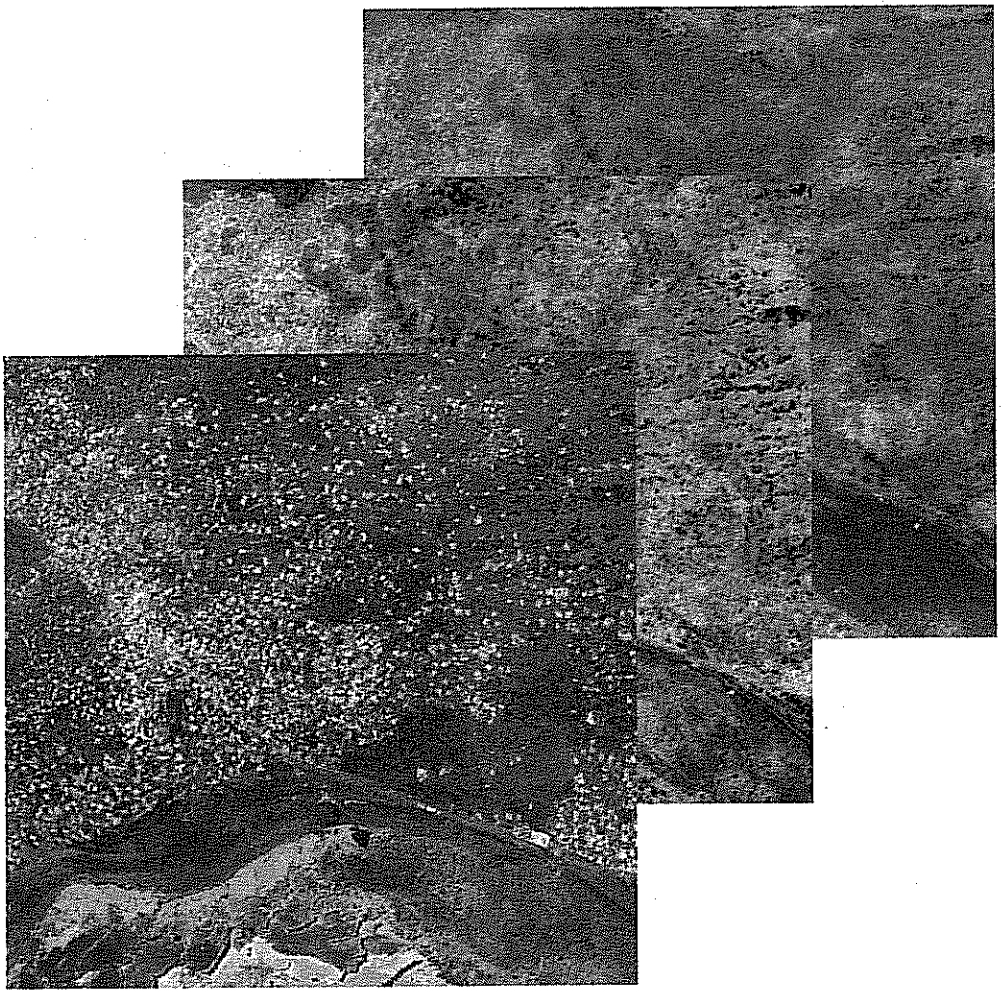
Expansion of Subsistence Agriculture In North-Central Namibia.

Spatial changes in agricultural area between 1973,1987 & 1997.



Northern Namibia Environmental Project

Ministry of Environment & Tourism
PO.Box 2881
Oshakati
Namibia

Expansion of Subsistence Agriculture In North-Central Namibia.

Spatial changes in agricultural area between 1973,1987 & 1997.

