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Applications of satellite remote sensing for monitoring of wildlife and national parks

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Project Leader Kenneth Campbell

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1. Executive Summary

Monitoring and timely management of change in extensive semi arid rangelands and protected areas is both expensive and difficult. The large areas of land involved, the major degree of spatial and temporal variation experienced in practice (see Figure 3 for example) together with poor surface access especially during the wet season, and shortages of trained manpower to monitor and collate the information, all serve to make range resource assessment problematic and management response uncertain.

Increasing human and animal pressure on these limited resources however, makes better management of existing areas increasingly important, and earlier research has shown the potential utility of the NOAA satellite data for aspects of range monitoring (e.g. Prince 1982, 1986, 1990 in Botswana and Sahel). By 1992, ongoing RAFS research (particularly the Local Application of Remote Sensing Techniques: LARST: R5149) had shown the technical feasibility of using local reception of free NOAA meteorological satellite data for monitoring large area changes on a daily/weekly basis. Etosha Ecological Institute (EEI) showed interest in co-developing new monitoring techniques appropriate to their own research and management needs, so a multi-component implementation plan was formulated.

The specific purpose of the research component was to try and adapt local reception of satellite data and information management techniques to meet the identified and prioritised needs of EEI researchers and managers (see Table 1). These needs were for immediate 'whole resource' information in order to facilitate timely decisions/interventions when and where appropriate both within and around the margins of the protected area. Implementation of the GIS and the land use change mapping in Etosha National Park (ENP) were undertaken in parallel with TC funding, to assist with understanding and managing longer term changes.

Research activities included work on suitable satellite techniques for animal tracking, vegetation monitoring, fire detection, water surface monitoring, dust monitoring and environmental change, all to be institutionalised through incorporation into an operational park management GIS.

Outputs included:

- Low value NDVI change detection and 'biomass' mapping techniques which were taken up and used by EEI for range status monitoring through the Africa regional project (ODA Africa Regional Remote Sensing Project, MIS 001506006Y).

- Fire mapping/response capability used by EEI for fire management,
- Prototype animal tracking hardware and software tested in use by EEI research staff,
- Surface water monitoring capability used by EEI for monitoring flood changes and timing response,
- Dust/anthrax spore dispersal assessment by EEI research staff,
- Demonstration and development of a prototype training workbook to help with transfer of techniques to other similar areas.

These techniques were tested during the project and the more promising were developed further into operational tools in the GIS under development by the APO (Associate Professional Officer). What was particularly encouraging about the research at Etosha was the way that the scientists and management took charge of the agenda and used the satellite data in novel and unanticipated ways, to their benefit. This allowed much to be learned of additional value for onward transfer elsewhere.

The outcome was a clear demonstration of how easily and cost effectively information useful to both range and wildlife managers can be obtained through local remote sensing, to supplement and complement data obtained on the ground through traditional means, so helping local resource managers to make better use of semi-arid range resources, co-ordinating environmental conservation with development and utilisation of resources.

2. Background

Increasing pressures on the diverse resources of 'protected areas' means that better management of existing areas is increasingly important, especially in the context of their margins and adjacent range areas. Productivity of these rangeland areas is dependent on highly variable annual rainfall, prone to frequent 'failure'. Many of these areas suffer from difficult surface access which, together with cost of transport, manpower shortages and inefficient traditional sampling methods, serves to make monitoring slow, tedious, expensive and unreliable. In the past many such areas were used more or less sustainably by the relatively low density of interested communities, with a minimum of 'centralised management'. Macro level changes may have been systematically monitored but the science of range management has been, and remains controversial (see for example Pratt and Gwynne 1977). Over the last 25 years, increases in domestic animal herds, increase in hunting pressure, increased frequency of fire, increased cultivation of more favourable areas, increased tourist demand for wild animal viewing and increased demand on local medicinal plants and animals have all put steadily growing pressure on land resources. Better management practices are required to ensure higher **sustained** levels of productivity with minimum conflict between all the different stakeholders.

Protected Area Managers in particular have to respond to short term and unpredictable seasonal variations balancing sustainable production with ecological priorities and the interests of paying visitors, who render the protection economic. For example, particular considerations for managers include:

- **animals:** their absolute and relative numbers, range and health,

- available **water** resources both within and near the areas of interest, opening/closing boreholes as necessary,
- available **vegetation** resources, burning back bush (for grass renewal and visitor viewing) when conditions allow,
- **fire** risk and prevention, fire outbreak management both to protect the park and adjacent areas.

In many such semi arid areas management efforts are largely confined to minimising poaching and trying to monitor major trends through field visits. It was postulated (based on the work of Prince and others) that the use of local NOAA satellite data reception would enable real-time understanding of the state of the whole land resource **as it changes**, so allowing better understanding of large scale processes and enabling more proactive and targeted management as appropriate. By working with the relatively strong research and management team at EEI, it was planned to develop generic techniques and test their operational utility, so facilitating uptake and use of similar techniques in areas where monitoring and managerial capacity were still being developed. Earlier LARST and other research had shown the basic viability of the principal techniques but taking them out of the laboratory and putting them into the hands of field researchers and resource managers on the ground for real time use in a protected area was a new departure.

Demand for the project arose from the realisation by staff of the Department of Wildlife HQ and at Etosha that integration of the real-time NOAA data into a protected area management GIS could assist them in their objective to manage the park and surrounding areas more as an integrated resource. They had identified their priority information requirements (see Table 1) in conjunction with a request for an ODA TC project (T0418: Support to the Etosha Ecological Institute). The vegetation monitoring requirements were elaborated further in the EEI Regional Environmental Change in Northern Namibia Project Implementation Plan, and subsequently addressed in some detail in the follow up Africa Regional project. Within the resources and time available, the project addressed EEI priorities as shown in Table 1 column 3 and 4.

3. Project Purpose

The wider objectives of the research were to enable more productive and better maintained semi-arid rangeland areas in Africa. The specific objective was to develop and test cost effective generic monitoring tools for helping resource managers with timely and appropriate information for improved management response in protected areas and extensive rangelands. This included:

- Identification of managers' needs and priorities
- Development of algorithms and systems for local operation of LARST NOAA satellite receiving systems, to provide pertinent data.
- Testing of the data outputs with researchers and managers.
- Development of strategies for incorporation of new kinds of information into researchers' and managers' decision chains
- Preparation of methods for transferring techniques effectively to other areas.

4. Research Activities and Outputs

4.1 Prototype animal tracking hardware and software

EEI were interested in using real time animal position fixing as part of research into minimising elephant damage in agricultural areas. Pilot systems and tracking algorithms were developed for local animal tracking based on ARGOS platform transmitter terminals (PTTs) attached to elephant in the Caprivi Strip, northern Namibia. Position fixes were analysed locally using data received by LARST NOAA satellite receiving systems in Etosha. A programme of ground validation of position fixes determined that locations were normally accurate to within 2.5 km. A programme to develop Windows based software for animal tracking using LARST systems was initiated (a screen from a beta version of this software is illustrated by Figure 1). The software design concept was modular, enabling future developments in tracking systems technology and new satellite sources to be incorporated as these systems come on line in the future. The potential for development of small ARGOS transmitters was explored by the project and prototype transmitters were built. Further work was postponed in the light of other developments of new satellite capabilities (Starsys and other Low Earth Orbiting satellite systems with onboard locational systems) likely to significantly change the course and utilisation of this type of technology in the future, and the likelihood of problems associated with production of these small transmitters in volumes great enough for them to be cost effective. A portable NOAA receiver system was developed and tested. This lightweight system has the capability to be used while mobile in the field, and in locations where permanent installation is either difficult or impractical. Since development of this portable system it has been used operationally at a number of locations, including Madagascar, Italy, Vietnam and the Central African Republic.

4.2 Fire mapping/response capability

ENP is financially responsible for making good damage caused to adjacent ranchland from fires originating in the park. It also needs to protect park animal grazing from wanton destruction by fire in the dry season. Bush and scrub encroachment of rangeland (reported to be a 12 million hectare problem in Namibia) also needs to be controlled by periodic controlled hot fires, on a rotating basis. Fire is a major management tool and as such fire breaks need to be maintained in good order, and origins of wild fires quickly determined. A system for recording burning fires on imagery received by the LARST NOAA satellite receiving system installed at EEI was developed by the APO stationed at EEI together with specialists from NRI. This system provides range resource managers with locations of fires identified using satellite imagery, with results being available either in map format or as geographical co-ordinates that can easily be transmitted to remote sites via phone/fax/radio. Images with identified fires were used by management as an important data source when combating fires. In addition, the imagery provided the ability to identify unambiguously the source of fires for the first time, this being particularly important where fires crossed boundaries, e.g. between the park and adjacent ranchland and vice versa.

Models for fire risk assessment using information provided by LARST systems were developed at NRI, and adapted, tested and implemented in Etosha National Park (see Figure 2). These models have considerable potential for application at other LARST sites within southern Africa and elsewhere.

4.3 Vegetation mapping and monitoring

Algorithms for effective local use of LARST NOAA systems monitoring vegetation change of protected areas and their environments were successfully evaluated in Etosha National Park (ENP). This included the development of procedures for the production of satellite image maps of vegetation greenness and of active fires. Ways were then explored for introducing these techniques into routine operation. This stimulated production of the EEI regional environment change in Northern Namibia Project Implementation plan, which pulled together the different research and TC activities and provided the basis for the Africa Regional Vegetation monitoring methodology developed by University of Cranfield and NRI (Sannier et al. 1996, Sannier et al. in press). Figure 3 illustrates the spatial variation of the status of vegetation over ENP at any one point in time. Such information was found to be of particular value to park managers, providing an overview of the entire park whereas their normal daily operations are limited to small restricted asreas of the park.

An initial vegetation stratification and updated maps of Etosha National Park were produced using Landsat TM satellite imagery purchased by the TC project. In addition, this Landsat TM imagery formed important components of a methodology for vegetation status mapping that was developed in conjunction with local researchers at the Etosha Ecological Institute and other research projects with activities in Etosha (ODA Africa Regional remote sensing project). Outputs of this vegetation / habitat mapping are presented in Annex 1 together with GIS ouptuts (Annex 1 Figure 2) and illustrate the utilization of these data for management related tasks.

4.4 Low value NDVI change detection and 'biomass' mapping techniques

Project activities showed that there was considerable information content in the low value NDVI images. Normally vegetation signals are swamped by bare soil spectral signatures when vegetation cover is low. Real-time low value data however was found capable of distinguishing relatively small differences of importance to animals subsisting through the dry season, albeit in a qualitative way. The effects of past fire patterns (and other signals in the data) were deciphered with the aid of local knowledge: much of what is often considered noise in the imagery by remote sensing specialists was found to be useful information when studied by persons more familiar with the park.

The Mopane woodland (*Colospermum mopane*) vegetation in ENP is an important source of food for elephants but is relatively difficult to monitor and quantify. Together with collaboration from Earthwatch who provided manpower, a study was carried out in Etosha to determine and quantify the green and woody biomass components of Mopane woodland. A destructive sampling system was developed and implemented at a 1 hectare level suitable for integration with satellite remote sensing based information. These data were incorporated, together with information on biomass levels in grasslands - also collected by the project - in research aimed at the classification of biomass levels from NOAA satellite imagery. This ongoing work was carried out in collaboration with Silsoe College of Cranfield University and the ODA Africa Regional remote sensing project. Additional information from these and other sites is required before a relationship between AVHRR imagery and grassland or woody biomass can be derived.

4.5 Surface water monitoring capability

Since Etosha lies in a particularly arid area, monitoring the water status of Etosha pan, its 'flooding' tributaries and western streams are all of major importance to park management. Procedures were developed for the utilisation of LARST images at the Etosha Ecological Institute in monitoring the status of Etosha Pan and tributaries during the wet season. This capability was utilised, for example, in assessing the breeding potential and survival of flamingo nesting on the pan, and with the timing of management efforts to rescue large numbers of stranded and abandoned nestlings following drying up of the water body. Understanding of the relative contribution of different drainage tributaries to the pan was obtained by studying successive wet season images. In addition, earlier research had shown that the elephants used the western areas of streams at critical times of the annual cycle: park management wanted the capability to monitor their flood status remotely (i.e. when local ground access was impossible). In addition ecological studies near the mouth of the Cunene benefited from NOAA imagery showing the asymmetrical influence of flood waters on the estuary and adjacent coastal zone.

