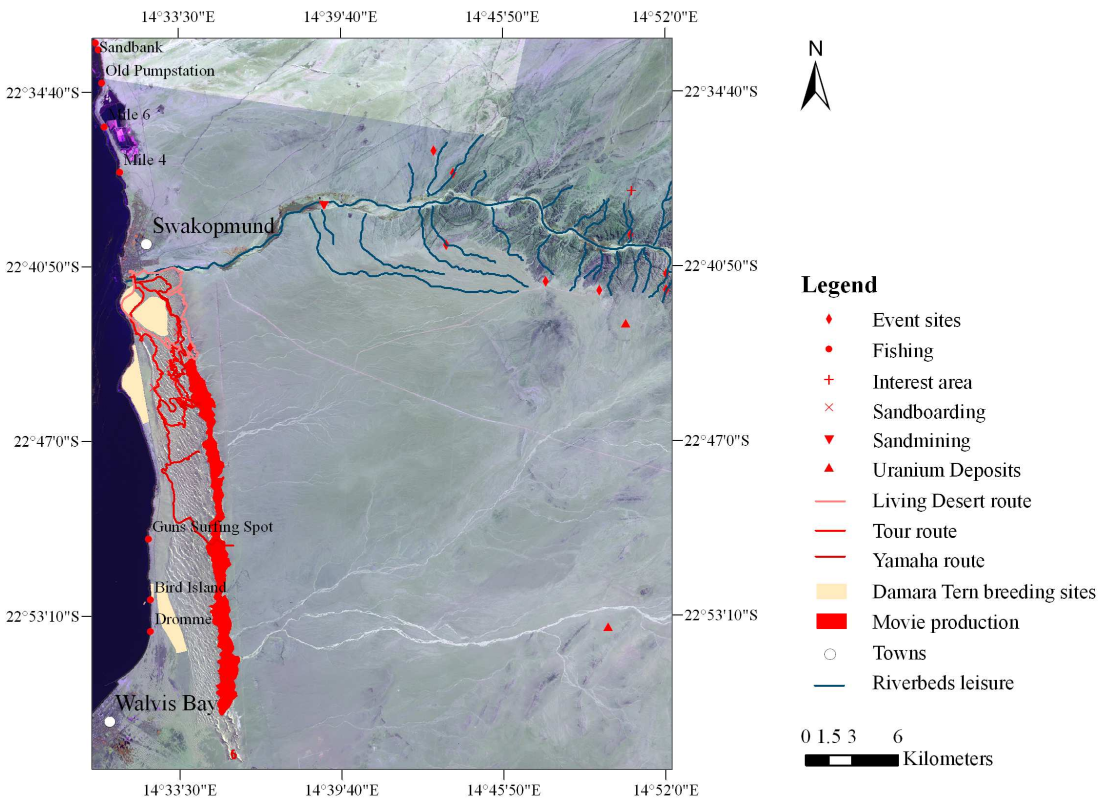


Figure 7: Example for data generation using the various techniques described in Table 3

On screen digitizing of river distributaries was confined to parts of the Swakop River and should only give an example of the differences in sensitivity between a main riverbed and its tributaries. The Swakop River was chosen, due to the importance for recreational and commercial tourist activities not only within the main riverbed, but also in its tributaries. Uranium deposits are used as a representation of exploitable natural resources in the area and how their deposits are related to ORD influence through prospecting activities.

2.4.4. Software used

ArcGIS 9.3 was used for vector data generation, while the raster data was processed with ILWIS 3.5. The latter software was in addition used for modelling and the analysis carried out.

2.5. Pre-Fieldwork

The pre-fieldwork phase was determined by geographical data preparation (Appendix 1) and the development of questionnaires for interviews (Appendix2).

2.5.1. Data Preparation

Field data preparation required the processing of geographical data that lead to a preliminary zoning map. The procedure was described in Chapter 2.4.3 and Appendix 1. This map was used to define the sampling areas for field data collection. As the preliminary SMCE was mainly based on assumptions, their groups and criteria were as expected revised in the field, due to new information acquired by stakeholders. This revision resulted in modifications of the defined sampling areas. A high degree in uncertainty in the pre-field analysis was considered and extra time scheduled.

2.5.2. Integration of stakeholders

A questionnaire was developed to generate information from the public. The obtained feedback was considered as important in terms of community and tourist needs. It focused on ORD behaviour and preferential areas visited by ORV users (Appendix 2). Individual interviews with experts and decision makers were arranged beforehand. Those included Namibian Coast Conservation and Development Project (NACOMA), Desert Research Foundation of Namibia (DRFN), a tour operation specialist and governmental officers. The results were considered as essential in validating the defined criteria used within the SMCE and the generated zone map.

2.6. Fieldwork

The fieldwork was carried out between the 9th of September and the 29th of October 2008. Interviews with experts, decision makers and local stakeholders were conducted in the towns of Windhoek, Swakopmund, Walvis Bay and Gobabeb. Ground data collection was focusing on three different areas, the Dune Belt, the coastal zone between Swakopmund and Cape Cross and the Swakop and Khan Rivers. Data collection included qualitative and quantitative, subjective and objective information, social-economical and environmental information.

2.6.1. Stakeholder interviews

Public associated to ORD was interviewed related to their interests, preferences and concerns. Interviews were carried out using a pre-prepared questionnaire (Appendix 2). The local ORD and fishing community, as well non ORD interest groups in different age ranges were targeted to obtain a most wide range of respondents for this case study. A total of 60 questionnaire interviews were conducted during 9 days. Where relevant, respondents indicated on an A2 Landsat ETM+ image (Table 2) their areas of interest. In addition, 23 individual interviews were carried out with decision makers, experts, businesses and public. 21 of those focused on environmental and socio-economic concerns that were suggested as important in the area. The results obtained during all interviews were used to review the criteria and their weighting within the SMCE. During a meeting with the governmental officers the predefined alternatives were discussed and the group weighting for those visions defined. Further, participatory mapping was carried out as part of the interviews. Appendix 3 shows the stakeholders, their function and the data generated as a result of the interviews.

2.6.2. Reconnaissance visits

Ground data was collected and reconnaissance visits were undertaken at 5 different locations. The selection of the study areas chosen was justified through the results obtained during the interviews. The Dune Belt, the coastal zone between Swakopmund and Cape Cross, the Swakop River and the wider Khan River area were identified as both, important in socio-economic and environmental terms. An area close to Walvis Bay was visited, as the site was expected to reveal insight in the longevity aspect of ORV. The site was used as an experimental research site for ORD in 1992 (Daneel). Table 4 highlights the importance of each area in relation to economic and tourist activity, as well as suggested environmental sensitivity.

Table 4: Importance of reconnaissance areas

Importance	Dune Belt	Coastal Zone	Swakop/Khan River	Khan area	Walvis Bay
Ecology	✓	✓	✓	✓	✓
Landscape	✓	✓	✓	✓	✓
Economic activities	✓	✓	✓	✓	No
Tourist activities	✓	✓	✓	No	No
ORD longevity	✓	✓	No	No	✓

Track age (T_a) and track density (T_d) of ORV's was recorded at 54 sites for comparison with the expected environmental sensitivity to ORD, respectively suitability of an area for ORD. Photographs were taken for validation and better illustration of track age and density. Time of the day and fixed camera angles were not considered, as field sites could only be visited once due to time constraints of the study. The images were taken from the site and angle that were regarded as most suitable to capture the features of the track at the given time of the day. Track age was based on track contours and to what extent they had changed through weathering processes (Figure 8).

8.1. Young **8.2.** Medium **8.3.** Old

Figure 8: Illustration of track age definition in the field.

Track density was estimated as percentage coverage of an area 100 x 100 m. The following classes were differentiated and shown in Table 5. Figures 9 to 12 illustrate the manner in which ground data was collected in the different areas of varying socio-economic importance. In addition, they show the variations in track density and age at those locations (Table 5). For a better understanding of track longevity a site was visited, where an experimental ORD study was conducted. Figure 13 shows one track from the bottom and the top of a slope, demonstrating the importance of climatic variability in the coastal area and its relation to landscape variations and ORD impact.

Table 5: Track density classes

Class	**Track coverage in %**	Description
1	0	Absent
2	0 - 10	Low
3	10 - 30	Moderate
4	>30	High

T_a young
T_d low

9.1. Sands 14°33'15.348"E 22°43'15.102"S

T_a old/medium/young
T_d medium to high

9.2. Gravel plain 14°33'02.658"E 22°42'14.784"S

Figure 9: Dune Belt (Tour operations, quad biking, public recreation, events, movie production)

T_a old/medium/young
T_d medium

10.1. Lichen fields 14°06'05.736"E 21°53'30.066"S

T_a old/medium/young
T_d high

10.2. River estuary 14°16'12.750"E 22°05'11.346"S

Figure 10: Coastal Zone (Recreational fishing, beach activities, quad biking)

T_a medium/young
T_d medium

11.1. River bed 14°48'040"E 22°39'664"S

T_a old/medium/young
T_d medium

11.2. Tributary 14°52'778"E 22°39'958"S

Figure 11: Swakop River (Recreation, tour operations, events)

T_a young
T_d high

12.1. Gravel plains 14°54'40.320"E 22°33'59.760"S

T_a old
T_d medium

12.2. Gravel plains 14°55'387"E 22°33'338"S

Figure 12: Khan Area (Mining, tour operations, recreation)

T_a 16 years
Visual appearance young

T_a 16 years
Visual appearance medium

Figure 13: Experimental ORV track by Daneel (1992)

13.1. Bottom

13.2. Top

2.7. Post-Fieldwork

The collected field data was combined and analysed and the preliminary SMCE revised accordingly. The following subsections describe the data and process used to generate the required ORD suitability Visions. It further elaborates on the method used that weight criteria, groups and alternatives within the SMCE. Figure 14 is illustrating the data input in the models and process flow, while Figures 15 shows the final comparison of the two spatial planning approaches used.

2.7.1. Data Description, process flow and model structure

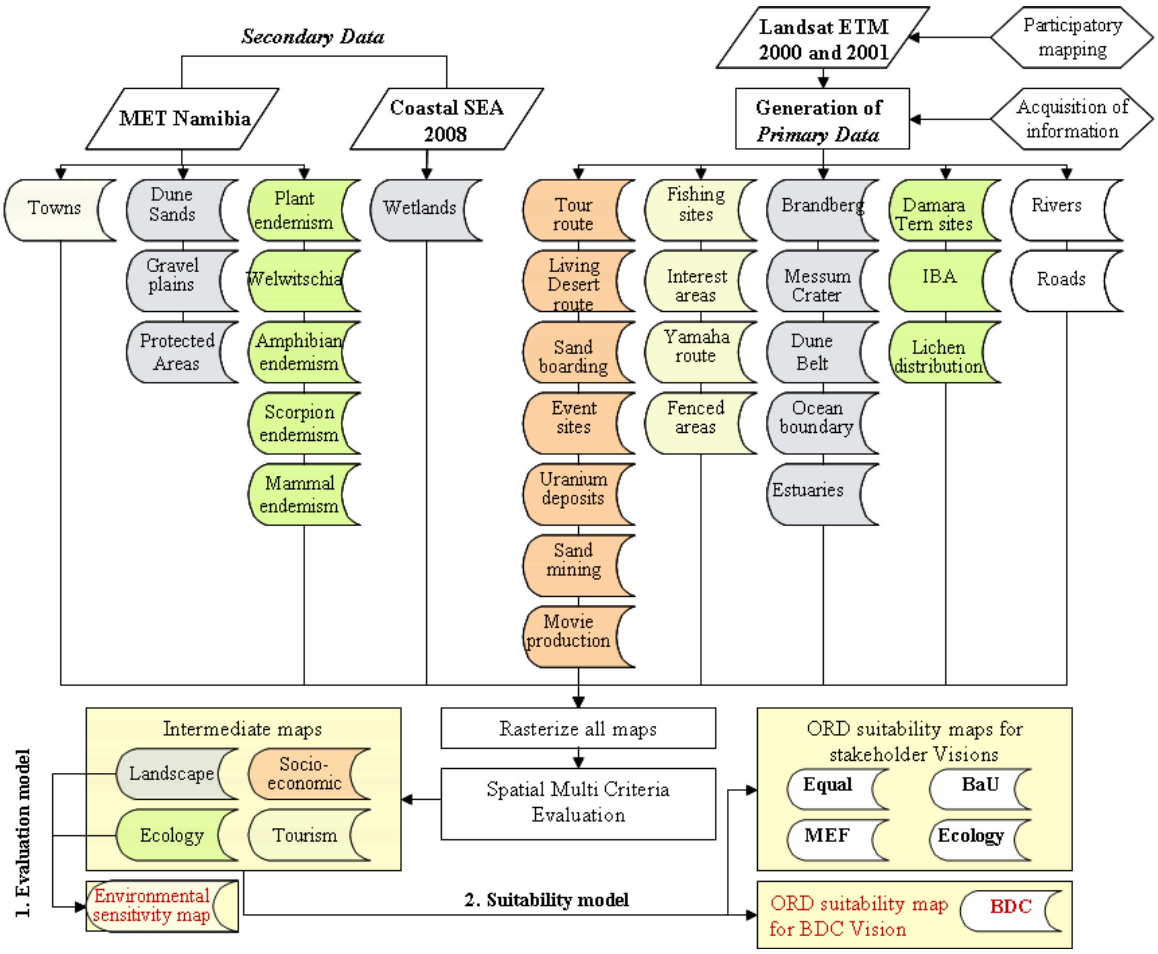


Figure 14: Flowchart of geographical data preparation

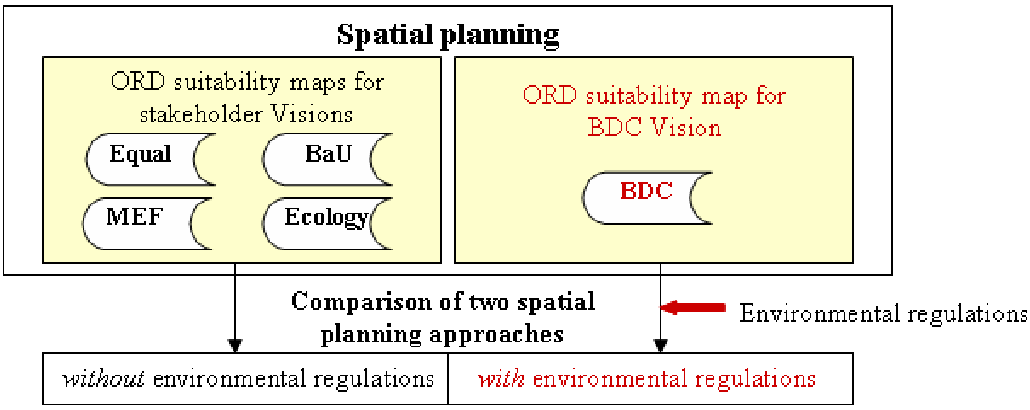


Figure 15: Flowchart showing the comparison of the two spatial planning approaches used

After rasterizing the vector files, the following primary data was used to create distance maps required for the later analysis; towns, rivers, roads, tour route, Living Desert route, sand boarding, event sites, uranium deposits, sand mining, fishing sites, interest areas, Yamaha route, beach access, ocean boundary. The Spatial Multi Criteria Evaluation shown in Figure 14 is broken down in the four main groups of Socio-Economic activities, Tourist activities, Landscape and Ecology shown in the criteria tree (Figure 16). Those groups are combining the criteria sensitive to changes within the system (Figure 6). Due to integration of expert knowledge in each group and an extensive revision process throughout the modelling period, a sensitivity analysis was omitted and low to non sensitive criteria excluded prior the analysis.

Table 6: Criteria function within Evaluation and Suitability Model[1]

Definition:

Nominal	Qualitative data / identity of things
Ratio	Quantitative data with an absolute zero
Spatial Constraint	A **Constraint** is a binding criterion, where no substitution is allowed
Spatial Benefit	A **Benefit** contributes positively to the output; the *more* you have (the higher the values), the better it is.
Spatial Cost	A **Cost** contributes negatively to the output; the *less* you have (the lower the values), the better it is.
1	Constraints in the suitability model have adjusted their function regarding their Measurement Scale within the evaluation model (Appendix 8)

Criteria	Measurement Scale	Unit	Function	Group
Movie production	Nominal		Area is classified as non suitable for ORD, as it should be preserved for movie production activities	Socio-economic activities
Distance to sand mining	Ratio	Meter	Spatial cost. Within 2500 m, the closer ORD areas are to sand mining locations the more economic the mining takes place.	
Distance to uranium deposits	Ratio	Meter	Spatial cost. Within 10000 m, the closer ORD areas are to uranium deposits the more economic future prospecting will be.	
Fenced Area	Nominal		Spatial Constraint. Fencing should prevent uncontrolled access to the Dune Belt and Damara Tern Breeding Sites	
Distance to Living Desert route	Ratio	Meter	Spatial cost. Within 500 m, the closer the ORD area will be to the tour operation route, the better it is.	
Distance to tour route	Ratio	Meter	Spatial cost. Within 500 m, the closer the ORD area will be to the tour operation route, the better it is.	

