Strengthening the National Protected Areas Systems in Swaziland Project

Swaziland Land Cover, Land Cover Change Analysis and Vegetation types for 1990, 2000, 2010 and 2015

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Finally I would like thanks the GIS and Remote Sensing technicians MS Rose Waswa and Ms Pauline Ogola who have assisted in putting up the landcover and change analysis maps.

List of Acronyms

ETM)	Landsat Enhanced Thematic Mapper
IPCC	Intergovernmental Panel on Climate Change
PAs	Protected areas
RMSE	Root Means Square Error
SNPAS	National Protected Areas System of Swaziland
TM	Landsat Thematic Mapper
TOA	Atmospheric corrections
UNDP	United Nations Development Programme
USGS	United States Geology Surveys

Executive Summary

In order to carry out a comprehensive biodiversity assessment for the Swaziland country, the SNPAS Project as one of their activity, hired a consultant to generate national land cover and vegetation type maps for four-time epochs; 1990, 2000, 2010 and 2015 to inform the biodiversity assessments, land use planning and provide insights on the trend of Landcover and vegetation changes. The objective of this assignment was to collect ancillary reference data for validating land cover derived from Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper (ETM) and Landsat 8 for the country, develop Land Cover Maps from 1990, 2000, 2010, and 2015 Landsat satellite images using remote sensing techniques and undertake Landcover change detection and accuracy assessment.

The Landsat imagery was acquired, pre-processed and pre-classified. The field validation points were generated for 2015 imagery, field work carried out in Swaziland and final classification carried out on all the epochs using IPCC Classes. The Landcover change analysis was done for 1990-2000, 2000-2010, 2010-2015 and 1990-2015. The change statistics were computed to show the Landcover change percentages per class. The accurate assessment was also carried out and the overall accuracy of classification imagery dated 2015 was 85.71% and the Kappa coefficient was 83.86%.

The schema-I Landcover maps have collapsed class legend from 13 classes to 11 IPCC classes while the schema-II Landcover maps have 13 classes that include open and closed bushland classes, open and closed woodland classes.

In 1990, the country was generally covered by natural vegetation. Woodland, Bushland and Grassland formed the major land cover in the area. Wetlands, Urban areas and bare areas covered a minimal area compared to the trend in the next epochs.

In 2000, Woodlands dominated the Swaziland landcover followed by grasslands and bushland. Cropland increased. There are areas that grasslands transitioned to bushland. Riverine vegetation decreased slightly. Woodlands decreased from 1990 to 2000 while bushland increased their coverage.

In 2010, Swaziland was dominated by bushlands and woodland and there was an increase of forestland. Large portions of new cropland areas emerged. Woodland decrease while bushland continued to increase. There is a visible increment in the size of the urban areas as witnessed in the expansion of the 2000 urban areas. As for the waterbody increment, it is likely that there is damming of rivers to assist in the irrigating of the plantations which have visibly increased in size.

In 2015, bushland, cropland small scale, woodland and grassland dominated the Landcover. There has been massive changes that have occurred in the area. Some are positive and others have negative impacts especially in the long run. The negative changes include the massive increase in cropland areas in both the pre-existing areas and new regions. The urban areas have increased significantly which indicates an increase in population. Riverine vegetation have reduced unlike water bodies which have cropped up in the entire region. It may be safe to say it's because of damming of the area for irrigation.

In Landcover change analysis of 1990-2000 Statistics (Annex I) indicate that 84.60% of the landcover remain unchange, 5.08% changed from woodland to bushland an indication of degradation, 2.61% changed from woodland to bushland which is an indication of degradation. 1.14% of the bushland and 0.90% of the woodlands were converted to cropland small scale.

In Landcover change analysis of 2000-2010 Statistics (Annex II) indicate that 66.16% of the total area of Swaziland remain unchanged, 10.51% landcover changed from woodland to bushland an indication of the degradation, 2.91% of the grasslands regenerated to bushland. 3.0% of the bushland regenerated to woodlands, 3.30% of the bushlands and 2.13% of thw woodlands were coverted to cropland small scale.

In Landcover change analysis of 2010-2015 Statistics (Annex III) indicate that 71.25% of the total landcover remain unchanged while 6.07% of the landcover changed from woodland to bushland an indication of degradation, 2.71% of the landcover changed from bushland to woodland an indication of regeneration and 1.59% landcover changed from bushland to grassland.

In Landcover change analysis of 1990-2015 Statistics (Annex III) indicate that 51.72% of the Swaziland landcover remaned unchanged, 14.79% of the lancover changed from woodland to bushland an indication of degradation, 4.15% of the landcover changed from bushland to woodland an indication of regeneration. 4.16% of the bushland and 4.31% of the woodlands were converted to cropland small scale.

Montane Grassland is the major vegetation type, followed by Lowveld Bushveld, Sour Bushveld and Lebombo Bushveld with the least acreage. As much as the vegetation types remain constant over the 1990 and 2000, 2010 and 2015 years, the various species within the categories keep on changing. The vegetation type changes are minor and were mainly observed in 1990 and 2015. There were slight changes from sour bushveld to grassland and vice versa. The changes were seen to take place along the boundary of transition.

The landcover and vegetation type maps were generated using imagery of Landsat sensor which is 30m resolution (Medium resolution). The appropriateness of remote sensing imagery for forest mapping and monitoring using medium resolution imagery has shortcomings. The medium resolution limits the accuracy of the results to low. High resolution imagery (0.5m resolution) gives high accurate results.

1.0 Introduction

1.1 Background from the terms of reference

Vegetation provides natural habitats that are vital for sustainable development, repositories of biological diversity and the raw material for natural selection and adaptation. They provide myriad of other ecosystem services that enrich and sustain human life with both tangible and intangible economic and social value. These services include watershed protection and maintenance, biological control of pest emergence, crop pollination – and other life-sustaining environmental services, such as breathable air and usable water.

For its size Swaziland is one of the most biologically diverse countries in the world and includes part of the Maputuland-Pondoland – Albany Hotspot. The country's biodiversity is also extremely important for the economy as well as the well-being of its people. Most of the Swaziland population is rural, many of whom depend on a variety of forest products for their livelihoods. It is for this reason the Strengthening the National Protected Areas System of Swaziland (SNPAS) project aims at developing, expanding and effectively managing the capacities of Swaziland's protected areas (PAs) network in order to adequately protect the biodiversity. This will be undertaken through the "landscapes" approach towards sustainable development and will involve integrated land and natural resource management that transforms the current PA patchwork into network and enhance vulnerable communities' livelihoods, in particular those adjacent to the PAs. In order to carry out a comprehensive biodiversity assessment for the country, the SNPAS Project intends to generate national land cover and vegetation type maps for four-time steps 1990, 2000, 2010 and 2015. These datasets will inform the assessments, land use planning and provide insights on the trend of changes.

1.2 Objectives

- To collect ancillary reference data for validating land cover derived from Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper (ETM) and Landsat 8 for the country.
- To develop Land Cover and vegetation types maps from 1990, 2000, 2010, and 2015 Landsat satellite images using remote sensing techniques;
- To undertake Landcover change detection and accuracy assessment;

2.0 Justification

According to the SNPAS project inception reports, it has been observed that there is a need for compiling land cover and vegetation types' data for the country to primarily inform biodiversity assessments as scheduled within the project. The data will be generated from supervised classification of satellite images to produce consistent wall-to-wall land cover maps of four-time slices (within the epochs of 1990, 2000, 2010, and 2015) for the country. The land cover maps will consist of the following classes (very dense forest, dense forest, moderately dense forest, sparse forest, water, wetlands, cropland, cropland Perennial, shrub lands (closed), open shrub land, grasslands closed, grasslands open, woodlands, builtup areas, bare areas and other lands that will be combined to six (6) main categories which include (1) forestland, (2) cropland, (3) grassland, (4) wetlands, (5) settlements and (6) other lands (Barren Areas); This assignment enabled the SNPAS project and stakeholders to have access and control over the applied auxiliary data, satellite imagery and the produced Land Cover and vegetation products, thus enhancing sustainability enhancing biodiversity assessment and conservation efforts in the country.

3.0 Approach & Methodology

3.1 Collection of Ancillary Data

Collection of ancillary data is important as a baseline for the project and was collected through national teams as reference material. This activity involved gathering information from previous reports, publications and studies within the scope of the project, historical reference locations, existing land use land cover maps, high spatial resolution imagery and other satellite imagery data. The sole purpose of this activity was to have sufficient spatial and related attribute information on land use land cover mapping and from relevant key stakeholders involved in the project.

On identifying and collecting existing ancillary data, stakeholder involvement was key in assessing and verification of the consistency and accuracy of the data collected. This also required reworking of the existing methodology and documenting of metadata from existing land use land cover maps. The specific tasks undertaken during this activity therefore include gathering existing and or historical land use maps and previously collected ground reference data, iidentifying through consultative forums the land use land cover classification scheme to be used within the country, re-working and documenting the metadata of the existing land use land cover and related vegetation products and eensuring that enough relevant ancillary data is made available for classification of satellite imagery to the required classes/categories.

3.2 Quality checking of the Ancillary data

Ancillary datasets collected from the various sources were checked for accuracy, consistency and completeness based on various quality standards. This was an important procedure to determine fitness-for-use of particular datasets collected from the various institutions related to the project, and was mostly facilitated through studying the metadata of a particular dataset. Quality control and quality assurance are a crucial component and are required continuously throughout the project period as it helps ensure data integrity before products are generated and used.

Quality checking and assessment of such datasets involved checking for consistency and completeness based on elements such as data Completeness that assesses the presence or absence of data at the various levels of coverage to determine if at these levels, the datasets are sufficient to adequately represent various spatial phenomena, lineage which assesses the historical significance of the dataset in terms of the original source that it was derived from and the various transformational changes it has undergone to its present format, positional accuracy which assesses the nominal accuracy of the dataset based on their true locations on the ground to determine the tolerance of a dataset, attribute accuracy that provided deviation of the descriptive information associated with a spatial dataset and their conformity to the true representation and topological consistency that addressed the fidelity of data structure relationships thus linking the datasets to the model structures used. The specific tasks under this activity included receiving ancillary data, performing initial quality checks and assessment and requesting for clarification from all relevant stakeholders, verification, re-working and validation of the ancillary data, subjecting the data to independent quality assessments and identified data gaps with relation to classification of the required land cover categories.

3.3 Acquisition of the Landsat Imagery and pre-processing

The images were acquired covering Swaziland for the epochs 1990, 2000, 2010 and 2015 at 30m spatial resolution with all the required bands and with a minimum cloud cover. The Landsat imagery scenes were acquired from the USGS site and pre-processed them using remote sensing applications such as IMPACT Tool (European Union's JRC), ERDAS Imagine and ArcGIS. Data pre-processing involved image orthorectification using ground control points and Digital Elevation Models represented using local coordinate systems. Image equalization and normalization was also performed for quality and uniformity of the images before they are calibrated and mosaicked for classification.

Quality checks are important for remote sensing imagery as it forms a critical component for achieving high quality results for the outputs intended. These quality checks were based on the geometric and radiometric aspect of the images using both visual means and statistical methods to achieve stipulated Root Means Square Error (RMSE) of 0.5m or better from orthorectification.

For image pre-processing, consideration was made to the various image parameters such as dates of acquisition, cloud cover and the type of sensor involved. This consideration is important in ensuring consistency in producing image mosaics and therefore consistency in the representation of land use and land cover characteristics of a particular area. For understanding of the various land covers in Swaziland, considerations were made to perform an initial unsupervised land image classification on the extracted image mosaics to get an initial picture of the representation of the various land use land cover characteristics.

The specific tasks within this activity therefore included carrying out image statistics to determine the suitability of maximum likelihood classification or Support Vector machine classifiers/ algorithms, acquisition of Landsat satellite imagery datasets for Swaziland for the epochs 1990, 2000, 2010 and 2015, image pre-processing where the satellite imagery data were orthorectified to match with existing data using ground control points and DEMs ,and thereafter based on the quality of the images, calibration, mosaicking and clipping was done to prepare them for classification, geometric and radiometric image corrections were applied to the 4 epochs including atmospheric corrections (TOA), initial parameters were established to ensure that the imagery collected and pre-processed met the needs of the project. Such parameters included image acquisition dates, amount of cloud cover, and the type of sensors for each of the imagery scenes selected, carried out image enhancement to improve on visual interpretation, carried out preliminary unsupervised image classification on the 4 epochs to provide for initial understanding of the various land use land cover types in Swaziland. The following imagery 1990, 2000, 2010 and 2015 were downloaded and processed;