4.6 Dust/anthrax spore dispersal demonstration

Procedures were developed for the utilisation of LARST images at the Etosha Ecological Institute for analysing the spread of dust clouds blown from the pan during the dry season. This application has potentially important implications for research into dust-borne diseases such as Anthrax, prevalent in Etosha. Park management used such imagery to show the trajectory of dust (and hence anthrax spore dispersal) from the pan over adjacent areas, indicating clearly priority areas where controls on (e.g.) cattle raising need be maintained.

4.7 Development of management GIS

To assist with the archival and long-term storage of NOAA satellite imagery received by the local receiving station at Etosha, an archive system was investigated that would be sustainable and easy to use at EEI. Within the available resources, the recommended option of Magneto Optical drive storage was chosen and installed at EEI, training being given on its use and on optimum approaches to archiving these data.

Following the success of the installation and training given on relatively simple PC mapping software (MapViewer), and the enthusiastic response from EEI and Etosha National Park management, a full GIS system (using Atlas GIS software) was selected and installed at Etosha Ecological Institute. Following installation, on the job-training was provided by NRI an staff member for the APO stationed at EEI to enable the development of a park information system and subsequent transfer of operations to EEI researchers and managers.

Response from local management to the GIS resulted in the development of a number of integrated GIS / database related projects of importance to the management of the park and its wildlife resources.

Applications included:

- Analysis of animal distribution and movements in relation to the quality and availability of water and vegetation.
- Fire risk analysis.
- Support for anti-poaching activities.

- A system of the retrieval and manipulation of map and satellite data.
- Spatial analysis of animal mortalities.

Annex 1 includes a series of Figures illustrating the outputs from the GIS system (from Slade 1996). These clearly indicates the broad scope of EEI and park management activities incorporated in the GIS by the time of this report in mid 1996.

Methods for utilising the capabilities of the Global Positioning System (GPS) in creating and updating maps of the national park's infrastructure were developed and techniques transferred to local management. Data recorded by a vehicle-based GPS unit were incorporated in maps of the park created using the GIS system. Information included tourist roads, different categories of tracks, and firebreaks. Figure 4 shows an example which includes an overview of the whole park where most of the geographic data was recorded using the GPS system. A system for displaying management related maps, with information content changing according to season and local circumstances was used by the management of the park (for example tourist roads). The same system was subsequently used by national park management elsewhere in Namibia for creating and updating maps of other protected areas. An example showing the transfer of this technique to other areas is shown by Figure 8 in Annex 1.

In addition to the above, technical support was provided for the APO stationed at Etosha Ecological Institute (related TC project T0418), and for the LARST satellite receiving system installed at Etosha (installed through a direct grant from British High Commission, Windhoek).

4.8 Prototype training workbook to help with transfer of techniques to other similar areas:

A draft GIS and remote sensing workbook was produced, aimed at training developing country staff working within the wildlife sphere. This workbook also has considerable application for other projects, particularly rangeland development, as well as a general source of applications oriented training material for more general GIS training.

The workbook (See Annex 2) presents and takes the user through a series of self-guided examples that can be used with easily available and implemented GIS and image analysis software, Idrisi, and the public domain remote sensing package IDA, widely used in Africa. Exercises included: Mapping wildlife species distribution and numbers; Analysing human settlements and distribution; Modelling and quantifying human-wildlife interactions, including the use of supply and demand models; Risk assessment and management priorities; Use of high resolution satellite imagery to map habitats; NOAA AVHRR data (from the LARST system) and fire risk assessment; Fire detection; Park zoning and planning; and Wildlife tracking. Examples and data were taken from real problems and situations within wildlife areas in Tanzania, Zambia, Namibia and Botswana. The Idrisi development group at Clark University have shown interest in using this workbook as part of a series of Idrisi workbooks.

5. Contribution of Outputs

The outputs contribute towards ODA's development goals by providing the generic basis and background for a management information system that can be installed and operated at a local scale at a large number of sites. These are not limited to wildlife and protected area applications, but due to the normally limited access that such sites have to other direct, real-time sources of information, the GIS and remote sensing information system developed is particularly suited for application in a wildlife context. At the end of the project, EEI have a much better understanding of park dynamics at the whole resource scale, which is very difficult and slow to obtain other than through the use of locally received satellite data. EEI now have ways of monitoring seasonal and spatial variability in real time over the whole of the park and its environs, enabling it to assess the implications for timely management response. They are much more capable of responding to fire management problems, both physically and legally, and have a better grip on the hydrological relations so important for integrated park management in such a dry area.

The broad utility of system outputs and wide area coverage of the NOAA system enabled EEI staff to be more confident in taking on the wider mandate of watchdog and advisory body responsible for overseeing environment and development of the whole of northern Namibia. Knowing that they could monitor the whole area remotely, and make best use of well targeted confirmatory field visits, allows the decision makers to have a better overall feel for the integrated resource in its wider context, and respond accordingly. This enables protection and improved management objectives of adjacent areas to be fully incorporated into priorities and work programmes rather than 'added on' as an afterthought.

Sustainability: The NOAA satellite data is available free of charge through direct reception. PC based receivers cost around £15-20 000. The larger the areas served or the higher the value of the resource that is monitored, and the greater the number of applications serviced by satellite applications, the more easy it is to justify the investment and manpower required to maintain the NOAA receiver system (e.g. at EEI: one person quarter time) in operation and data flowing. Considering the combined value derived from the combination of park management GIS with regular access to up-to-date NOAA data, it seems likely that these standard techniques will soon be indispensable tools for cost- effective protected area management. At EEI, the position of GIS and Remote Sensing officer has recently been confirmed as an official post recognised by the Ministry, clearly demonstrating the committment of the Namibian authorities to these systems, as well as the sustainability of LARST systems and the approach in general.

No further specific market studies need to be carried out in relation to LARST systems installed in a national park setting in southern Africa, the Etosha situation being considered representative of a wide range of southern African situations. However, different conditions and skill levels applicable elsewhere in Africa, as well as in other institutional settings in southern Africa, are likely to require further work centred on adapting techniques for information management and dissemination before the approach can be adopted over a majority of the arid to semi arid protected areas and rangelands in Africa.

Outputs will be made available to national park management through the continued development of the LARST system as a whole, and through the further development of the GIS and Remote Sensing workbook which is intended as an aid to training in these approaches using an-on-the-job approach. Funding is being sought in order to publish this workbook. The ARGOS animal tracking system, and specifically its use at LARST sites will form an important resource for wildlife (and rangeland) managers. Further funding is being sought to complete the development of the Windows-based tracking software, and also to test the system as a component of an integrated wildlife management system.

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ACRONYMS

Argos	A satellite based locational system onboard the NOAA series of satellites
APO	Associate Professional Officer
AVHRR	Advanced Very High Resolution Radiometer (referring to temporal rather than spatial resolution). This instrument is carried onboard the NOAA series of polar orbiting satellites.
BURS	Bradford University Remote Sensing Ltd.
EEI	Etosha Ecological Institute
ENP	Etosha National Park
GIS	Geographic Information System
GPS	Global Positioning System
LARST	Local Application of Remote Sensing Techniques
NDVI	Normalised Difference Vegetation Index
NOAA	National Oceanic and Atmospheric Administration
NRI	Natural Resources Institute
PTT	Platform Transmitter Terminals
TC	Technical Co-operation

Table 1 Etosha Ecological Institute: Operational Priorities for GIS and Remote Sensing.

Overall objective: GIS development for multipurpose, long-term park management and research, to help ensure effective uptake of research results into operational practice. Within this goal, the requirements identified below represent EEI perceived needs for monitoring tools, with the highest priorities at the top. The project worked to develop appropriate satellite tools to assist as many of these targets as possible, which EEI staff tested.

Bilateral TC	Africa Regional	Adaptive Research	Strategic Research
Satellite animal tracking	Multiple animal tracking, linked to other projects and countries, esp. Botswana, Zambia, Angola. Operational software integrated with GIS.	ARGOS animal tracking capability: e.g. elephant / human conflict, rainfall vegetation stimulus. Portable ARGOS receiver system.	Small ARGOS transmitters for birds (e.g. flamingo) and small mammals (SMRI link).
Land use and land use change mapping: Vegetation using Landsat and time series of NOAA		Fire: fire hazard potential, fire occurrence, frequency and after effects. Burnt areas. Animal movements.	
	Operational software enabling integration of NDVI information with animal movements etc.	NDVI - biomass estimation link with plains ungulate project. Quantity of biomass varying through season/site/soil.	Low value NDVI: what does it all mean? How reliable for dry season discrimination? Nutrient cycling and range biomass quality.
Rainfall monitoring water body size, hydrology. Effects of light rains on vegetation and animals.	Operational software. Rainfall related to animal movements	Wetland: Etosha flood detection in western river valleys. Effect on animals and ecology. (Link with Water Affairs)	Rainfall: topographic trigger effects and local variation in quantity.
Topographic drainage survey and GIS and GPS installations.		Soil moisture estimation. Mapping soil effects detected by Germans. Long term monitoring of specific sites.	Micromet: dust, aerosol, mist, offshore mapping of temperature, gradients relating to vegetation and to pathogens (Anthrax etc.) occurrence.

Figure 1

ARGOS tracking software: Screen illustrating the tracking system in operation. tracking observations received by the satellite are seen in the smaller window. These data are used in the local calculations of Latitude/Longitude of the transmitter, much reducing the running costs on data telemetered from ARGOS Toulouse.

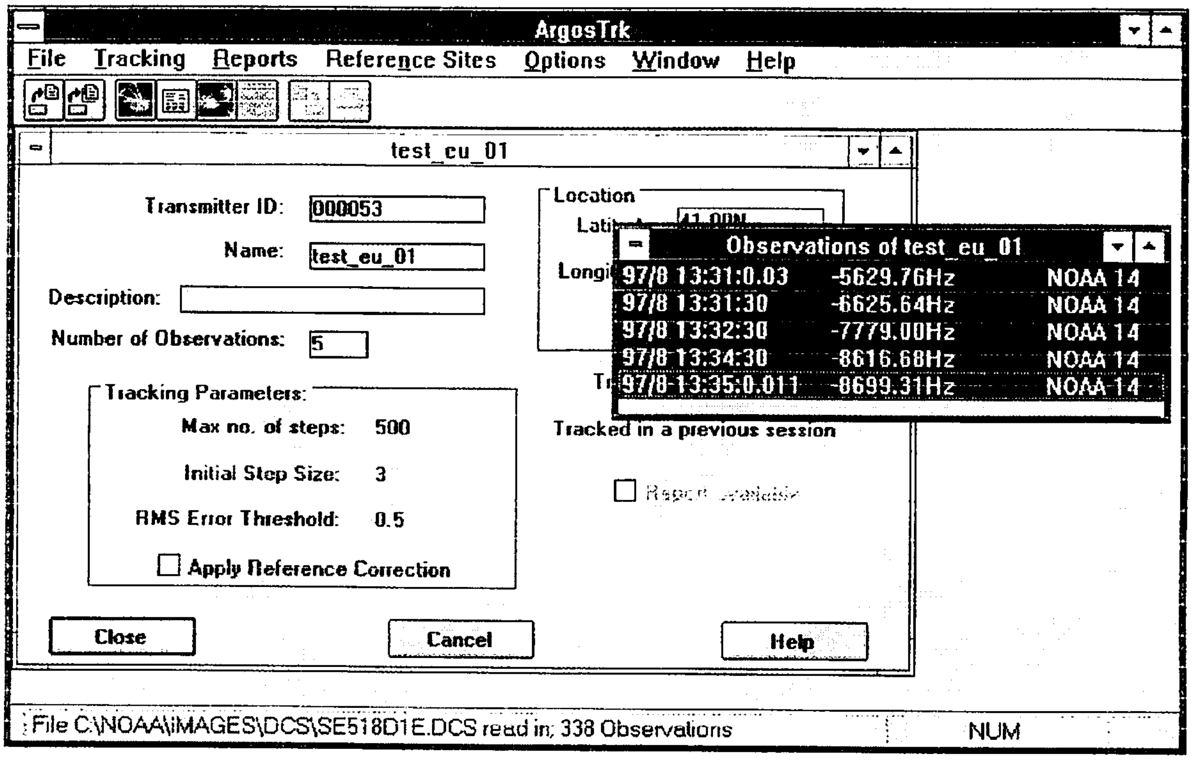


Figure 2. Schematic representation of a model for assessing the potential fire risk. This model was tested and adapted for use in Etosha National Park, Namibia.