Criteria	**Measurement Scale**	**Unit**	**Function**	**Group**
Distance to sand boarding sites	Ratio	Meter	Spatial cost. Within 500 m, the closer the ORD area will be to the tour operation route, the better it is.	Socio-economic activities
Distance to event site	Ratio	Meter	Spatial cost. Within 500 m, the closer the ORD area will be to the tour operation route, the better it is.	
Distance to riverbeds	Ratio	Meter	Spatial cost. The closer ORD areas are to the riverbeds the more economic for commercial tour operators; no entrance licences needed	
Distance to roads	Ratio	Meter	Spatial cost. Within 2500 m, the closer ORD areas are to existing roads the better the future accessibility.	Tourist activities
Distance to towns	Ratio	Meter	Spatial cost. The closer ORD areas are to towns the less time involved for tourists to go there and the more economic it is due a shorter distance for transportation.	
Distance to fishing spots	Ratio	Meter	Spatial cost. Within 2500 m, the closer ORD areas are to fishing spots the better their accessibility	
Fishing spots	Nominal		The higher the number of consumptive catch fish, the higher the attractiveness of the fishing spot, the higher the necessity for ORD. Spots including sharks are ranked highest, as sharks are regarded lion species indicating an abundance of fish in the area.	
Distance to areas of specific interest	Ratio	Meter	Spatial cost. Within 10000 m, the closer ORD areas are to areas of specific interest, the better.	
Distance to riverbeds for leisure	Ratio	Meter	Spatial cost. Within 5000 m, the closer the riverbed to the ORD area the better for leisure activities	
Distance to Yamaha route	Ratio	Meter	Spatial cost. Within 1000 m, the closer ORD areas area to the Yamaha route, the better.	
Distance to estuaries	Ratio	Meter	Spatial benefit. Highest sensitivity within the estuary. Within 1000 m, the closer the ORD area is the worse.	Landscape
Distance to ocean boundary	Ratio	Meter	Spatial benefit. Highest sensitivity along the beach. Within 1000 m, the closer the ORD area is the worse.	
Gravel plains	Nominal		Area that is not suitable for ORD, as it has a high landscape value.	

Criteria	Measurement Scale	Unit	Function	Group
Distances to rivers main	Ratio	Meter	Spatial cost. Highest aesthetic value and sensitivity within the riverbed. Within 2500 m, the closer the ORD area is the better.	Landscape
Distances to rivers distributaries	Ratio	Meter	Spatial benefit. Highest aesthetic value and sensitivity within the riverbed. Within 2500 m, the closer the ORD area is the worse.	
Dune Belt	Nominal		Area is moderately suitable for ORD	
Dune Sands	Nominal		Area that is not suitable for ORD, as it is to more than 80 % under a protected status (Namib Naukluft Park, IBA) and has a high aesthetic value.	
Messum Crater	Nominal		Spatial Constraint. Part of proposed Gondwana Park Project (Unesco); high conservation priority	
Plant endemism	Nominal		The higher the number of endemic species the less suitable for ORD.	Ecology
Welwitschia	Nominal		Area with Welwitschia not suitable for ORD.	
Amphibian endemism	Nominal		The higher the number of endemic species the less suitable for ORD.	
Reptile endemism	Nominal		The higher the number of endemic species the less suitable for ORD.	
Scorpion endemism	Nominal		The higher the number of endemic species the less suitable for ORD.	
Mammal endemism	Nominal		The higher the number of endemic species the less suitable for ORD.	
Damara Tern	Nominal		Spatial Constraint. Endangered species; breeding areas in the dune belt between Swakopmund and Walvis Bay.	
Lichen distribution	Nominal		Spatial Constraint. Lichen fields are identified as unique and important vegetation in the Namib, including endangered species; high conservation priorities.	
IBA	Nominal		Spatial Constraint. International Bird Areas are areas that are identified as globally important; high conservation priorities	

Due to the prior problem evaluation and subsequent suitability analysis two different models were required that are shown in Figure 16 and Appendix 8. The approach described is identical for both models, but with minor differences in standardization and weighting for the evaluation model (Appendix 8). Within the Evaluation Model Damara Tern, lichen distribution, International Bird Area's (IBA) were integrated in the *Ecology*, Messum Crater in the *Landscape* and fenced areas in the *Socio-economic activity* Group. Those criteria were defined as spatial constraints within the Suitability Model.

2.8. Spatial Multi Criteria Evaluation

2.8.1. Criteria, groups and alternatives

Chapter 1 explained the author's arguments for using SMCE to undertake the analysis of data during this study. The group definition (Figure 1) was based on stakeholder information and the literature review undertaken. Figure 16 is a representation of the criteria tree including group, criteria and constraint description for the suitability model. Spatial constraints (Table 6) are those factors that are prior the analysis excluded from off-road driving. Damara Tern breeding areas, Lichen Distribution, IBA's and Messum Crater are defined as constraints due to their ecological or landscape importance in the area. A fenced area was demarcating from the Dune Belt in the east to the main road connecting Swakopmund and Walvis Bay in the west in order to prevent uncontrolled access of ORV into the environmentally sensitive Damara Tern breeding sites. This area was predefined as no-go zone based on stakeholder interest. Details about group, criteria and constraint functions, units and measurement scales that were integrated in the SMCE are given in Table 6.

2.8.2. Standardization and weight assigning

Standardization of all criteria had to be applied, as the input maps required one single unit in order to be compared. Therefore, different standardization methods have been used depending whether the input map represented a *Value*, *Class* or *Boolean* map. Based on the defined function, the map or attribute column was converted in values between 0 and 1. Standardization and weight assignment for the group's landscape and ecology was based on expert knowledge, while tourist activities were based on questionnaire results (Appendix 4) and community interviews; socio-economic activities were standardized and weighted according to information obtained by local authorities and businesses.

2.8.3. Alternatives

Following, group weighting was applied for the different alternatives discussed and ranked by the competent decision makers. The four visions were discussed as spatial planning approach *without* environmental regulations.

- Business as usual vision (BaU – reflect the current situation and no future chance)
- Ecology vision (Ecology – focuses on environmental factors)
- Most environmental friendly vision (MEF – equal emphasis on socio-economic activities and ecology, as well as tourist activities and landscape)
- Equal vision (Equal – equal weights for all groups)

As described in Chapter 1.5.5, a Biological Diversity Convention (BDC) was included that tries to follow the *Ecosystem approach COP 9 Decision IX/7* (Secretariat of the Convention on Biological Diversity, 2000) of the *International Convention of Biological Diversity*, joining social, economic, cultural and environmental values. The BDC Vision was discussed as spatial planning approach with environmental regulations (Chapter 4). ORD suitability maps were generated for all alternatives based on the weighting shown in Table 7.

Figure 16: Example Criteria Tree for *suitability analysis* under an Equal Vision

Criteria Tree	Alternative 1
ORD suitability assessment -- Direct	Equal Vision
Damara Tern breeding areas -- Std:Attr='Bool'	damara_tern2
Fenced areas to prevent public access to Damara Tern breeding areas -- Std:Attr='Bool'	fenced_areas2
Lichen distribution -- Std:Attr='Bool'	lichen_distribution2
Messum Crater -- Std:Attr='Bool'	messum_crater2
International Bird Areas (IBA) -- Std:Attr='Bool'	iba2
0.50 Socio-economic and tourist activities inducing off-road driving -- Direct	Equal_socio_activities
0.50 Socio-economic activities -- Direct	Equal_socio
0.10 Movie production activity -- Std:Attr='Id'	movie_production2
0.50 Natural Resource (NR) prospecting and exploration activities -- Direct	Equal_NR
0.40 The closer to the sand mining sites, the better 2500 m -- Std:Goal(0.000,2500.000)	sand_mining_dist
0.60 The closer to the uranium deposits, the better 10000 m -- Std:Goal(0.000,10000.000)	uranium_distance
0.40 Tour operation activities -- Direct	Equal_tour_operation
0.05 The closer to the Living Desert tour route, the better 500 m -- Std:Goal(0.000,500.000)	Living_Desert_dist
0.35 The closer to the commerical quad bike route, the better 500 m -- Std:Goal(0.000,500.000)	tour_distance
0.05 The closer to the sandboarding sites, the better 500 m -- Std:Goal(0.000,500.000)	sandboarding_dist
0.20 The closer to the event sites, the better 500 m -- Std:Goal(0.000,500.000)	event_distance
0.35 The closer to the riverbeds, the better 2500 m -- Std:Goal(0.000,2500.000)	rivers_leisure_dist
0.50 Tourist activities -- Direct	Equal_tourist_activity
0.05 The closer to the road network, the better 2500 m -- Std:Goal(0.000,2500.000)	roads_distance
0.15 The closer to the town, the better -- Std:Goal(0.000,171433.000)	towns_distance
0.50 Fishing -- Direct	Equal_fishing
0.75 The closer the fishing spot, the better 2500 m -- Std:Goal(0.000,2500.000)	fishing_distance
0.25 The higher the number of consumptive fish, the better -- Std:Attr='class'	fishing2
0.30 Other leisure activities -- Direct	Equal_leisure
0.50 The closer the area of specific interest, the better -- Std:Goal(0.000,10000.000)	interest_distance
0.25 The closer the riverbeds for wildlife observations, the better 5000 m -- Std:Goal(0.000,5000.000)	rivers_leisure_dist
0.25 The closer the public Yamaha quad bike route, the better 1000 m -- Std:Goal(0.000,1000.000)	yamaha_distance
0.50 Environmental sensitivity -- Direct	Equal_sensitivity
0.50 Landscape sensitivity -- Direct	Equal_landscape
0.15 The closer to the estaury, the worse 1000 m -- Std:Goal(0.000,1000.000)	estauries_distance
0.10 The closer to the ocean boundary the worse 1000 m -- Std:Goal(0.000,1000.000)	ocean_distance
0.45 Gravel plain sensitivity -- Std:Attr='Class'	gravel_plains2
0.15 Rivers -- Direct	Equal_rivers
0.75 The closer to the main river beds the better -- Std:Goal(0.000,2500.000)	rivers_main_dist
0.25 The closer to the river distributaries the worse -- Std:Goal(0.000,2500.000)	rivers_distibutery_dist
0.15 Dunes -- Direct	Equal_dunes
0.50 Dune Belt sensitivity (Protected Area) -- Std:Attr='Class'	dune_belt2
0.50 Dune Sands sensitivity -- Std:Attr='Class'	dune_sands2
0.50 Ecological sensitivity -- Direct	Equal_eco
0.20 Welwitschia sensitivity -- Std:Attr='Class'	welwitschia2
0.80 Species_endemism -- Direct	Equal_species
0.05 The more endemic amphibian species there are, the worse -- Std:Attr='Class'	amphibian_endemism2
0.40 The more endemic reptile species there are, the worse -- Std:Attr='Class'	reptile_endemism2
0.40 The more endemic scorpion species there are, the worse -- Std:Attr='Class'	scorpion_endemism2
0.05 The more endemic mammal species there are, the worse -- Std:Attr='Class'	mammal_endemism2
0.10 The more endemic plant species there are, the worse -- Std:Attr='Class'	plant_endemism2

Table 7: Group weights for different policy visions:

Group weights	Vision				
	Equal	BaU	MEF	Ecology	BDC
Socio-economic activities	25	40	30	25	15
Tourist activities	25	30	20	15	15
Landscape	25	10	20	25	20
Ecology	25	20	30	35	50

2.8.4. Algorithm

Table 8 describes the additional steps undertaken within the raster software, without considering the previously described model process. Following the distance calculation the input maps were incorporated in the model; the output maps were sliced in classes and area calculations were carried out. Raster maps were represented on a pixel by pixel basis of 500 m^2; however the calculations within the models were based upon 1m by 1 m.

Table 8: Algorithm

<table>
<tr><th>Procedure</th><th colspan="4">Functions and details</th></tr>
<tr><td>Polygon to Raster</td><td>Output=MapRasterizePolygon(InputPolygonMapName, Georeference)</td><td colspan="3"></td></tr>
<tr><td>Define undefined areas</td><td>Output2=IFUNDEF(Output,”UndefinedClassNumber”)</td><td colspan="3"></td></tr>
<tr><td rowspan="3">Distance calculation</td><td rowspan="3">For each pixel the distance to its neighbouring pixels is calculated using a 3 * 3 matrix with the following values:</td><td>7</td><td>5</td><td>7</td></tr>
<tr><td>5</td><td>0</td><td>5</td></tr>
<tr><td>7</td><td>5</td><td>7</td></tr>
<tr><td rowspan="4">Slicing (suitability classes)</td><td rowspan="4">Value ranges of values of the input map are grouped together according to predefined output classes</td><td>Upper Boundary</td><td colspan="2">Class</td></tr>
<tr><td>0.25</td><td colspan="2">non suitable</td></tr>
<tr><td>0.50</td><td colspan="2">conditional suitable</td></tr>
<tr><td>1</td><td colspan="2">suitable</td></tr>
<tr><td rowspan="4">Slicing (activity classes)</td><td rowspan="4">Value ranges of values of the input map are grouped together according to predefined output classes</td><td>Upper Boundary</td><td colspan="2">Class</td></tr>
<tr><td>0.1</td><td colspan="2">low</td></tr>
<tr><td>0.2</td><td colspan="2">moderate</td></tr>
<tr><td>0.5</td><td colspan="2">high</td></tr>
<tr><td rowspan="4">Slicing (sensitivity classes)</td><td rowspan="4">Value ranges of values of the input map are grouped together according to predefined output classes</td><td>Upper Boundary</td><td colspan="2">Class</td></tr>
<tr><td>0.6</td><td colspan="2">high</td></tr>
<tr><td>0.8</td><td colspan="2">moderate</td></tr>
<tr><td>1</td><td colspan="2">low</td></tr>
<tr><td>Study area calculation</td><td>GroupOutputArea=IFF(StudyArea=”1”,GroupOutputSlice,?)</td><td colspan="3"></td></tr>
<tr><td>Raster Histogram</td><td>Calculates the area for each class by using the number of pixels per class</td><td colspan="3"></td></tr>
</table>

2.8.5. Assumptions

The primary and secondary data used was regarded as correct; imprecise data did not affect the overall results due to the scale, the analysis was carried out. ORD and environmental sensitive areas were only influenced by the selected groups and the defined factors. The factors revised on the basis of the data collected in the field were considered as valid. No other factor was affecting ORD suitability in the area. Model parameters were constant and did not change between the analyses. Although subjectivity included through stakeholder opinions and own perceptions could not be omitted, the collected data was considered as objective and valid. Thus, the ranking of the different policy vision was regarded as valid, too.

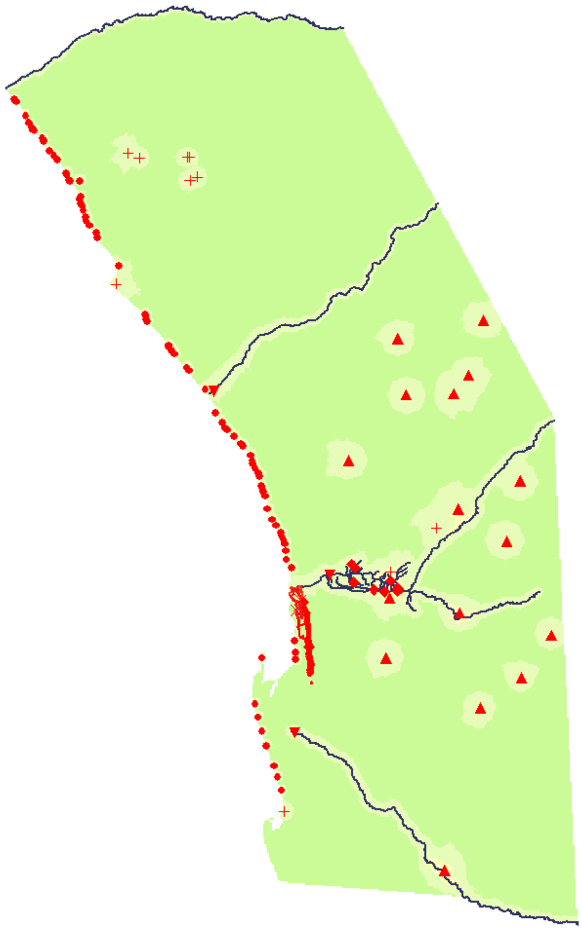
The results described in the following Chapter are a simplified representation of reality, as only the major criteria responsible for ORD were included in the analysis.

3. Results

3.1. Evaluation of ORD activities on the environment

3.1.1. Socio-economic and tourist activities

The maps in Figure 17.1 and 17.2 show socio-economic and tourist activities leading to ORD in three activities categories; low, moderate and high.