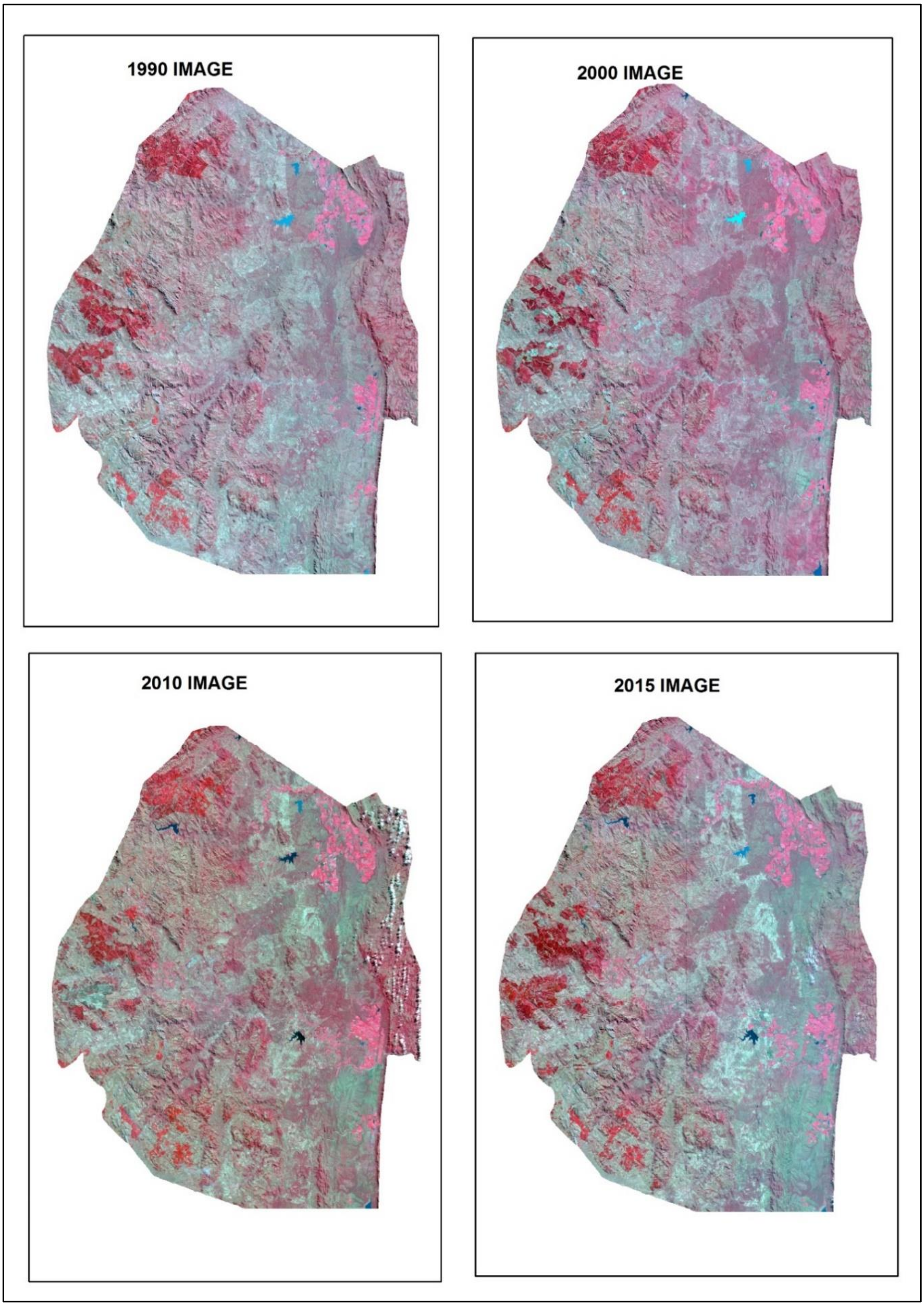


Figure 1: Landsat Images used for classification

3.4 Image Classification

To achieve adequate land use land cover classification, a proper classification scheme consistent with the existing classification schemes and definitions in Swaziland was selected in order to properly represent the land use land cover characteristics. Selecting the appropriate levels of detail for image classification was important as an over-abundance of land cover categories can lead to considerable confusion among cover types, whilst an under-representation may sometimes not meet the user demands.

This therefore called for a detailed study of the existing classification schemes to guide in choice of an appropriate structure to represent the land cover characteristics of Swaziland with guidance from policy documents, the objectives of the mapping exercise, specific stakeholder interests, area definition and set standards through consultative forums.

Reference was also made to the IPCC guidelines used in developing globally used standards that also meet country specific classification scheme standards. IPCC land use land cover categories for schema 1 level of classification contains the following classes: Forest land (Dense Forest, Moderate Forest, Sparse Forest, Planted Forest), Woodland (Closed and Open woodland); Grassland (Open Grassland, Closed Grassland), Bushland (Open Bushland, Closed Bushland); Cropland (Perennial Cropland, Annual Cropland); Wetland (Wetland, Water Body); Settlement; Other Land (Bare Soil, Rocks).

These classes were subjected to consultation and verification through stakeholder discussions. The following thirteen classes were settled on for Schema II:

- Forestland
- Open Bushland
- Closed Bushland
- Grassland
- Open Woodland
- Closed Woodland
- Riverine Vegetation
- Bare Area
- Urban Area
- Cropland Plantation
- Cropland Small Scale

- Waterbody
- Wetland

For schema 2, the thirteen classes were narrowed down to eleven with the merging of open and closed woodland to woodland and open and closed bushland to a single bushland class.

Before classification, image processing steps of image selection for identification of cloud free images; layer stacking of image bands to obtain scene composites; band combination analysis and image enhancements and corrections were performed. The figure below provides a summary of all the steps carried out from image acquisition to the final classification product.

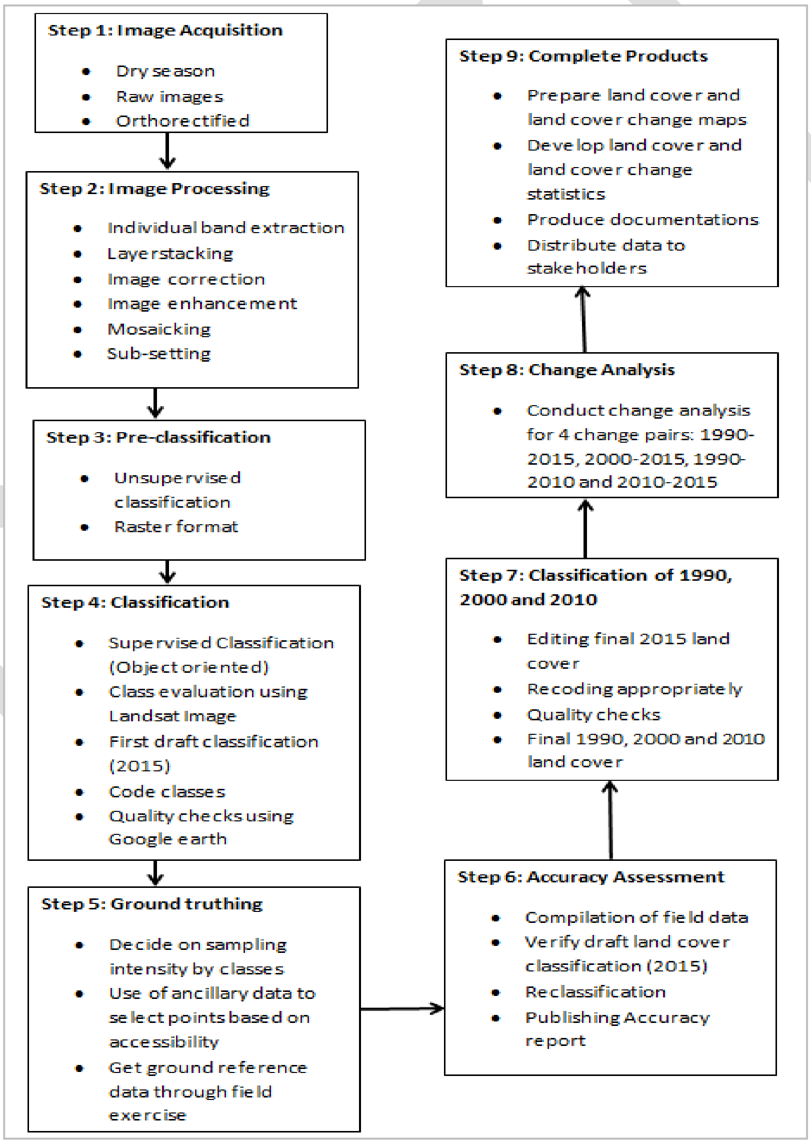


Figure 2: Flow chart showing the steps taken to come up with the final products

The initial stage of image processing involved extraction of the individual bands followed by layerstaking where the various bands of the multispectral Landsat image were composited into a single multi-band image. This ensures that the various bands of a multispectral image are utilized in determining the land use land cover characteristics of a given area. Considerations were made to the thermal band and the panchromatic band to ensure consistency in the spatial resolutions of the images since they differ in spatial resolution from the rest of the bands.

Statistical computation using Eigen values, Eigen vectors and mean spectral values are useful in assessing the spectral quality of the imagery. Generating such statistical information from satellite imagery was useful in determining variability and correlation between bands of the multispectral image that is significant in indicating the ability to discriminate various classes during classification.

Image mosaics were created from the composites as products of layer stacking to represent wall-to-wall coverage of Swaziland. Subsets representing Swaziland extracted using the AOI file depicting the country boundary were produced for the 4 epochs of the dataset. IMPACT Tool and Erdas Imagine were used for image processing.

Supervised classification (object oriented) was done in Arc GIS to produce output files in vector format. On screen digitization was employed to conduct the classification. Visual interpretation was essential in determining the classes. This process involved extraction of information from the satellite images as polygons which were then coded by assigning them to the correct class. The figure below shows the generated polygons.

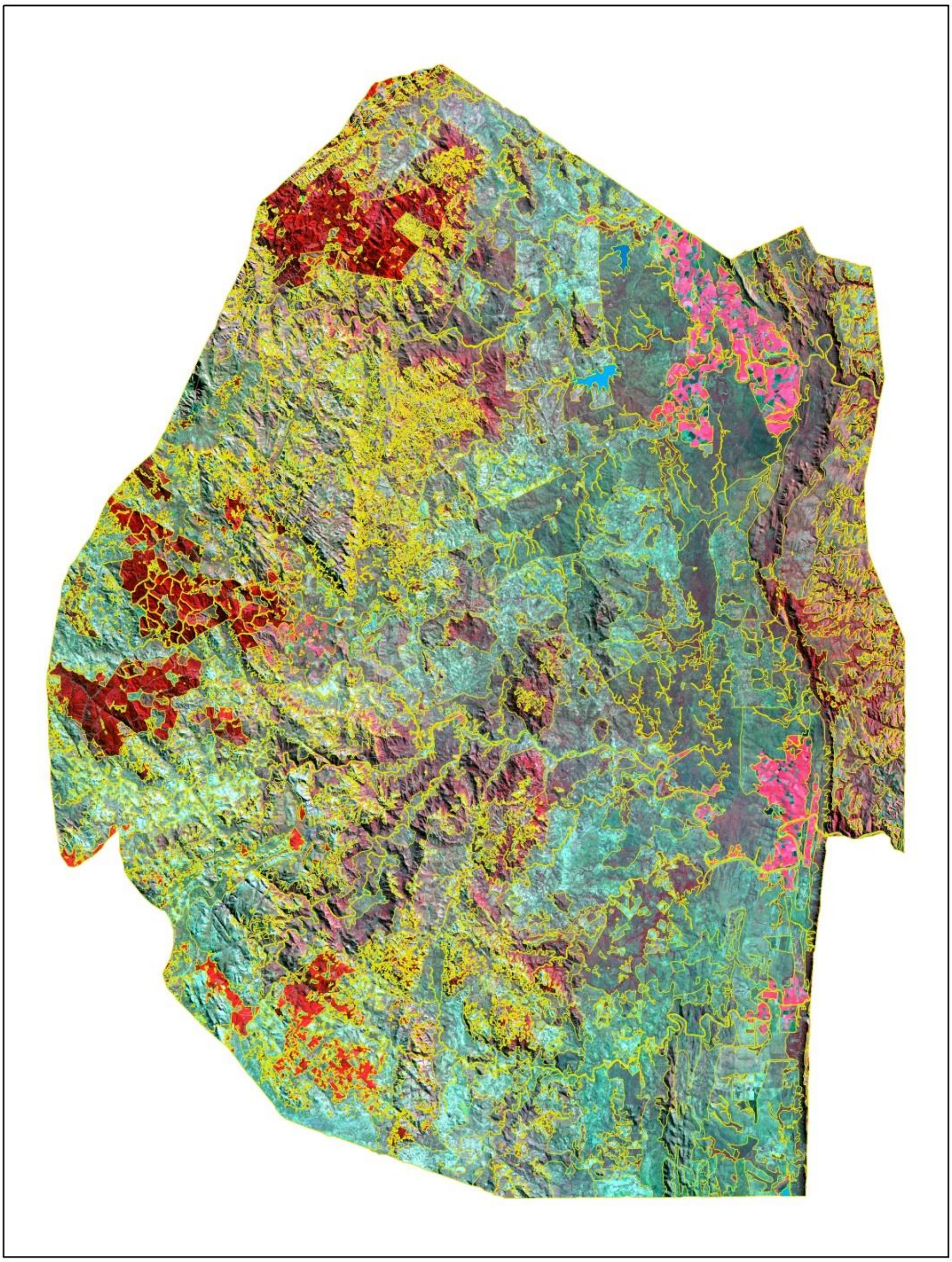


Figure 3: Generated polygons

Thorough knowledge of the different land cover classes is important. The most current year which is 2015 was the first to be classified. Quality checks were performed on the first draft 2015 classification using high resolution imagery that was accessed through the Google Earth platform before the ground truthing exercise. The first draft 2015 was verified using field validation points. Necessary corrections were done and the final draft produced followed by the generation of the accuracy report.

The 2015 Land Cover served as the base file for classifying the years 1990, 2010 and 2000. The 2015 file was saved as the 1990, 2000 and 2010 to avoid confusion or replacement of the file. The 1990, 2000 and 2010 images were then overlaid. The changes are easily noticed. Editing of the 2015 file based on the 1990, 2000 and 2010 images produced the Land Use Land Cover files for the years 1990, 2000 and 2010.

Change analysis was conducted to generate change maps that show the exact areas where changes occurred and the transition among classes. The land use and land cover statistics were generated in ArcGIS and tables created in Excel. The ddevelopment of land cover land use maps were done at the scale of 1:850,000 for the country maps and 1:50,000 for the individual zone maps.

3.5 Using ground reference data to carry out accuracy assessments

This activity involved collection of ground reference points in order to train the computer to recognize the various land cover categories in the imagery and to assess the categorical accuracy of the resulting classification. The collected reference data for accuracy assessment for 2015 imagery was also used to establish random ground control points for follow up monitoring.

Reference information and training data for classifying imagery for earlier dates i.e. 1990-2010 was developed from review and study of existing land use land cover and vegetation data, reports and publications and through use of Google Earth platform for the high resolution times-series imagery. Change detection was also used to distinguish irregular changes and for identification of erroneous classes. Ground reference data is collected from the field on randomly generated points at selected zones for image classification accuracy assessment. A number of criteria were considered when evaluating the suitability of any ground reference data set for land cover classification such as: Sufficiency of reference samples to achieve required confidence levels; a random method has to be considered and should be systematic and representative of the area of study; and the reference data must be of around the same time as the satellite image.

A plan for selecting locations for collecting ground control points for data verification using stratified random sampling involved identifying a sample of each land cover class proportionate to the population size of the class when viewed against the entire population. Then the number of points per land use category was identified and used to generate the number of such points within a sampling frame. The stratified random sampling technique was then be applied to randomly distribute points across the sampling frame and across each land cover category in relation to their area coverage in the sampling zone.

Accuracy assessment to analyze and modify the result of the classification was conducted for the 2015 land cover classification with a recorded accuracy of 85%. The accuracy assessment of the land use land cover maps was produced using a confusion matrix to compare the reference points generated from the land cover classification to the sample points collected from ground reference locations. A report of accuracy analysis with the methods used and source of reference points being indicated.