Johan le Roux

Etosha Ecological Institute

March 2000

Prepared for

Northern Namibia Environmental Project
Ministry of Environment & Tourism
PO. Box 2881
Oshakati
Namibia

Contents

Tables and Figures

1. Introduction

Namibia is a large country with a small population. The population density of 2 people per square kilometre belies the fact that human settlement is highly clustered, with the majority of the population residing in the northern parts of the country. The land tenure in these densely populated areas is predominantly communal, while subsistence agriculture and animal husbandry are the main forms of land use. The importance of natural resources is emphasised by the fact that more than a quarter of the population lives on just over one percent of the land, within the Omusati, Ohangwena, Oshana and Oshikoto regions (Ashley, 1996, in Tarr, 1996).

Namibia won political independence from South Africa in March of 1990. This ended decades of war, and brought peace and stability to Namibia. The north-central regions of the country were particularly affected, and post-war growth in both the economic and agricultural sectors are obvious. However, quantitative information on rates of expansion as well as past and present spatial extents of subsistence agriculture in particular, is not available. This information is essential for strategic planning, and may serve to focus private sector and non-governmental organisation activities.

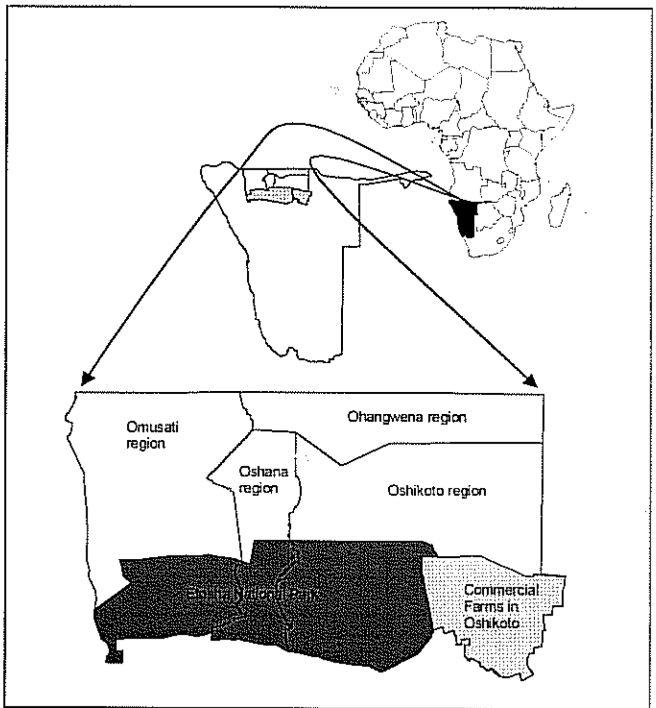


Figure 1. North central Namibia, showing the four regions of Omusati, Ohangwena, Oshana and Oshikoto. The commercial farming area of Oshikoto region, and the Etosha national park (shaded areas) were excluded from the study.

This study, which produced crop area estimates for historical as well as contemporary dates, was conducted within the framework of the Northern Namibia Environmental Project (NNEP). The purpose of the NNEP is to promote information based and participatory planning processes, for sustainable environmental management in Northern Namibia (NNEP project document, 1999). NNEP activities are largely confined to the four administrative regions of Omusati, Ohangwena, Oshana and Oshikoto (Figure 1.) in north-central Namibia.

2. Crop area estimation overview.

Crop area estimation with remote sensing has been used operationally in various parts of the world for over a decade.

The basic methodology relies on direct expansion of area estimates obtained from an area frame sampling scheme. The land area under investigation is divided into regular shaped grid cells of fixed size. This establishes the sampling frame. Smaller, regular shaped, fixed-size areas, are selected at random within this grid. These form the sample segments. The number and size of these segments determine the sample fraction. This is commonly between 1 and 2 percent of the total area which is being surveyed. The proportion of each crop within each segment is determined. The mean proportion for each crop for all segments, is taken as the estimator for that particular crop, and is used to obtain the direct expansion estimate.