17.1. Map of socio-economic and tourist activities including towns for discussion

17.2. Map of socio-economic and tourist activity including ORD activity

Legend:

Activity class	*Socio-economic activity*	*Tourist activity*
Low	Event site	Area of interest
Moderate	Sand boarding site	Fishing
High	Sand mining site	Riverbed for leisure
	Uranium deposit	Yamaha quad bike route
	Living Desert route	
	Tour operation route	0 50 km
	Movie production	

Table 9: Area of socio-economic and tourist activities inducing ORD in ha and %

Activity Class	**Area**	
	ha	**%**
low	2517500	83.0
moderate	466325	15.4
high	47925	1.3

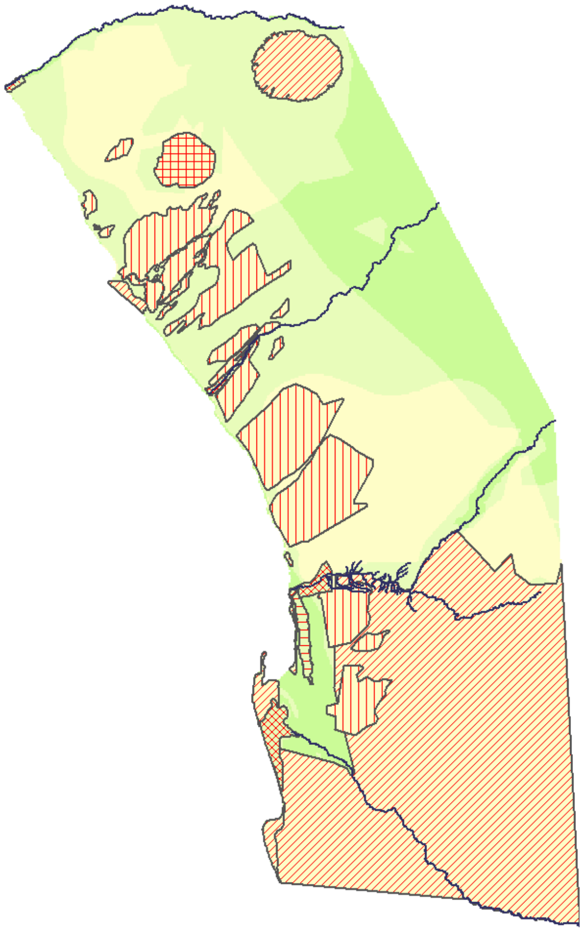
Figure 17 shows potential ORD areas, reflecting socio-economic or tourist interest and their related activities. For an improved illustration the activities leading to ORD are overlaid (Figure 17.2.) on the activity map in Figure 17.1. Tourist activities are considered highest along the coast, the Swakop River and the Dune Belt; areas that required a large extended use of ORV for access. Fishing and recreational beach activities are taking place along the coast, while the Swakop River is used for wildlife watching, day or overnight drives. Adventure, sport and fun are associated to the Dune Belt, where mainly quad biking is carried out.

Further potential ORD mirror economic interest areas and linked activities that can roughly be divided in commercial tour and event operations, movie production and mining. While mineral deposits are found further inland, the broader tourist sector and movie production is concentrated in the Dune Belt and along the Swakop River. The 10 km buffer zone around the uranium deposits highlights that ORD associated to potential mining areas, occurs during the phase of prospecting, while ore extraction is generally confined to a relatively small area, where a road network is usually established before extraction begins. Event operations (e.g. 4 x 4 self-driving rallies in the riverbed, desert dinners or product launches) usually take place in the Swakop River and the Dune Belt. Group sizes involved in event activities range from 30 up to several hundred or even thousand persons, if activities include the management of cruise line travellers. However, all are characterized by having one event site that serves as a catering location, hereby defining an area of impact. Frequency of events and number of participants are determining the number of ORV targeting the locations. Table 9 shows that 1.3 % of the area is associated with high, respectively 15.4 % with moderate activities related to ORD.

3.1.2. Environmental sensitivity

The maps of Figure 18.1 and 18.2 show environmental sensitivity of the area in three sensitivity categories; low, moderate and high.

18.1. Map of environmental sensitivity including towns for discussion



18.2. Map of environmental sensitivity showing IBA's, lichen distribution, Dune Belt, Messum Crater and estuaries

Legend:

Sensitivity class
- Low
- Moderate
- High
- Rivers
- Towns

Environmental factors
- IBA
- Lichen distribution
- Messum Crater
- Dune Belt
- Estuary

Table 10: Area of environmental sensitivity in ha and %

Sensitivity class	Area	
	ha	%
low	473925	15.6
moderate	1040850	34.3
high	1516975	50.0

Landscape and ecological factors are weighed to 50 % each and combined in Figure 18. Comparable to the activity map, the environmental sensitivity map is evaluated using 3 sensitivity classes. The classes are divided into low, moderately and high sensitive areas. Although the combination of landscape and ecological features in one map is causing the loss of some spatial information, the prominent environmental features are well illustrated. Environmental sensitivity is suggesting a moderate to high sensitivity for 84.3 % of the total study area. The total area in ha and % is given in Table 10.

The landscape weight is determined by the gravel plain dominance. The gravel plains stretch from the south-east to the north-west in the study area with the exclusion of the Swakop and Khan River areas. Based on expert knowledge, the gavel plains were ranked as highly sensitive in the landscape group, but a large extent of the area is resulting in a moderate sensitivity after combining landscape and ecology factors. The results also show the Dune Belt and the Swakop River are considered as moderate or low sensitive, hereby showing no difference between an individual group or combined classification. The importance of ecological factors was based on a concurrence of various criteria that are ranked highest in terms of their sensitivity, their international importance and on species endemism. Namibians lichen fields are a unique ecosystem, hereby justifying the priority given by environmental agencies. IBA’s are globally defined, both protected and unprotected and are likewise of international significance. Both, reptile and scorpion diversity and endemism are high in the Namib Desert, adding to the overall ecological importance of the area.

Figure 18 shows that areas with high conservation priorities and landscape value were dominant, resulting in the classification of 50.0 % of the study area as highly sensitive. 34.3 % of the area was classified as moderately sensitive, covering the Dune Sands and the Dune Belt in the south-west and parts of the central and northern study area. Low environmental sensitivity was shown to be in the eastern part of the coast, around Swakopmund and Walvis Bay, as well as in the north-east. Adding to the overlaid factors shown in Figure 18.2, the high sensitivity of the central area was induced through the importance of species endemism, particular of reptiles and scorpions.

3.1.3. Environmental sensitivity showing socio-economic and tourist activities

The map in Figure 19 shows the environmental sensitivity in the three sensitivity categories; low, moderate and high and activities inducing ORD.

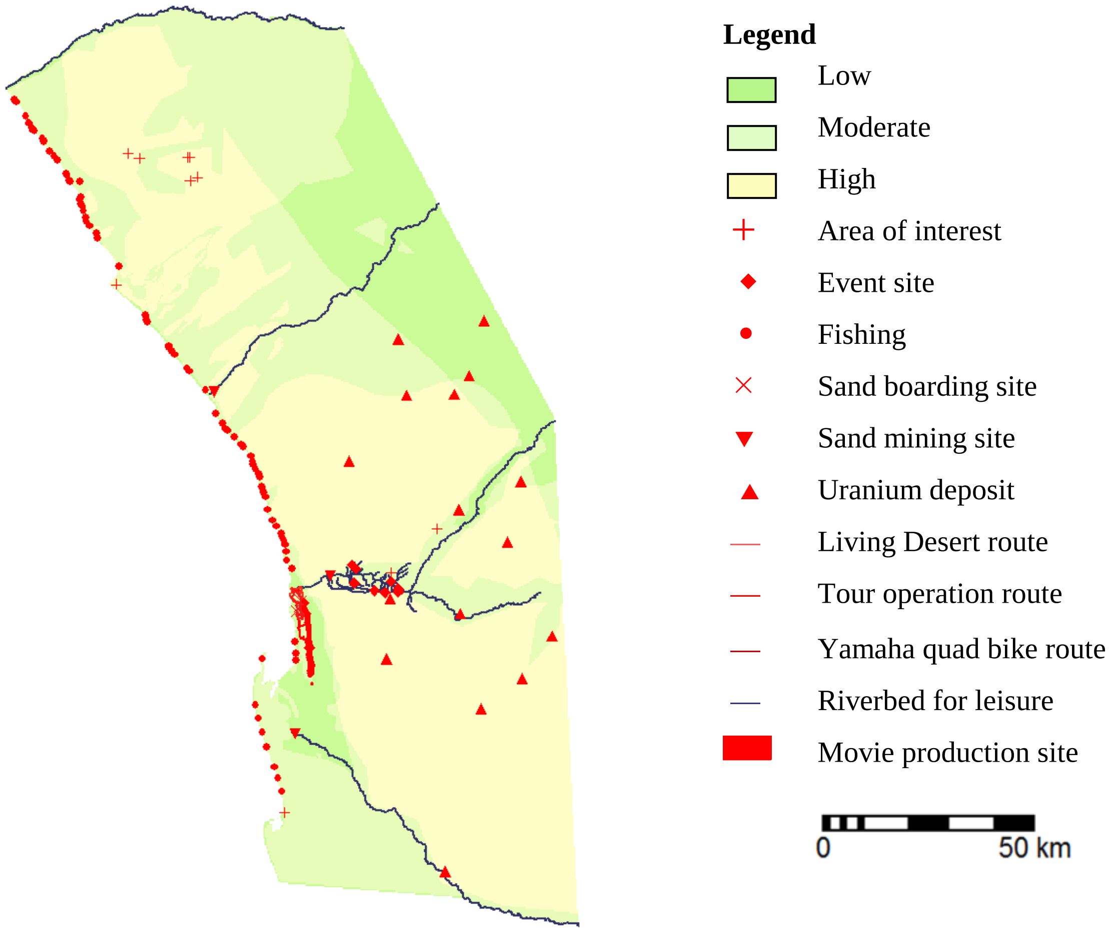


Figure 19: Activities leading to ORD overlaid on the environmental sensitivity

Table 11 shows a table where activities and sensitivity of the area were crossed (Appendix 9).

Table 11: Cross Table of activities on sensitivity

Activity	Sensitivity		
	low	**moderate**	**high**
Areas of interest		x	x
Event sites	x	x	x
Fishing sites	x	x	x
Living Desert route	x	x	
Movie production		x	
Riverbeds leisure	x	x	x
Sand boarding		x	
Sand mining	x	x	
Tour route	x	x	
Uranium deposits	x	x	x
Yamaha route	x	x	

An overlay of tourist and socio-economic activities showed that recreational activities, tour and event operations, as well as movie production were taking place along the coast and the Swakop River; areas defined as environmental moderate or highly sensitive. Uranium deposits are scattered, however occur predominantly in highly environmental sensitive areas. Sand mining sites are located within the riverbeds, but close to their estuaries resulting their being classified as a moderate sensitive area. Hence, the activities assigned to both groups of interest, are taking place to a major extent in the 84.3 % of the study area suggesting a moderate to high sensitivity under combined landscape and ecology criteria. The remaining 15.6 % of the area classified as non sensitive, shows only a minor overlap with tourist and socio-economic activities. The map also highlights that fishing sites are located in direct proximity to lichen fields and IBA's. By comparing fishing site density, edible fish diversity and abundance (Appendix 6) with distance to towns, the area around Wlotzkasbaken (Figure 17.1.) showed an overlap of important tourist, ecology and landscape criteria, influencing ORD suitability (Chapter 3.2.). Beach access points were omitted as an overlay, but will be considered further in the discussion. A low to moderate ORD impact was estimated for tour and safari companies (Figure 17.2.), as they tend to use existing fixed access roads with few variations. In contrast to event and tour operators, prospecting activities are to a large extent taking place in pristine, undeveloped terrain, where new ORV tracks are generated.

The results (Table 9) reveal that around 1.3 % of the study area was associated with high, 15.4 % with moderate and 83.0 % with low socio-economic and tourist activities that induced off-road driving. They further reveal (Table 10) that the environmental sensitivity of the area was estimated to be; high 50.0 %; moderate 34.3 %; and low 15.6 %. The overlay of activities on the environmental sensitivity map (Figure 19) showed that the area classified as low sensitive also had low activity. Conversely areas with moderate or high sensitivity indicate moderate and high activities, but restricted to isolated, partly clustered, locations.

ORD activities occurring in areas with variations on environmental sensitivity are causing differences in environmental effects. Those are dependent on the recovery of the environment and the spatial extent the activity was carried out. Figure 20 shows variations in ORV track longevity and spatial scale; factors of importance for the Chapters Discussion and Recommendations.

Longevity: short
Spatial scale: localised

Figure 20.1. Dune Belt

Longevity: long
Spatial scale: extensive

Figure 20.2. Coastal area

3.1.3.1. The coastal area

The results indicate that high environmental sensitivity and tourist activities are meeting each other along the coast. The interviews reveal that fishing along the coast has to be considered as a problem through the use of 4 x 4 vehicles and quad bikes. Figure 21 shows an aerial image (NACOMA) of the coast and ORV tracks generated for different purpose.

Track circles generated by quad bikes for fun

Tracks generated by 4x4 vehicles to gain beach access

Figure 21: Aerial coastal view

Reasons for ORV tracks are that access to the beach is gained in an uncontrolled way and that 4x4 vehicles are used to drive up and down the beaches in order to identify the best fishing site for the day. 21 of 60 respondents did not consider access points as relevant, instead entering the beach by driving from the main road through the sands and vegetation wherever the best catch of the day was expected, without considering the effect onto the gravel plains that have to be traversed. Distance to towns and family interest were stated in interviews as additional factors for determining beach access points. Due to these reasons the area surrounding of Wlotzkasbaken was suggested as a priority area for protection of lichen fields and gravel plains, as it meets all requirements defined by respondents. In addition, quad biking is leading to environmental changes at the beaches. Quad bikes are brought, during peak holiday seasons in hundreds, as additional piece of equipment, when fishing is not the desired recreational activity, but rather used as a day out at the beach for the whole family. Those are used predominantly by children to keep occupied, while parents focused on fishing or braaing. In most cases children ignored, existing rules and regulations, partly due to the quad bike users being unaware, but also partly due to a wilful ignorance related to the coastal environment. Figure 22 shows ORV tracks in the gravel plains along the coast, with an estimated high environmental sensitivity (See Figure 18).

22.1. Different ORV tracks

22.2. Detailed view on various lichens species

Figure 22: ORD in the gravel plains at 14°06'05.736"E 21°53'30.066"S

3.1.3.2. The Dune Belt

Figure 17 shows that the Dune Belt is one centre of socio-economic and tourist activities related to ORD. Tour operations as quad bike tours, environmental education tours (Living Desert tour) and sport quad biking was carried out to a major extent within the dunes. Those tours routes are confined and can be regarded as fixed, when a buffer zone of 500 m was drawn around the route restricting the influence of the tour operators to a small area. Similar to locations for sand boarding and special events as desert dinners, as they are taking place at distinct point locations at the outer boundary of the dunes. As sand dunes are changing their forms on a rapid scale driven by winds, the recovery rate of ORV tracks is short. Figure 20.1 showed that sand covered a 4x4 buggy track within 5 minutes supporting the low to moderate environmental sensitivity.

Based on community interviews, recreational quad biking takes place on a wider scale, but also on a more or less fixed route or area. To capture this variation, a buffer of 1000 m was created around the Yamaha quad bike route. Interviews did not reveal that the general public and local quad bike users act less responsibly using their quad bikes in the dunes than commercial tour operators. Moreover, the interviews showed that there was a great interest on among the quad bike community to show a responsible behaviour, in order to prevent open conflicts enhanced by biased press articles. Based on the results, the Dune Belt area is considered as a moderate sensitive environment that with the exception of the Damara Tern breeding sites has a comparably low environmental sensitivity when contrasted to areas with lichen fields or gravel plains.

3.1.3.3. The Swakop and Khan River

The results have shown that an overlap of socio-economic activity and moderate to high environmental sensitivity is given further in the Swakop and Khan River area. Riverbeds and the riverine areas are used by local tour operators and the community for day and overnight tours and for event operations. These routes and events are confined to the main riverbed and their tributaries. ORV users try to follow pre-established tracks due to various reasons. Provided that sands are not too soft and tracks not too deep, ORV’s are easier to drive and have a better fuel economy, if using existing tracks. In addition, local community or tour operators driving into the riverbeds or carrying out event operations are searching for an environment that is kept as pristine as possible, to experience nature at its best.

The interviews reveal that due to that reason, a general environmental awareness was given and the creation of more tracks than necessary avoided. In addition, event managers tend to use areas undisturbed by human influence, as this is often a requisite of selling an event site to the customer. Compared to the main riverbed, an increase in sensitivity was suggested for the river tributaries, as flooding is a rare event and permanent driving has resulted in a decrease of track quality and hence the establishment of new tracks for both, a better drive comfort and to prevent the damage of the ORV used. In contrast, the major riverbeds are flushed seasonally, but also in an irregular way, hereby naturally restoring affected areas by ORD. In summary, the results showed that the riverbeds have a moderate sensitivity and a confined area of ORD influence. Increasing distance to the riverbeds leads to a decrease of distance to the gravel plains and hence raises the environmental sensitivity of the area.