Ground referencing activity was done for from 22nd May 2016 to 4th June 2016. Ground reference data (a total of 248 points) were collected from the field on randomly generated points at selected zones using field verification form (Annex I). The probability sampling design was the preferred approach. It combines random or stratified sampling to get points to validate the land cover predefined in the first draft classification and perform accuracy assessment of the same. In view of this, the data collection method was systematic, and representative of the entire area that had been classified. The randomness of selection was to avoid selection bias of the land cover. Time constraint contributed to 248 points being selected.

Technical Team member carrying out vegetation and landcover ground truthing

3.6 Accuracy Assessment Procedure

The acceptable threshold for overall accuracy according to USGS classification is 75%. Ground Referencing points were split in two ways. Some of the points were used in refining the classification and the remaining points were used for accuracy assessment. Of the 248 points collected, 143 points were used in improving the classification by correcting the wrongly classified regions while 105 points were used in checking the accuracy of the classification. Accuracy assessment is critical for a map generated from any remote sensing data. Error matrix is the most common way to present the accuracy of the classification results. Overall accuracy, user's and producer's accuracies, and the Kappa statistic were derived from the error matrices. The Kappa statistic incorporates the off diagonal elements of the error matrices and represents agreement obtained after removing the proportion of agreement that could be expected to occur by chance.

$$\textbf{Kappa}\ (\hat{K}) = \frac{\textit{observed accuracy} - \textit{chance agreement}}{1 - \textit{Chance agreement}}$$

Table 1: Compliance matrix between interpreter and validation based results

	FIELD DATA														
2015_LULC CLASSIFICATION	Bare Area	Closed Bushland	Closed Woodland	Cropland Plantation	Cropland Small Scale	Forest land	Grass land	Open Bushland	Open Woodland	Riverine Vegetation	Urban Area	Water body	Wetland	TOTAL	PA %
Bare Area	2	0	0	0	0	0	1	0	0	0	0	0	0	3	66.67
Closed Bushland	0	9	1	0	0	0	0	1	1	0	0	0	0	12	75.00
Closed Woodland	0	0	5	0	0	0	0	0	1	0	0	0	0	6	83.33
Cropland Plantation	0	0	0	16	1	0	0	0	0	0	0	0	0	17	94.12
Cropland Small Scale	0	0	0	0	10	0	0	0	0	0	0	0	0	10	100.00
Forestland	0	0	1	0	0	9	1	1	0	0	0	0	0	12	75.00
Grassland	0	0	0	0	1	0	18	0	0	0	0	0	0	19	94.74
Open Bushland	0	0	0	0	0	0	0	7	1	0	0	0	0	8	87.50
Open Woodland	0	1	1	0	0	0	0	1	7	0	0	0	0	10	70.00
Riverine Vegetation	0	0	0	0	0	0	0	0	0	1	0	0	0	1	100.00
Urban Area	0	0	0	0	1	0	0	0	0	0	4	0	0	5	80.00
Waterbody	0	0	0	0	0	0	0	0	0	0	0	1	0	1	100.00
Wetland	0	0	0	0	0	0	0	0	0	0	0	0	1	1	100.00
TOTAL	2	10	8	16	13	9	20	10	10	1	4	1	1		
CA%	100	90	62.50	100	76	100	90	70	70	100	100	100	100		

Overall Accuracy (%) = (2+9+5+16+10+9+18+7+7+1+4+1+1)/105 * 100 = 90/105 * 100 = 85.71%

$$\text{Kappa} = \frac{105(90) - ((3*2)+(12*10)+(6*8)+(17*16)+(10*13)+(12*9)+(19*20)+(8*10)+(10*10)+(1*1)+(5*4)+(1*1)+(1*1))}{(105)^2 - ((3*2)+(12*10)+(6*8)+(17*16)+(10*13)+(12*9)+(19*20)+(8*10)+(10*10)+(1*1)+(5*4)+(1*1)+(1*1))}$$

Kappa = 0.8386 (indicating a high agreement) Kapp

The overall accuracy of classification imagery dated 2015 was 85.71% and the Kappa coefficient was 83.86%.

3.6 Preparation of final land cover and vegetation maps

This activity ensured that well designed land use land cover maps for each of the 4 epoch, as well as the change maps well represented at suitable scales depended on the spatial extents of Swaziland. Consideration was made to the various map elements discussed and agreed upon between the consultant and related stakeholders to ensure proper representation of map features.

Preparation of the final land cover maps for the 4 epochs resulting from the land use land cover classification were presented in user appropriate formats and to the required cartographic standards in both hard and soft copy formats. A proper legend was developed. Country maps for the years 1990, 2000, 2010 and 2015 were produced at a scale of 1:850,000. In addition, grids covering an area of 50 by 50Km were created in ArcGIS. These generated grids were twelve in number and were used to create maps at a scale of 1:250,000.

3.7 Land covers change detection and assessment

This activity involved carrying out change detection analysis on the land use land cover thematic data generated from classification in the previous stages. Four change pairs: 1990-2000, 2000-2010, 2010-2015 and 1990-2015 were generated. Vector based approach gives out the best change files showing the exact areas of change, transition among classes, positive and negative changes (losses and gains) and areas. The generated change files were used to create land cover change maps between the 4 epochs of study representing the various changes in vegetation types and land use land cover. Degraded areas will be easily identifiable with changes such as transition from forestland to grassland/bare area.

Changes detection results were represented in form of tables and graphs. Maps were used to represent areas of potential deforestation from various spatial analysis techniques that would reveal vulnerable areas within the ecosystem of Swaziland and the potential drivers of such changes. The maps were prepared in a uniform coordinate system (projected coordinate system WGS 84 36S).

3.8 Derivation of Statistics

It is always important to derive statistics from the classification files created in a study. This goes a long way in helping the researcher and the other stakeholders in conducting environmental assessment. The transition among the classes as gains and losses are determined through the use of statistics. Statistics for the land cover, land cover change; vegetation type and vegetation type files for the four epochs were extracted and displayed in the form of tables and graphs. Area was presented in hectares with the minimum mappable unit set at 0.5 hectares. This involved extraction of statistics from the land cover, land cover change files and importing the statistics into Excel and generation of tables and graphs.

4.0 Results

4.1 Landcover Collapsed Legend

The schema-I Landcover maps have collapsed class legend from 13 classes to 11 IPCC classes.

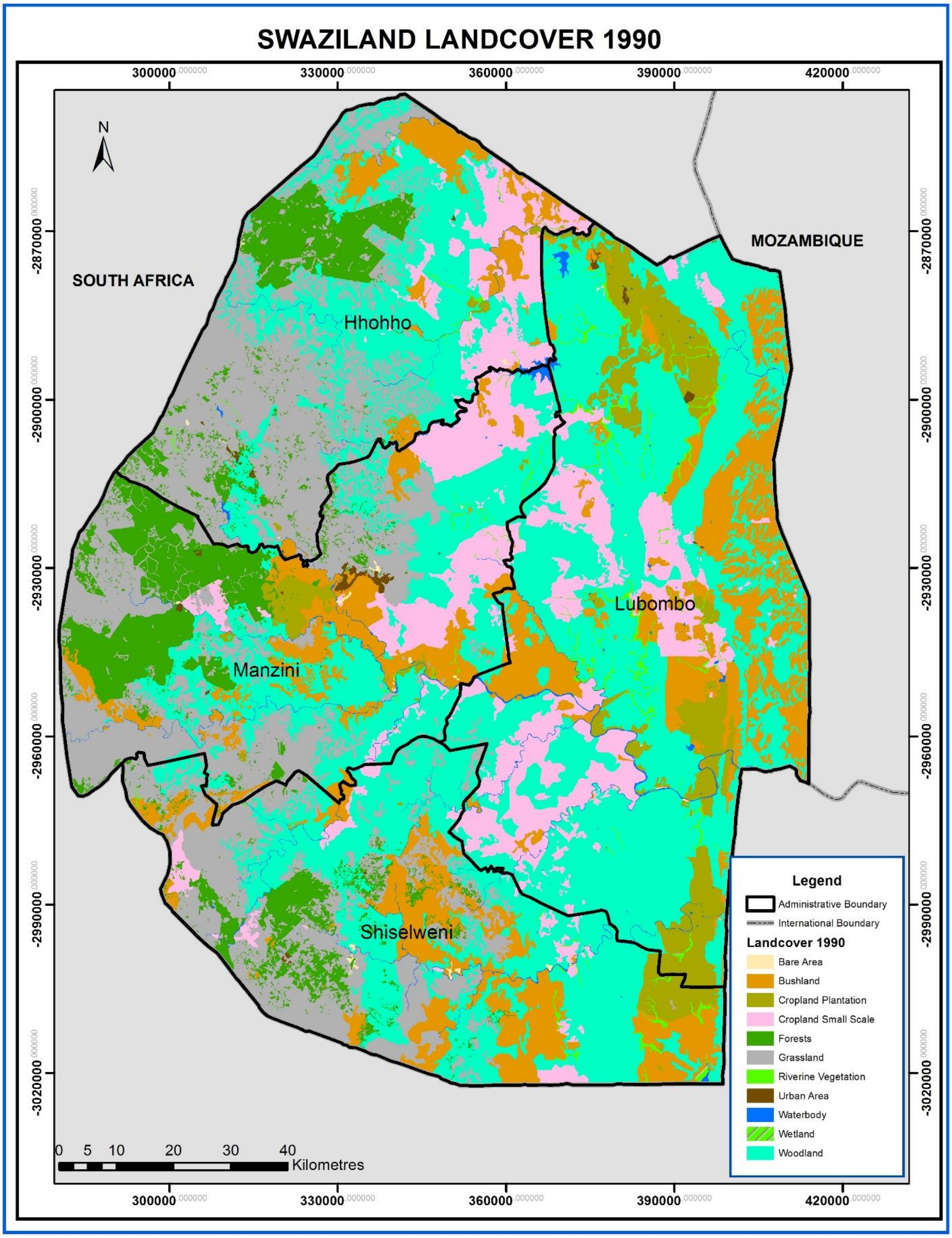
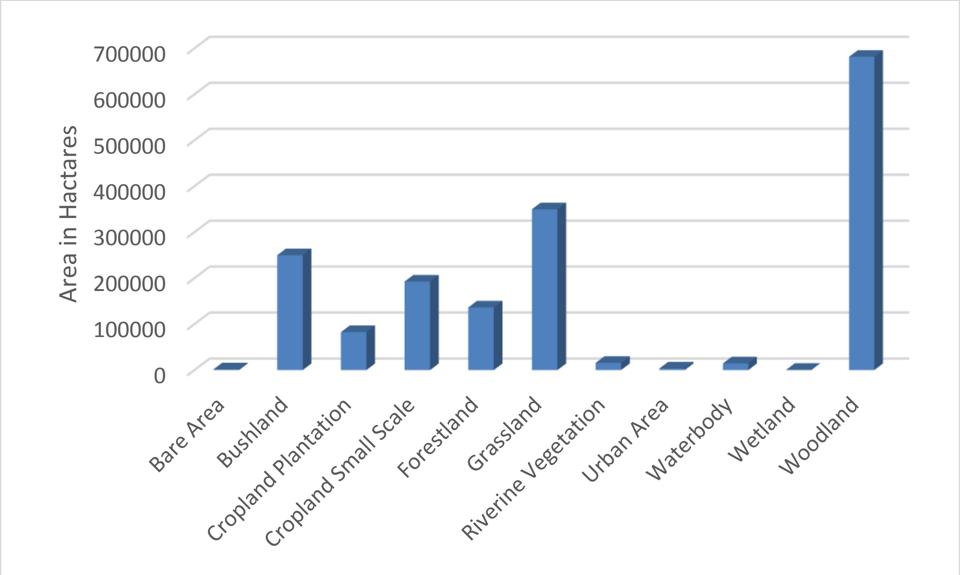


Figure 4: Swaziland Landcover for 1990

Statistics for Swaziland Landcover of 1990



In 1990, the country was generally covered by natural vegetation. Woodland, Bushland and Grassland formed the major land cover in the area. Wetlands, Urban areas and bare areas covered a minimal area compared to the trend in the next epochs.

