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National level monitoring of desertification

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Abstract

National level monitoring of desertification is one of the components (1a) within Namibia's Programme to Combat Desertification, Phase 3. The overall objective for this component is to establish a national level desertification monitoring system. At this stage a set of potential indicators, i.e. availability to water, population pressure, soil properties, climate and land use/management have been defined. A few essential datasets required by these indicators have been located and evaluation of their quality has been initiated.

Field evaluation of the indicators has been done in Uuvudhiya constituency, Oshana region. The preliminary findings indicate that the assumptions made for the indicators correspond to actual situations.

Several methodologies of using NOAA AVHRR data for the continuous monitoring of desertification have been tested. Relationships between vegetation type and density, amount of rainfall and spectral signatures have been established.

Introduction/background

Desertification defined as loss of productivity in arid systems, is a growing problem in drylands of developing and developed countries worldwide. Identifying causes and monitoring changes resulting from desertification are essential for decision-makers ranging from government to individual farmers and from macro-economists to natural resource managers (Seely and Jacobson, 1994). Debate on land degradation in drylands of Africa is fraught with confusion and disagreement concerning magnitude, severity and causes of observed changes (Warren and Agnew, 1988). One reason for this is the uncertainties and inaccuracies inherent in the methodological tools and analytical models.

One component of the third phase of Napcod is to establish a national level desertification monitoring system. A number of initiatives producing land resource inventories and land degradation assessments have been undertaken in Namibia, producing valuable information that can be incorporated in this monitoring system (Coetzee, 1999).

This paper reports on the current status of this project, therefor, results and conclusions should not be interpreted as final, they should rather be seen as first approximations.

2. Reflection on the terms of reference

In the terms of reference for Napcod III it was clearly pointed out that there is a lack of readily available information of the location and extent of desertification in Namibia. It was recommended that an indicator based monitoring system for monitoring of desertification on national level was developed and made operational. The monitoring system should make use of relevant data, both historical and frequently updated information. The monitoring system should generate readily available information that is frequently updated and being of use to decision-makers and resource managers in general.

3. Objectives

The over all objective for the National Monitoring and Information System is to establish a monitoring system that can, in a reliable way, provide information about the state of desertification in Namibia, to increase the knowledge and thereby the awareness of desertification and its causes. The monitoring system should generate relevant information that can serve as a support to decision-makers on all levels, natural resource managers in general and the public.

3.1. Specific objectives

A number of specific objectives have been defined:

- Evaluate existing methods that have been/are used for national scale monitoring of desertification/land degradation
- Define primary and secondary indicators of desertification/land degradation to be used by the monitoring and information system
- Develop a monitoring and information system optimised for Namibian conditions
- Identify all areas affected by land degradation in Namibia
- Determine the present rate of land degradation in Namibia
- Provide a comprehensive manual that describes the design and methods used for the monitoring system

4. Methodology

4.1. Development of indicators

In order to understand the causes and effects of land degradation and to identify the main driving forces influencing the state of the environment in Namibia a literature review was done and a theoretical framework was developed. This information together with the State of the Environment reports (DEA, 1999) formed the basis for the development of a first set of potential indicators.

These indicators were presented and discussed with the members of the Napcod counterpart network. After consulting the members a list of indicators was compiled (appendix 1). Based on these indicators Napcod defined five potential primary indicators directly influencing the state of the environment in regard of land degradation in Namibia. The potential primary indicators defined are water availability, population pressure by humans and livestock, climate variability, soil properties and land use/land management (table 3). These assumptions are in line with findings from the LERIS based on a field survey made in the Uuvudhiya constituency programme (Trippner, 1996).

LERIS used soil properties, relief, water availability, vegetation status and climatic conditions as the main parameters influencing the ecological condition in the Uuvudhiya constituency.

4.2. Data requirements and quality control

The identified potential primary indicators gave guidance to what data are required for the monitoring system. A number of data sets are readily available (table 1)

Before any data set can be incorporated into the monitoring system its quality must be determined. Most data sets with a national coverage has regions as the smallest entity, i.e. census data, stock numbers and general statistics. In order to evaluate the usefulness of these coarser datasets, data of higher resolution collected through various case studies have been compared with data of coarser resolution in order to find out if they are correlated. A high correlation between these data sets would imply that the coarser data would generate reliable results. An example is presented below, where population density based on settlements in the 4 "O" regions was compared to the population density given by enumeration areas for the same area (figure 1).