3.1.3.4. The Khan area

Different results were obtained during the evaluation of uranium deposits. The deposits are located in areas classified as low to highly sensitive, with the gravel plains regarded as having the highest environmental sensitivity. Protected areas are regarded as having equal importance as unprotected areas. The deposits are representative for the natural resource importance in the area and should only give an impression about their widespread distribution. Focusing on uranium deposits oversimplifies the issue and the extent of potential prospecting and mining areas. Currently over 100 prospecting licences (Makuti, pers.com. 2008) for various minerals, of varying commercial value have been issued for the area. The process of prospecting leads to an extensive disturbance of the natural environment through ORD (Figure 23), although regulations are in place that ensures a following full restoration of the area. During prospecting, ORV's are entering areas that were previously undisturbed by human activities. By breaking the soils crust, the fine sands underneath the crust are exposed and transported by the winds from their original location.

23.1. Prospecting site

23.2. Lichen cover at prospecting site

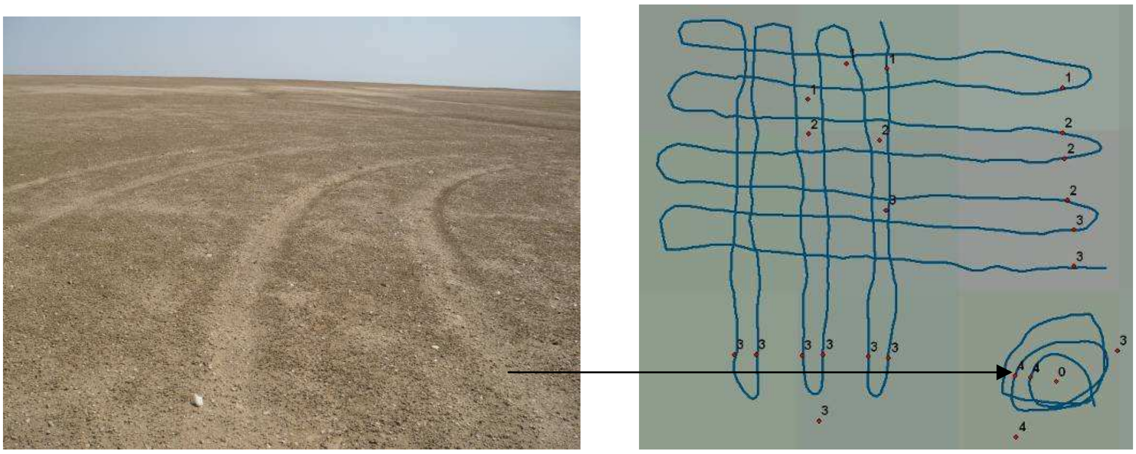
Figure 23: Prospecting site at 14°54'40.320"E 22°33'50.760"S

This process changes the environmental conditions and the visual appearance of the area in the same way as ORD changes the gravel plains along the coast. Later restoration of ORV tracks have shown limited effectivity. Figure 24 shows the experimental research site of Daneel (1992), where tracks were restored in 1992 and since left undisturbed. The location was remote due to the vicinity of the Military Base in Rooikop.

3.1.4. Environmental sensitivity, longevity and restoration

The research by Daneel (1992) focused on differences in ORD impact due to vehicle type, load and driving behaviour. As the experimental research site was not exposed to external disturbances since, the tracks were regarded as authentic and the longevity of off-road tracks could be investigated; a factor playing an important role when considering environmental sensitivity. Observations (Figure 24) reveal that there was no difference in ORV tracks between restored and non restored tracks. Tracks were ranked into 4 groups according their recovery rate and longevity aspect. Rank one showed the best recovered and ranks four the least recovered tracks. The results showed that recovery of tracks was induced through natural weathering processes; recovery was higher on top of the slope with grade 1 than on the bottom of the slope with grade 4. Restored tracks show the same grade of recovery (3 or 4) than the adjusted non restored tracks, as they were lying on the bottom of the slope.

Grade 1	Excellent recovered
Grade 2	Well recovered
Grade 3	Moderately recovered
Grade 4	Bad recovered (positive track effect)



24.1. Rehabilitated track, Grade 4 **24.2.** Digitized tracks using a Mobile GIS

Figure 24: Experimental research site of Daneel (1992)

3.2. Off-road driving suitability maps for Stakeholder Visions

Figure 25: Equal Vision

Figure 26: BaU Vision

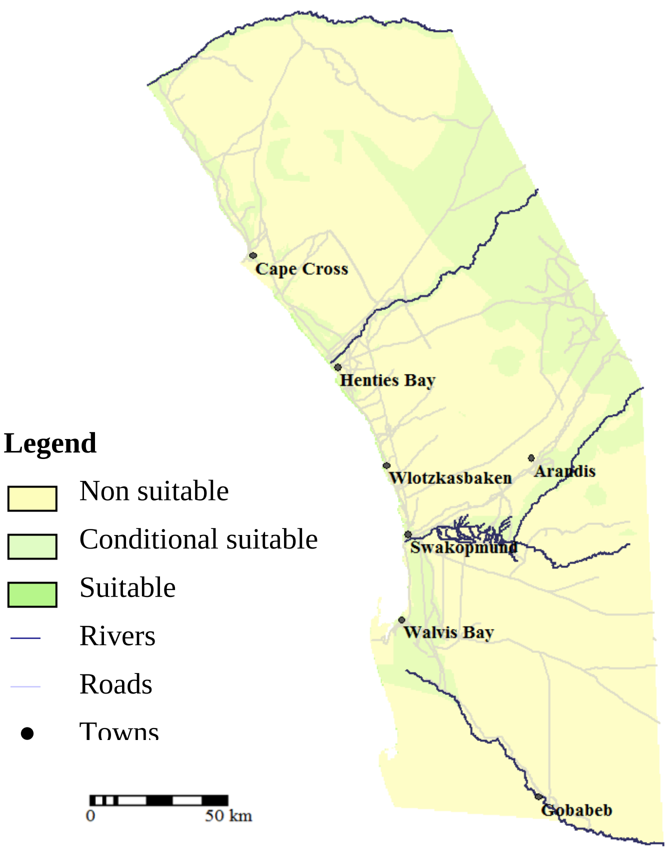


Figure 27: MEF Vision

Figure 28: Ecology Vision

The four alternative stakeholder visions are classified in three suitability classes; non suitable, conditional suitable and suitable. Table 12 combines the results obtained through the SMCE suitability assessment (Figure 25 – 28).

Table 12: Area in % suitable for off-road driving under alternative policy visions

Suitability	% Area			
	Equal	BaU	MEF	Ecology
Non suitable	68	97	76	57
Conditional suitable	32	3	24	42
Suitable	0	0	0	1

Table 12 shows that there is only 1 % of suitable area for ORD in the Ecology Vision, in contrast to the three alternatives, where there is no suitable area at all. The results further reveal one clear class difference for the BaU Vision; 97 % of the area is classified as non suitable and 3 % as conditional suitable. This explains the dominance of socio-economic criteria in the vision in combination with the very restricted area of influence where socio-economic activities take place. The conditional suitable area is reflecting uranium deposit sites, riverbeds for tour operators and parts of the Dune Belt that is assigned to movie production. The visions also show that with increasing weight on socio-economic factors, areas suitable for ORD activities decreased. Hence, increasing area suitable for ORD implies an increase in importance of environmental factors.

Except for the BaU Vision, all visions show a conditional ORD suitability for the Swakop, Omaruru and Ugab River, area located east of Swakopmund and Walvis Bay and area with variations in size and locations along the coast and in the north-eastern section of the study area. The lower Kuiseb was classified as suitable in the Ecology Vision and for the Equal, BaU and MEF as conditional suitable. The conditional suitable areas for ORD correlate to some extend with tourist and economic interest that are taking place in the riverbeds and the Dune Belt.

3.3. Off-road driving suitability map for Biological Diversity Convention Vision

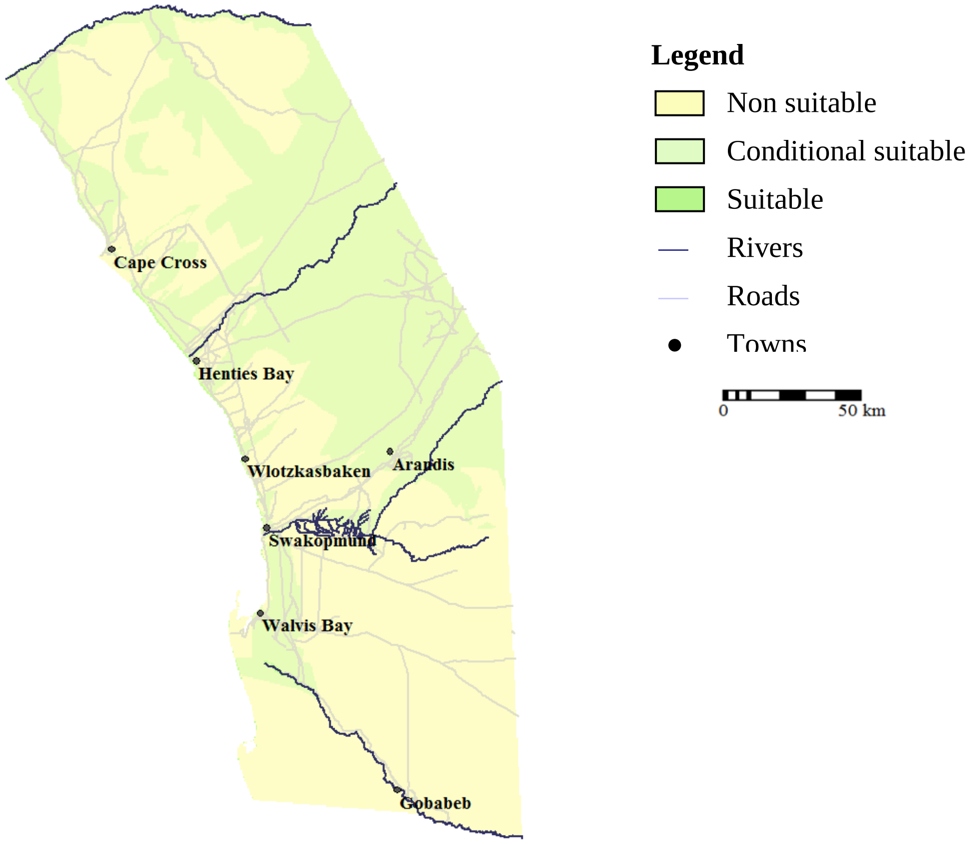


Figure 29: BDC Vision

Table 13: Area in ha and % suitable for off-road driving und a BDC Vision

Suitability	Area	
	ha	%
Non suitable	2025025	67
Conditional suitable	998350	33
Suitable	11250	0

The BDC Vision is as well resulting in no suitable area for ORD. The resultant non and conditional suitable ORD areas are comparable to the Equal Vision with 68 % of and 32 % of respectively. The major difference between all alternatives is the distribution of non suitable and conditional suitable area. The differences can be assigned to variations in weights for the individual groups.

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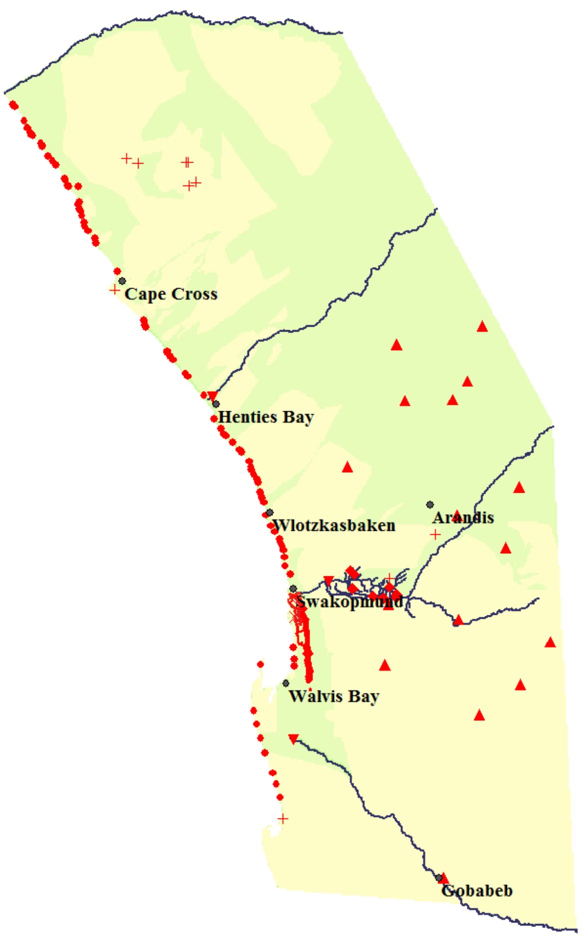
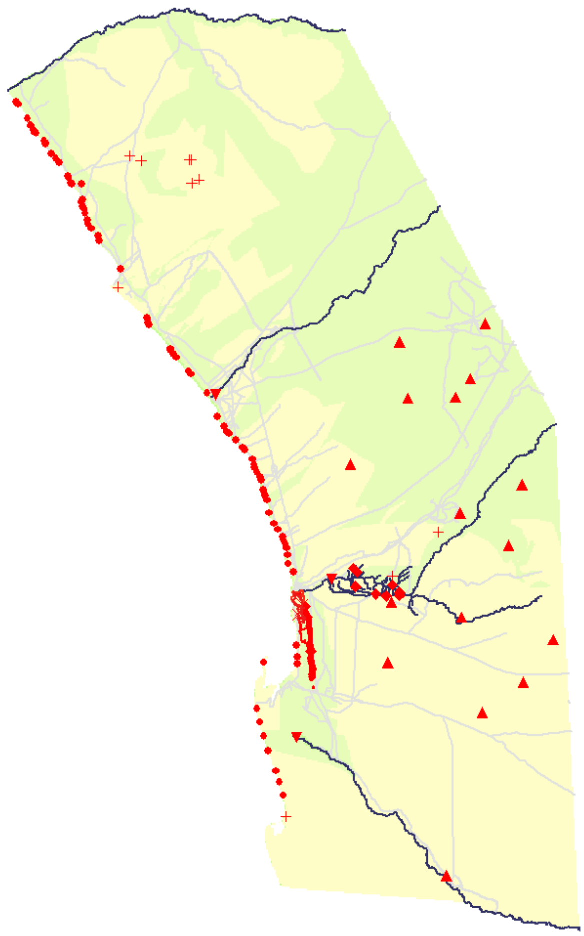
3.3.1. The Biological Diversity Convention Vision showing socio-economic and tourist activities

The maps in Figure 30.1 and 30.2 show the BDC Vision and activities inducing ORD





30.1. ORD suitability for BDC Vision and activities **30.2.** BDC Vision including road network

Legend for ORD suitability under a BDC Vision and activities inducing ORD

Non suitable	Event site	Area of interest
Conditional suitable	Sand boarding site	Fishing
Suitable	Sand mining site	Riverbed for leisure
Roads	Uranium deposit	Yamaha quad bike route
Towns	Living Desert route	
	Tour operation route	
	Movie production	

Table 14 shows the crossing of activities and ORD suitability under a BDC Vision (Appendix 10).

Table 14: Cross Table of activities on ORD suitability under a BDC Vision

Activity	**ORD suitability**		
	non suitable	**conditional suitable**	**suitable**
Areas of interest	x	x	
Event sites	x	x	
Fishing sites	x	x	x
Living Desert route	x	x	
Movie production		x	
Riverbeds leisure	x	x	x
Sand boarding		x	
Sand mining		x	x
Tour route	x	x	x
Uranium deposits	x	x	
Yamaha route	x	x	

The BDC Vision tries to capture the environmental sensitivity of the area through assigning the major weight on the ecological and landscape factors within the SMCE. Conditional suitability is suggested for the Dune Belt, parts of the riverbeds and the north-eastern section of the study area. Suitable area is located along the lower Kuiseb River bed. Figure 30 reveals that fishing sites, tourist's interest areas and tributaries of the Swakop Rivers are to a large extent located in areas non suitable for ORD. It also shows that commercial and recreational quad bike route, eco-tour routes, sand boarding sites, event sites and movie production are located within conditional suitable areas in the Dune Belt. Uranium deposits are distributed in non and conditional suitable areas, while sand mining sites were located in the riverbeds classified as conditional suitable.

Figure 30.1 reveals that ORD is of less concern in the Dune Belt than along the coast due to the direct distance to gravel plains and lichen fields and in the Messum Crater area that has a high landscape and ecology value. Figure 30.2 show further that there is predominately no road connection between major socio-economic and tourist activity sites and the existing road network, suggesting that ORD is used as a means of accessing the desired area of activity. It further shows a narrow road network in the eastern section of the study area that is related to uranium deposits where mining is carried out. Hence, if successful prospecting of natural resource deposits occurred, following mining was expected. This causes the establishment of roads and hereby defragmentation of the landscape and a decrease in environmental values.

4. Discussion

Areas of investigation were the Dune Belt, the coastline, the Swakop and Khan River and the Khan area. The results indicated that particular the coastline shows susceptibility to ORD effects due to the high sensitivity of the area. However, Nature Conservation NGO's emphasizing the importance of the Dune Belt in ecological and landscape terms, hereby conflicting with community interests that regard the area as a centre of recreational activity. Based on stakeholder interviews is can be inferred that the activity itself more than the actual environmental sensitivity is basis for controversy. However, the sensitivity and the spatial dimension (Defeo *et al.*, 2009) of the activity have to be brought in focus, as those factors are determine the extent of environmental change induced through ORD.