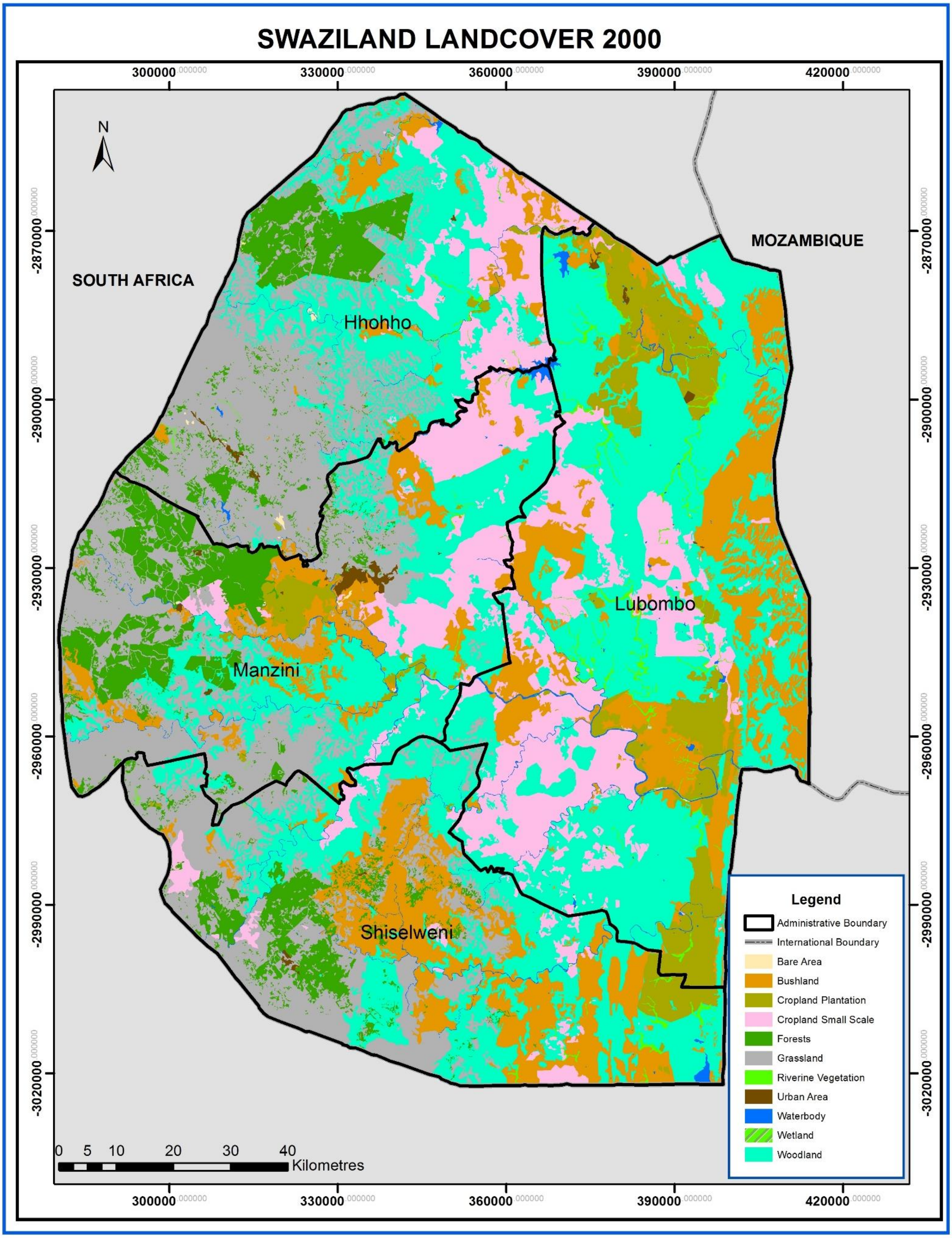
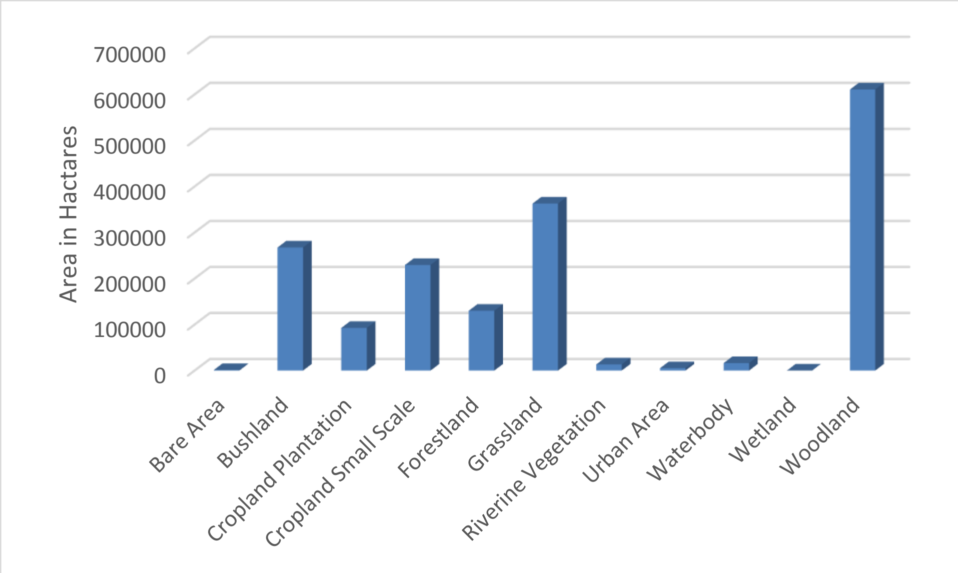


Figure 5: Swaziland Landcover for 2000

Statistics for Swaziland Landcover of 2000



In 2000, Woodlands dominated the Swaziland landcover followed by grasslands and bushland. Cropland increased. There are areas that grasslands transitioned to bushland. Riverine vegetation decreased slightly. Woodlands decreased from 1990 to 2000 while bushland increased their coverage.

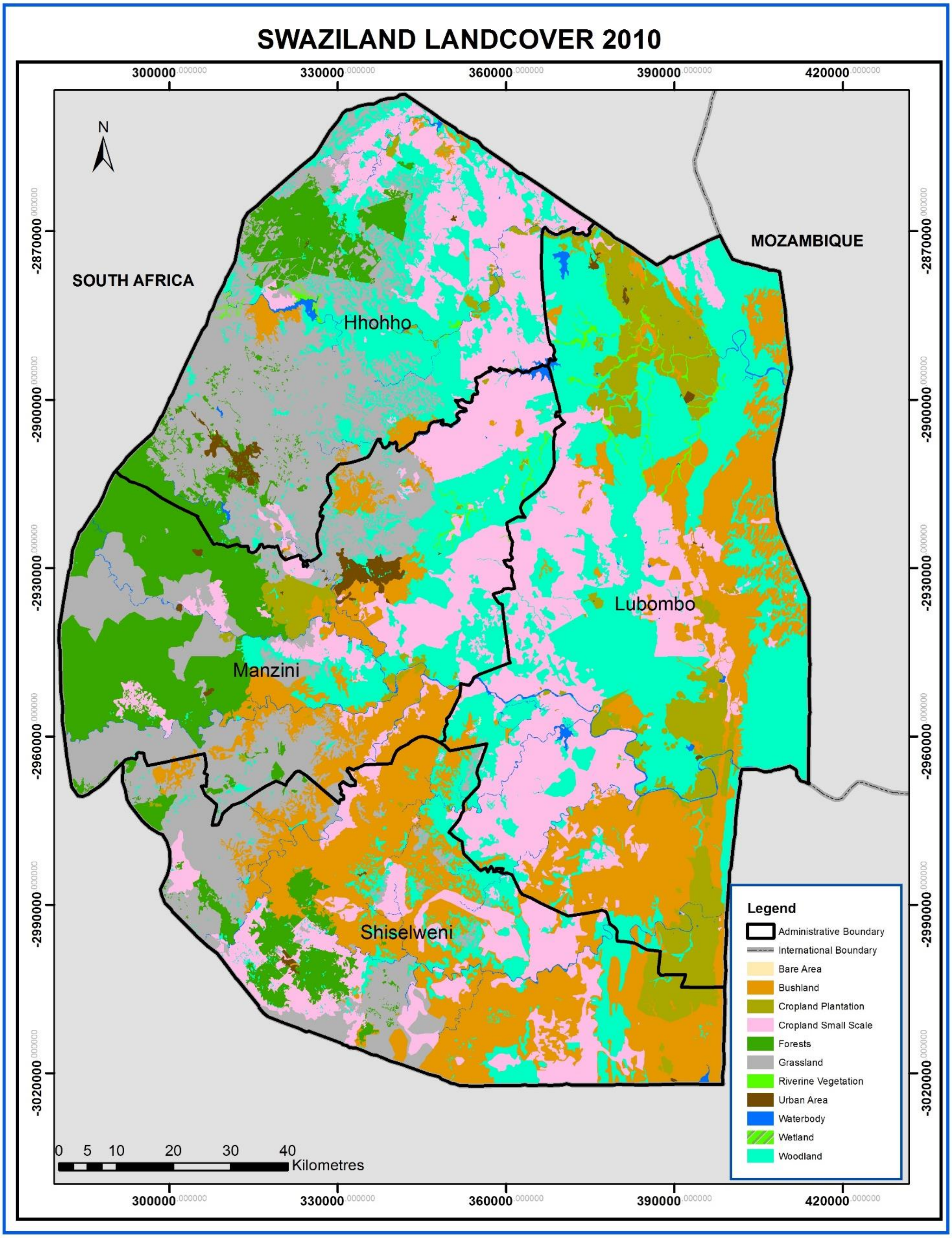
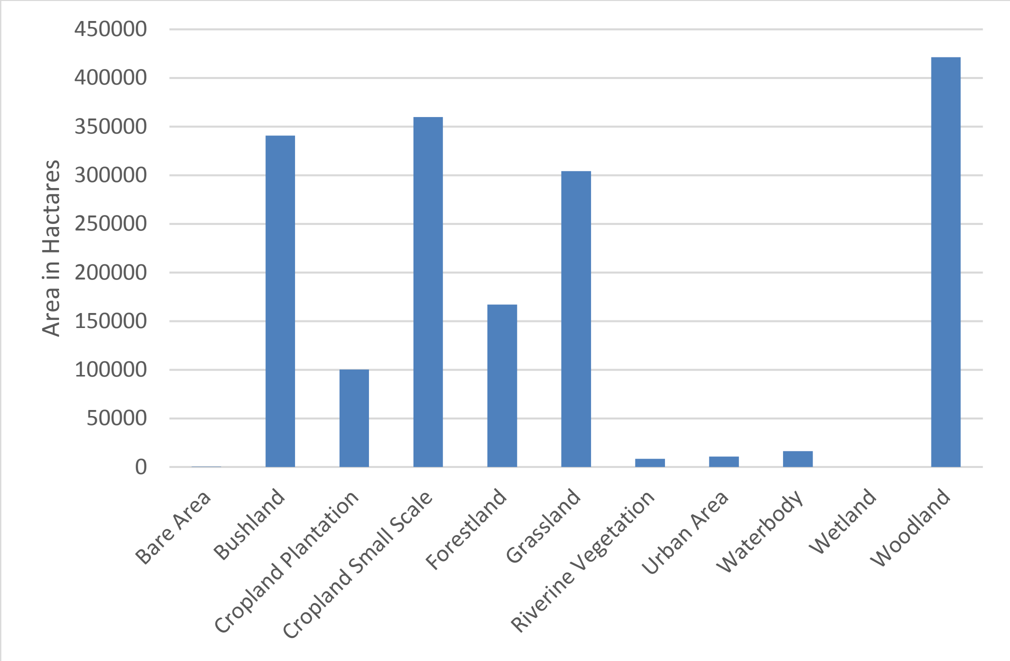


Figure 6: Swaziland Landcover for 2010

Statistics for Swaziland Landcover of 2010



In 2010, Swaziland was dominated by bushlands and woodland and there was an increase of forestland. Large portions of new cropland areas emerged. Woodland decrease while bushland continued to increase. There is a visible increment in the size of the urban areas as witnessed in the expansion of the 2000 urban areas. As for the waterbody increment, it is likely that there is damming of rivers to assist in the irrigating of the plantations which have visibly increased in size.

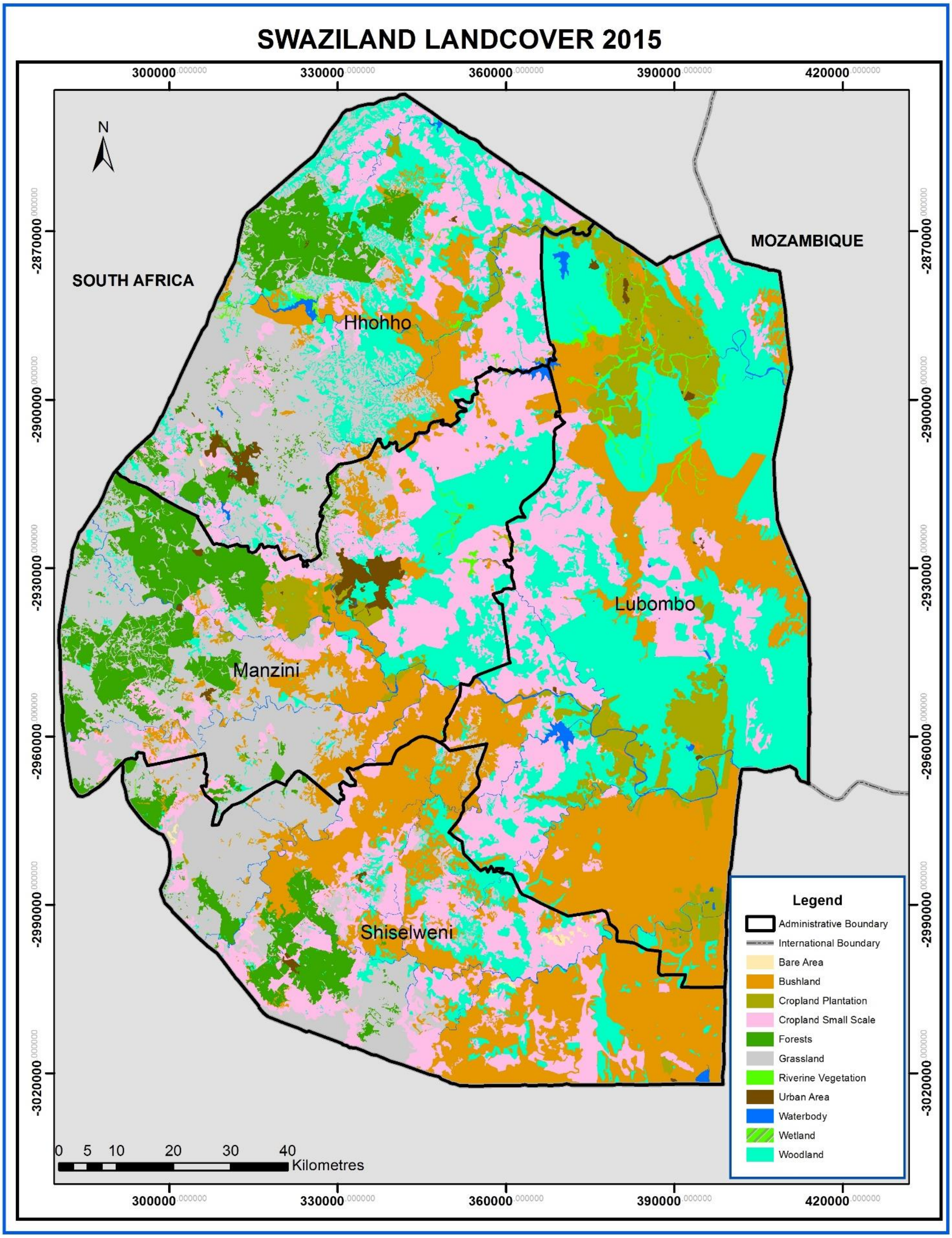
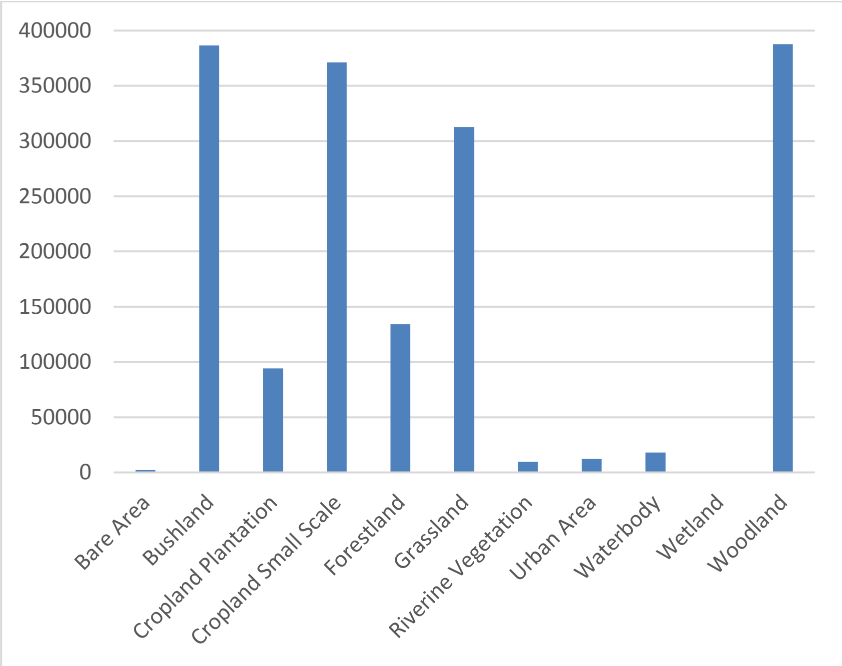


Figure 7: Swaziland Landcover for 2015

Statistics for Swaziland Landcover of 2015



In 2015, bushland, cropland small scale, woodland and grassland dominated the Landcover. There has been massive changes that have occurred in the area. Some are positive and others have negative impacts especially in the long run. The negative changes include the massive increase in cropland areas in both the pre-existing areas and new regions. The urban areas have increased significantly which indicates an increase in population. Riverine vegetation have reduced unlike water bodies which have cropped up in the entire region. It may be safe to say it's because of damming of the area for irrigation.