Figure 3. Vegetation Index (NDVI) image and derived vegetation status map of Etosha National Park, 27 March 1995. **The upper image** shows the normalised difference vegetation index data for ENP from NOAA data received on 27 March. (NDVI= difference between NOAA channel 2 and channel 1 values, normalised by dividing by the sum of the two channel values: it is proportional to active chlorophyll in leaves as viewed from above) The bare major and minor pans can be seen (brown) as well as areas of greater (dark green) and lesser (yellow) active vegetation. **The lower image** shows how the park vegetation varies from the conditions normally expected during the last decad in March. Purple and red areas, particularly the west and extreme south-east are in fine condition with above average vegetation quality: other areas (brown and yellow) are below average. This situation is fairly typical of wet season variability and emphasises the difficulty of sub-sampling, and importance of whole resource monitoring. The research project identified the need for the status map (lower) approach from the difficulty EEI staff had in using the straight NDVI (upper image) for assessing park status, and arranged for this issue to be addressed through a generic methodology developed by the Africa Regional Project.

Figure 2.

Schematic representation of a model for assessing the potential fire risk. This model was tested and adapted for use in Etosha National Park, Namibia.

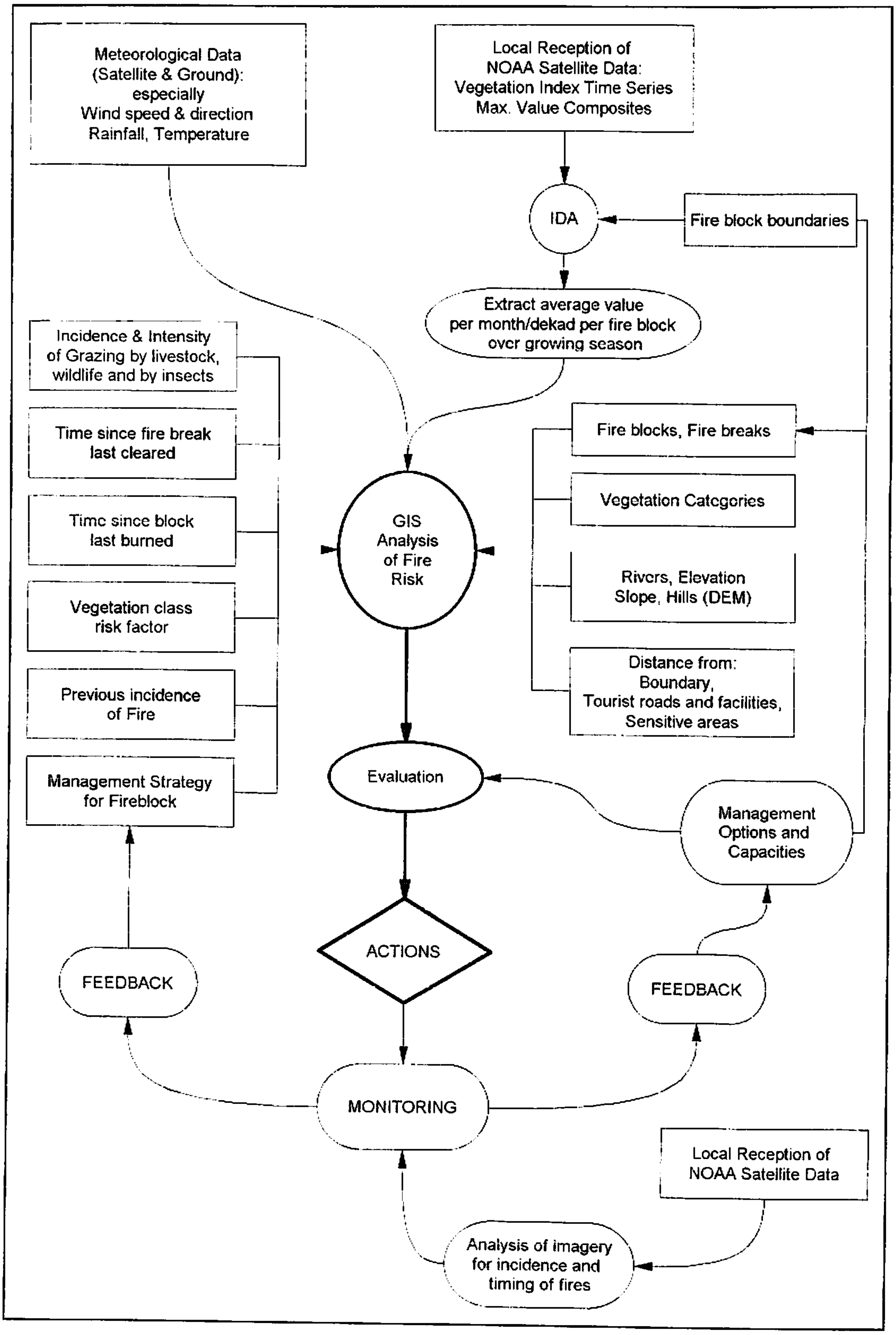


Figure 3. Vegetation Index (NDVI) image and derived vegetation status map of Etosha, 27 March 1995

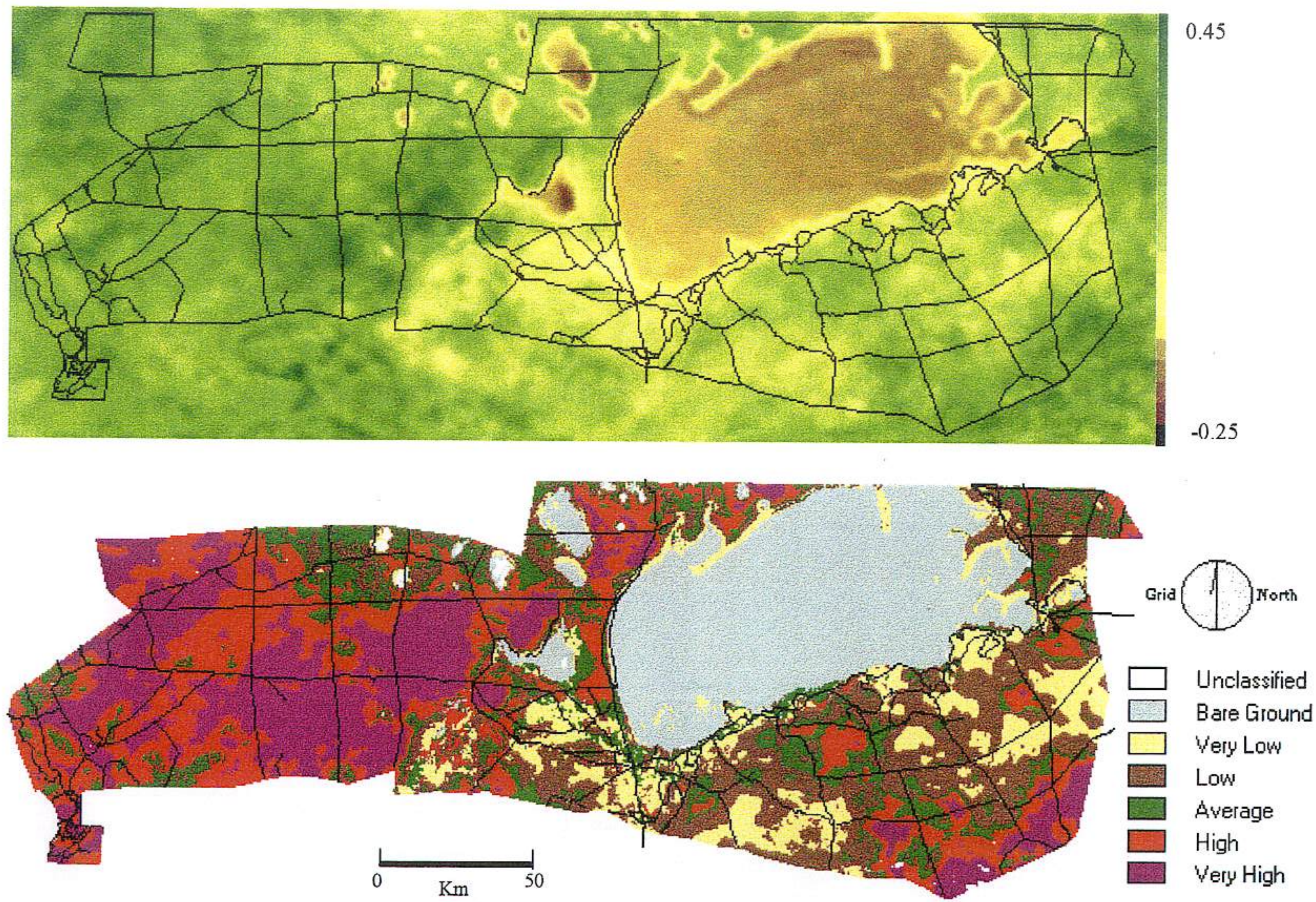
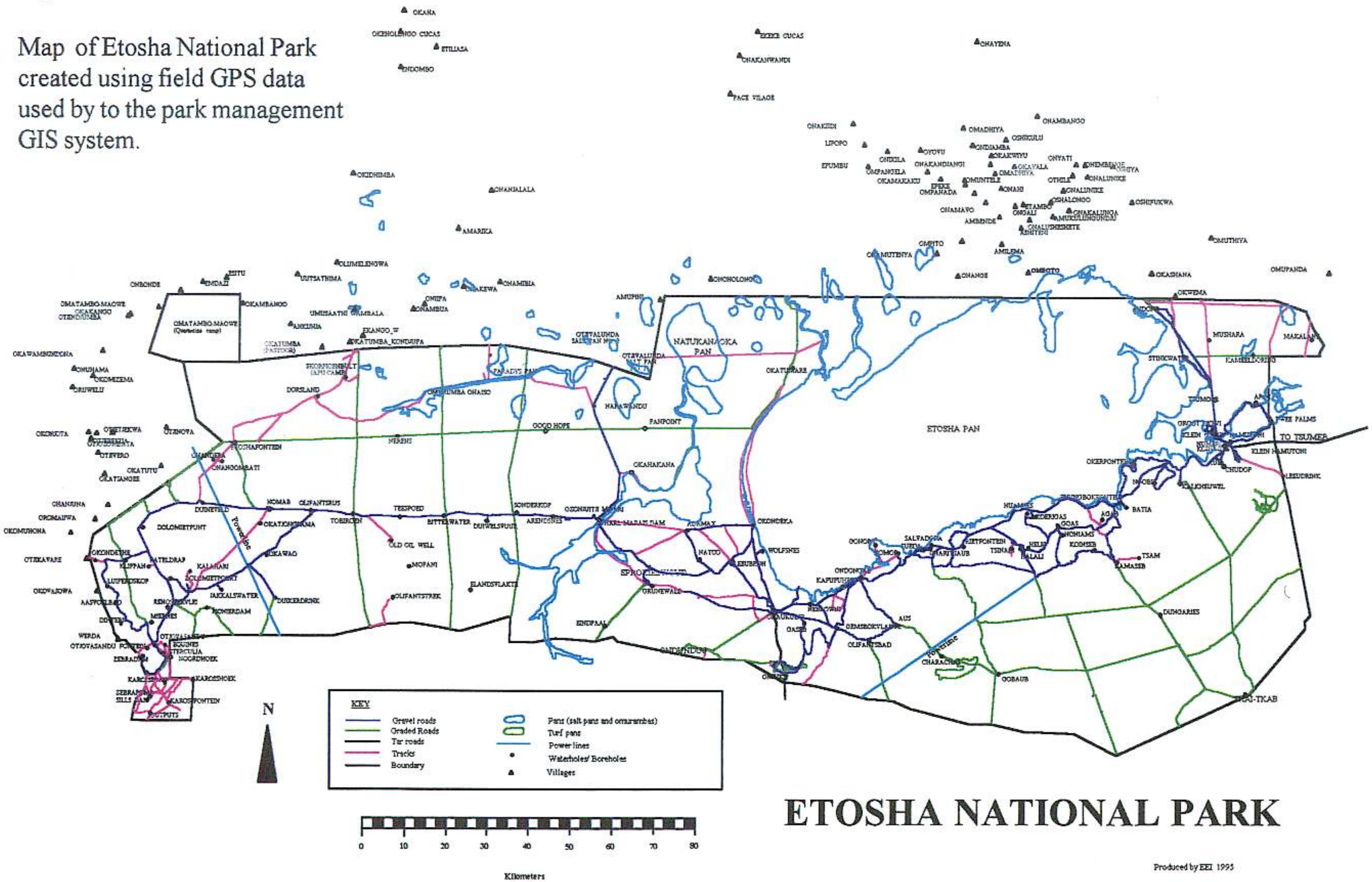


Figure 4.