4.1. Current impacts of off-road driving

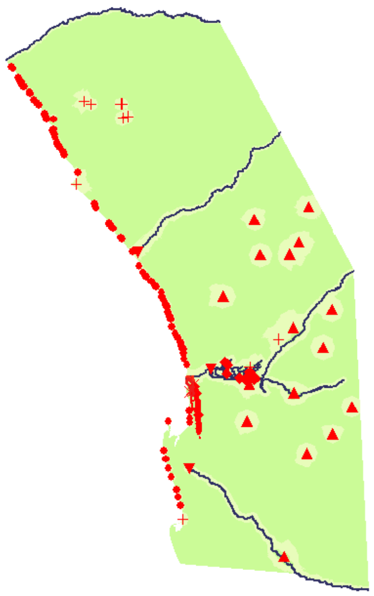
The research showed that approximately 16 % of the study area has low, 34 % moderate and 50 % high environmental sensitivity. Socio-economic and tourist ORD activities were taking place in restricted and partly clustered locations. The crossing of activities and sensitivity confirmed that negative environmental effects are caused by activities through the use of ORV. Beside areas of interest, movie production and sand boarding, all investigated activities were taking place in a low and all activities in moderate sensitive environment. In addition, tourist areas of interest, event sites, fishing sites, riverbeds for leisure activities and uranium deposits are located in areas of high sensitivity. Table 15 therefore supported Claim 1 and 2.

Claim 1: A number of socio-economic activities inducing ORD lead to negative effects on the environment.
Claim 2: A number of tourist activities inducing ORD lead to negative effects on the environment.

Table 15: Cross Table of activities on sensitivity

Activity	Sensitivity		
	low	moderate	high
Areas of interest		x	x
Event sites	x	x	x
Fishing sites	x	x	x
Living Desert route	x	x	
Movie production		x	
Riverbeds leisure	x	x	x
Sand boarding		x	
Sand mining	x	x	
Tour route	x	x	
Uranium deposits	x	x	x
Yamaha route	x	x	

As the crossing does not take the spatial scale of the activity in account, the environmental effects have to be evaluated by comparing the spatial dimension of activities and the estimated sensitivity of the area shown in Figure 31 and 32.



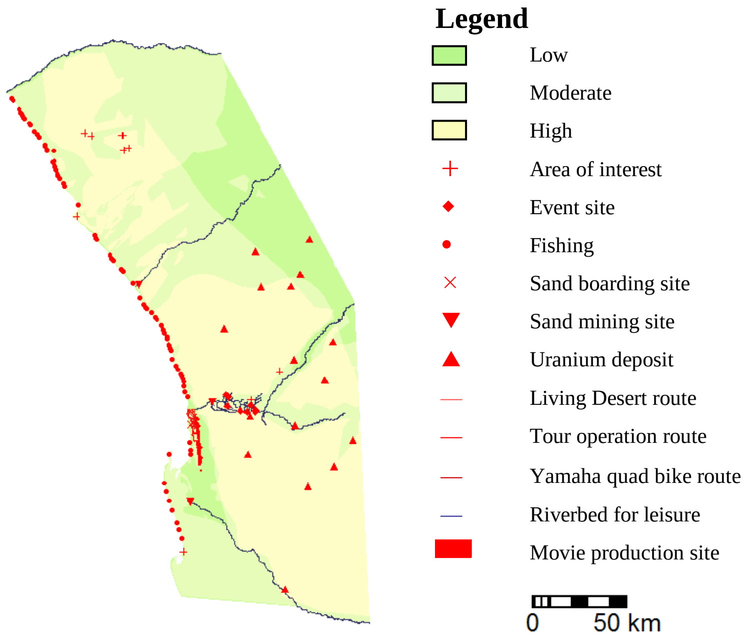


Figure 31: Area of activity **Figure 32**: Area of environmental sensitivity and activities

This causes limitations of the impact assessment; however those could be avoided through a further, more detailed analysis that is recommended for future work and was not undertaken in the study due to time constraints. Therefore, the comparison of the two maps through visual interpretation only delivered a preliminary result. Areas of interest and fishing sites were used to show that the sensitivity itself does not necessarily indicate the ORD impact and has to be seen in combination with the spatial dimensions of the activity. Areas of interest close to Messum Crater are located within high sensitive areas; however the distance to towns is further away than fishing sites that are located between Swakopmund and Henties Bay, where the area likewise shows high sensitivity. The spatial dimension of the activity and the distance to town are important factors that result in differences of ORD effect on a location.

4.2. Spatial planning under stakeholder visions

Avoidance and mitigation of negative ORD impacts by spatial planning can be achieved through the shift of socio-economic and tourist activities from non to conditional suitable or suitable areas. However, the results (Figure 25 to 28) showed that area suitable for ORD did not exceed 1 % in all four Visions and that the Ecology Vision with the highest value of 42 % of conditional suitability, still showed 57 % of area non suitable for ORD. Therefore within those alternatives, there is little scope left to shift activities to more suitable areas. Instead the figures indicated the dominance of environmental factors and that ORD suitability based on economic and tourist activities is much defined. These results were significant as during the classification process the upper boundaries for the non and conditional suitability classes were set very low, such as 0.25 for non suitable and 0.5 for conditional suitable area (Table 8).

Even so, the results were revealing meaningful information for spatial planning. Conditional ORD suitability was suggested for most of the riverbeds and the Dune Belt in the Equal, MEF and Ecology Vision and likewise ORD suitability for the lower Kuiseb area. However it raises also the following questions; how to justify and approve activities inducing ORD in areas conditional or non suitable for ORD? How can socio-economic and tourist activities be carried out in areas conditional or non suitable for ORD? Which value has such decision option per se, if no precise suggestions are made how to target socio-economic and environmental sustainability in those areas, if activities are carried out?

Instead of trying to solve the problem with SMCE, the model could be misused by manipulating the results, such as changing the ranks of the interest groups according to their requirement, or through changing the upper boundaries during the classification. Modified areas of the different ORD suitability classes were resultant; non suitable could be reclassified in conditional suitable and conditional suitable in suitable areas and vice versa. Without justification, such as measures or regulations that would support a change in suitability class, the method supports a laissez-faire attitude that leads to a decrease in landscape and ecology values. However, what is required is an approach that takes into account the actual environmental sensitivity of that region. A spatial planning approach using environmental regulations is suggested as appropriate in areas that are of moderate to high sensitivity.

4.3. Spatial planning using environmental regulations

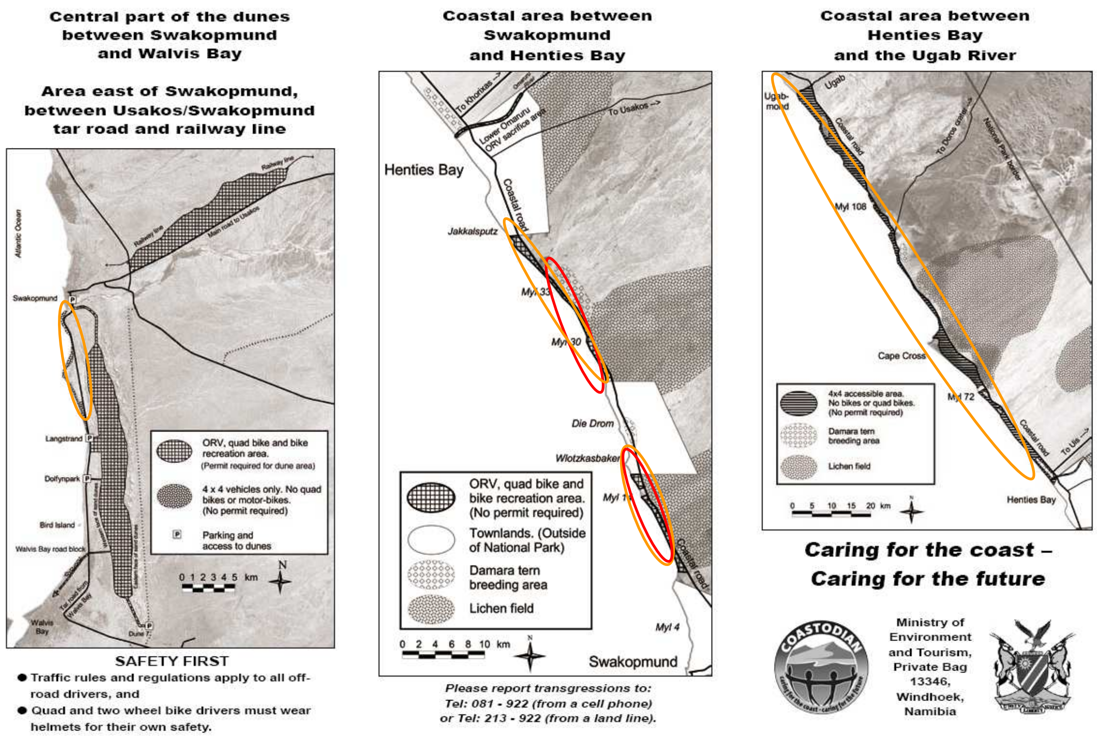
The BDC Vision tries to follow the *Ecosystem approach COP 9 Decision IX/7* (Secretariat of the Convention on Biological Diversity, 2000) of the *International Convention of Biological Diversity*, joining social, economic, cultural and environmental values. Core of the BDC Vision are strict environmental regulation for ORD and their enforcement in order to achieve social economic, cultural and environmental sustainability. As a major centre for economic development in Namibia, the Erongo District is reliant on economic activities in the area. Given the high weight on environmental parameters in this vision, a link between the values appears paradox. However, socio-economic and tourist activities may well be integrated under fulfilment of defined requirements. The following paragraphs suggest a strategy for future activities in those areas in order to avoid and mitigate long term environmental changes due to ORD. Areas classified as non suitable or conditional suitable may be upgraded to conditional suitable or respectively suitable areas, if regulations are determined and implemented. The discussion focuses on some activities within the coastal area, the Dune Belt and the Khan area, previously described (Figure 19) in terms of sensitivity and activity.

4.3.1. The coastal area

Figure 19 and Table 11 show that high environmental sensitivity and fishing sites are overlapping at the coast between Swakopmund and Henties Bay, resulting in area conditional or non suitable for ORD. Through the provision of the measures suggested in Chapter 4.3.1, the area can be upgraded to suitable respectively conditional suitable ORD area. As the coastline is already highly effected by ORD (Figure 21) and public beach access is essential, new ORD rules were given out on a trail basis from December 2008 (Ministry of Environment and Tourism, 2008), that open the area west to the main road for ORV's without permit.

This official opening for ORD is expected to enhance the impact on the area due to an increase in tourist numbers, from countries where beach ORD is restricted, such as South Africa. However, under a BDC Vision this area is regarded as important in buffering ORD activities to lichen fields and Damara Tern breeding areas that are located east of the main road. Figure 33 shows the new ORD rules and indicates the areas that are suggested as crucial if nature conservation of those areas is targeted. Although lichen fields are partly fenced off, such fencing cannot be regarded as stand alone provision, instead has to be incorporated in an overall package of measures. If ORD would be regulated and confined in a strict way, implying also a strong enforcement of regulations, the area could recover over time, hereby increasing both environmental and socio-economic values of the area.

An exclusion of quad bike and limited 4x4 vehicle use along the coast through defined beach access points and adjusted driving zones creates a very restricted area of ORD influence and allows a natural restoration of the area through weathering processes. By regulating instead of banning ORD along the coast, public acceptance can be gained over time, if socio-economic and environmental benefits are explained in depth. As the area between Swakopmund and Walvis Bay is the richest shoreline in terms of shorebird density in Southern Africa (Simmons *et al.*, 1999), in addition gives habitat to the densest *Sterna balaenarum* breeding colonies, it is considered as non suitable for ORD (Figure 29). Under a BDC Vision a general closure for ORV suggested. This stays as well in contrast to the current rules (Figure 33) that open parts of the area for 4x4 vehicles.



Legend:

—— Areas of high ORD activity and high environmental sensitivity

—— Areas open to 4x4 vehicles without permit

Figure 33: New rules for off-road driving, applicable on a trial basis from December 2008 (page 2)

4.3.1.1. Access points for fishing

In order to restore the area to its previous state, 4x4 vehicle use has to be regulated. Prerequisite is the establishment of adequate beach access points for 4x4 vehicles in areas of high fishing site density and within 75 km distance to the major towns. This area of influence was defined by respondents and consistent through the interviews. Those factors are again pointing on the importance of the area between Swakopmund and Henties Bay for fishing and recreational beach activities. Based on observations insufficient access points are established, some of those in addition poorly notified. Even with good intentions, ORV users have difficulties to gain access at important fishing sites without creating new tracks, as no proper access is defined.

4.3.1.2. Fishing

If access to the beach is confined to access roads, it is likewise important to define an area of ORV use along the beach. Except for Townlands (See Figure 33), 4x4 vehicles are under new regulations allowed to access the beach between Swakopmund and the Ugab River mouth nearly continuously. This stays in strong contrast to the BDC Vision that would also regulate 4x4 vehicle uses along the beach. The interviews reveal that ORV's are used to search for the best fishing spot of the day within a distance of about 1000 meters to each site of the beach. Assuming 10 to 15 access points within 75 km distance, established at the most attractive fishing sites would result in 20 to 30 km of beach open to ORD. This in turn would reduce the area of ORD influence around 60 to 75 %.

4.3.1.3. Quad Biking

Quad bike use between Swakopmund and Henties Bay is regarded as problematic and not as a sustainable activity, as their tracks may last for decades or even longer on the bordering gravel plains (See Chapter 3.1.3.1). Even more significant is the destruction of lichen crust (Figure 22) as it is habitat for endemic reptiles and scorpions and may take up to 500 years to recover after ORD impact (Lalley and Viles, 2008). Based on community interviews, quad biking is considered of lowest importance in comparison with fishing and beach recreation and only of high importance during holiday peak season, when international tourist crossing the Namibian border to enjoy ORD with limited regulations. Whether those short periods and a minority of prosperous tourists justify the opening of those sensitive areas for ORD and hereby directly affecting the Districts social and environmental sustainability can be argued. In contrast, a general closure for quad biking would long-term increase the environmental and aesthetic value of the area that is of considerable relevance for community recreation. This can be inferred by 63 % of respondent stating that ORD reduces the quality of life through the negative impact on the scenic beauty of the area. The establishment of a quad bike fun park close to a popular fishing and recreational site might compensate quad bike enthusiasts for this radical measure.

4.3.1.4. Enforcement of regulations

Enforcement of regulations has to be efficient in terms of purpose, cost and labour. Community and expert interviews reveal that through the establishment of an honorary warden system, environmental awareness raising and law enforcement can be combined. In addition, the integration of honorary wardens bridges a gap between the public and local authorities, hereby mediating potential conflicts between the different stakeholders. Further, it is recommended that during holiday peak seasons additional enforcement takes place through responsible authorities. If few examples are made in case of regulation disregard, it is expected to translate in a long-term adaptation of tourists that by the time did not consider environmental responsible behaviour as self evident.

4.3.2. The Dune Belt

The results in Figure 29 reveal that the Dune Belt area is under a BDC Vision conditionally suitable for ORD. However, Chapter 3.1.3.2 indicates that the environmental sensitivity of the area is low to moderate. Due to the socio-economic and tourist activity importance of this area an opening of the inner Dune Belt for controlled quad biking and an upgrading into a suitable ORD area can be justified.

4.3.2.1. Quad biking

An open zone would be bounded by an area reserved for movie production in the east and a closed area that prevents uncontrolled access form the main road in the west. Those areas were defined by stakeholders and are in agreement with the results of the study. However, what is required are confined access point that manage ORV access to the Dune Belt and likewise act as control points for ORV users. This control would focus on the prevention of individual ORD misbehaviour through awareness raising and possible inspection that currently drives arguments between bike community, environmentalists and authorities.

4.3.2.2. Commercial tour operations and events

Table 11 showed that Living Desert Tours, commercial quad bike and sand boarding operators, as well event operations are carried out their activities in low to moderate sensitive areas, where the spatial and temporal scale of the activity is confined. However, as suitability classes were also based on socio-economic criteria, these areas were classified under a BDC Vision in all three suitability classes as non suitable, conditional suitable and suitable. Given the economic importance and the low impact of commercial tour and event operations, persisted activities are suggested to cause no long term change of the Dune Belts environment, but instead encourage economic growth through tourism. However as the area is limited, attention has to be given on the number of issued tour operation licences, in order to prevent the exceeding of the areas carrying capacity.