The results of this analysis are not conclusive but some similarities can be observed. The correlation between the two datasets is 0.65, which is considered to be acceptable, i.e. enumeration areas can be used to describe population density on a national scale.

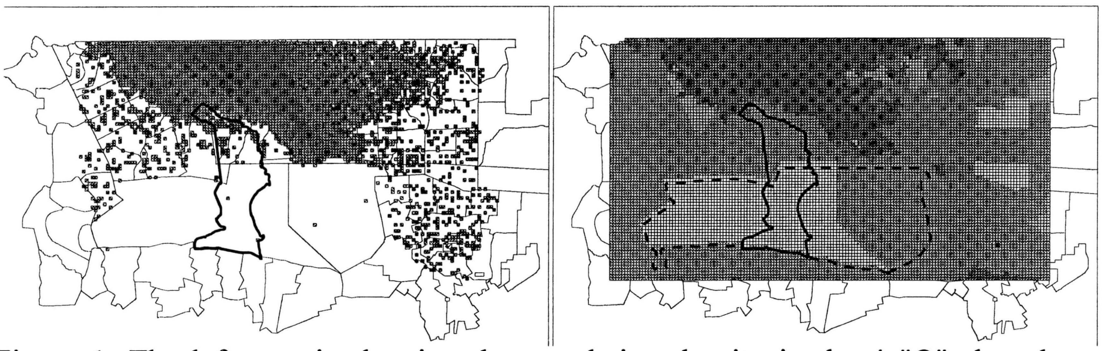


Figure 1. The left map is showing the population density in the 4 "O"s based on the distribution of settlements and the right map is showing the density based on enumeration areas. The settlements were mapped by aerial photo interpretation. The data was made available by NNEP 2000. Population by enumeration area has been compiled by the Office of the President, Central Bureau of Statistics (1991).

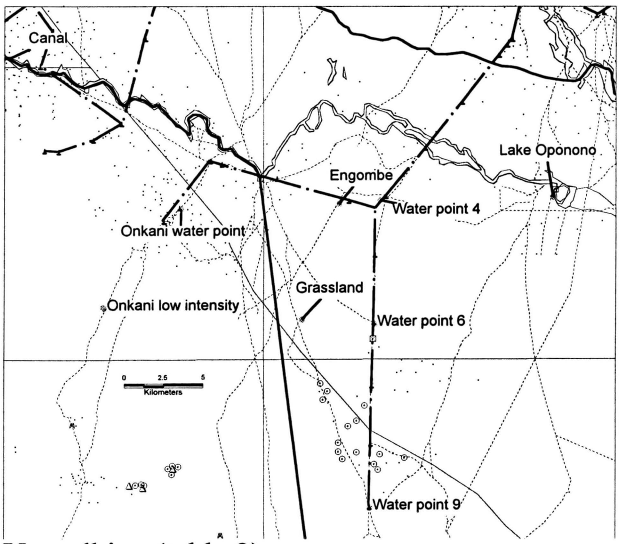
Table 1. Available data sets and the quality

Data set	Comment
Human population	Enumeration areas. This data set has been compiled by the Office of the Prime Minister (General Statistics Office). It is based on the 1991 census and will be updated 2001. The data has a national coverage and is the best available at this time.
Livestock numbers	The Veterinary Services do animal counts every year. Data on a regional scale is published annually. This is on a far too course scale to be of any use for a monitoring system. More detailed information is required.

Water availability	DWA has compiled a data set with national coverage of "all" boreholes in the country. The quality of this data set is questionable but it is the most complete data available. A detailed survey of Namibian water resources is now being done by the HYMNAM project (DWA)
Soil properties	A number of surveys have been done on a regional scale. At least one soils map with national coverage is available but does not have information about all soil properties outlined above. A 1:1000 000 soil map is now being produced for Namibia (MAWRD in co-operation with the Spanish Government).
Climate	Rainfall data is readily available from the Weather Bureau although not all rainfall stations have been maintained, it seems like the number of operational stations is decreasing. For local level monitoring this is a problem but for national level monitoring interpolation between stations might be sufficient.