The operational methodology relies on ground survey to determine crop types and aerial cover for each crop in every segment. The study reported on here, applied visual interpretation techniques to satellite imagery, in order to determine these parameters.

3. Methodology.

This study followed the methodology as outlined in section 2, after it had been tested in Oshikoto region (le Roux, 1999). The finite population was defined by a regular grid over the study area. A systematically aligned, random sample was used to select one sample segment from each grid cell. This was repeated to produce 2 replicates. Satellite imagettes were produced for each sample segment for each of the three dates under investigation. Field boundaries were deliniated on each imagette, based on visual interpretation of the sample segments, and the results subjected to classical statistical analysis in order to arrive at an estimate for agricultural areas for the whole study area.

3.1 Statistical design.

A regular grid based on northing and easting and measuring 25 km. per side, was produced to cover the area of interest. This resulted in 102 grid cells covering the study area (Figure 2.).

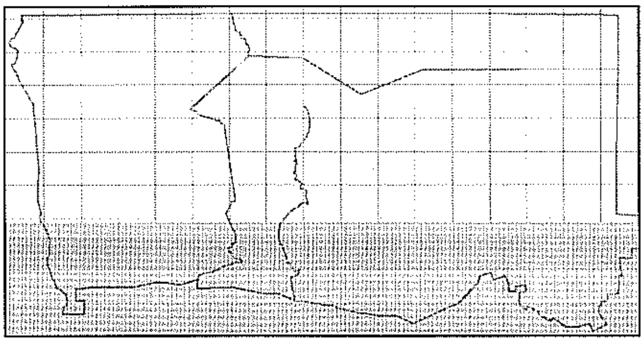


Figure 2. The sampling frame, consisting of a regular 25 x 25 km. grid over the study area.

Each grid cell was sub-divided into one hundred 2.5 x 2.5 km. segments, from which two cells were randomly selected to produce a systematic random sample scheme (Figure 3). No stratification was applied.

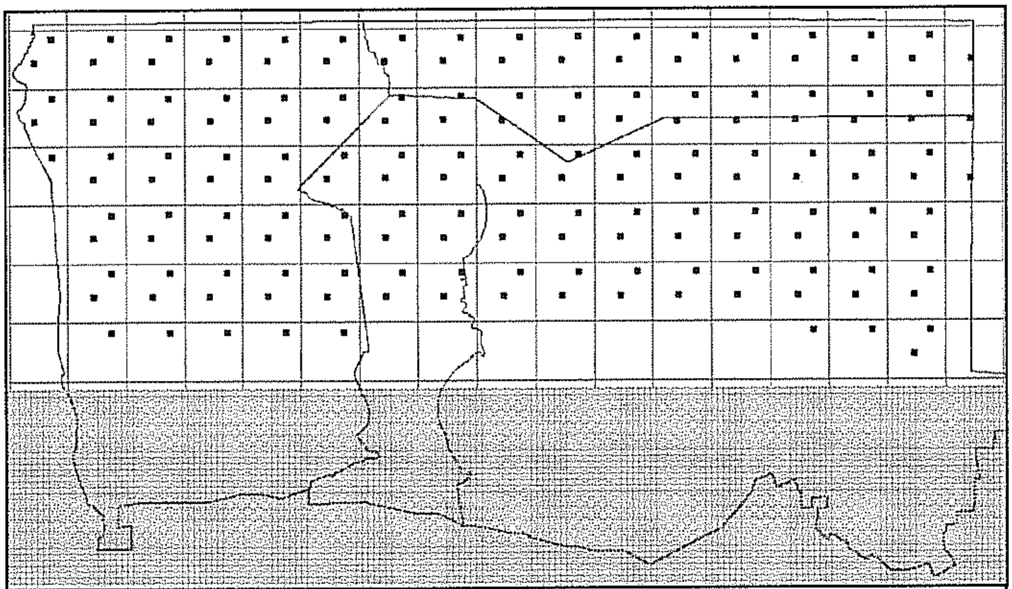


Figure 3. The distribution of study sites (black squares) which form the systematic random sampling scheme.