Comparison of changes from 1990-2015

Landcover	1990 Area (Ha)	2000 Area (Ha)	2010 Area (Ha)	2015 Area (Ha)
Bare Area	1715	1172	106	2074
Bushland	249985	267321	340649	386411
Cropland Plantation	82622	92587	100274	94241
Cropland Small Scale	192601	229349	359687	371126
Forestland	136079	129925	167063	134249
Grassland	349890	362819	304120	312721
Riverine Vegetation	15603	13366	8419	9724
Urban Area	3344	5130	10588	12357
Waterbody	14543	16263	16165	18103
Wetland	475	36	0	0
Woodland	681707	610594	421492	387557
TOTAL	**1728563**	**1728563**	**1728563**	**1728563**

4.2 Landcover Change Detection Analysis

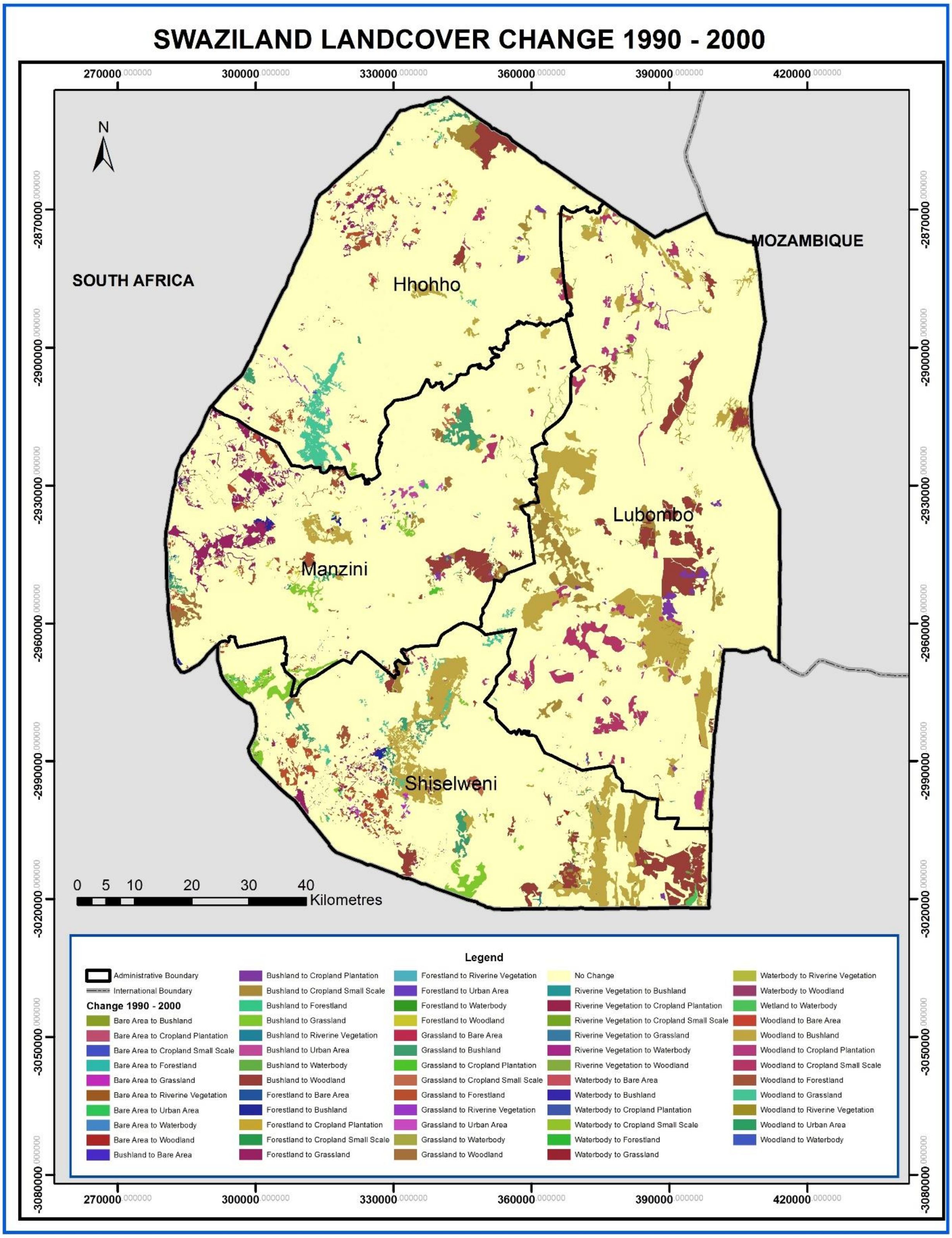


Figure 12: Swaziland Landcover change analysis for 1990-2000

In Landcover change analysis of 1990-2000 Statistics (Annex I) indicate that 84.60% of the landcover remain unchange, 5.08% changed from woodland to bushland an indication of degradation, 2.61% changed from woodland to bushland which is an indication of degradation. 1.14% of the bushland and 0.90% of the woodlands were converted to cropland small scale.

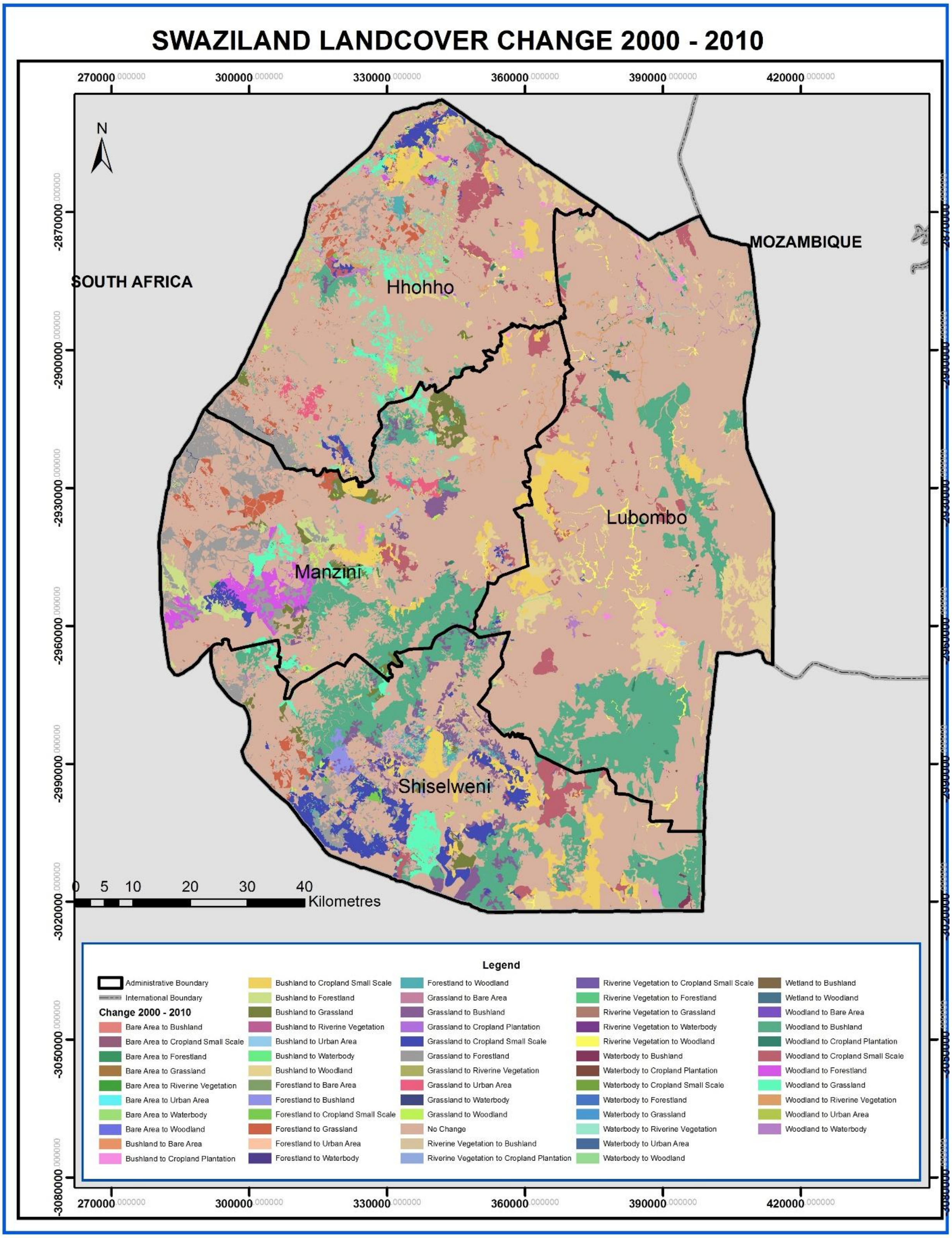


Figure 13: Swaziland Landcover change analysis for 2000-2010

In Landcover change analysis of 2000-2010 Statistics (Annex II) indicate that 66.16% of the total area of Swaziland remain unchanged, 10.51% landcover changed from woodland to bushland an indication of the degradation, 2.91% of the grasslands regenerated to bushland. 3.0% of the bushland regenerated to woodlands, 3.30% of the bushlands and 2.13% of thw woodlands were coverted to cropland small scale.

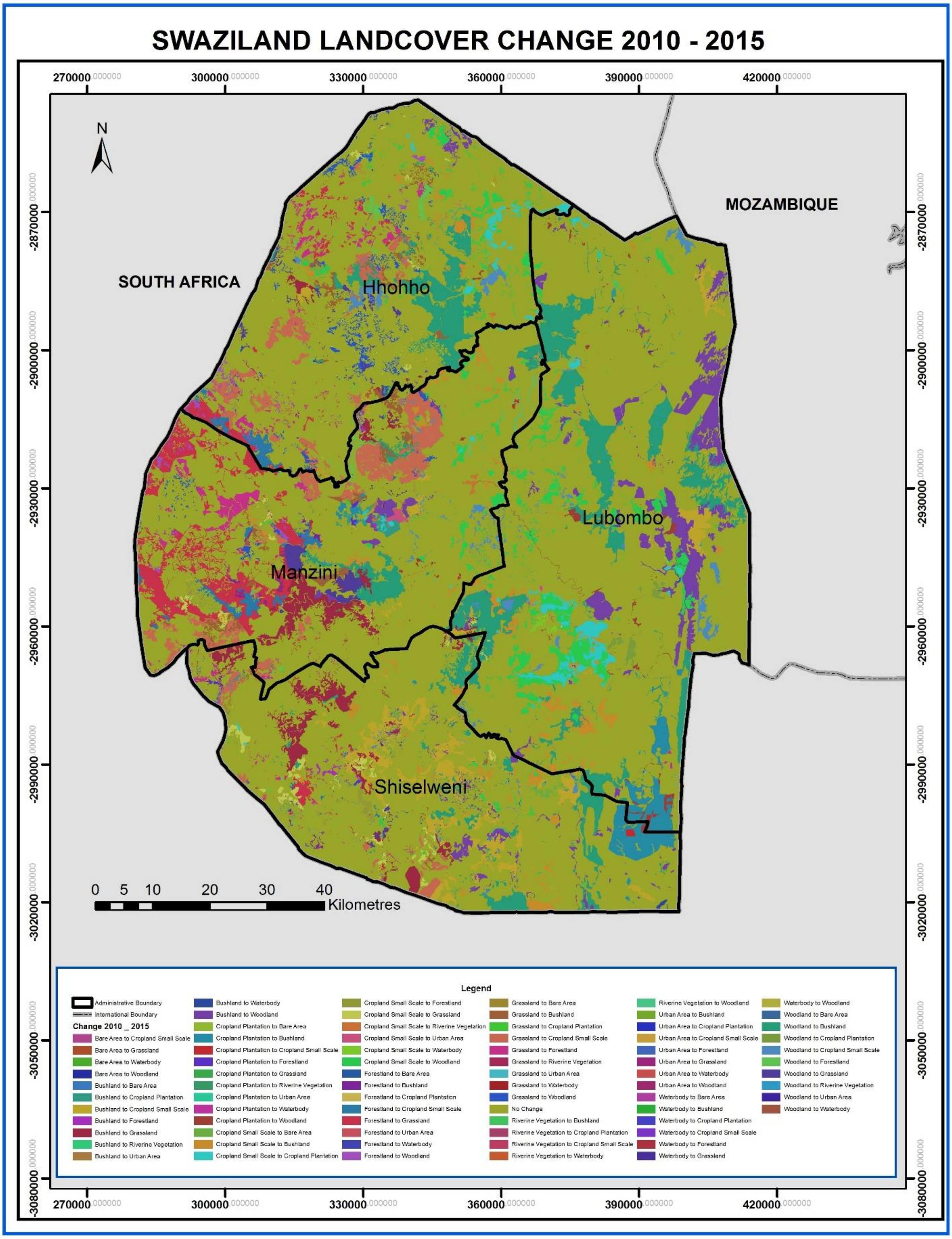


Figure 14: Swaziland Landcover change analysis for 2010-2015

In Landcover change analysis of 2010-2015 Statistics (Annex III) indicate that 71.25% of the total landcover remain unchanged while 6.07% of the landcover changed from woodland to bushland an indication of degradation, 2.71% of the landcover changed from bushland to woodland an indication of regeneration and 1.59% landcover changed from bushland to grassland.