4.3.3. The Khan area

4.3.3.1. Prospecting of natural resource deposits

Uranium deposits are found within moderate and high sensitive areas (Table 11). Table 14 reveals that these areas are classified as non suitable and conditional suitable for ORD. Later restoration of ORD sites comprised amongst others professional racking of disturbed areas and is used as an argument to carry out the activity in moderate or high sensitive zones. However, racking may even exacerbate the situation, as during this process still intact surface is disturbed as side effect. Questions have been raised as to what extent restoration measures are effective at all. Due to their observed limitations (see Chapter 3.1.4.) and the environmental effects caused by ORV during prospecting, a general exclusion of prospecting low value commodities in high sensitive areas is suggested as essential, when targeting environmental sustainability of those sites. High value commodities, such as uranium deposits will increase their socio-economic importance in the future and therefore negative environmental impacts through ORV cannot be avoided. However, long term impact may be mitigated through considering access routes to prospecting sites based on topography and related weathering rates (Figure 13). Further research focusing on this aspect is recommended. For prospecting in highly sensitive areas, a BDC contribution might be established that assist the implementation of nature conservation measures along the coast and a public environmental awareness rising programme. The decision whether an area can be upgraded into a conditional suitable or suitable area would be dependent on the Environmental Impact Assessment's (EIA) outcome that is carried out for prospecting and mining activities.

Using environmental regulations for the coast and for prospecting activities in the wider Khan area (see Chapter 4.3.1. and 4.3.3.) lead to avoidance and mitigation of ORV effects on the environment and hence support claim 3.

Claim 3: Restricting ORD areas using strict environmental regulations lead to avoidance and mitigation of negative effects on the environment.

4.4. Comparison of spatial planning approaches

Table 16: Short and long term comparison between spatial planning approaches

↗ Benefits

↘ Cost

→ Constant

Importance	**Group**	**Criteria**	Spatial planning **without** environmental regulations		Spatial planning **with** environmental regulations	
			short-term	**longterm**	**short-term**	**longterm**
Public		Agreement of regulations	↗	→	↘	→
		Abidance by the laws	↗	→	↘	→
		Environmental awareness	→	↘	→	↗
Authoroties		Public support	↗	→	↘	↗
		Implementation of regulations	↗	→	↘	↗
		Law enforcement	↗	→	↘	↗
Environment	Landscape	Estauries	→	↘	→	↗
		Beach	→	↘	→	↗
		Gravel plains	→	↘	→	↗
		Rivers	→	→	→	→
		Dunes	→	→	→	→
	Ecology	Lichen fields	→	↘	→	↗
		Welwitschia	→	→	→	→
		Species endemism	→	↘	→	↗
		Damara Tern	→	↘	→	↗
	Services	Provision of species habitat	→	↘	→	↗
		Dune stability	→	↘	→	→
		Aestetic value	→	↘	→	↗
		Recreation services	↗	↘	→	↗
		Provision of employment	↗	↘	→	↗
Activities	Socio-economic	Movie production	↗	↘	↗	→
		Natural resource exploration	↗	↘	↘	→
		Tour operation	→	↘	→	→
	Tourist	Fishing	↗	→	↘	→
		Quad Biking	↗	↗	↘	↘
		Visiting of interest areas	↗	→	↗	→

Table 17: Comparison of sustainability between spatial planning approaches

Importance	**Criteria**	Spatial planning **without** environmental regulations		Spatial planning **with** environmental regulations	
		short-term	**longterm**	**short-term**	**longterm**
Sustainability	social	X	↘	X	↗
	economic	X	↘	X	↗
	cultural	X	↘	X	↗
	environmental	X	↘	X	↗

Table 16 and 17 compared the estimated short and long term effects of spatial planning with and without environmental regulations. Table 16 showed that spatial planning without regulations is expected to result only in socio-economic benefits, when considering a short term period. In contrast, including environmental regulations is expected to result in overall socio-economic cost. Over the short term period, both approaches were not suggesting any changes in environmental conditions and therefore were kept constant. This trend changed when focusing a long term period. Public acceptance was suggested for both approaches as humans are likely to adapt new established regulations over time. However, the major difference was the change in landscape and ecology factors. Those would recover or kept in balance long term and hence would improve environmental conditions for future generations. Therefore such a planning approach would be also beneficial for social and economic, as well cultural aspects. Cultural aspects are particular important for the Messum Crater area, as it is regarded as site of ecological, landscape and archaeological importance. Consequently, Table 16 and 17 support the claims 4 and 5:

Claim 4: Spatial planning for ORD areas without environmental regulations leads long term to social, economic, cultural and environmental unsustainable development.
Claim 5: Spatial planning for ORD areas with strict environmental regulations leads long term to social, economic, cultural and environmental sustainable development.

From a decision-makers perspective, a short term vision without environmental regulations is obvious as there are no costs (socio-economic, political or environmental) involved. Overall presentable benefits to the public, increases the chances of getting re-elected for an additional legislative period. Instead, major socio-economic costs (Table 16) decreases politicians re-election chances significantly, as the public and the industry are directly negatively affected, when activities are restricted through the implementation of environmental regulations. However, when social, economic, cultural and environmental sustainability are considered, there is only one long term beneficial planning alternative; one that incorporates strict environmental regulations. Such a vision assists spatial planning through a legal framework, where law enforcement agents can take action against illegal activities. Policy makers that recognize the importance of high short term costs, in order to achieve a long term socio-economic and environmental sustainability for the region, act as mentors for global nature conservation. By defining off-road driving areas taking into account socio-economic and tourist activities, but likewise under environmental regulations may serve as an example for spatial planning for ORD areas in comparable environments.

4.5. Limitations

Limitations of the study are associated to the data used and to the inevitable subjectivity when investigating socio-economic and environmental coupled problems. The former is related to the point data used for towns, uranium deposits and sand mining areas. Points do not reflect the spatial extent of the actual area, however were used for the purpose of the study as no alternative data was available. In addition, the general vector data is regarded as coarse and hence lead to limitations when focusing on a specific parameter at a specific location. The scale of the area has therefore always to be taken into account. Further, no rate for natural restoration of plants and soil surfaces, e.g. weathering factors or lichen recovery time were included in the analysis, as now data layer for those factors were available; however the aspect was incorporated through the different weights given for the environmental sensitivity of the criteria. A vector layer showing rates of natural rehabilitation of an area would improve the results. The latter limitation is related to human perceptions and their views and interests when specific questions are posed; this is valid for all stakeholders included in the study – experts, the public, NGO's, authorities and businesses. Subjectivity is finally also incorporated through the author's judgements and hereby causes a limitation, as well.

5. Conclusion

The research suggested a method that allowed on a District level, the evaluation of ORD activities and resultant environmental effects. SMCE was used for the spatial analysis and considered as appropriate and cost effective tool to assess ORD effects and to identify areas suitable for ORD. The integration of stakeholder's expertise and interest was essential for the models development and criteria weighting. The results indicated that 84 % of the study area has a moderate to high environmental sensitivity, where part of the area overlapped with socio-economic and tourist ORD activities. The concurrence of high sensitivity and high tourist activities along the coastline between Swakopmund and Henties Bay was critical where ORD effects should be avoided or mitigated in future planning. In contrast, activities and sensitivity within the Dune Belt were indicated to be low to moderate, hereby leading to a low to moderate environmental effect. The incorporation of environmental regulations in a spatial planning approach for ORD areas was recommended for high sensitive zones, when the areas long term goal is social, economic, cultural and environmental sustainability.

In general terms, planning without environmental regulations was possible and adequate in areas of low environmental sensitivity. However, increasing sensitivity seeks for a planning approach that with assistance of environmental regulations confine areas of ORD activity, hereby channelizing their effects. Consequently, negative ORD impacts can be avoided in areas susceptible to ORD and mitigated in areas where ORD activities are carried out. In addition, regulations challenge policy makers to suggest alternative ways and areas where socio-economic and tourist activities can take place, while economic and environmental drawbacks are limited. Instead, spatial planning without regulations in environmentally sensitive areas results in detrimental effects, as areas have been sacrified for ORV use as government does not demand corporate and public environmental responsibility. In order to follow the *International Convention of Biological Diversity*, limitations and commitments have to be accepted and implemented by individuals and enterprises. Over time, a personal and corporate identity has to be developed that translates into daily environmental awareness. The short term costs for spatial planning using environmental regulations are high, but are paid off over a longer term period.

6. Recommendation

- Additional, adequate access points for 4x4 vehicles between Swakopmund and Henties Bay
- Closure of uncontrolled 4x4 vehicle access to the beach
- Confined areas for 4x4 vehicles close to fishing sites, other beach areas closed for 4x4 vehicles
- General closure of coastal areas for quad bikes between Swakopmund and Henties Bay
- General closure of coastal areas for all ORV between Walvis Bay and Swakopmund
- General opening of Dune Belt for ORV use with controlled access points
- No changes regarding tour and event operations within Dune Belt
- Establishment of quad bike fun park between Swakopmund and Henties Bay at a most popular fishing and recreation location
- Establishment of honorary warden system
- Strict enforcement of environmental regulations
- No prospecting of low value commodities in environmental high sensitive areas
- Assign BDC contribution for prospecting in environmental sensitive areas that assist the implementation of nature conservation measures along the coast and a public environmental awareness rising programme
- Long term research on the effectiveness of ORV track rehabilitation
- Long term research on experimental ORV track sites areas of Daneel (1992)
- Inclusion of data layer in the analysis showing longevity aspect of ORD or natural recovery rate for fauna and flora

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7.3. Personal communications

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Mulike, Lelley 26.09.2008 (Regional Development Planner) *Ministry of Lands and Resettlement*, Swakopmund, Namibia

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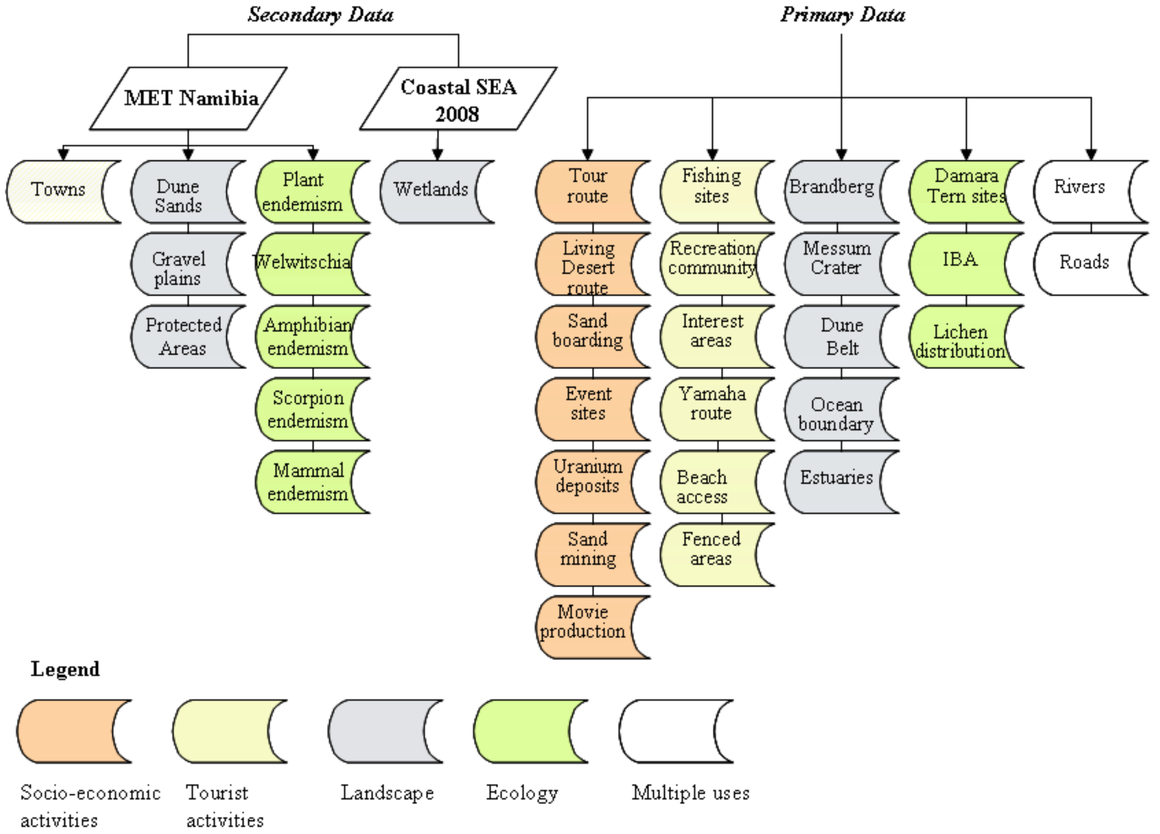
Tarr, Peter (Dr.) 28.10.2008 (Executive Director) *Southern African Institute of Environmental Assessment*, Windhoek, Namibia

Tromp, James 23.09.2008 (Owner – Quad Bike Operator) *Desert Explorers*, Swakopmund, Namibia

Van Wyk, Willi 23.09.2008 (Owner – Event Operator) *Africa Leisure Travel*, Swakopmund, Namibia

8. Appendices

Appendix 1: Flowchart of primary and secondary vector data



Appendix 2: Questionnaire for public opinion on ORD

Questionnaire for off-road driving (English/German):

Location of Interview

Date **Time** **Language** **Interview ID**

1. **Age** ________

1. **Gender**

   Female ☐ Male ☐

2. **ORV in household**

   Yes ☐ No ☐

   If yes, please specify number ________

3. **Frequency of going of a paved or gravel road**

4. **Type of off-road vehicle us**ed

   4x4 ☐ Quad bike ☐ Others ☐ __________

5. **Purpose for ORD**

   a) **Employment**

   Tourism ☐ Mining ☐ Public Sector ☐

   Research ☐ Others ☐ ___________

   b) **Time saving** ☐

   c) **Recreation**

   Fishing ☐ Adventure/Attraction ☐

   Wildlife observation ☐ Areas of specific interest ☐

6. **Other reasons to go off-road**

   No road network ☐ Beach access ☐ Others ☐ __________

7. **Does off-road driving in the area affect your life?**

   Yes ☐ No ☐

8. If yes, in what way?

a) Income generation through tourism

Accommodation ☐ ORV rental ☐ Tourist operator ☐

Tour guiding ☐ Others ☐ ____________

b) Raise quality of life through

Recreational activities ☐ Adventure and remoteness ☐

Accessibility of otherwise inaccessible areas ☐ Others ☐ __________

c) **Lowers quality of life through**

Noise ☐ Scenic impact in the area ☐ Others ☐ __________

9. Personal interest to participate in zoning activities for ORD areas

Yes ☐ No ☐ Do not know ☐

10. Indicate on map the areas of interest to you

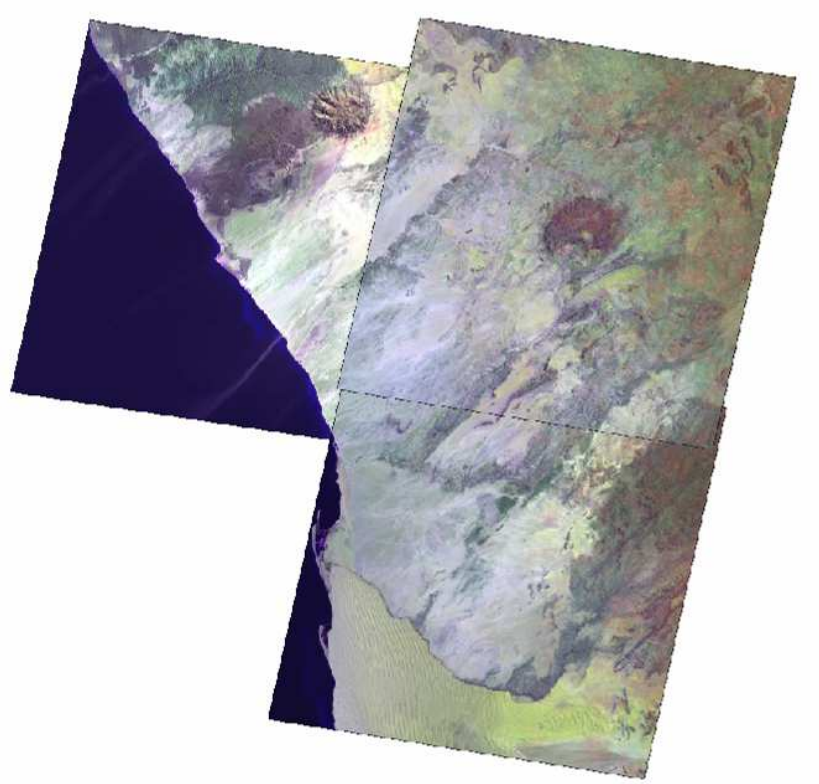
Suitable ORD areas in **black**

Most frequently used ORD areas in **red** (please give reason)

Personal preferred areas in **orange** (please give reason)

No suitable ORD areas in **blue** (please give reason)

Known ecological sensitive areas in **green**



Appendix 3: Stakeholders, their function and the data generated as a result of the interviews

Stakeholder	**Function**	**Resultant new data**
Ministry of Environment and Tourism	Decision Maker	Wetlands
Ministry of Land and Resettlement	Decision Maker	
Erongo Regional Council	Decision Maker	
Municipality of Swakopmund	Decision Maker	Sand mining
Municipality of Walvis Bay	Decision Maker	
NACOMA	Decision Maker	Damara Tern, fenced area, Wetlands
DRFN	Expert	Lichen distribution
NNF	Expert	Movie production, recreation community
SAIEA	Expert	
Birdlife International	Expert	IBA
NEGT	Expert	
Gobabeb Research Centre	Expert	Literature
Tourbrief	Expert	
Desert Explorer	Business	Tour route
Outback Orange	Business	Tour route
Living Desert Tours	Business	Living Desert tour
Henties Bay Tourist Associate / Cape Cross Lodge	Business	Fishing, Messum Crater interest points
Adventure Africa	Business	Event sites, event access, interest areas
Cymot	Business	
Africa Leisure Travel	Business	
Sport quad bike community	Public	Yamaha route
Sport quad bike community	Public	Yamaha route

Appendix 4: The results obtained from the questionnaire are combined in Part 1 and 2.