4.3. Field evaluation of potential primary indicators, establish threshold values for primary indicators

The linkage between the assumptions made and the actual situation were evaluated in the field. At this stage detailed sampling of biophysical parameters along transects has been done in all three Napcod pilot sites (Uuvudhiya in the north, Omatjette in the west and Gibeon in the south). The most detailed studies have so far been done at the study sites in Uuvudhiya constituency in Oshana region (figure 3). Nine different sites were selected in



Uuvudhiya (table 2).

Figure 3. The map is showing the location of the nine study sites selected in the Uuvudhiya constituency. The high intensity sites are located close to water points and other water bodies, i.e. the canal and Lake Oponono. The low intensity sites are mainly far away from water points.

Table 2. Sites selected in the Uuvudhiya constituency

Site name	Land use	Intensity
Onkani water point (1 transect)	Grazing	High
Onkani Low Intensity Site (2 transects)	Limited grazing	Low
Engombe (1 transect)	Grazing	Low
Water point 4 on the main pipeline	Grazing	High
Water point 6 on the main pipeline (3 transects)	Grazing	High and low
Lake Oponono (3 transects)	Grazing	High
Canal (2 transects)	Grazing	High
Water point 9 on the main pipeline (3 transects)	Grazing	High
Grassland (1 transect)	Grazing	Low

The assumptions tested at the Uuvudhiya sites were the relationship of water availability, population density (pressure) by humans and livestock, and soil properties to land degradation. For the purpose of this study the mean rainfall and the rainfall variability were considered to be the same throughout the study area. Two different methods were used, the landscape Functional Analysis (Tongway and Hindley, 1995) and the Index of Biological Integrity (Zeidler, 1999).

The Landscape Function Analysis (LFA) is based on a 50 meter transect. The length and width of permanent obstructions (patches) and the length of bare patches (fetch) are measured. This methodology gives a measure of the environments ability to collect and store water and nutrients, and is therefor a measure of the functionality of the environment.

An area with few patches of vegetation or other obstacles and long fetches, i.e. bare grounds, is regarded as being less functional compared to an area with many patches and short fetches.

The Index of Biological Integrity is measured along the same transect by using a 50*50 cm quadrate which is placed at each 2nd meter along the transect. The ground cover and the three dominating species are observed in each quadrant. The amount of standing biomass within each quadrant is determined in four classes. Samples from each class are clipped for weighing in laboratory. Soil samples are collected at three points along the transect. Further, morphological and ecological features are observed at each site, i.e. soil crusts, erosion features, soil porosity, slope, amount and composition of litter.

The use of indicators requires threshold values to be established for each indicator used, i.e. what population density would lead to degradation given a specific land use? At this stage no threshold values have been established for the potential primary indicators.

4.4. Monitoring of degradation: the monitoring system

To monitor spatial and temporal trends or changes of the extent of desertification, information has to be regularly updated. Considering the vast area that has to be covered by a national monitoring system and the frequent updates of the information required, satellite imagery is the most reasonable solution.

To use satellite remote sensing for the national monitoring system is both cost and time efficient. The major benefits of using satellite imagery together with ground based field work instead of any method only relying on ground based field sampling are that satellite imagery makes it possible to, simultaneously, cover large areas and to get frequently updated information on a national level. There are several types of satellite imagery available, the differences being the spatial and spectral resolution and the costs involved.

The potential indicators defined above will identify areas that are likely to be degraded, or are in risk of being degraded. These "hot spots" will be further analysed by use of NOAA AVHRR satellite images over time. The data used at this stage is decadal NDVI data extending back to 1993 with a spatial resolution of approximately 1*1km (at nadir). This is a rather short times series and will not give any conclusive results regarding the causes of any temporal changes of biomass or ground cover. A second NOAA AVHRR data set is available extending as far as to 1982 but with a spatial resolution of approximately 10*10 km. No final decision has been taken at this stage towards what data that will be used for the continuos monitoring. At this stage the NOAA AVHRR data with a higher spatial resolution is used.

5. Results

5.1. The selection of potential primary indicators

The development of potential indicators and the selection of a set of primary indicators were outlined above. The resulting indicators are presented in table 3.