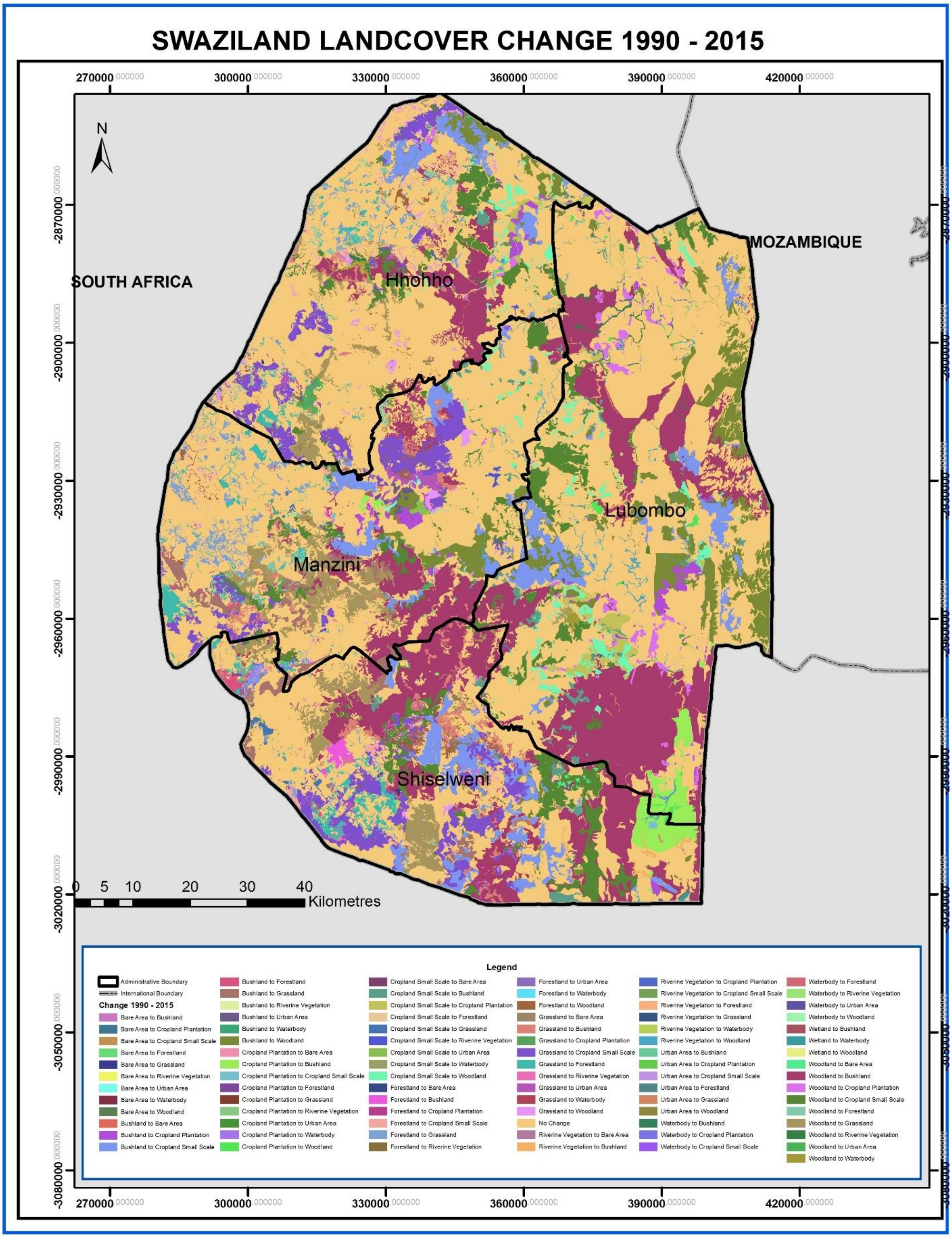


Figure 15: Swaziland Landcover change analysis for 1990-2015

In Landcover change analysis of 1990-2015 Statistics (Annex III) indicate that 51.72% of the Swaziland landcover remaned unchanged, 14.79% of the lancover changed from woodland to bushland an indication of degradation, 4.15% of the landcover changed from bushland to woodland an indication of regeneration. 4.16% of the bushland and 4.31% of the woodlands were converted to cropland small scale.

5.0 Vegetation Type Mapping

Vegetation types of Swaziland are based on the physiographic zones. These physiographic zones differ in altitude, topography, geology, climate and vegetation types. All these factors play a big role in the types of vegetation that thrive in each zone. According to Linda and Loffler (2005), the different physiographic zones and their altitude include:

Table 6: Different physiographic zones and their altitude

Physiographic Zone	Elevation
Highveld	900-1800m
Upper middleveld	600-900m
Lower middleveld	400-600m
Western Lowveld	250-400m
Eastern Lowveld	200-300m
Lebombo Range	250-600m

5.1 Stratification of Vegetation Types

This study relied heavily on secondary and ancillary data to map the main vegetation types in Swaziland. Swaziland country environment profile draft report asserts that there are eleven vegetation types in Swaziland. However, the study used the classification system by Sweet and Khumalo that narrows down the various vegetation types into four categories. The various categories rely on elevation and each vegetation type supports several species of plants. The four grouped zones are:

5.1.1 Lebombo Bushveld

This vegetation type falls within Lebombo range that ranges from 200m up to 800m. Lebombo range supports combretum rich bushveld thinning out to a tall grassy plateau surrounded by rocky outcrops and cliff faces. Bush clumps around rocky outcrops are frequent on the plateau with seasonal pans occasionally forming in natural depressions. Characteristic trees and shrubs include Combretum species, Olive, Pink Ivory, lavender tree and poison peach. Lebombo bushveld supports a similar community of subtropical forms to that of the lowveld bushveld.

5.1.2 Lowveld Bushveld

Lowveld bushveld consists of different vegetation types that have been merged. These include basalt sweet arid lowveld, Zululand lowveld and Delagoa lowveld. Lowveld bushveld generally occurs between 200-400m and is split into western and eastern lowveld bushveld. Western lowveld is typically broadleaved woodland on sandy soils characterised by Combretum species and cluster leaf on steep to gentle slopes. Typical trees are and shrubs are similar to the higher altitude savannas but also include fig, weeping watle, Acacia species, poison-pod Albizia, Grewia species, confetti tree, buffalo thorn, natal mahogany and apple-leaf. Typical grasses include red grass, gewone buffels grass, lovegrass species, finger grass and Digitaria species.

5.1.3 Montane Grassland

Montane Grassland is found in the Western part of Swaziland. It is common in elevations of above 900m. This type of vegetation includes Kangwane and Barbeton montane grasslands that have been grouped together. This vegetation type is characterised by fairly dense, short, sour to very sour grassland in rugged terrain with patches of evergreen forest occurring in ravines and river valleys. Typical grass species include red grass, blue grass, clayton grass and common russet grass. Shrubs and herbs also occur. Characteristic trees and shrubs which often occur in woody clumps at rock outcrops are Englerophytum species, water-berry tree, velvet wild medlar, Cussonia species and Maesa lanceolata. Expansive stands of exotic acacia species (wattle) smother many river and stream banks and infestations of weeds, bug weed and lantana are common in disturbed areas including industrial timber plantations of conifer and eucalyptus. Much of the remaining land is settled by subsistence farmers.

5.1.4 Sour Bushveld

Mixed bushland, quartzite sourveld, Zululand sourveld and granite lowveld bushveld have been confirmed to form this type of vegetation. This type of vegetation occurs at altitudes between 400-900m and the vegetation is characterised by tall grassveld with scattered trees. Some dense forest and thicket patches are often associated with rocky outcrops. Sour bushveld is generally located on steep slopes rolling hills flattening out to the east. Typical grasses include thatching grass, yellow thatching grass, spear grass, Cymbopogon excavates, bufflalo grass and red grass. Typical trees and shrubs include acacia species, wild pear, African black wattle, marula, spike-thorn, Kalahari Christmas tree, Rhus species, wild teak, lannea discolour, custard apple, combretum specie, Euclea species and African plume. This vegetation category is prone to human encroachment in form of settlement and agricultural fields.

5.2 Approach & Methodology for vegetation types mapping

Methodology used for classifying vegetation types was similar to that used for Land Use Land Cover Mapping (Figure 2). The main difference was that image classification was based on only the four vegetation types. In essence, collection of ancillary data, quality checking of the ancillary data, acquisition of Landsat Imagey and pre-processing applied to vegetation mapping. The images used for vegetation mapping are as shown below in Figure 3.

5.2.1 Image Classification for Vegetation types

A proper classification scheme consistent with the existing classification schemes for vegetation types in Swaziland was settled upon (Figure 2). Vegetation type characteristics were agreed on based on publications and ancillary data from various stakeholders. Montane grassland, sour bushveld, Lowveld bushveld and Lebombo bushveld are the main vegetation types that were classified. Figure 2 provides a summary of all the steps carried out from image acquisition to the final classification product.

Supervised classification (object oriented) was done in Arc GIS to produce output files in vector format. On screen digitization was employed to conduct the classification. Visual interpretation was essential in determining the classes. This process involved extraction of information from the satellite images as polygons which were then coded by assigning them to the correct class. The figure below shows the generated vegetation types polygons.

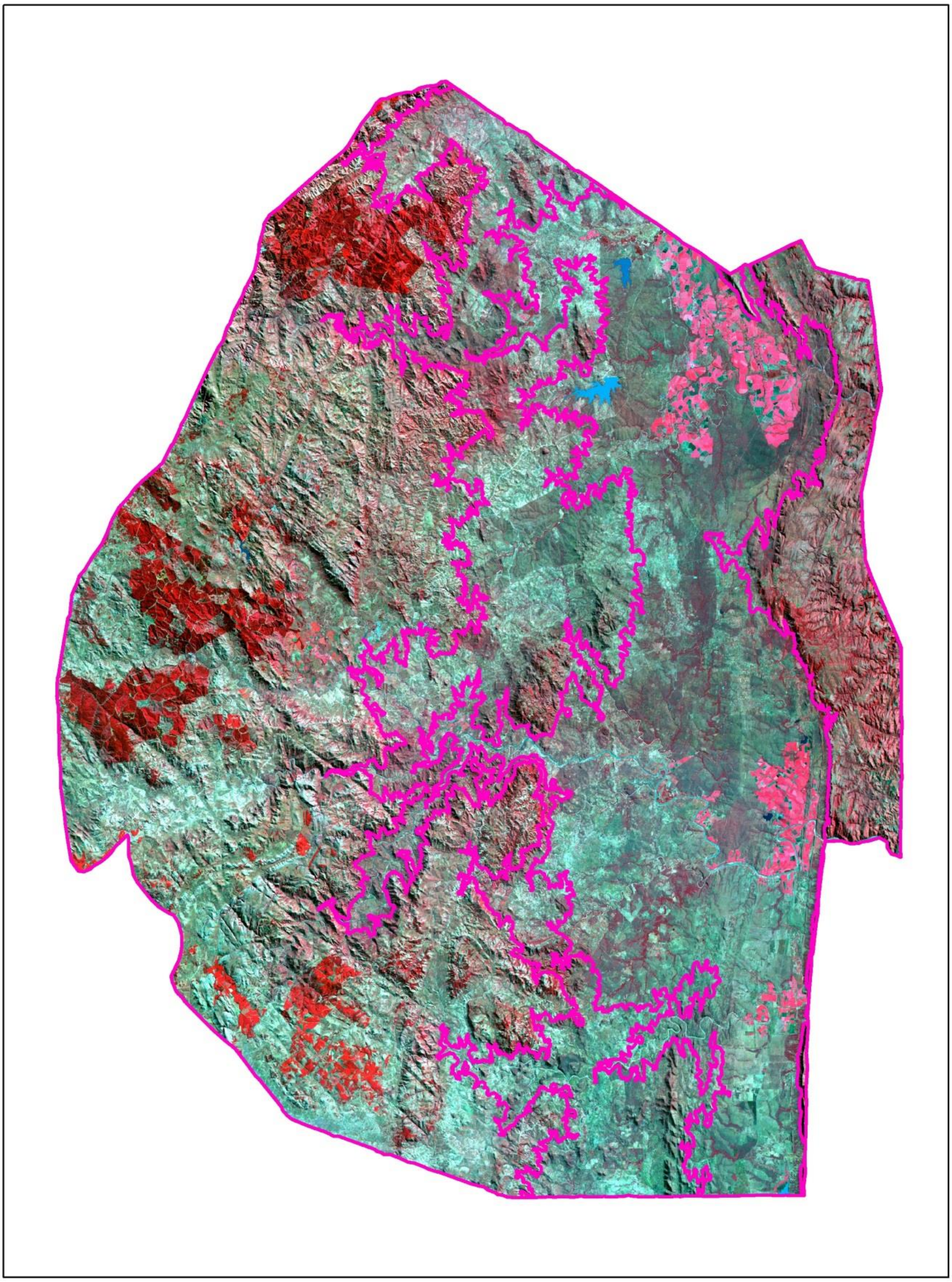


Figure 16: Generated vegetation type polygons

The most current year which is 2015 was the first to be classified. Quality checks were performed on the first draft 2015 classification using ancillary data obtained from various stakeholders in Swaziland. Unlike land cover classification; there was no much difference in vegetation types. The 2015 file aided in coming up with the 1990, 2000 and 2010 files. Change analysis was conducted to generate change maps that show the exact areas where changes occurred and the transition among vegetation types. The vegetation type statistics were generated in ArcGIS and tables created in Excel. The development of vegetation type maps were done at the scale of 1:850,000 for the country maps.

5.3 Vegetation Type Maps

All the vegetation files generated for the four epochs were similar. This is attributed to the fact that elevation was used to come up with the files. All the maps were similar too. As a result no change maps could be generated.