Map of Etosha National Park created using field GPS data used by to the park management GIS system.



Application of Remote Sensing and GIS for Monitoring Vegetation in Etosha National Park

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ABSTRACT

The monitoring of vegetation in Etosha National Park, Namibia, is essential if the interactions between the wildlife population, the possibility of climate change, and the vegetation resources, are to be understood. Such an understanding is necessary for establishing management strategies to ensure that the Park is sustainable as an important unit for the conservation of wildlife and for tourism. This study aims to produce maps of vegetation status in near real time from NOAA images acquired from the local LARST receiving station. In order to assess vegetation status, map products based on the NDVI need to be put into historical context and stratified to remove the effects of the different vegetation types. A classification scheme for the Etosha vegetation, based mainly on the dominant species composition and the physiognomy of the woody component, has been designed. A combination of field measurements and analysis of Landsat TM imagery has provided a stratification of the Park. Historical data were extracted from the ARTEMIS NDVI GAC archive and processed to obtain, in combination with the stratification, standard NDVI profiles for each of the main types of vegetation. These are related to the LAC NDVI data obtained in real time from the receiving station to derive a vegetation status map for each 10-day period.

BACKGROUND

The monitoring of vegetation in the 22 300 km^2 Etosha National Park, Namibia, is essential if the interactions between the wildlife population, the possibility of climate change, and the vegetation resources, are to be understood. Such an understanding is necessary for establishing management strategies whch ensure that the Park is sustainable as an important unit for the conservation of wildlife and for tourism.

Relating vegetation conditions to rainfall is one way of monitoring vegetation. However, the climate in Etosha is semi-arid with a highly variable, temporal and spatial distribution of rainfall, and the existing network of rain gauges is not dense enough to allow for this approach. Satellite images provide complete coverage of the Park from which map products can be derived.

A receiving station was installed in Etosha Ecological Institute by the LARST project (Williams and Rosenberg, 1993) to acquire NOAA-AVHRR images. These are usually processed to produce maps showing the spatial variation in terms of the NDVI (Normalized Difference Vegetation Index) which is related to the vegetation greeness. However, NDVI images are not easily interpretable by users. The objective of this study is to derive a product which overcomes this problem.

NDVI TIME RESPONSE OF DIFFERENT VEGETATION TYPES

NDVI image maps are difficult to interpret, firstly, because an explicit relationship between NDVI and vegetation condition is not available and secondly, because there may be different relationships for each vegetation type.

The FAO-ARTEMIS (Africa Real Time Environmental Monitoring Information System) NOAA AVHRR NDVI image bank was used to investigate the influence of vegetation type on the NDVI. The data consist of an archive of GAC (Global Area Coverage) 10-day maximum value composite images at 7.6 km resolution covering the whole of the African continent from August 1981 to June 1991.

Figure 1 shows the 10 year averaged values of NDVI for each 10-day period over the season for some locations in Etosha with different known cover types. The NDVI over High Tree Savanna is systematically higher than that for Shrub Savanna, which is systematically higher than that for Grassland. This established the need to stratify the Park into the main vegetation types.

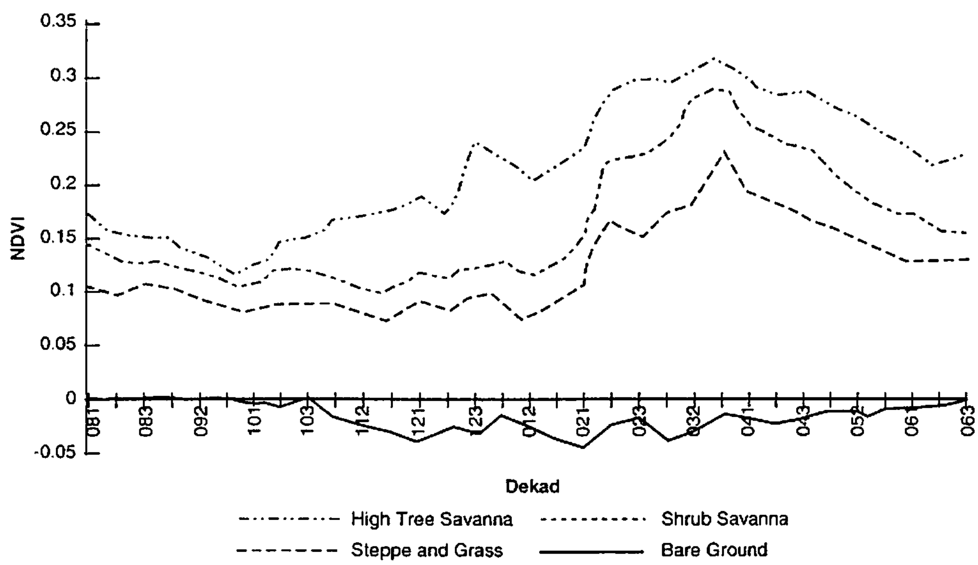

Figure 1. Average profile of four land cover types from the ARTEMIS archive

CLASSIFICATION OF ETOSHA NATIONAL PARK FOR STRATIFICATION INTO THE MAIN VEGETATION TYPES

A classification scheme was developed following the philosophy described by Boughey (1957). It was adapted to the semi-arid conditions of Etosha and was based primarily on physiognomic characteristics of the woody vegetation component. Figure 2 shows the decision tree which was produced to assist the field data collection. The dominant tree species were also recorded.

There was a need for an unbiased method of collecting field data to enable classification errors to be measured objectively. This was adapted from that described by Taylor and Eva (1992). The vegetation types were mapped in a randomly aligned systematic sample of 1 km square areas. In all, 220 sites were selected over the whole Park but only 173 of them were surveyed because 47 were situated on the salt pan where the cover was known.

Survey documents were produced to assist the field mapping. Landsat TM imagery was geometrically corrected, with an RMS error better than 30 m, using the UTM (Universal Transverse Mercator) projection. This allowed the whole Park to be covered with a single co-ordinate system which was also available on most GPS (Global Positioning System) receivers. All the 173 sites were surveyed by air, navigating by the GPS. A video recording of each site was made to facilitate checking. Some sites were also surveyed on the ground in order to calibrate and check the interpretation from the air.

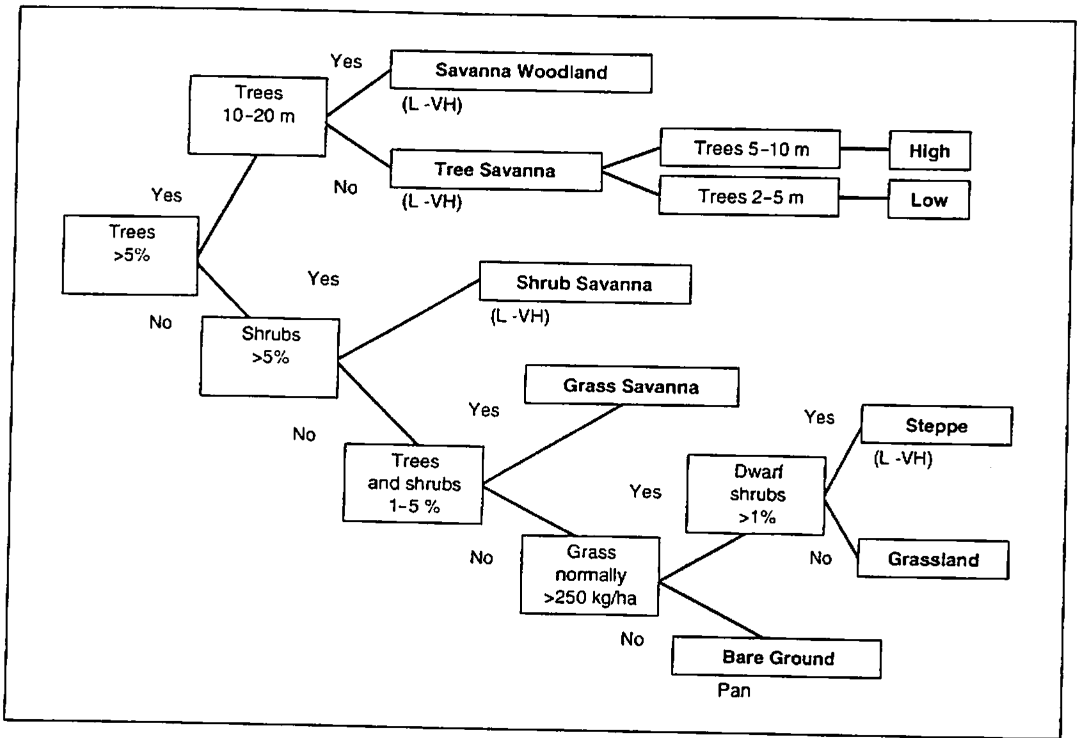

Figure 2. Decision tree for identification of Etosha vegetation classes

The data collected were entered into a database and a sub-set was used to train the maximum likelihood classifier. The supervised classification was performed using 33 classes grouped into four categories: bare ground (pan), grassland (and steppe), shrub savanna and tree savanna. For these broad classes, the overall agreement of the vegetation map with ground observations was estimated to be 89%.

TIME SERIES ANALYSIS OF NDVI FOR STATUS CRITERIA

The vegetation classification of Etosha allows the time-series NDVI profiles to be extracted for each vegetation type.

The probability distribution of the NDVI was calculated for each 10-day period during the growing season. This was achieved by applying a methodology similar to that used for assessing the probability of extreme hydrological events (Linsley *et al.*, 1975). The analysis was used to define quintile ranges of NDVI for each vegetation class and each 10-day period. Five classes were chosen as defined in Table 1. Figure 3 shows the flow chart corresponding to the described processes.

Table 1. Definition of vegetation status classes

Probability of a lower NDVI (%)	Vegetation status
<20	Very poor
20 to 39	Poor
40 to 59	Normal
60 to 79	Good
≥80	Very good

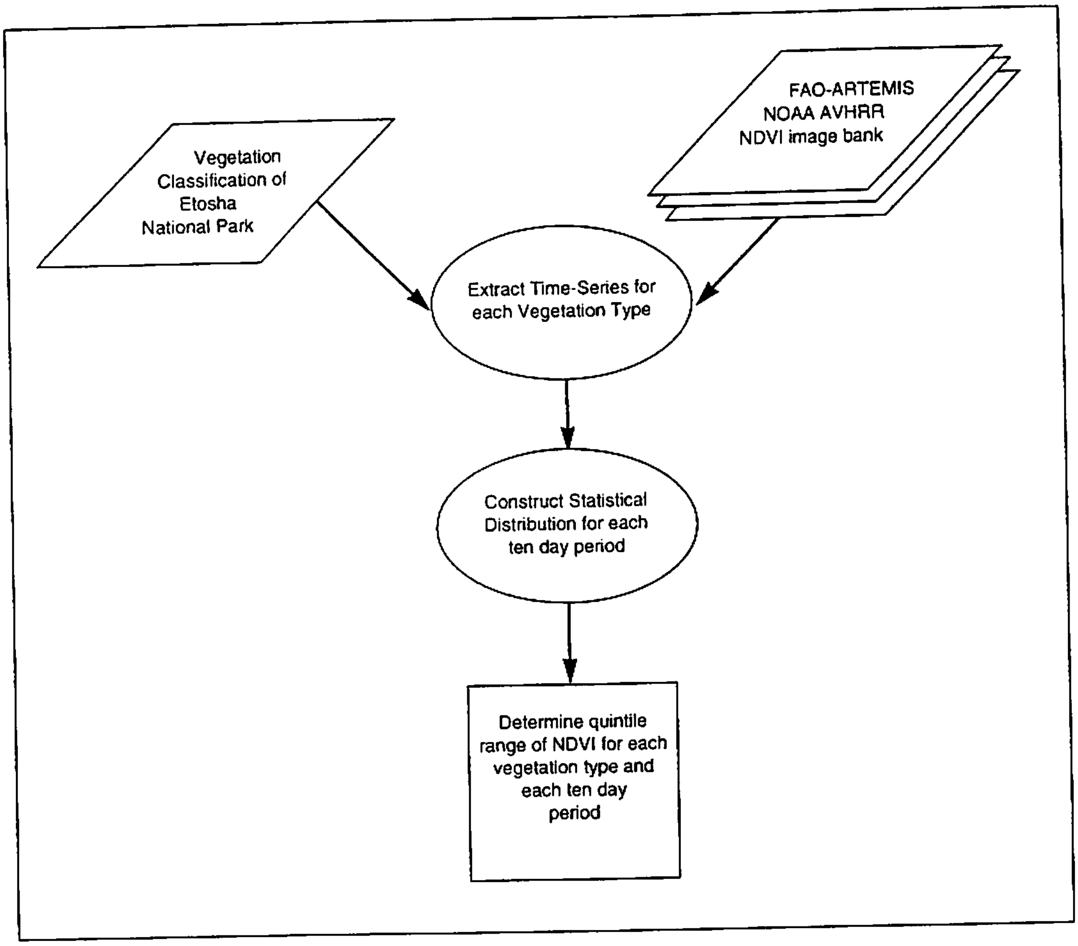

Figure 3. Time series analysis of NDVI for status criteria

PRODUCTION OF STATUS MAPS FOR CURRENT IMAGES

A number of NOAA-AVHRR LAC images acquired at the local receiving station in Etosha National Park during the last rainy season were used. The images were geo-referenced to the vegetation map of the Park. Final RMS errors were between 0.5 and 0.9 pixel. The LAC images were resampled using cubic convolution and a 500 m output pixel size. This was to preserve maximum spatial detail.