Table 3. Potential primary indicators identified and the basic assumptions

Indicator	Assumptions	Comment
Availability to water	A high number of water sources per area unit would indicate an increased risk of land degradation. It is assumed that boreholes, water points, taps, wells and open water bodies form focal points for grazing and other agricultural activities.	The availability to water is a very strong indicator of land degradation as most activities based on natural resources depend on availability to water.
Population density	The basic assumption is that a higher population depending on natural resources leads to an increased risk of land degradation	Human and livestock density is treated separately.
Climate, mean rainfall, variability, seasonality and inter annual variations	The basic assumption is that low and highly variable rainfall leads to an increased risk of land degradation	Mean rainfall and annual and inter annual rainfall variability are considered to be the most important indicators
Soil properties	A soil that has a low nutrient content, has a low permeability, high fraction of fine sand and silt, low clay content and easily eroded when protective cover is removed is assumed to have an increased risk of being degraded	Nutrient content, soil maturity, soil fractions, soil porosity and erosion susceptibility, salinity and compaction are important factors that gives important information about the state of the environment
Land use/management	It is assumed that no management is more likely to lead to land degradation than if there is a	Land use and its management has a profound influence on the state of the environment. This information is

	management plan. It should be noted that mismanagement due to lack of understanding could damage the environment far more than no management.	difficult to access

5.2. The Landscape Function Analysis

The LFA analysis was done at 9 sites in the Uuvudhiya constituency. The sites were selected based on differences in land use intensity, population pressure and water availability. The number of patches per 10m, the patch width and the average fetch lengths recorded at the nine study sites are presented in figure 3 to 5 below.

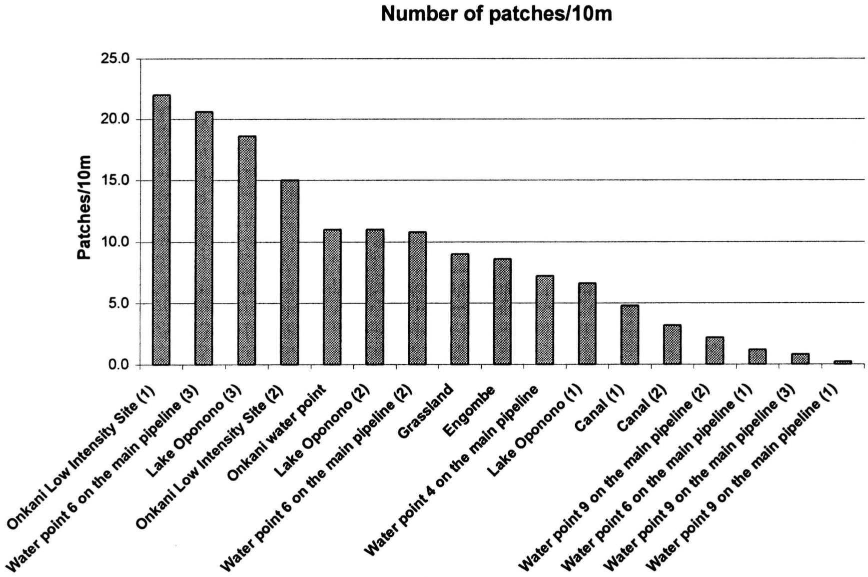


Figure 4. The graph is showing the number of patches per 10 meters. The higher the number the higher the functionality of the landscape. In this case the low intensity sites have a far higher number of patches compared to the high intensity sites.