Interview Community / Part 1

ID	Date	Time	Live in	Origin	Language	Age	Gender	ORV/household	Frequency	Type			Employment			
		min			E/G		f/m	y/n	l/w	4x4	Quadbike	Motorbikes	Tourism	Mining	Farming	Others
1	18.09.	10	Windhoek	NAM	E	25	f	y	l/w	1	0	0	n	n	n	n
2	18.09.	25	Swakopmund	A	G	42	m	y	l/w	4	0	0	n	n	n	Landscape/gardening
3	18.09.	10	SA	SA	E	51	m	y	w	2	0	0	n	n	n	n
4	18.09.	45	Swakopmund	NAM	G	58	m	y	w	1	0	0	n	n	n	n
5	18.09.	45	Swakopmund	NAM	G	54	f	y	w	1	0	0	n	n	n	n
6	18.09.	10	Swakopmund	NAM	E	15	f	n	w	0	0	0	n	n	n	n
7	18.09.	15	Swakopmund	NAM	G	53	f	n	l	1	0	0	y	n	n	n
8	18.09.	10	Okahanja	NAM	E	15	m	y	r	4	0	2	y	n	y	Hunting Farm
9	18.09.	50	Swakopmund	FIN	E	58	m	y					y	n	n	n
10	18.09.	15	Karibib	NAM	G	28	m	y	r	3	0	0	y	n	n	Hunting Farm
11	18.09.	10	Henties Bay	NAM	E	50	m	y	r	3	8	0	y	n	n	n
12	18.09.	10	Windhoek	NAM	G	29	f	y	w	2	0	0	y	n	y	Hunting Farm
13	18.09.	10	Windhoek	B	E	64	m	n	n	0	0	0	n	n	n	n
14	19.09.	20	Swakopmund	NAM	E	63	m	y	w	1	0	0	n	n	n	y
15	19.09.	15	Windhoek	NAM	G	44	m	y	w/l	2	1	1	n	n	n	n
16	19.09.	10	Swakopmund	NAM	E	40	f	n	r	1	0	0	y	n	n	n
17	19.09.	10	Swakopmund	SA	E	36	m	n	n	0	0	0	n	n	n	n
18	19.09.	15	Swakopmund	NAM	E	37	f	y	w/l	2	0	0	n	n	n	n
19	19.09.	10	Germany	GER	G	22	m	n	l	0	1	0	n	n	n	n
20	19.09.	25	Swakopmund	NAM	G	59	m	y	r	3	0	0	y	n	n	n
21	19.09.	15	Swakopmund	NAM	E	18	f	n	l	0	1	0	n	n	n	n
22	19.09.	10	Swakopmund	NAM	E	44	m	y	l	1	0	0	n	n	y	n
23	19.09.	10	UK	UK	E	57	m	n	n	0	0	0	n	n	n	n
24	20.09.	10	Windhoek	UK	E	42	m	y	r	1	0	0	y	n	n	n
25	20.09.	10	Swakopmund	NAM	E	54	m	n	n	0	0	0	n	n	n	n
26	20.09.	10	Swakopmund	NAM	G	46	m	y	w	1	0	0	n	y	n	n
27	20.09.	10	Walvis Bay	Spain	E	33	f	y	r	2	0	0	y	n	n	n
28	20.09.	5	Swakopmund	NAM	E	57	m	n	n	0	0	0	n	n	n	n
29	20.09.	5	US	USA	E	20	m	n	l	1	1	0	n	n	n	n
30	20.09.	10	Swakopmund	NAM	E	45	f	y	w/l	2	0	0	n	n	n	n
31	20.09.	35	Swakopmund	NAM	E	61	m	n	n	0	0	0	n	n	n	n
32	21.09.	15	Germany	GER	G	54	f	n	n	1	0	0	n	n	n	n
33	21.09.	10	Windhoek	Armenia	E	30	m	n	s	0	0	0	n	n	n	n
34	21.09.	15	Karibib	NAM	E	42	m	n	n	0	0	0	n	n	n	n
35	21.09.	10	Reoboth	NAM	E	31	m	n	n	0	0	0	n	n	n	y
36	21.09.	5	Swakopmund	NAM	E	86	m	n	n	0	0	0	n	n	y	n
37	21.09.	10	Windhoek	NAM	E	34	m	y	l	1	1	0	n	n	n	n
38	21.09.	10	Swakopmund	NAM	E	18	m	n	s	0	1	0	n	n	n	n
39	21.09.	10	Swakopmund	NAM	E	24	m	n	s	0	1	0	n	n	n	n
40	21.09.	10	Windhoek	NAM	E	28	f	y	w/l	1	0	0	n	n	n	n
41	21.09.	10	Swakopmund	NAM	E	45	m	y	w/l	1	0	0	n	n	n	n
42	21.09.	10	Windhoek	NAM	E	37	f	n	w/l	1	1	0	n	n	n	n

43	21.09.	60	Swakopmund	NAM	G	39	m	y	w/l	1	1	0	n	n	n	y
44	21.09.	90	Swakopmund	NAM	E	26	m	y	r	0	1	0	n	n	n	n
45	21.09.	40	Swakopmund	NAM	E	43	m	y	r	4	0	0	y	n	n	n
46	22.09.	15	Swakopmund	NAM	E	21	f	y	w/l	1	1	0	n	n	n	n
47	22.09.	15	Cape Town	SA	E	27	f	n	n	0	0	0	n	n	n	n
48	22.09.	10	Swakopmund	NAM	E	43	m	n	w	1	0	0	n	n	n	n
49	22.09.	10	SA	SA	E	30	m	n	n	0	0	0	n	n	n	n
50	23.09.	15	Walvis Bay	NAM	E	25	f	n	n	0	0	0	n	n	n	n
51	23.09.	15	Walvis Bay	NAM	E	72	f	n	n	0	0	0	n	n	n	n
52	23.09.	10	Usikos	NAM	E	15	f	y	w/l	1	0	1	n	n	n	n
53	23.09.	5	Swakopmund	SA	E	37	f	y	w/l	1	0	0	n	n	n	n
54	23.09.	10	Walvis Bay	NAM	E	33	m	n	n	1	0	0	n	n	n	n
55	23.09.	10	Swakopmund	NAM	E	41	m	y	r	1	0	0	y	n	n	n
56	24.09.	10	Omaruru District	NAM	E	15	m	y	r	5	0	3	y	n	y	n
57	24.09.	10	Omaruru District	NAM	E	15	m	y	r	10	2	2	y	n	y	n
58	27.09.	30	Cape Cross	NAM	E	36	m	n	n	0	0	0	n	n	n	n
59	27.09.	15	Swakopmund	NAM	E	47	f	n	n	1	0	0	n	n	n	n
60	28.09.	30	Johannesburg	NAM	E	47	m	y	n	1	1	0	n	n	n	n

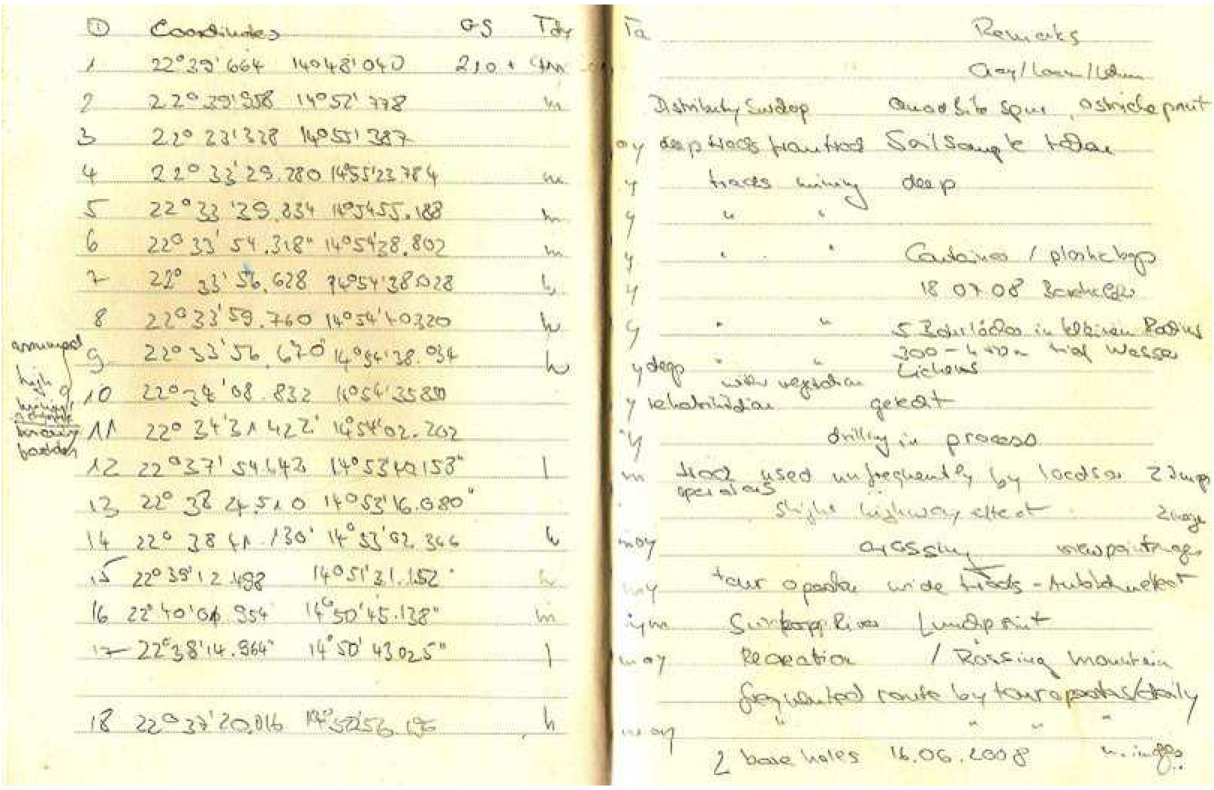
Interview Community Part 2

ID	Time saving	Recreation					Other reasons			Affect life	Income generation					Raise quality of life				Lowers quality of life		
	y/n	Fishing	Wildlife	Adventure	Interest area	Hunting	no road	Beach access	others	y/n	Accommodation	Tour operator	Tour guiding	ORV rental	Others	Recreation	Adventure/remotness	Accessebility	Others	Noise	Scenic impact	Others
1	n	n	n	y	n	n	n	n	fun	y	n	n	n	n	n	y	y	y	going to more place, challenge	n	n	n
2	n	n	y	n	y	n	n	n	n	y	n	n	n	n	n	y	y	y	n	n	y	n
3	n	y	y	y	y	y	y	y	fun	y	n	n	n	n	n	y	y	y	n	n	n	n
4	n	n	y	y	y	n	y	n	n	y	n	n	n	n	y	y	y	n	n	y	y	n
5	n	n	y	y	y	n	y	n	n	y	n	n	n	n	y	y	y	n	n	y	y	beach safty
6	n	n	n	y	n	n	n	n	fun	y	n	n	n	n	n	y	y	n	n	n	y	n
7	n	n	y	y	y	n	n	n	n	y	y	n	n	n	n	y	y	y	n	n	y	n
8	n	n	y	n	n	n	y	n	n	y	y	n	n	n	y	n	n	n	n	n	y	n
9	n	n	n	y	y	n	n	n	n	y	n	n	n	y	n	y	y	y	n			
10	n	y	n	y	y	n	n	y	n	y	y	n	n	n	y	n	y	y	n	n	n	n
11	n	y	y	y	y	n	n	y	n	y	n	y	y	y	y	y	y	y	n	n	y	n
12	n	n	y	y	y	n	n	n	n	y	n	n	n	n	y	y	y	n	n	n	y	n
13	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n
14	n	y	y	y	y	n	y	y	n	y	n	n	n	n	y	y	y	y	n	y	y	y
15	n	n	n	y	y	n	n	y	n	y	n	n	n	n	n	y	y	y	n	y	y	n
16	n	n	y	y	y	n	y	n	n	y	n	n	y	n	n	y	y	y	n	y	n	n

17	n	n	n	n	n	n	n	n	n	y	n	y	n	n	n	n	n	n	n	n	y	n
18	n	y	y	y	y	n	n	y	n	y	y	n	n	n	n	y	y	y	n	n	n	n
19	n	n	y	y	n	n	n	n	fun	y	n	n	n	n	n	n	n	n	n	n	y	n
20	n	n	y	y	y	n	n	n	n	y	n	y	n	n	n	y	y	y	n	y	y	y
21	n	y	n	y	n	n	n	n	fun	y	n	n	n	n	n	y	y	n	n	n	n	n
22	n	y	y	y	n	n	n	n	n	y	n	n	n	n	n	y	y	y	n	y	y	n
23	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	y	n
24	n	n	y	y	y	n	n	n	n	y	n	y	y	n	n	y	y	y	n	n	y	n
25	n	y	y	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	y	y	n
26	n	y	y	y	y	n	n	y	n	y	n	n	n	n	n	y	y	y	n	n	y	n
27	n	n	y	y	y	n	n	n	n	y	y	y	y	y	n	y	y	y	n	y	y	n
28	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	y	n
29	n	n	n	y	n	n	n	n	fun	n	n	n	n	n	n	n	n	n	n	n	n	n
30	n	n	y	n	y	n	n	n	n	y	n	n	n	n	n	y	y	y	n	n	n	n
31	n	y	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	y	n
32	n	n	y	y	y	n	n	n	n	n	n	n	n	n	n	y	y	n	n	n	y	n
33	n	n	n	y	y	n	n	n	n	y	n	n	n	n	n	y	y	y	n	n	n	n
34	n	y	n	n	n	n	n	y	n	y	n	n	n	n	n	n	n	n	n	n	y	n
35	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
36	n	n	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	y	n	n
37	n	n	n	n	y	n	n	y	n	y	n	n	n	n	n	y	n	y	n	n	n	n
38	n	n	n	n	n	n	n	n	fun	y	n	n	n	n	n	n	n	n	n	n	n	n
39	n	n	n	n	n	n	n	n	fun	y	n	n	n	n	n	n	n	n	n	n	n	n
40	n	y	y	y	y	n	n	y	n	y	n	n	n	n	n	y	y	y	n	y	y	n
41	n	y	y	y	y	n	n	n	n	y	n	n	n	n	n	y	y	y	n	y	y	n
42	n	n	n	y	y	n	n	y	n	y	n	n	n	y	n	y	y	y	n	n	n	n
43	n	y	n	y	y	n	n	y	n	y	n	n	n	n	y	y	y	y	n	n	n	n
44	n	y	y	y	y	n	n	y	n	y	n	n	y	n	n	y	y	y	y	n	y	n
45	n	y	y	y	y	n	n	y	n	y	n	y	n	y	n	y	y	y	n	n	y	n
46	n	y	y	y	n	n	n	n	fun	y	n	n	n	y	n	y	y	y	n	n	y	n
47	n	n	n	n	n	n	n	y	n	n	n	n	n	n	n	n	n	n	n	n	n	n
48	n	y	n	n	n	n	n	y	n	y	n	n	n	n	n	n	n	n	n	n	y	n
49	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y
50	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n
51	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	n	y	n
52	n	y	n	n	n	n	n	y	n	y	n	n	n	n	n	y	n	n	n	n	n	n
53	n	y	n	y	n	n	n	y	n	y	n	n	n	n	n	y	y	y	n	y	y	n
54	n	y	n	y	n	n	n	y	n	y	n	n	n	n	n	y	n	n	n	n	n	n
55	n	y	n	n	n	n	n	y	n	y	n	y	n	n	n	y	n	n	n	n	y	n
56	n	y	y	y	y	y	n	n	n	y	y	n	y	n	n	y	y	y	n	n	y	n
57	n	y	y	y	y	y	n	n	n	y	y	n	y	n	n	y	y	y	n	n	y	n
58	n	y	n	y	n	n	n	n	n	y	y	n	n	n	n	n	n	n	n	n	y	y
59	n	y	y	y	y	n	n	n	n	y	n	n	n	n	n	y	y	y	n	n	n	n
60	n	y	y	y	y	n	n	y	n	y	n	n	n	n	n	y	y	y	n	n	y	n

E	English	l	leisure
G	German	w	weekend
F	female	r	regular
m	male s	s	sometimes
y	yes		
n	no		