The AVHRR channels 1 and 2 were radiometrically corrected using the method described by Kaufman and Holben (1993). NDVI images were computed, and a further correction was applied to remove atmospheric noise by using part of the Etosha pan as a standard target. The same correction was also applied to the ARTEMIS data so that NDVI values computed from each source were compatible.

The status maps were produced as illustrated in Figure 4. The vegetation type of the LAC pixel was determined by reference to the vegetation map. The NDVI value at that location was then compared with the status criteria for the vegetation type at that time and assigned to the appropriate status class. This process was repeated for the whole image, producing the vegetation status map for the period considered.

CONCLUSIONS AND FURTHER DEVELOPMENTS

This study is still on-going but some useful conclusions can already be drawn:

- a cost-effective methodology for vegetation mapping in Africa, using satellite imagery and a statistically designed field survey for calibration and validation, has been demonstrated;
- as the vegetation status maps could be produced using data collected from the low-cost LARST receiving stations and the FAO-ARTEMIS archive, the methodology is potentially applicable to other countries in Africa.

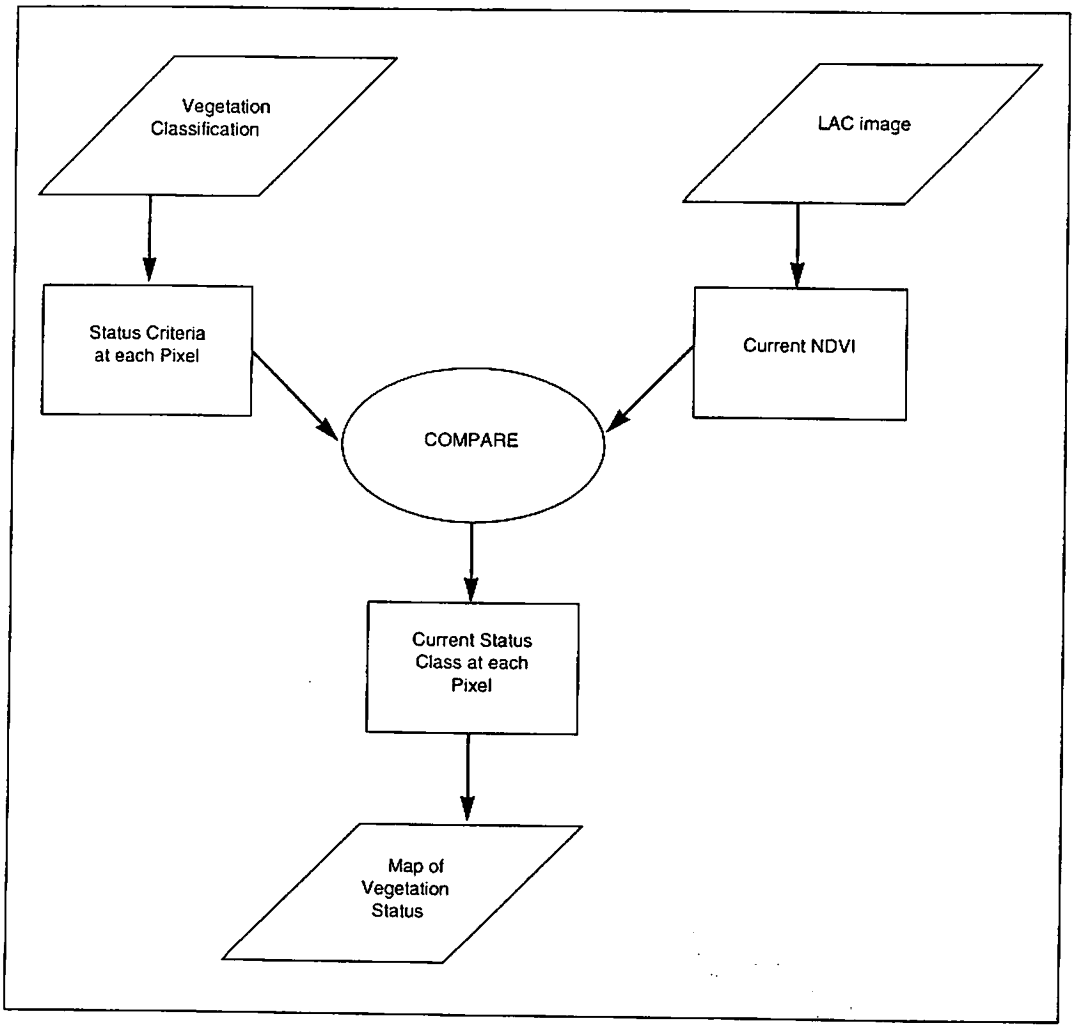

Figure 4. Production of status maps

The status maps from the 1995 rainy season appear to relate very well to the actual conditions on the ground. However, there is a need for a more formal assessment of the status maps, for which work is on-going. A similar product is being developed, based on the cumulative NDVI, which will assess the vegetation conditions for a whole season. The methodology will be tested operationally in the next rainy season at the Etosha Ecological Institute.

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Annex 1

Overseas Development Administration
Associate Professional Officers Scheme (APOS)

2nd Quarterly Progress Report / End of 6 Month Placement Report
May - July 12 1996
Glenn Slade, APO, Etosha Ecological Institute, Namibia.

Project

Support to Etosha Ecological Institute (T0418). Posting Etosha Ecological Institute (EEI), Okaukuejo, Namibia.

1. Overall Objective

The overall objective of this post is to develop the Park Environment Research and Management Information System (PERMIS) to provide a common link between researchers, park managers and those interested in the park margins and the wider environmental and social context.

2. Summary

The PERMIS is now in an advanced state of development and forms an integral part of research work at the Institute. Training has been a high priority this quarter and most research staff are now competent at the transferral of data into the GIS and the production of maps and images. The Geographical Information System (GIS) been enthusiastically adopted by staff. The project has made a significant contribution to the capacity and capability at Etosha Ecological Institute for the storage, display and dissemination of information and the analysis of research data. As a direct result of the increased capability that the PERMIS has established, the Etosha Ecological Institute has produced its first seasonal report. The report makes extensive use of the GIS to communicate research results and provides a common focus for ongoing work in research and management.

A large volume of data has been integrated into the GIS and is being used to produce data layers and maps for the developing GIS applications. Four GIS applications are well advanced and are producing a wide variety of outputs and data analysis. The Anti Poaching application is still in an early stage due to data not yet becoming available.

Further assistance is required at Etosha to complete the GIS application development and continue training thus helping the Institute to reach the full research potential of the system. In particular the use of GIS for analysis and modelling is an area in which EEI would benefit greatly from further support. Specific objectives for future work required to complete the development of the GIS applications are included in Annex B.

My placement at Etosha finishes on the 12 July and I will be moving to take up a new 6 month placement in Botswana at the Meteorological Services Department. This placement will develop remote sensing and GIS capabilities for Early Warning System and Rangeland Monitoring applications. Diane Davies is due to arrive at EEI on 10 July to take up a position on the Northern Namibia Project.

3.0 Project Achievements this Quarter

The principal achievements which relate to the project objectives (outlined in the terms of reference for the placement, Annex A) are presented in the following sections.

3.1 Data Capture

At the beginning of the APO placement in February 1996 a Data Capture Plan (DCP) was produced which assessed the types of data available for integration into the GIS and gave an approximate timetable for transferral into the GIS (Forward Work Plan Feb.-July 1996). A report on the current status of progress in data capture is given in Annex B. The status report details the actions completed and outputs achieved for the data sources identified in the DCP and also includes additional data capture not outlined in the original DCP.

The majority of targets set in the DCP have been met or exceeded. A large volume of data on aspects as diverse as water quality, lion sightings, mortalities, rainfall, burning, vegetation, animal distribution, tourist predator sightings and location and size of gravel pits has been compiled into databases and integrated into the GIS. The captured data provides data layers for the developing GIS applications and a valuable resource for current and future research at the Institute.

The main area in which data has not become available is the Anti Poaching Unit (APU) data neccessary to develop the APU application. Data capture tasks still to be completed are outlined in the 'actions remaining' column of the data capture status report (Annex B).

3.2 GIS Development

The GIS development has made considerable progress leading to an increased capacity at the Institute for disseminating research and management data, and analysing results. Several of the applications are now fully functional and in routine use by research staff. The progress made in each of the applications is discussed in the sections below.

Application 1: Analysis of animal distribution and movements in relation to the quality and availability of water and vegetation.

The analysis of animal distribution in relation to food availability and water quality is an important research area at the Institute. This application has progressed well during this quarter with new data layers having been added to the GIS and techniques developed for the integration of remote sensing data. Once all information has been collected the application has the potential to analyse 14 layers of research data. It is hoped that results from this study will help to identify reasons for the decline in plains ungulate numbers in the park and provide information on the over or under utilisation of vegetation.

A fully functioning water quality database has been established containing data from chemical analyses and electro-conductivity measurements from 1587 water samples taken at boreholes, waterholes and reservoirs. The Access database has been linked to the corresponding waterholes in Atlas GIS thus providing the capability to display and analyse the changes in water quality over the period 1974 -1996. Maps showing the variation in water quality across the park in relation to yearly changes, seasonal changes and type of water source are now being produced (figure 1). The Water Quality Database now provides an important data layer set in the GIS application with which to compare animal distribution and movements.

Animal distribution data from the 12 month co-ordinated road count study conducted in 1995 has been integrated into Atlas to produce monthly distribution maps for the major plains species. The 2.5 km grid used to record animal counts has also been used to extract statistical information from NOAA AVHRR products and the Landsat TM vegetation classifications. The data is now being combined in Atlas to correlate the distribution and movement of animals with vegetation type and food availability (figure 5).

Rainfall measurements for the entire park are now being integrated into the GIS system. The location of 170 rain gauges have been recorded using the global positioning system (GPS) and rainfall readings from 1983-1996 have been linked to these positions. The data has been interpolated in the surfer software package to produce rainfall isohyet maps for each year and produce average rainfall and comparison to mean rainfall maps.

The completed research database on lion sightings, pride relations and genetic data is now being used for analysing pride ranges, overlapping territories and habitat use. Analysis of vegetation type in pride ranges (figure 2) has provided new information and indicated future requirements for lion research and management.

The techniques established for the integration of mortality records into the GIS have been extended to capture all animal records from staff dataforms and tourist sightings. A grid system for recording location co-ordinates for all of the Institute data has been designed around the original 2.5 km grid used in road count surveys. The grid has been extended across the park and a data base containing the co-ordinates of all the blocks can be used to geo-reference all new data collected by management and research. Maps showing the recorded distribution of all predators and rare species sighted have now been produced.

Application 2: Fire risk analysis

The fireblock monitoring application appears to be fully functioning and will be updated to produce fire risk and burning strategy maps for the 1996 dry season using the 1996 rainfall data just collected.

Rain gauge data collection for the 1996 rainy season has included recording the GPS positions of the rain gauges. Accurate maps of rain gauge location will now allow a refinement of the rainfall data stored for each fireblock and hopefully a refinement of the application to take into account variation in rainfall and vegetation status across fireblocks.

Application 3: Anti Poaching

A poaching data base has been set up which has been designed in order to demonstrate the utility and applicability of GIS techniques for assisting the Anti Poaching Unit in data storage and analysis. At present the data can be employed to examine summary poaching statistics, these include the seasonal variation in poaching between species (figure 3) and the spatial distribution of poaching incidents compared to surrounding villages (figure 4).