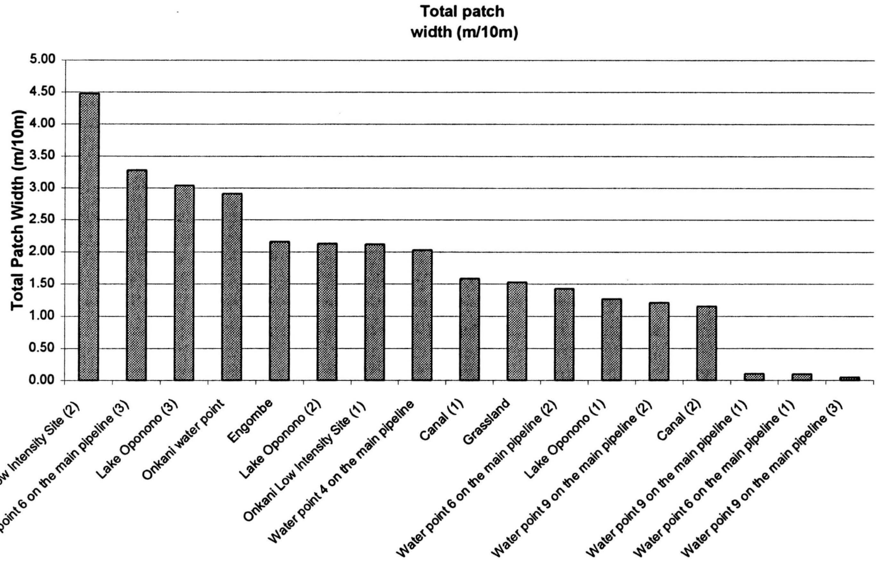


Figure 5. The graph is showing the total patch width per 10 meters along the transect. The wider the patches the more run off can be prevented, indicating a more functional landscape. The low intensity sites have significantly wider patches than the high intensity sites.

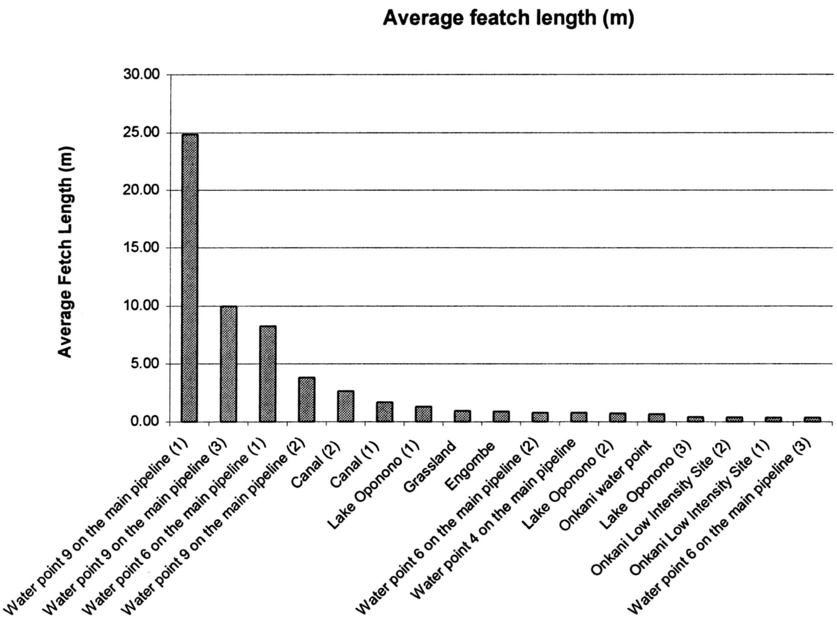


Figure 6. The graph is showing the average fetch length along the transects. The results are not significant but in general the low intensity sites have a shorter fetch length compared to the high intensity sites.

5.3. The monitoring system

At the time of writing this paper only preliminary results of the extent and location of desertification in Namibia have been established. These results will not be published until further analysis has been done.

Several methodologies of using NOAA AVHRR data for the continuous monitoring of the state of the environment have been tested. The spectral signatures of different vegetation classes in the Uuvudhiya constituency have been investigated in order to establish a relationship between vegetation density, NDVI and rainfall (figure 7). These relationships have to be established and understood in order to use the satellite images for monitor any changes in vegetation cover.