3.2 Production of imagettes

Sample segments were subset from the individual Landsat TM and MSS scenes according to the area frame sample scheme outlined in section 3.1. This resulted in 501 geo-referenced imagettes (167 for each of the three dates of imagery). Each imagette covered an area of 2.5 x 2.5 km on the ground, and contained three spectral bands corresponding to the green, red and near-infrared parts of the electromagnetic spectrum. This corresponds to bands 2,3,4 for the TM data, and bands 1,2,4 for the MSS data. Matching high-resolution imagettes were sub-set from aerial photographs acquired for 1996.

3.3 Classification.

Visual interpretation techniques were applied to a sample of the 1997 data. These results were subjected to field validation, in order to refine the classification decision rules. This was done by drawing a randomly selected 10% sample from the total population of sample segments for 1997. These were displayed as false colour composite images and printed onto A4 sheets at a scale of 1:15000. Boundaries of land cover types were delineated on acetate overlays prior to the field survey, and each parcel was assigned to one of five classes: agriculture; woodland; grassland; mixed woodland/grassland, and other. The field survey showed that natural vegetation types, although readily distinguishable on the imagery, could not be labelled with any degree of accuracy by visual interpretation. Classification of natural vegetation was therefore abandoned, since validation of the historical data would not be possible.

The only land cover type of interest that could be identified and labelled accurately through visual interpretation, was agriculture. This consisted of land used for subsistence dry-land crop cultivation. Peripheral areas between the fields and newly erected steel-wire fences could not be distinguished from natural vegetation, and is therefore not included in the definition of agricultural areas.

Sample segments were displayed as false colour composite images, with the near infrared band assigned to red, the red band assigned to green, and the green band assigned to blue. This band combination highlighted areas under cultivation, which showed up as bright areas in the image. Decorrelation stretches were applied to the MSS data to bring the colour saturation closer to that of the TM imagettes.

Boundaries of agricultural areas in the 1997 imagette were determined by visual interpretation, and defined through on-screen digitising. The corresponding imagette for 1987 was then displayed alongside, and the vector layer derived from the 1997 imagette overlaid on it. Special attention was given to areas covered by the 1997 vector polygons, to determine whether changes had occurred. Polygon boundaries were shifted, or entire polygons were deleted/added, based on the interpretation of the 1987 imagette. This was repeated for the corresponding 1973 imagette. In cases where a particular farming area had not changed shape or size between dates, but slight mis-registration between imagettes caused a poor polygon fit, the whole polygon was shifted without altering the shape. This ensured that changes that were detected, were due to observed differences rather than inconsistent digitising. Inter-dependant image analysis also meant that the datasets for 1987 and 1973 which were derived from lower spatial resolution MSS data, could be interpreted in the light of information gained from the relatively high-resolution TM data.

ER Mapper software was used to calculate area sizes for the polygons defined in each segment. These figures were imported into a Microsoft Excel spreadsheet for further analysis. Spatial analysis and map production was performed using ArcView software.

3.4 Accuracy assessment

Aerial photographs which were available for the whole area for 1996, and for a portion of the area only for 1970, were used as surrogate ground data against which to validate the results of the visual interpretation. Imagettes which corresponded to the satellite image derived sample segments, were subset from scanned geocoded airphotos. A grid of points based on 10 seconds of latitude and longitude, was overlaid on the airphoto imagette. This produced either 64 or 72 systematic random points per imagette, spaced at 300 metre intervals. The land cover under each point was determined through visual interpretation, and scored as either agriculture or other. This was done for all airphoto imagettes, and the procedure repeated on the 1997 TM derived imagettes. These data were then tabulated in a confusion matrix in order to assess the accuracy of the interpretation. The same procedure was followed to produce a confusion matrix for the 1973 Landsat MSS derived data.