Only a limited amount of data has become available for the development of the anti poaching application due to the continued absence of the Head of the Anti Poaching Unit and hence the application remains in the early stages of development. Once a full poaching records database can be completed the application could be developed to include demographic information and poacher questionnaire data and enhance the spatial analysis of poaching incidents and movements of poachers.

Application 4: System for the retrieval and manipulation of map and satellite data.

The GIS has been used to produce inventories and maps of management areas and produce regular vegetation status maps and maximum NDVI composite images for management purposes. Maps have also been supplied for the location of new water supply pipelines.

A 19 page seasonal report has been produced by EEI outlining the research that has been undertaken and the results of data analysis for the 1996 rainy season. The report is intended to keep staff in all the Etosha management areas and in other MET offices informed of current research at EEI. The report, containing 33 Atlas and Idrisi maps, has made extensive use of GIS and demonstrates the extent to which GIS is becoming a routinely used tool by individual staff in their respective research areas.

Management have used the output from the GIS to display the results of the Tourist Predator Sightings Survey in the tourist reception areas. The summary maps of number of sightings in each area give an indication of where predators are most likely to be found and also how visitors are contributing to research work at the Institute (Figure 7). This feedback to the tourists will hopefully encourage more predator forms to be completed and returned thus helping staff to quickly locate predators for research and management requirements.

Application 5: Spatial analysis of mortalities

The mortalities database and GIS application is now fully functional. The 1996 rainy season mortality data has been recently integrated into the GIS and staff now work with the database independently. Analysis of the distribution of diseases, such as anthrax, is ongoing (figure 6) and there is a great potential for further analysis as rainfall data, water quality and soils data becomes available.

3.3 Environmental Monitoring

Environmental monitoring work has concentrated on the development of methodologies for the integration of remote sensing data into the GIS applications. The transfer of raster data into the vector based Atlas GIS system has been achieved by the extraction of summary and statistical data from vegetation status, fire and NDVI imagery for features defined in the vector system. The extraction of fire data from imagery is still problematic and further development of the fire algorithm is needed.

3.4 Training

Training has progressed well and research staff appear to be confident in using both Atlas and Idrisi GIS packages for basic mapping and data presentation. Staff have received training during the development of the GIS applications with at least one researcher or technician working on each application. Training has been given in data storage and database design, query design, integration of data into the GIS, map composition and basic analysis techniques.

3.5 Liaison with other RS/GIS users in Namibia

A visit was made to The National Marine Information and Research Centre (NatMIRC) in Swakopmund to discuss the LARST system and also provide advice on the possible establishment of a GIS capability at the Centre. Notes on the visit were produced giving some suggestions for the future direction of GIS and remote sensing at the centre (Annex C).

Visits to the Weather Bureau and National Remote Sensing Centre (NRSC) were continued. Andre Kooiman is leaving the NRSC in July. Simon Dirkse from the Weather Bureau is currently on a 6 month study leave and in his absence contact should be made with Franz Uirab.

3.6 Additional work

An Atlas GIS map of the Mangetti Game Reserve has been produced (figure 8) which gives an accurate map of the reserve and the villages surrounding the reserve. This base map will now be used for developing a fire risk and burning strategy GIS application similar to the Etosha fire application.

There has been great interest from staff at the Ministry of Environment and Tourism (MET) in establishing a GIS capability at the Head Office. In particular assistance has been given in identifying the correct software and hardware requirements and data base design and MET are now purchasing Atlas GIS software. The major use for the GIS system will be to store and analyse game farm data and provide a decision support system for the issuing of game hunting and trophy hunting concessions and permits.

4.0 Recommendations for future work

Etosha Ecological Institute has adopted GIS as a routinely used tool and the PERMIS has an important role in future research and management plans at the Institute. To fully achieve project objectives and put the PERMIS on a sustainable footing, further assistance is required at Etosha to complete the GIS applications development, continue training and help the Institute reach the maximum potential of the system.

The main tasks that need to be completed for the GIS development are detailed in the data capture status report (Annex B). The 'actions remaining' column gives an indication of the work required to complete data capture and GIS application development. The personnel involved and approximate targets for completion have been suggested after discussions with research staff. Tasks thought to be an immediate priority for the next quarter are highlighted in bold.

The main priority for GIS application development is the anti poaching application. The progress in this area is dependent on data becoming available from various sources. The other GIS applications require further development work in the form of data integration, analysis and modelling. In particular 'the analysis of animal distribution and movements in relation to the quality and availability of water and vegetation' (application 1) needs substantial development of analysis techniques to address some of the complex research questions which are involved with this subject.

Further training is required to allow researchers to use the GIS system to its full potential. In particular there is a need for training in the use of GIS for analysis and modelling. General training would also be valuable to increase understanding of the theoretical basis of GIS and improve problem solving ability.

5.0 General Comments

I would like to thank all the management and research staff and volunteers at the Etosha Ecological Institute for the friendship, hard work, support and enthusiasm that has made my time here so enjoyable. I have gained a great deal of knowledge and experience from working at Etosha and feel that my APOS placement has been very successful and rewarding.

I start my final 6 month placement in Botswana on 19 July 1996. The placement will be as ODA Remote Sensing Specialist on a project providing assistance to the Department of Meteorological Services (DMS), Botswana. The main objectives of the project are to set up and provide training for a LARST system being installed at DMS and develop the capacity and capability to provide an Early Warning System for Botswana.

5.1 Visitors

The following people have visited the project this quarter:

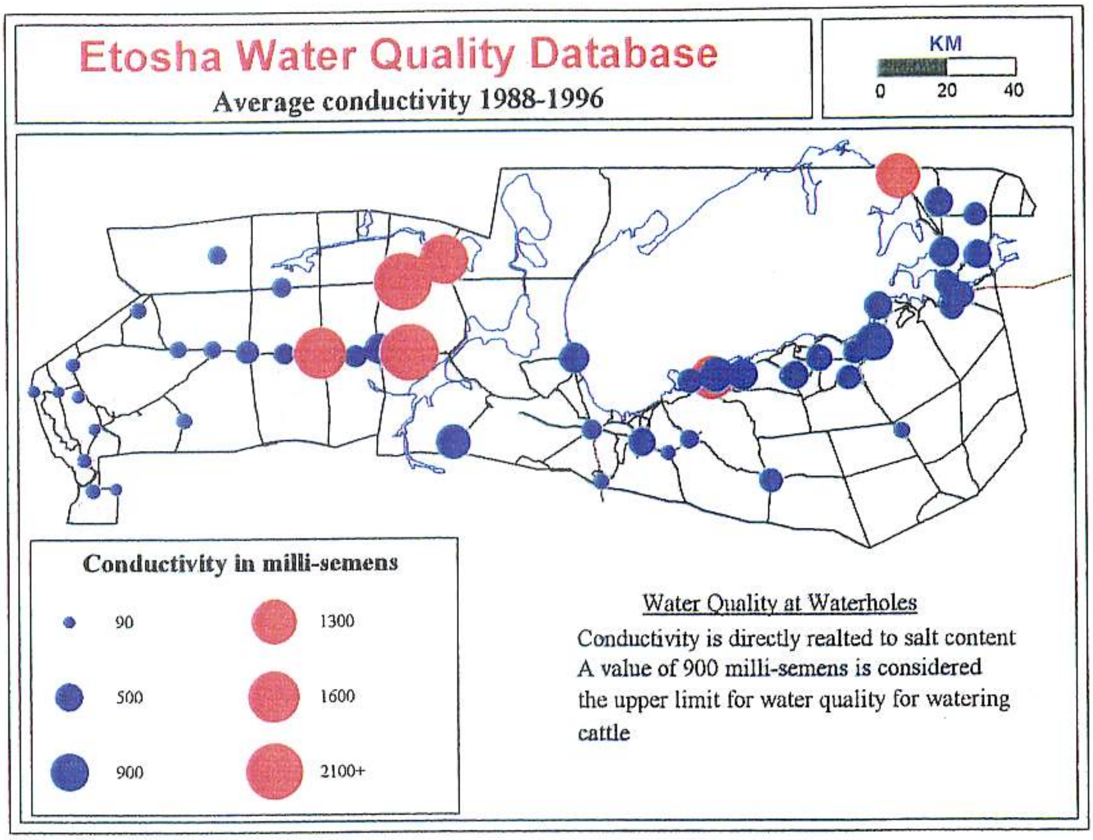
Dr Brian Grimwood	BDDSA	27-29 June
Keith Lindsay, Mike Mason	EDG	22-24 June
Dr Jonathon Cox	Pastoral Development Network	27-28 June
Dr Stuart Green	NRI (Entomologist)	8-9 June
Sandy Davies	APO (Fisheries in WHK)	13-17 June
Dr Roy Behnke	NILIDEP	4 June
Dr Carol Kerven	ODI	4 June

5.2 Accounts and project vehicle

The NRI vehicle account stood at N$ 13,632.69 at the end of May. At the request of Earthwatch N$ 10,724.09 has so far been spent on costs associated with sending an EEI staff member on an Earthwatch expedition to Cameroon. N$ 1068.31 of Earthwatch money remains in the NRI vehicle account.

The project landrover has currently covered 72,000 km and appears to be in good working order and had no detectable problems in a recent full service. A new radio has been installed allowing communication on the new Etosha radio network.

Glenn Slade
APO, Etosha Ecological Institute
July 1996



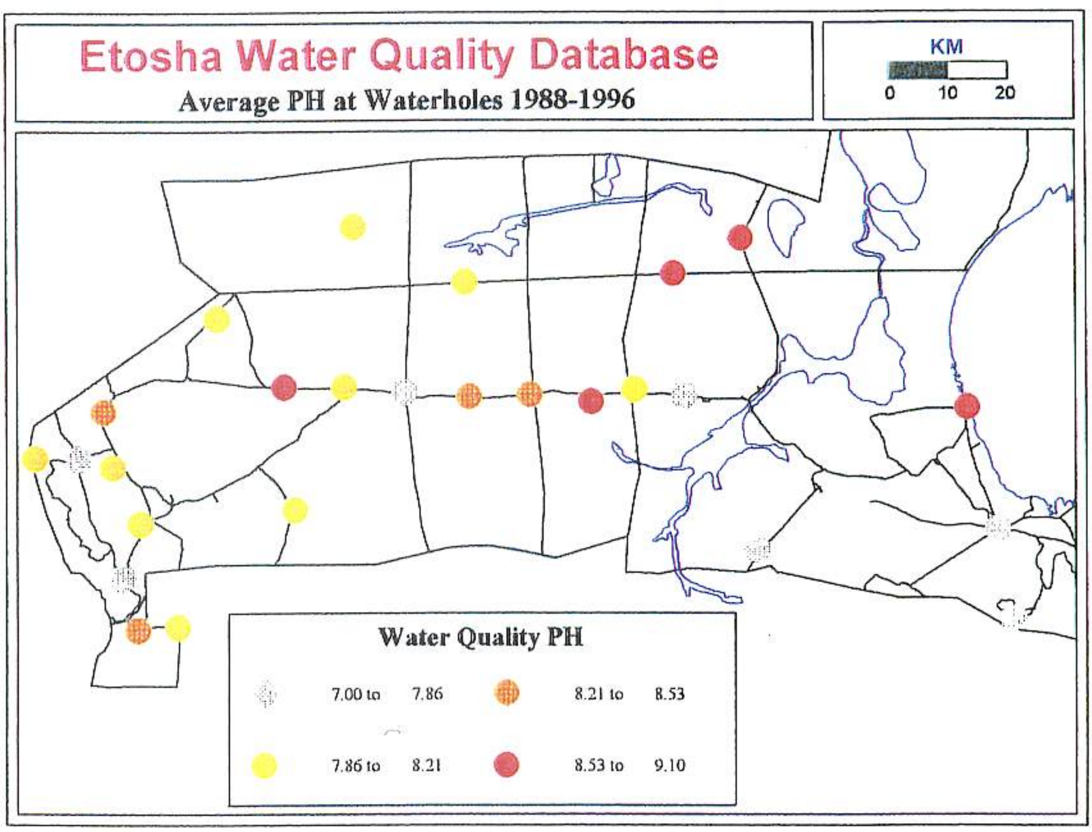
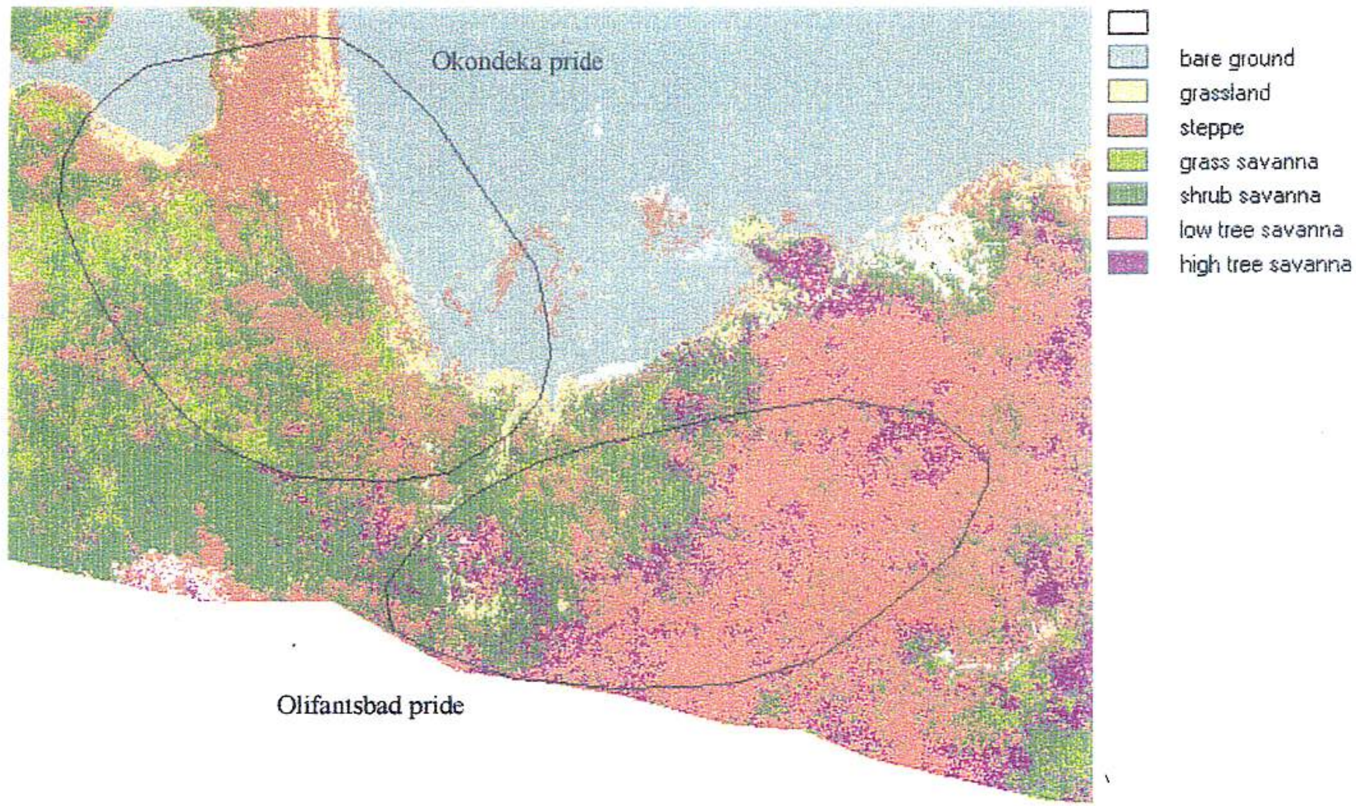