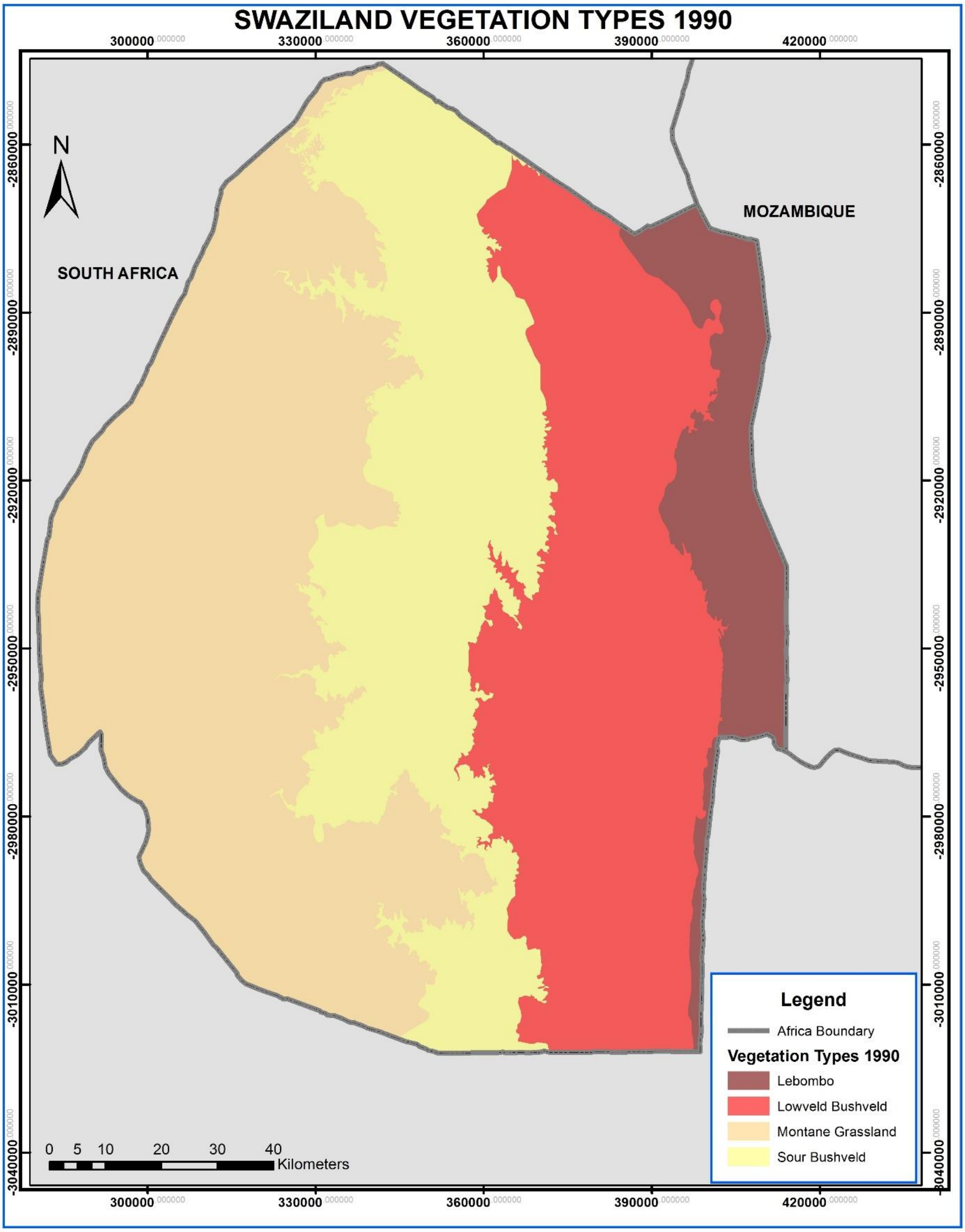


Figure 17: Swaziland vegetation type 1990

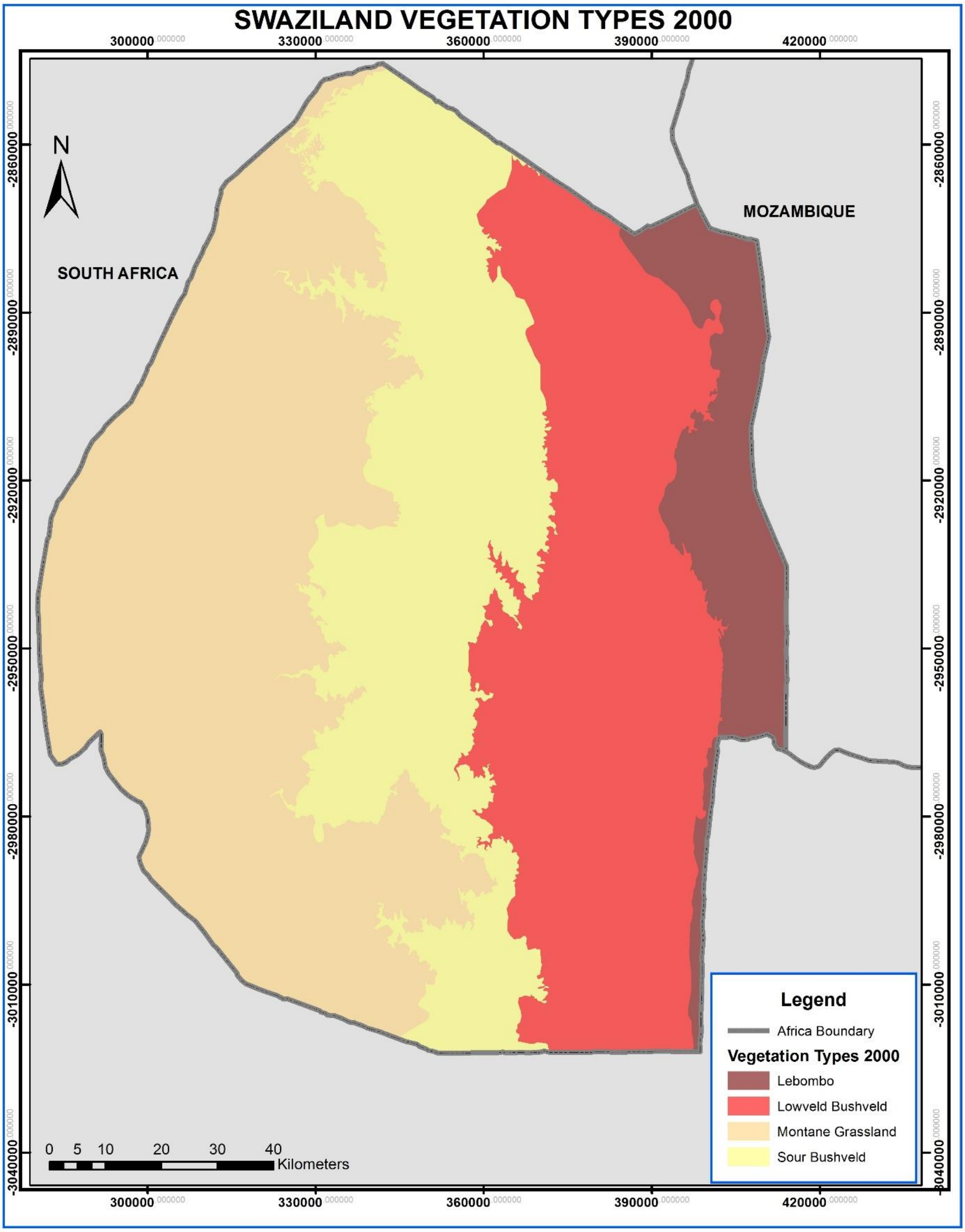


Figure 18: Swaziland vegetation type 2000

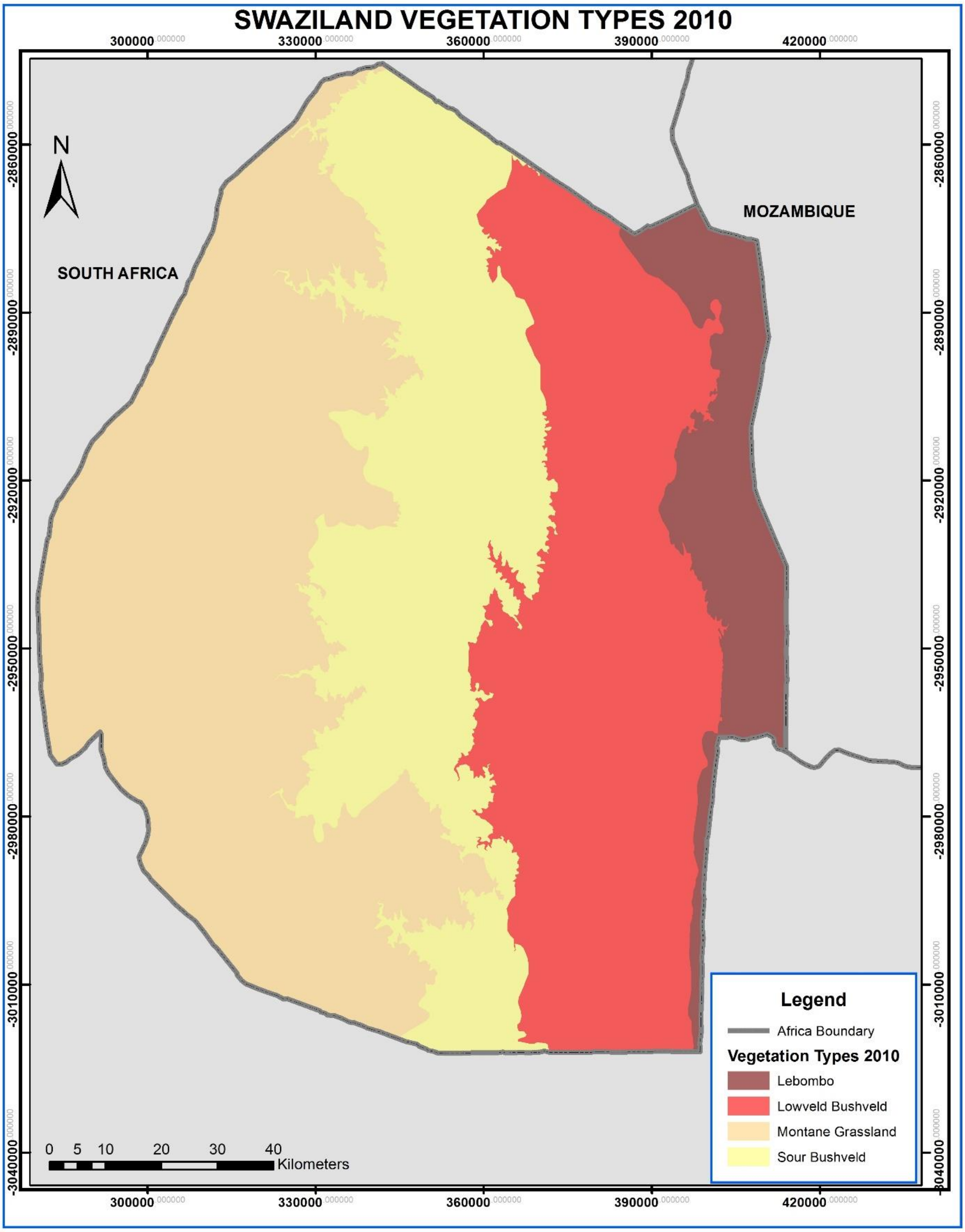


Figure 19: Swaziland vegetation type 2010

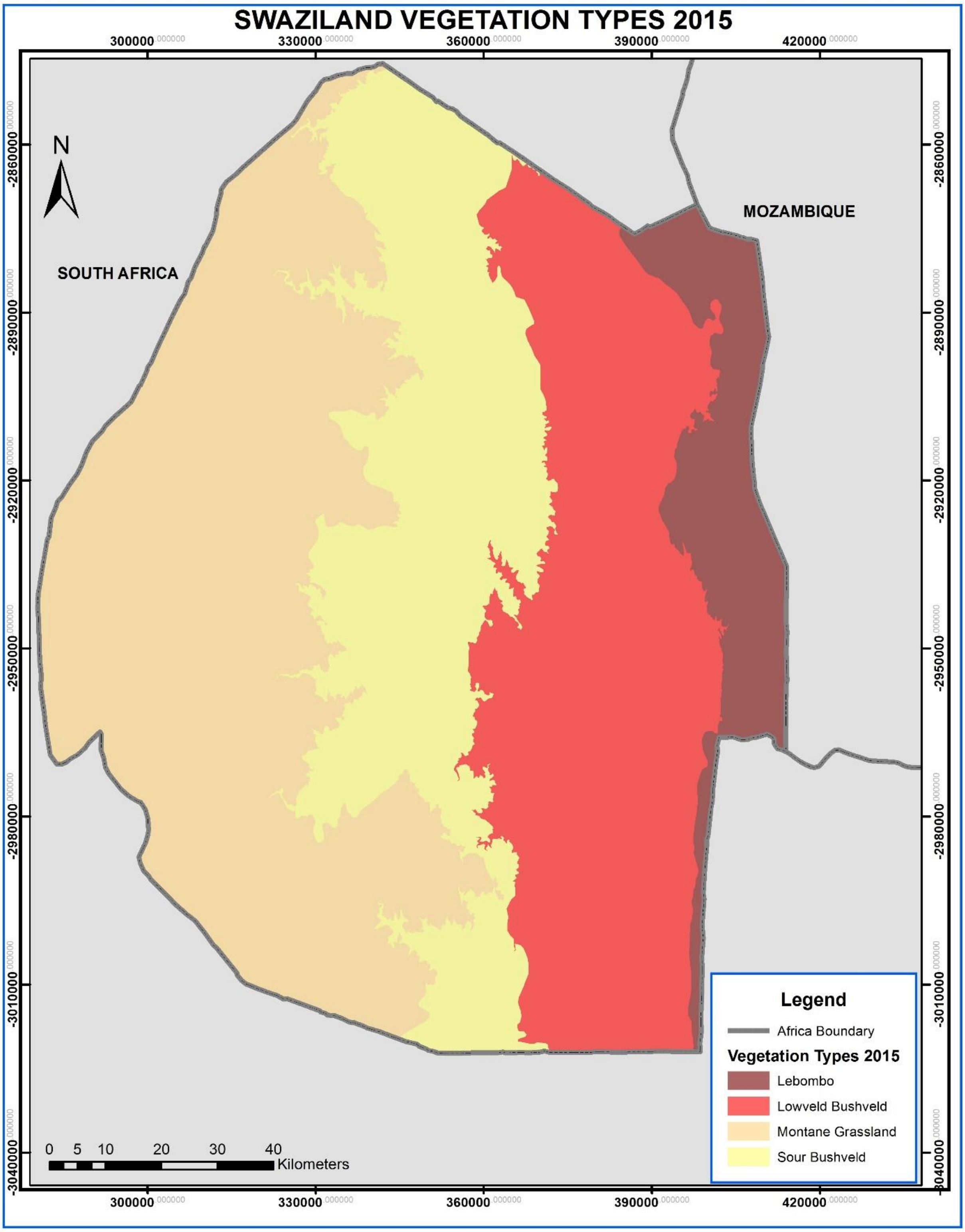


Figure 20: Swaziland vegetation type 2015

The table below shows the areas for the various vegetation types. Montane Grassland is the major vegetation type, followed by Lowveld Bushveld, Sour Bushveld and Lebombo

Bushveld with the least acreage. As much as the vegetation types remain constant over the years, the various species within the categories keep on changing.