4. Results.

4.1 Area estimates.

Agricultural expansion as indicated by the presence of fields used for dry-land cropping grew by 6.8 % per annum between 1973 and 1987. This meant that the area under agriculture in Omusati, Ohangwena, Oshana and Oshikoto regions more than doubled (Figure 4).

Between 1987 and 1997 the area under agricultural practise again doubled (Figure 4), driven by an annual growth rate of 7.1 %. By mid-1997 more than 10 % of the area had been converted to agricultural land. These results are summarised in Table 1.

	% of total study area occupied by agricultural land	Area occupied by agricultural land (hectares)	% Change in agricultural area between dates	Annual rate of change from natural area to agriculture	Overall accuracy of the mapping and classification	% Relative standard error of the area estimate
1973	2.1 %	77862			60.9 %	24 %
1987	5.2 %	195814	+ 3.1 % of total area	1973 to 1987 + 6.8 % per annum	Not determined	19 %
1997	10.4 %	392964	+ 5.2 % of total area	1987 to 1997 + 7.1 % per annum	80.9 %	14 %

Table 1. Direct expansion estimates of agricultural areas (subsistence dry-land crops)

4.2 Spatial changes

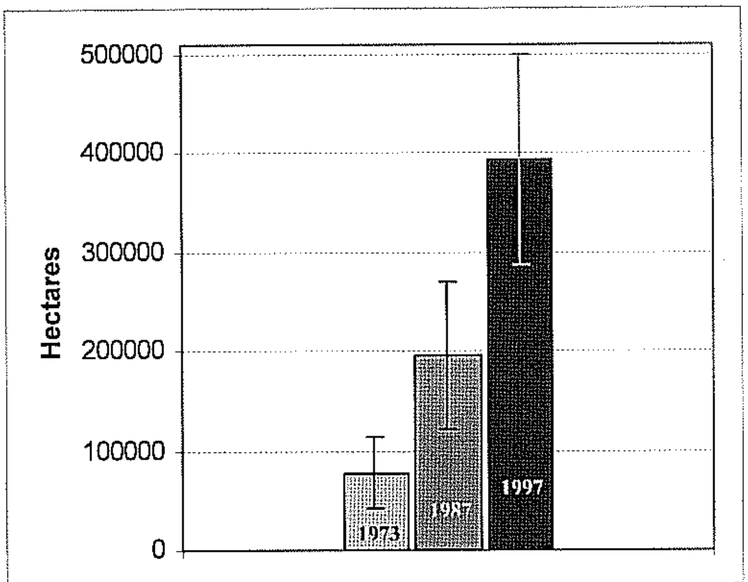


Figure 4. Estimated area (in hectares) under agriculture for 1973, 1987 and 1997. The I-bars indicate upper and lower 95% confidence limits.

Expansion of agricultural activities took place in two ways: 1) The appearance of fields in areas which were formerly not occupied at all, and 2) The expansion of existing fields or the establishment of new fields in areas already culivated to some extent. Both types of change are evident in Figure 5, where the slow outward spread of the pale pink area is indicative of the establishment of agriculture on previously uncultivated land, while changes in the shading show increase in relative density of agriculture in previously settled areas.

The 1973 data (uppermost map, figure 5) shows that agricultural activities and associated human settlement were predominant along the border with Angola in what is now Ohangwena region, and to a lesser extent along the main road south-east of Ondangwa.

The density of agricultural areas in the Cuvelai / Oshana system was generally lower than in the open woodland areas to the east of the main drainage area, with the exception of one relatively intensively cultivated area to the north of Oshakati, along the boundary between Omusati and Ohangwena regions.

Expansion between 1973 and 1987 was mainly in a southerly direction away from the Namibia/Angola border, although previously established fields along the border area remained under cultivation. This period also marks the appearance of cultivated fields in the grasslands and Mopane savanna areas south of the Oshana drainage system in what is now Omusati region (centre map, figure 5).