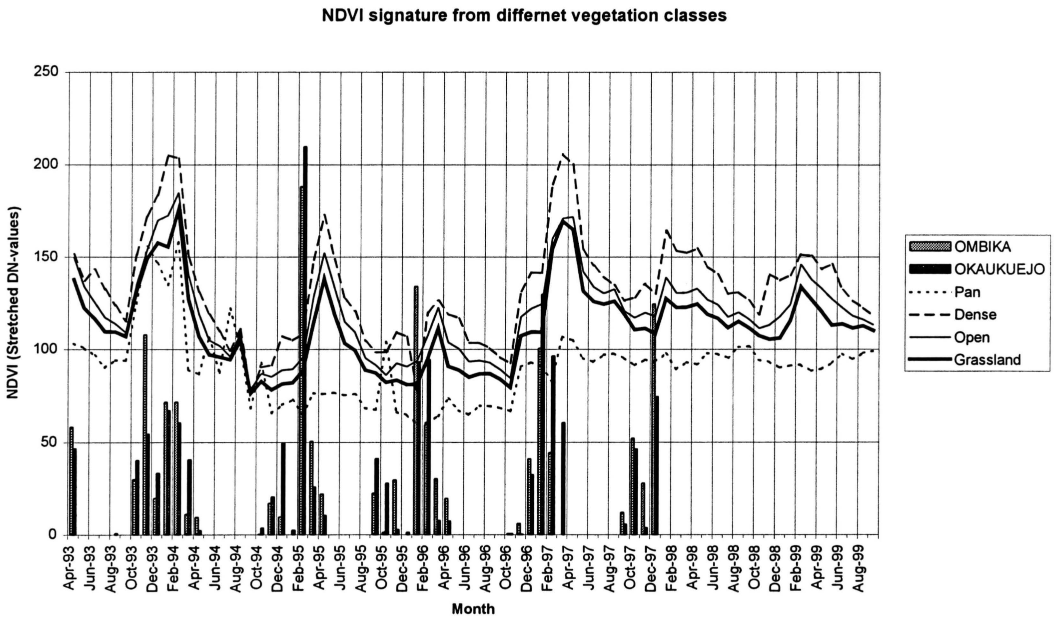


Figure 7. The relationship between NDVI and rainfall for different vegetation types in the Uuvudhiya constituency. The vegetation classes shown in the graph are pan, grassland, open shrubland, and dense shrubland. The Ombika rainfall station is located north of Uuvuhdiya constituency and Okaukuejo is located in the Etosha National Park.

6. Conclusion

The preliminary results outlined above indicate that the main assumptions regarding the causes and effects of land degradation in Namibia corresponds to the actual situation in Uuvudhiya constituency. The low intensity sites have a general higher number of patches per 10 meters and a lager patch width compared to the high intensity sites. The fetch length is shorter in the low intensity sites than in the high intensity sites. This all indicates that the low intensity sites are less disturbed and that more water and nutrients are likely to be absorbed and therefor promote the functionality of the environment.

These results should only be seen as indications. The results will only be useful when threshold values have been determined, i.e. what number of patches and what patch width is required for a landscape to be considered functional for the present land use? And how long does the average fetch length have to be for severe erosion to take place? It is important to acknowledge that threshold values will differ depending on various site-specific parameters, e.g. slope, and soil properties. It should also be stressed that the field methodologies applied here are still being tested in order to develop rapid and accurate methods that are applicable both for local and national level monitoring. A need for standardisation of methodologies in Namibia has been identified.

It is important to emphasis that the primary indicators identified at this stage are the starting points for the monitoring of land degradation in Namibia. Although they are considered to be major factors influencing the state of the environment in regard of land degradation in Namibia, other potential primary indicators and also secondary indicator will be developed to further increase the accuracy and usefulness of the system.

The initial tests of the quality of data sets with national coverage are not finished and can not be elaborated further at this stage. One important data set, the population density in enumeration areas has proven to be of high enough resolution to be used for the analysis. All data sets used in the final monitoring system will have to undergo similar tests before they can be fully incorporated.

The tests of the NOAA AVHRR data with a pixel resolution of 1*1 km has shown that there is a difference in spectral signature between different densities and types of vegetation. This is important especially in regard of detection of changes in vegetation cover and composition over time, i.e. decreased ground cover and bush encroachment. Further a clear correlation between rainfall and response in NDVI can be seen. This has to be compensated for before any conclusions regarding long term changes in vegetation composition and its causes can be drawn.

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Appendix 1

The potential primary indicators proposed to the Napcod Counterpart Network members

Indicator name
Population pressure
Land cover change
Capacity to do regional and local land use planning
Total grazing pressure and rainfall to net primary productivity (biomass)
Normalized Difference Vegetation Index (NDVI)
Rainfall indicator
Water Consumption by resource type
Routine monitoring of water levels in the non-strategic, regional aquifers
Value added (to water)
water quality within water resources
Soil erosion indicators
Human poverty index
Economic diversification
GDP spent on environmental resource research