Figure 1. Selection of maps from the Water Quality Database and GIS application. Water quality and chemical analyses have been linked to waterhole positions giving the capability to display and analyse the results of 1578 samples analysed for 30 water qualiy parameters.

Okondeka and Olifantsbad lion pride ranges: analysis of vegetation types



Pride		Grassland	Steppe	Grass Savanna	Shrub Savanna	Low Tree Savanna	High Tree Savanna	Total
Okondeka	**%**	8.86	47.45	12.23	26.37	4.48	0.61	100.00
Olifantsbad	**%**	1.15	4.20	1.51	22.78	56.24	14.12	100.00
Okondeka	**km²**	58.31	312.29	80.49	173.58	29.48	4.05	658.19 km²
Olifantsbad	**km²**	7.86	28.68	10.28	155.42	383.65	96.30	682.19 km²

Figure 2. Analysis of habitat types in two pride ranges using the 7 class vegetation classification derived from TM imagery. Recent movement of the Okondeka pride to the south of its range has resulted in lions in prides to the south being forced onto neighbouring farmland where there is a high risk of being shot or poisoned. The Etosha lion population has declined from 500 to 160 individuals in the last 15 years and the population is under severe threat from losses on farmland. The developing GIS applications are being used to analyse habitat type and prey density movements to try to understand and predict migration of lions out of the park boundaries.

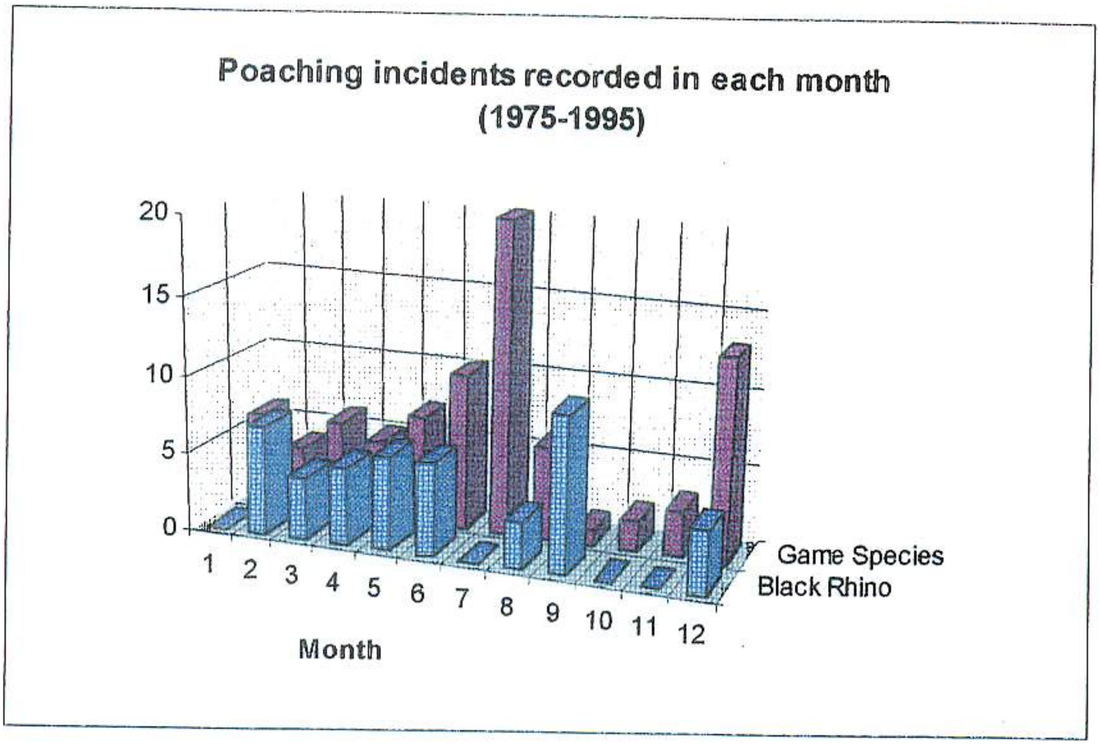


Figure 3. Recorded numbers of black rhino poached in different months compared to game species. Poaching of game corresponds to the traditional hunting season, rhino poaching peaks in September.

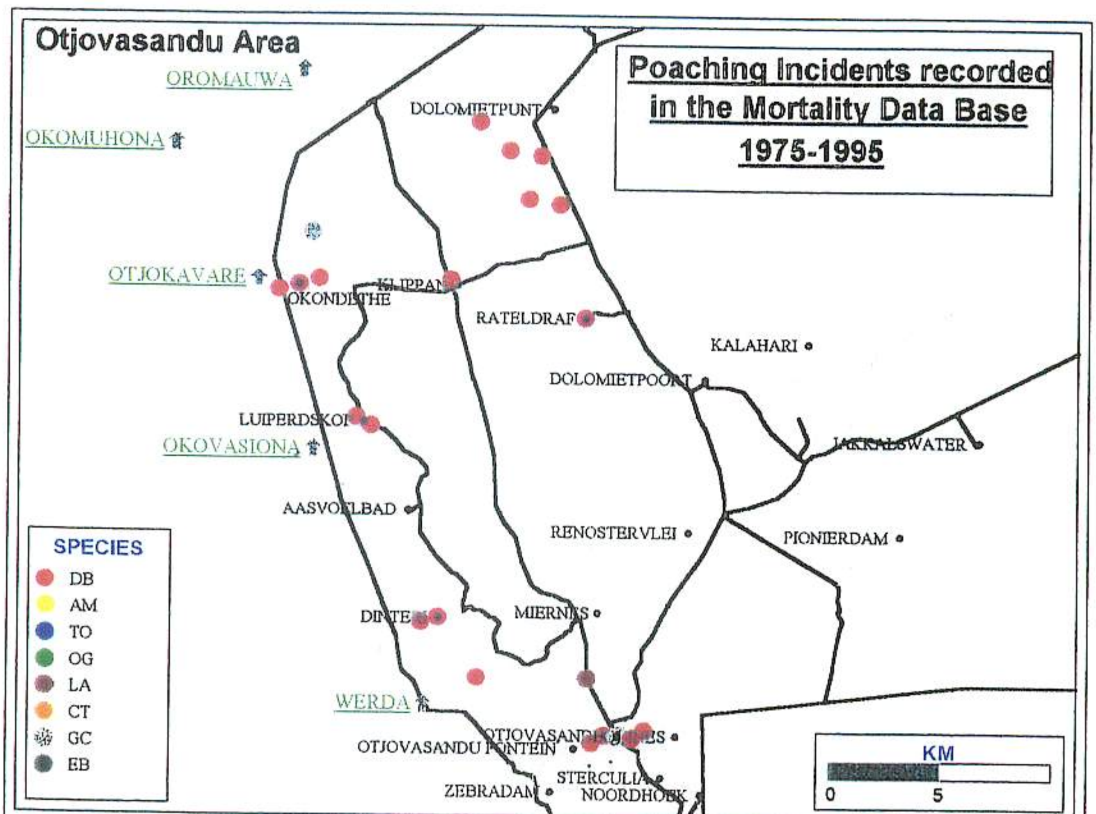


Figure 4. Atlas GIS map of the Otjovasandu (western) area of Etosha showing the high incidence of black rhino poaching incidents (red points - DB). Most poaching incidents are within 5 km of the park boundary and close to waterholes where the poachers can wait for rhino to come to drink or pick up the tracks of a recent visit. Villages bordering the park are labeled in green.