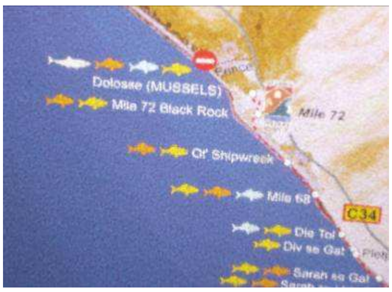
Appendix 5: Ground data collection point

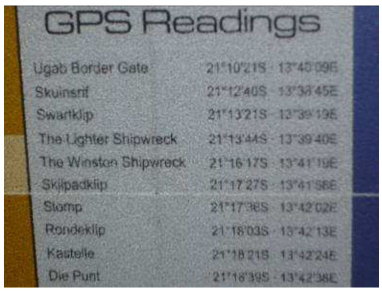


Appendix 6: Example and source of attribute table for fishing

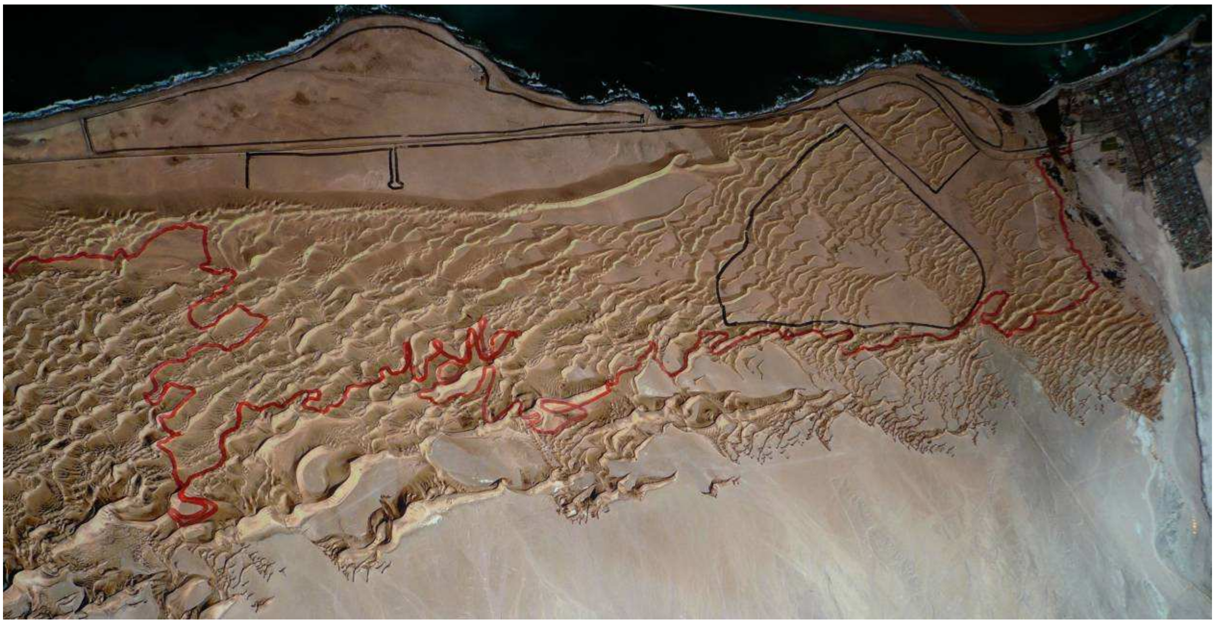
Attributes of fishing

FID	Shape	Id	Name	Bronzie_Sh	Spotted_gu	Sharks	Black_tail	Kabeljou	Galjoen	Steenbras
0	Point	1	Ugab Border Gate						galjoen	steenbras
1	Point	2	Skuinsrif	bronzie Shark	spotted gully s	sharks	black tail	kabeljou	galjoen	steenbras
2	Point	4	The Lighter Shipwreck	bronzie Shark	spotted gully s	sharks	black tail	kabeljou	galjoen	steenbras
3	Point	3	Swartklip	bronzie Shark	spotted gully s	sharks	black tail	kabeljou	galjoen	steenbras
4	Point	5	The Winston Shipwreck	bronzie Shark	spotted gully s	sharks	black tail	kabeljou	galjoen	steenbras
5	Point	6	Skilpadklip	bronzie Shark	spotted gully s	sharks	black tail	kabeljou	galjoen	steenbras
6	Point	7	Stomp	bronzie Shark	spotted gully s	sharks	black tail	kabeljou	galjoen	steenbras
7	Point	8	Rondeklip					kabeljou		
8	Point	10	Die Punt					kabeljou		steenbras
9	Point	9	Kastelle					kabeljou		
10	Point	11	Die Galg					kabeljou		steenbras
11	Point	12	Stoompype					kabeljou		
12	Point	13	Blare					kabeljou	galjoen	steenbras





Appendix 7: Example or participatory mapping approach for Damara Tern breeding sites and Yamaha route



Arial photo (NACOMA)

Appendix 8: Criteria Tree for problem evaluation

Criteria Tree

- Evalution of activities inducing off-road driving (ORD) and the environment the activity is carried out -- Direct
  - 0.50 Socio-economic and tourist activities inducing off-road driving -- Direct
    - 0.50 Socio-economic activities -- Direct
      - 0.10 Area of ORD influence through movie production activities -- Std:Attr='Id'
      - 0.50 Natural Resource (NR) prospecting and exploration activities -- Direct
        - 0.40 The closer to the sand mining sites, the more ORD is expected 2500 m -- Std:Goal(0.000,2500.000)
        - 0.60 Area of ORD influence through uranium deposit prospecting activities 10000 m -- Std:Goal(0.000,10000.000)
      - 0.40 Tour operation activities -- Direct
        - 0.05 Area of ORD influence through the Living Desert tour route 500 m -- Std:Goal(0.000,500.000)
        - 0.35 Area of ORD influence through the commercial quad bike tour route is 500 m -- Std:Goal(0.000,500.000)
        - 0.05 Area of ORD influence through the sandboarding sites 500 m -- Std:Goal(0.000,500.000)
        - 0.20 Area of ORD influence through the event sites is 500 m -- Std:Goal(0.000,500.000)
        - 0.35 The closer the riverbeds , the more ORD is expected -- Std:Goal(0.000,2500.000)
    - 0.50 Tourist activities -- Direct
      - 0.05 The closer to the road network, the more ORD is expected -- Std:Goal(0.000,2500.000)
      - 0.15 The closer to the town, the more ORD is expected -- Std:Goal(0.000,171433.000)
      - 0.50 Fishing -- Direct
        - 0.75 The closer the fishing spot, the more ORD is expected -- Std:Goal(0.000,2500.000)
        - 0.25 The higher the number of consumptive fish, the more ORD is expected -- Std:Attr='class'
      - 0.30 Other leisure activities -- Direct
        - 0.50 The closer the area of specific interest, the more ORD is expected -- Std:Goal(0.000,10000.000)
        - 0.25 The closer the riverbeds for wildlife observations, the more ORD is expected within 5000 m -- Std:Goal(0.000,5000.000)
        - 0.25 Area of influence through the public Yamaha quad bike route 1000 m -- Std:Goal(0.000,1000.000)
  - 0.50 Environmental sensitivity -- Direct
    - 0.50 Landscape sensitivity -- Direct
      - 0.10 The closer to the estaury, the higher the sensitivity -- Std:Goal(0.000,1000.000)
      - 0.05 The closer to the ocean boundary the higher the sensitivity -- Std:Goal(0.000,1000.000)
      - 0.40 Gravel plain sensitivity -- Std:Attr='Class'
      - 0.15 Messum Crater -- Std:Attr='Class'
      - 0.15 Rivers -- Direct
        - 0.75 The closer to the main river beds the less the sensitivity -- Std:Goal(0.000,2500.000)
        - 0.25 The closer to the river distributaries the higher the sensitivity -- Std:Goal(0.000,2500.000)
      - 0.15 Dunes -- Direct
        - 0.50 Dune Sand sensitivity -- Std:Attr='Class'
        - 0.50 Dune Belt sensitivity -- Std:Attr='Class'
    - 0.50 Ecological sensitivity -- Direct
      - 0.10 Welwitschia -- Std:Attr='Class'
      - 0.30 Lichen distribution -- Std:Attr='Class'
      - 0.35 Species_endemism -- Direct
        - 0.05 Amphibian endemism -- Std:Attr='Class'
        - 0.40 Reptile endemism -- Std:Attr='Class'
        - 0.40 Scorpion endemism -- Std:Attr='Class'
        - 0.05 Mammal endemism -- Std:Attr='Class'
        - 0.10 Plant endemism -- Std:Attr='Class'
      - 0.25 Birds -- Direct
        - 0.75 International Bird Areas (IBA) -- Std:Attr='Class'
        - 0.25 Damara Tern breeding areas -- Std:Attr='Class'

Appendix 9: Cross table (ILWIS) of activities and sensitivity

CROSS_SENSE↕	FISH_YAMAHA	SENSITIVITY
? * rl * ? * L	? * rl * ?	Low
? * rl * ? * M	? * rl * ?	Moderate
f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ? * L	f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ?	Low
f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ? * M	f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ?	Moderate
? * ia * ? * ? * ? * ? * ? * ? * ? * ? * H	? * ia * ? * ? * ? * ? * ? * ? * ? * ?	High
f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ? * H	f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ?	High
? * ud * ? * ? * ? * ? * ? * ? * L	? * ud * ? * ? * ? * ? * ? * ?	Low
? * rl * ? * H	? * rl * ?	High
? * ud * ? * ? * ? * ? * ? * ? * M	? * ud * ? * ? * ? * ? * ? * ?	Moderate
? * sm * ? * ? * ? * ? * ? * M	? * sm * ? * ? * ? * ? * ?	Moderate
? * ud * ? * ? * ? * ? * ? * ? * H	? * ud * ? * ? * ? * ? * ? * ?	High
? * es * ? * ? * ? * ? * ? * ? * ? * H	? * es * ? * ? * ? * ? * ? * ? * ?	High
? * es * ? * ? * ? * ? * ? * rl * ? * M	? * es * ? * ? * ? * ? * ? * rl * ?	Moderate
? * ia * ? * ? * ? * ? * ? * ? * ? * ? * M	? * ia * ? * ? * ? * ? * ? * ? * ? * ?	Moderate
? * sm * ? * ? * ? * rl * ? * M	? * sm * ? * ? * ? * rl * ?	Moderate
? * es * ? * ? * ? * ? * ? * rl * ? * H	? * es * ? * ? * ? * ? * ? * rl * ?	High
? * LD * ? * rl * ? * L	? * LD * ? * rl * ?	Low
? * LD * tr * ? * ? * L	? * LD * tr * ? * ?	Low
? * LD * ? * ? * ? * L	? * LD * ? * ? * ?	Low
? * LD * ? * rl * ? * M	? * LD * ? * rl * ?	Moderate
? * LD * tr * rl * yr * L	? * LD * tr * rl * yr	Low
? * tr * rl * yr * L	? * tr * rl * yr	Low
? * rl * yr * L	? * rl * yr	Low
? * yr * L	? * yr	Low
? * yr * M	? * yr	Moderate
? * LD * tr * ? * ? * M	? * LD * tr * ? * ?	Moderate
? * tr * ? * ? * L	? * tr * ? * ?	Low
? * LD * ? * ? * yr * M	? * LD * ? * ? * yr	Moderate
? * LD * ? * ? * ? * M	? * LD * ? * ? * ?	Moderate
? * tr * ? * ? * M	? * tr * ? * ?	Moderate
? * tr * ? * yr * M	? * tr * ? * yr	Moderate
? * sb * ? * tr * ? * yr * M	? * sb * ? * tr * ? * yr	Moderate
? * LD * ? * ? * yr * L	? * LD * ? * ? * yr	Low
? * LD * tr * ? * yr * M	? * LD * tr * ? * yr	Moderate
? * es * ? * ? * ? * LD * ? * ? * ? * L	? * es * ? * ? * ? * LD * ? * ? * ?	Low
? * m * ? * ? * ? * ? * ? * ? * ? * ? * ? * M	? * m * ? * ? * ? * ? * ? * ? * ? * ? * ?	Moderate
? * sb * ? * tr * ? * ? * M	? * sb * ? * tr * ? * ?	Moderate
? * m * ? * es * ? * ? * ? * ? * ? * ? * yr * M	? * m * ? * es * ? * ? * ? * ? * ? * ? * yr	Moderate
? * tr * ? * yr * L	? * tr * ? * yr	Low
? * m * ? * ? * ? * ? * ? * ? * ? * ? * yr * M	? * m * ? * ? * ? * ? * ? * ? * ? * ? * yr	Moderate
? * m * ? * es * ? * ? * ? * ? * ? * ? * ? * M	? * m * ? * es * ? * ? * ? * ? * ? * ? * ?	Moderate
? * sm * ? * ? * ? * ? * ? * L	? * sm * ? * ? * ? * ? * ?	Low

Appendix 10: Cross table (ILWIS) of activities and BDC Vision for ORD suitability

CROSS_BDC	FISH_YAMAHA	BDC_AREA
? * rl * ? * CS	? * rl * ?	Con Suit
? * rl * ? * S	? * rl * ?	Suit
f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ? * S	f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ?	Suit
f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ? * CS	f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ?	Con Suit
? * ia * ? * ? * ? * ? * ? * ? * ? * ? * NS	? * ia * ? * ? * ? * ? * ? * ? * ? * ?	Non suit
f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ? * NS	f * ? * ? * ? * ? * ? * ? * ? * ? * ? * ?	Non suit
? * ud * ? * ? * ? * ? * ? * ? * CS	? * ud * ? * ? * ? * ? * ? * ?	Con Suit
? * rl * ? * NS	? * rl * ?	Non suit
? * sm * ? * ? * ? * ? * ? * CS	? * sm * ? * ? * ? * ? * ?	Con Suit
? * ud * ? * ? * ? * ? * ? * ? * NS	? * ud * ? * ? * ? * ? * ? * ?	Non suit
? * es * ? * ? * ? * ? * ? * ? * ? * NS	? * es * ? * ? * ? * ? * ? * ? * ?	Non suit
? * es * ? * ? * ? * ? * ? * rl * ? * CS	? * es * ? * ? * ? * ? * ? * rl * ?	Con Suit
? * ia * ? * ? * ? * ? * ? * ? * ? * ? * CS	? * ia * ? * ? * ? * ? * ? * ? * ? * ?	Con Suit
? * sm * ? * ? * ? * rl * ? * CS	? * sm * ? * ? * ? * rl * ?	Con Suit
? * es * ? * ? * ? * ? * ? * rl * ? * NS	? * es * ? * ? * ? * ? * ? * rl * ?	Non suit
? * LD * ? * rl * ? * CS	? * LD * ? * rl * ?	Con Suit
? * LD * tr * ? * ? * CS	? * LD * tr * ? * ?	Con Suit
? * LD * ? * ? * ? * CS	? * LD * ? * ? * ?	Con Suit
? * LD * tr * rl * yr * CS	? * LD * tr * rl * yr	Con Suit
? * tr * rl * yr * CS	? * tr * rl * yr	Con Suit
? * rl * yr * CS	? * rl * yr	Con Suit
? * yr * CS	? * yr	Con Suit
? * LD * tr * ? * ? * NS	? * LD * tr * ? * ?	Non suit
? * tr * ? * ? * CS	? * tr * ? * ?	Con Suit
? * LD * ? * ? * yr * CS	? * LD * ? * ? * yr	Con Suit
? * LD * ? * ? * ? * NS	? * LD * ? * ? * ?	Non suit
? * tr * ? * yr * CS	? * tr * ? * yr	Con Suit
? * tr * ? * ? * NS	? * tr * ? * ?	Non suit
? * tr * ? * ? * S	? * tr * ? * ?	Suit
? * sb * ? * tr * ? * yr * CS	? * sb * ? * tr * ? * yr	Con Suit
? * LD * tr * ? * yr * CS	? * LD * tr * ? * yr	Con Suit
? * es * ? * ? * ? * LD * ? * ? * ? * CS	? * es * ? * ? * ? * LD * ? * ? * ?	Con Suit
? * m * ? * ? * ? * ? * ? * ? * ? * ? * ? * ? * CS	? * m * ? * ? * ? * ? * ? * ? * ? * ? * ? * ?	Con Suit
? * sb * ? * tr * ? * ? * CS	? * sb * ? * tr * ? * ?	Con Suit
? * m * ? * es * ? * ? * ? * ? * ? * ? * ? * yr * CS	? * m * ? * es * ? * ? * ? * ? * ? * ? * ? * yr	Con Suit
? * tr * ? * yr * NS	? * tr * ? * yr	Non suit
? * yr * NS	? * yr	Non suit
? * m * ? * ? * ? * ? * ? * ? * ? * ? * ? * yr * CS	? * m * ? * ? * ? * ? * ? * ? * ? * ? * ? * yr	Con Suit
? * m * ? * es * ? * ? * ? * ? * ? * ? * ? * ? * CS	? * m * ? * es * ? * ? * ? * ? * ? * ? * ? * ?	Con Suit
? * sm * ? * ? * ? * ? * ? * S	? * sm * ? * ? * ? * ? * ?	Suit