The southward expansion continued over the next ten years, and by 1997 well established fields were evident in much of northern Oshana region and south-western Ohangwena.

Agricultural activity also increased in Oshikoto region, particularly along the main tar road south of Ondangwa (lowermost map, figure 5).

The magnitude of changes in agricultural area is illustrated in Figure 6. Change is evident across most of the area which was used for agriculture in 1997, although much of the change is of relatively low intensity, involving a gradual outward spread. The greatest change between 1973 and 1987 occurred in western Ohangwena region (Figure 6a). During the period between 1987 and 1997 the expansion shifted south, and most of the change in the area under agriculture occurred in northern Oshana and western Oshikoto regions (Figure 6b).

5. Accuracy.

Accuracy measures were obtained for the visual interpretation/classification as well as the direct expansion estimates.

Classification accuracy was assessed by checking the thematic data against reference data. Results from these checks were tabulated in a confusion matrix, from which user, producer, and overall classification accuracies could be determined. Of these, the user accuracy is probably the figure which should most often be adopted (Richards, 1995).

The producer accuracy evaluates results from the image classifier's perspective. A producer accuracy of 90% would mean that any particular location on the ground had a 90% probability of being correctly represented/classified on the map. This is not a particularly usefull measure, since classifying the whole study area as agriculture would result in a producer accuracy of 100%.

The user accuracy on the other hand refers to the number of pixels on the thematic map which have been labelled correctly by the classifier, and takes the number of pixels wrongly assigned to other classes into account. These commission errors are equal to the inverse of the user accuracy.

Overall classification is simply the average of the producer and user accuracy figures.

The accuracy of the direct expansion estimates are expressed in terms of the percentage relative standard error. This figure expresses the standard error of the estimate as a percentage of that estimate, thus allowing easy comparison of the standard error for different figures.