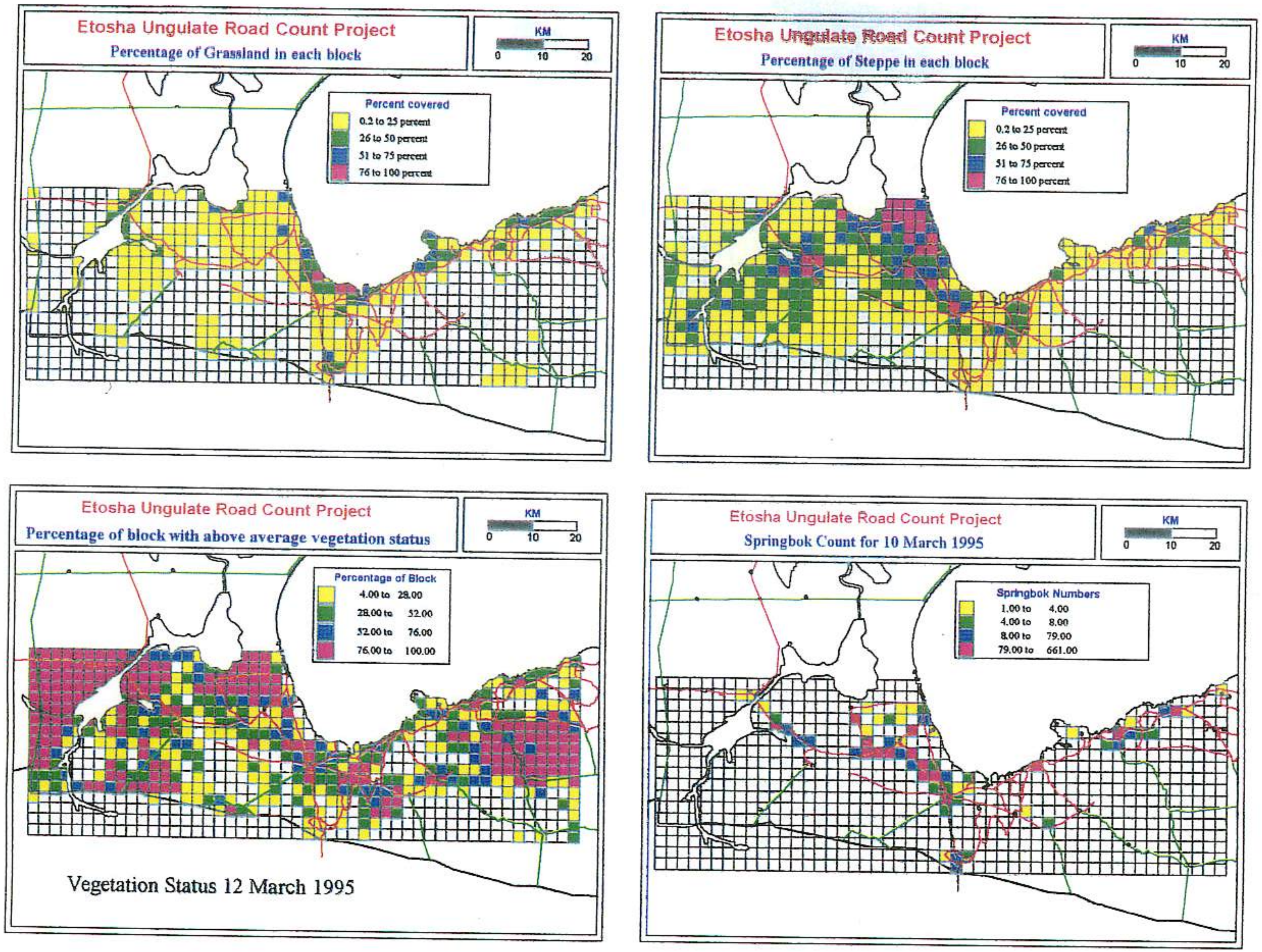


Figure 5. Examples of data contained in the road count data base. Data on the percentage cover of different vegetation types and the vegetation status for a particular period are held for each grid square. This Information from grid squares covered by the road count gives an indication of food type and availability and can be analysed in relation to the numbers and movements of ungulates for that period. The application will provide information on over and under utilised areas and will also provide an opportunity to analyse the effect of water availability and quality on animal distribution.

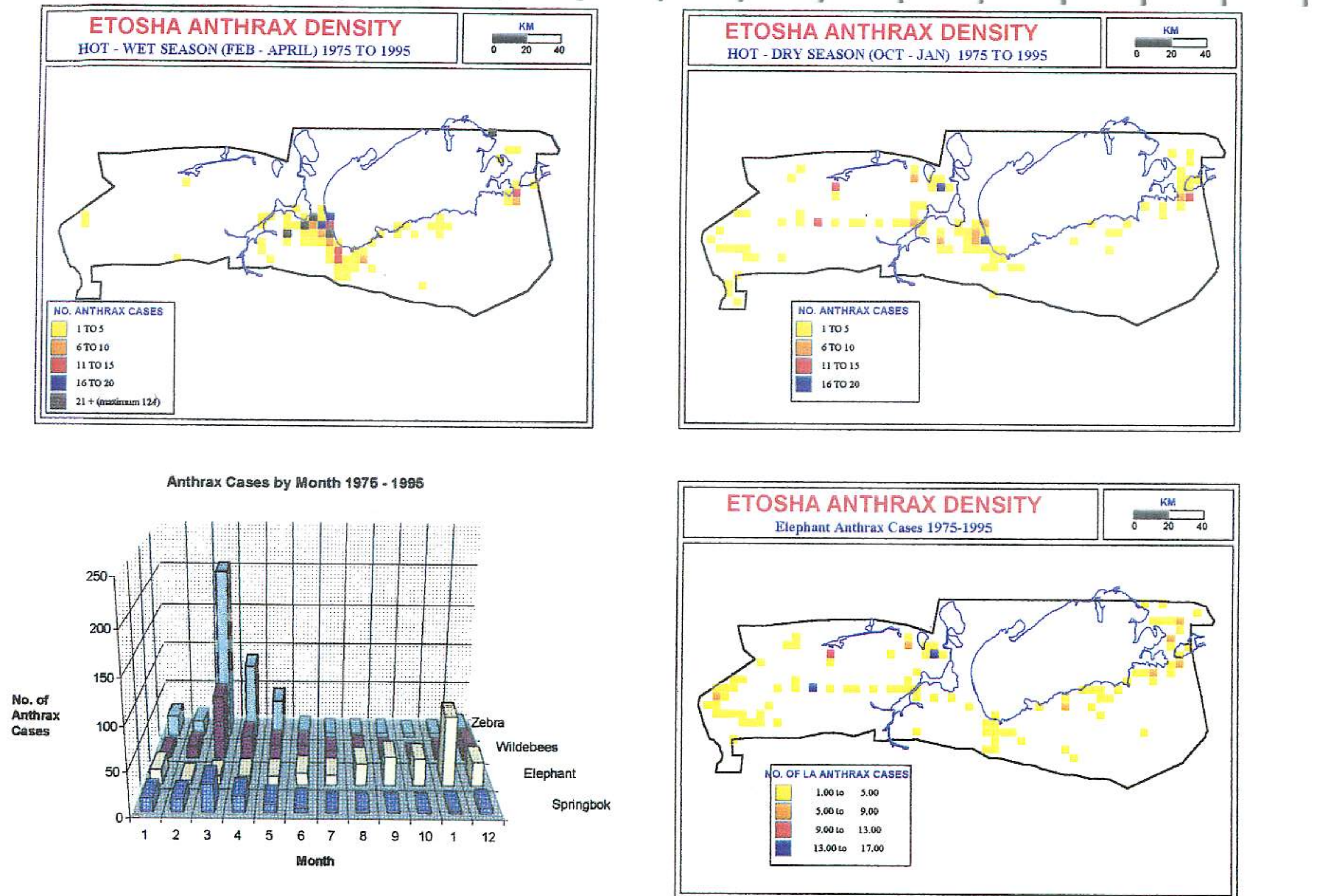


Figure 6. Selection of maps from the analyses of anthrax distribution in the park. The majority of anthrax cases occur in the rainy season where they are concentrated at a number of well defined sites. In the Hot-Dry season anthrax cases are spread out at a much lower density right across the park and correspond to the distribution of elephant anthrax mortalities which peak in November. Elephants are suspected to be the major cause of the spread of anthrax to the west of the park.

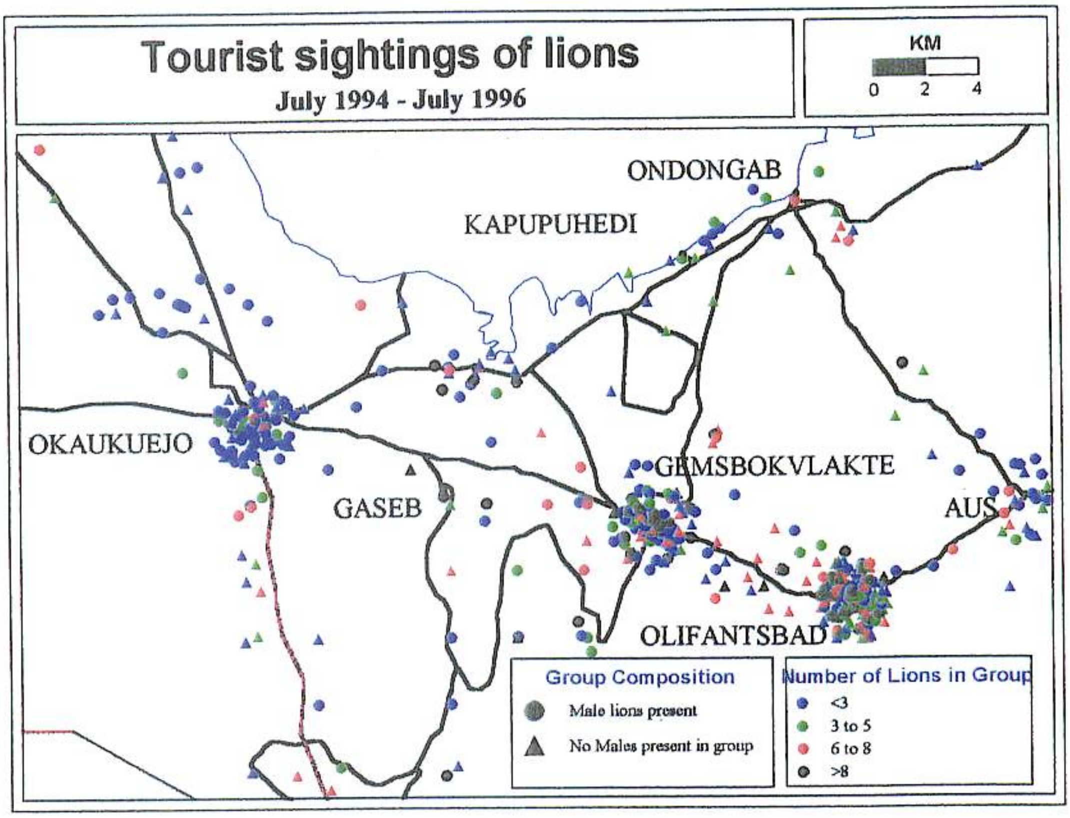


Figure 7. Map showing tourist sightings of lions. The map was produced using the Etosha dataforms database which has been integrated with the GIS to provide the capability to instantly produce maps for information dissemination and data analysis.

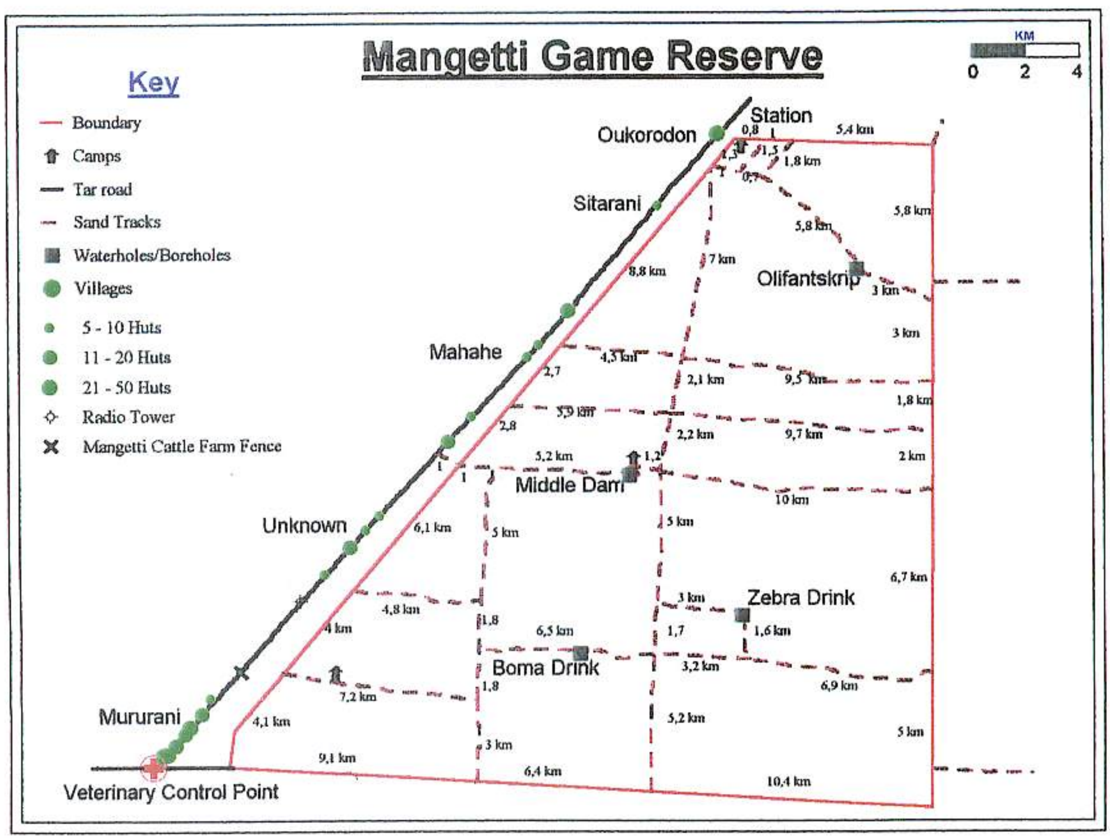


Figure 8. Map of the Mangetti Game Reserve, Okavango Region. The entire area was surveyed in 2 days using a Global Positioning System (GPS) with tracking feature.