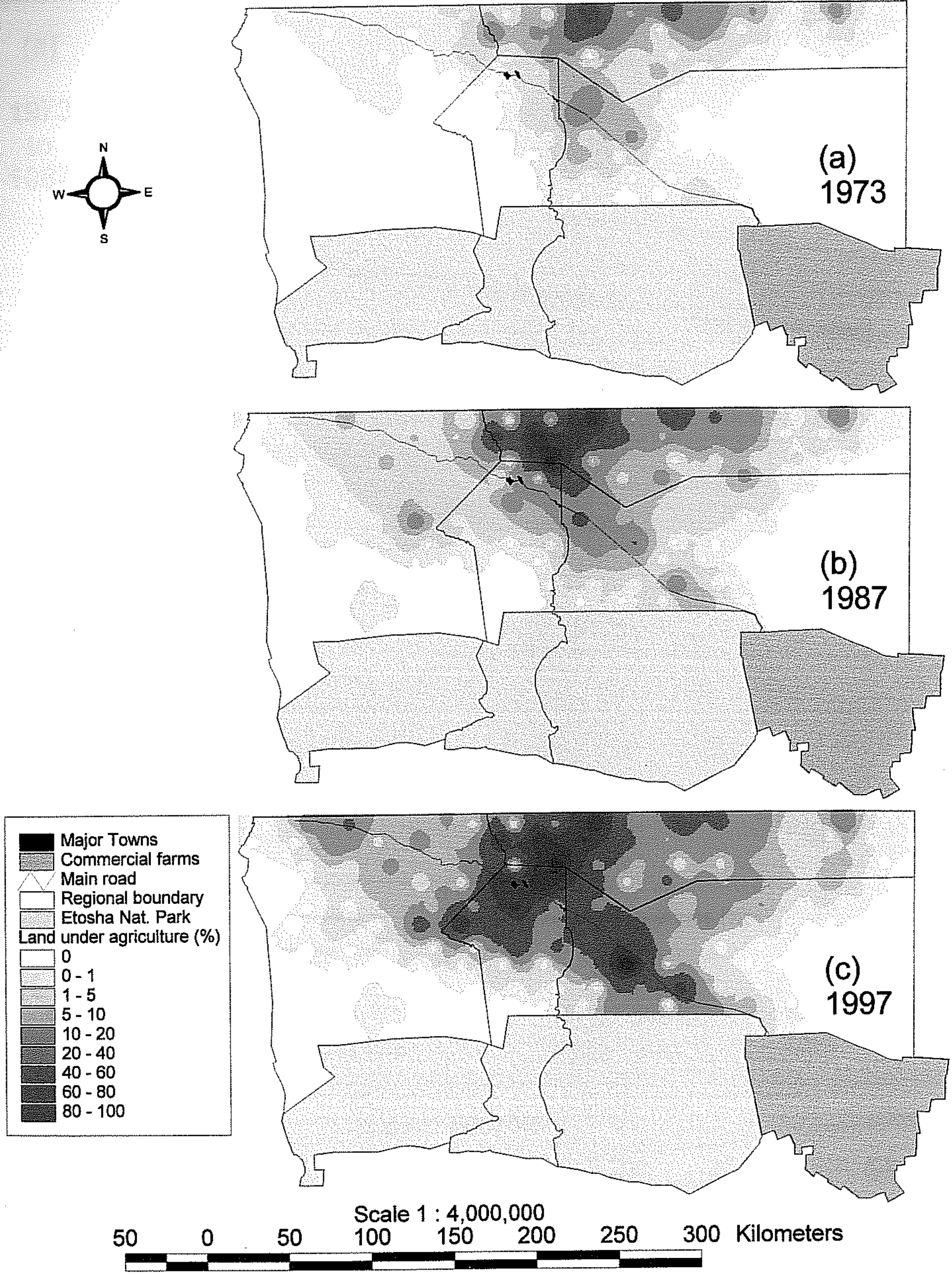


Figure 5. Schematic representation of the percentage land under agriculture for each date. (Derived from a statistical interpolation of the proportion agriculture in each sample segment)

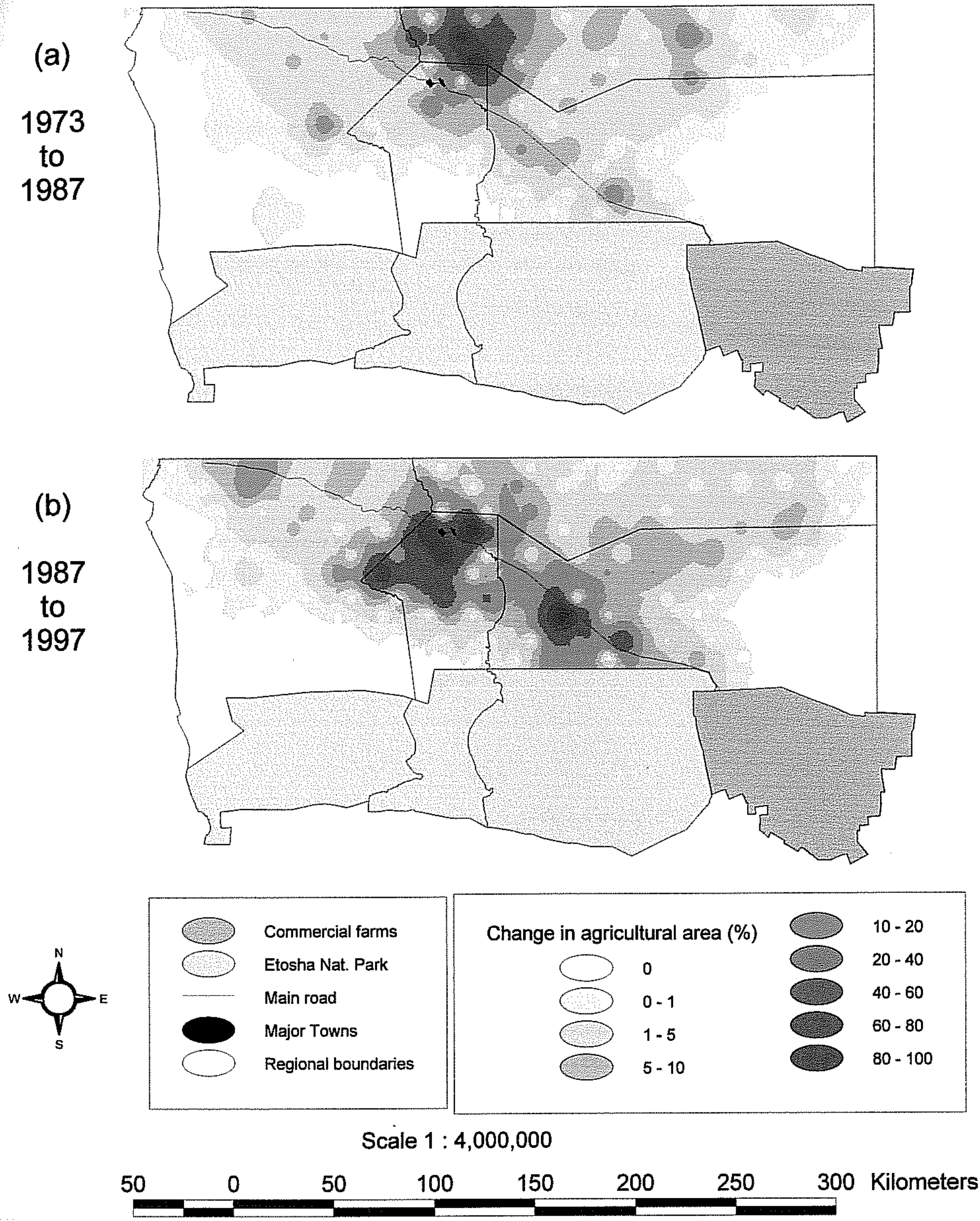


Figure 6. Schematic representation of the percentage change in the area under agriculture between dates. (Derived from a statistical interpolation of the proportion change in corresponding sample segments, between dates)

5.1 Classification accuracy.

Overall classification accuracy for the 1997 data was 80.9 %, while the 1973 data produced results with an overall accuracy of 60.9 %. No validation data was available for 1987, but it is reasonable to expect that the accuracy would lie within this range.

User accuracy for the 1997 data is 86.7 %. This corresponds a commission errors of 13.3 %.

For the 1973 data the user accuracy is 68.2 %, which corresponds to errors of commission of 31.8 %. The decrease in interpretation accuracy is due to the dry season acquisition date of the 1973 imagery, which made it difficult to distinguish different land cover types.

5.2 Direct expansion estimate accuracy.

The percentage relative standard error for the 1973, 1987 and 1997 data was 24 %, 19 % and 14 % respectively. The decrease in the error is a direct result of the reduction in the number of field segments containing no agricultural areas.

***

References

Ashley, C. (1996) Can population growth and environmental sustainability be reconciled? (In Tarr, P.W. editor, 1996. Namibia Environment, vol. 1.)

Le Roux, J.L. (1999) Expansion of Subsistence Agriculture in North-Central Namibia: 1973 to 1997. A pilot study of rapid land cover area estimation using remote sensing. M.Sc. thesis. Applied Remote Sensing: Land Resources Monitoring & Remote Sensing. Cranfield University.

NNEP (1999) Amendments to the NNEP Logical Framework. Unpublished steering committee minutes: 15th October 1999. Northern Namibia Environmental Project.

Richards, J.A., (1995) Remote Sensing Digital Image Analysis. 2nd Ed. Springer-Verlag, Berlin, Heidelberg, New York.