5.4 Statistics for the vegetation types

Below in figures 7 -10, show the statistics in area (ha) for the 1990, 2000, 2010 and 2015. The vegetation types 1990 is similar to 2000 and also that of 2010 is similar to 2015.

Table 7: Areas for the various vegetation types

Vegetation Type 2015	Area (Ha)
Lebombo	139,754.94
Lowveld Bushveld	488,672.34
Montane Grassland	669,026.80
Sour Bushveld	431,097.37
TOTAL	**1,728,551.45**

Table 8: Areas for the various vegetation types

Vegetation Type 2010	Area (Ha)
Lebombo	139,754.94
Lowveld Bushveld	488,672.34
Montane Grassland	669,026.80
Sour Bushveld	431,097.37
TOTAL	**1,728,551.45**

Table 9: Areas for the various vegetation types

Vegetation Type 2000	Area (Ha)
Lebombo	138,181.31
Lowveld Bushveld	487,458.27
Montane Grassland	664,237.86
Sour Bushveld	438,674.00
TOTAL	**1,728,551.45**

Table10: Areas for the various vegetation types

Vegetation Type 1990	Area (Ha)
Lebombo	138,181.31
Lowveld Bushveld	487,458.27
Montane Grassland	664,237.86
Sour Bushveld	438,674.00
TOTAL	**1,728,551.45**

5.5 Vegetation types change analysis

The vegetation change analysis was carried out on 1990 and 2015 where there was an indication of change especially along the transition boundary of different vegetation types.

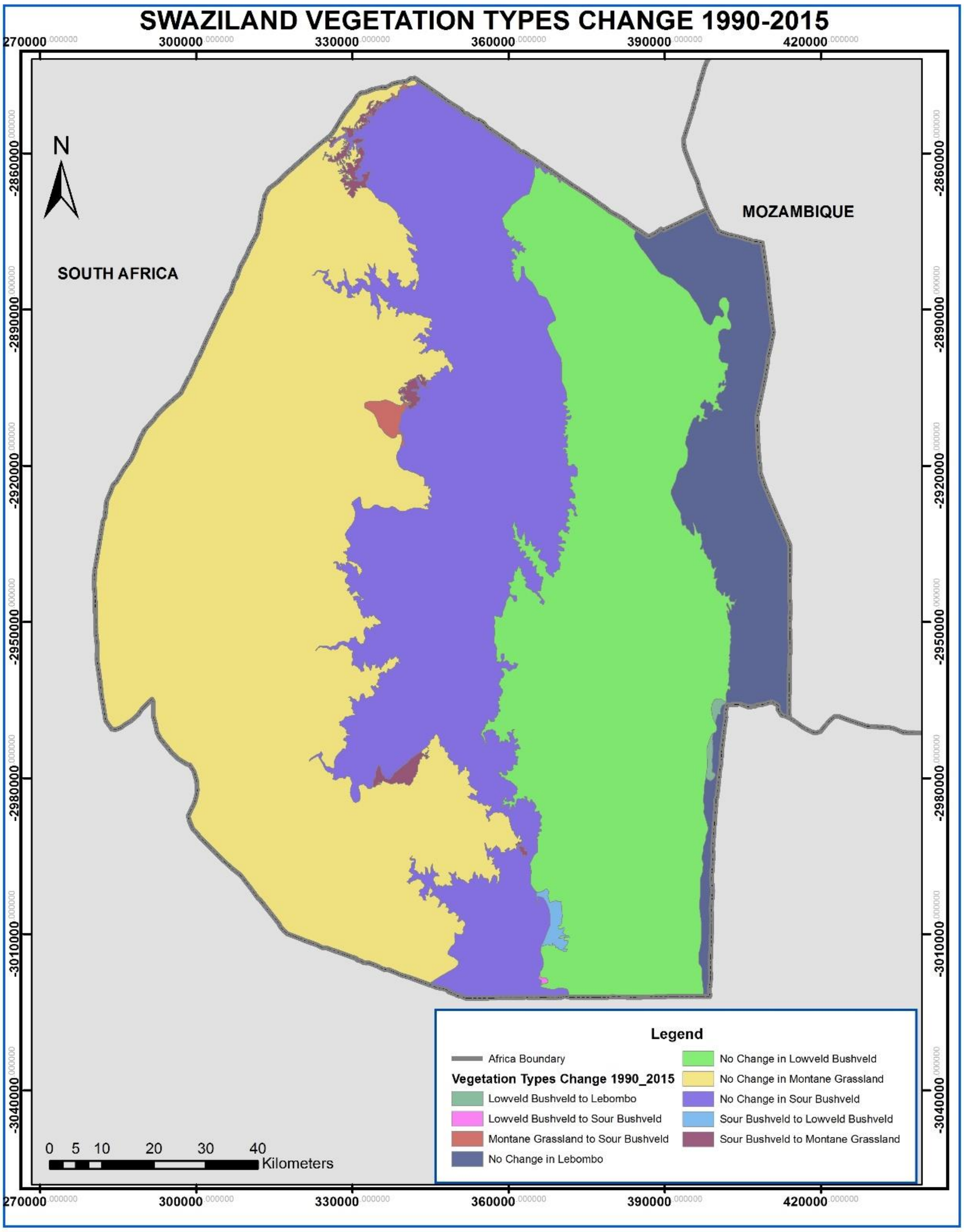


Figure 21: Swaziland vegetation type change 1990-2015

Table 11: ***Vegetation type change 1990-2015***

Vegetation type change 1990-2015	**Area in Ha**	**% change**
Lowveld Bushveld to Lebombo	1,573.63	0.09
Lowveld Bushveld to Sour Bushveld	162.55	0.01
Montane Grassland to Sour Bushveld	3,705.93	0.21
No Change in Lebombo	138,181.31	7.99
No Change in Lowveld Bushveld	485,722.09	28.10
No Change in Montane Grassland	660,531.93	38.21
No Change in Sour Bushveld	427,228.89	24.72
Sour Bushveld to Lowveld Bushveld	2,950.25	0.17
Sour Bushveld to Montane Grassland	8,494.87	0.49
TOTAL	**1,728,551.45**	

From the table 11 above, the vegetation types changes are minor, there were slight changes from sour bushveld to grassland and vice versa. The changes were seen to take place along the boundary of transition.

6.0 Conclusions and Recommendations

6.1 Conclusions

In 1990, the country was generally covered by natural vegetation. Woodland, Bushland and Grassland formed the major land cover in the area. Wetlands, Urban areas and bare areas covered a minimal area compared to the trend in the next epochs.

In 2000, Woodlands dominated the Swaziland landcover followed by grasslands and bushland. Cropland increased. There are areas that grasslands transitioned to bushland. Riverine vegetation decreased slightly. Woodlands decreased from 1990 to 2000 while bushland increased their coverage.

In 2010, Swaziland was dominated by bushlands and woodland and there was an increase of forestland. Large portions of new cropland areas emerged. Woodland decrease while bushland continued to increase. There is a visible increment in the size of the urban areas as witnessed in the expansion of the 2000 urban areas. As for the waterbody increment, it is likely that there is damming of rivers to assist in the irrigating of the plantations which have visibly increased in size.

In 2015, bushland, cropland small scale, woodland and grassland dominated the Landcover. There has been massive changes that have occurred in the area. Some are positive and others have negative impacts especially in the long run. The negative changes include the massive increase in cropland areas in both the pre-existing areas and new regions. The urban areas have increased significantly which indicates an increase in population. Riverine vegetation have reduced unlike water bodies which have cropped up in the entire region. It may be safe to say it's because of damming of the area for irrigation.

In Landcover change analysis of 1990-2000 Statistics (Annex I) indicate that 40% of the landcover remain unchange, 12% changed from bushland to woodland an indication of regeneration, 10% changed from grassland to bushland an indication of regeneration, 7.3% changed from woodland to bushland and there was 5% change from bushland to grassland which is an indication of bushland degradation.

In Landcover change analysis of 2000-2010 Statistics (Annex II) indicate that 38% of the total area of Swaziland remain unchanged, 8% landcover changed from woodland to bushland an indication of the degraded woodlands, 8% of the landcover regenerated from grassland to bushland.

In Landcover change analysis of 2010-2015 Statistics (Annex III) indicate that 40.8% of the total landcover remain unchanged while 9.3% of the landcover changed from bushland to woodland an indication of regeneration, 7.4% of the landcover changed from woodland to bushland an indication of degraded woodland and 6.5% landcover changed from bushland to woodland an indication of regeneration.

In Landcover change analysis of 1990-2015 Statistics (Annex IV) indicate that 66.6% of the Swaziland landcover remained unchanged, 9.6% of the landcover changed from woodland to bushland an indication of degraded woodland, 9.3% of the landcover changed from bushland to woodland an indication of regeneration and 9.1% changed from cropland fields to bushland an indication of regeneration.

Montane Grassland is the major vegetation type, followed by Lowveld Bushveld, Sour Bushveld and Lebombo Bushveld with the least acreage. As much as the vegetation types remain constant over the 1990 and 2000, 2010 and 2015 years, the various species within the categories keep on changing. The vegetation type changes are minor and were mainly observed in 1990 and 2015. There were slight changes from sour bushveld to grassland and vice versa. The changes were seen to take place along the boundary of transition.

The landcover and vegetation type maps were generated using imagery of Landsat sensor which is 30m resolution (Medium resolution). The appropriateness of remote sensing imagery for forest mapping and monitoring using medium resolution imagery has shortcomings. The medium resolution limits the accuracy of the results to low. High resolution imagery (0.5m resolution) gives high accurate results.

6.2 Recommendations

- In areas that have regenerated to closed wood, a forestry inventory should be carried out to ascertain the forest composition species, species abundance and richness. Such closed woodland that 5m high with a canopy crown density of 30% and more than I hactare should be gazzeted as Forests.

- Since the Strengthening the National Protected Areas System of Swaziland project aims at developing, expanding and effectively managing the capacities of Swaziland's protected areas (PAs) network in order to adequately protect the biodiversity, there is need to map the landcover, vegetation types and carry out vulnerability mapping of individual protected areas using high resolution imagery of 5m or 10m sentinel imagery in order to understand the habitat and changes that have taken place over years.

- During the implementation of this assignment, I realised that the staff of Swaziland National Trust Commission and sister ministries don't have the capacity to carry out the landcover and vegetation types mapping using satellite imagery and remote sensing software applications. I recommend a two weeks training of the selected staff from the Swaziland National Trust Commission and sister ministries in use of GIS and Remote sensing software in developing landcover and vegetation types maps.

- During the ground truthing field data collection mission in Swaziland, I noticed the invasion of invasive species in the montane grassland and in other vegetation types. There is need to map out these invasive species locations and extent so that the Government can implement an eradication programme. These invasive species are spreading at high rate and are out competing the local vegetation species.

Annex 1: Land Cover Change Statistics from 1990-2000

Landcover Change 1990 to 2000	Area (Ha)	%age
Bare Area to Bushland	252.75	0.01
Bare Area to Cropland Plantation	65.40	0.00
Bare Area to Cropland Small Scale	34.75	0.00
Bare Area to Forestland	16.87	0.00
Bare Area to Grassland	306.39	0.02
Bare Area to Riverine Vegetation	17.71	0.00
Bare Area to Urban Area	151.03	0.01
Bare Area to Waterbody	15.05	0.00
Bare Area to Woodland	218.55	0.01
Bushland to Bare Area	23.19	0.00
Bushland to Cropland Plantation	4,076.54	0.24
Bushland to Cropland Small Scale	19,647.32	1.14
Bushland to Forestland	559.05	0.03
Bushland to Grassland	12,138.37	0.70
Bushland to Riverine Vegetation	263.99	0.02
Bushland to Urban Area	605.26	0.04
Bushland to Waterbody	472.19	0.03
Bushland to Woodland	45,190.70	2.61
Forestland to Bare Area	29.44	0.00
Forestland to Bushland	1,480.20	0.09
Forestland to Cropland Plantation	183.82	0.01
Forestland to Cropland Small Scale	152.52	0.01
Forestland to Grassland	20,454.55	1.18
Forestland to Riverine Vegetation	9.69	0.00
Forestland to Urban Area	82.26	0.00
Forestland to Waterbody	15.93	0.00
Forestland to Woodland	637.15	0.04
Grassland to Bare Area	307.60	0.02
Grassland to Bushland	10,495.97	0.61
Grassland to Cropland Plantation	330.64	0.02
Grassland to Cropland Small Scale	1,454.89	0.08
Grassland to Forestland	13,367.37	0.77
Grassland to Riverine Vegetation	24.61	0.00
Grassland to Urban Area	837.24	0.05
Grassland to Waterbody	146.13	0.01
Grassland to Woodland	4,312.00	0.25
No Change in Bare Area	635.68	0.04
No Change in Bushland	167,008.07	9.66
No Change in Cropland Plantation	82,621.86	4.78
No Change in Cropland Small Scale	192,603.99	11.14
No Change in Forestland	113,035.53	6.54
No Change in Grassland	318,610.90	18.43

No Change in Riverine Vegetation	12,186.90	0.71
No Change in Urban Area	3,344.34	0.19
No Change in Waterbody	14,417.95	0.83
No Change in Wetland	36.17	0.00
No Change in Woodland	557,870.83	32.27
Riverine Vegetation to Bushland	205.72	0.01
Riverine Vegetation to Cropland Plantation	147.04	0.01
Riverine Vegetation to Cropland Small Scale	143.80	0.01
Riverine Vegetation to Grassland	17.38	0.00
Riverine Vegetation to Waterbody	583.16	0.03
Riverine Vegetation to Woodland	2,318.23	0.13
Waterbody to Bare Area	2.10	0.00
Waterbody to Bushland	20.42	0.00
Waterbody to Cropland Plantation	5.31	0.00
Waterbody to Cropland Small Scale	20.72	0.00
Waterbody to Forestland	12.76	0.00
Waterbody to Grassland	1.65	0.00
Waterbody to Riverine Vegetation	14.21	0.00
Waterbody to Woodland	46.57	0.00
Wetland to Waterbody	438.79	0.03
Woodland to Bare Area	174.35	0.01
Woodland to Bushland	87,857.54	5.08
Woodland to Cropland Plantation	5,156.12	0.30
Woodland to Cropland Small Scale	15,289.84	0.88
Woodland to Forestland	2,935.52	0.17
Woodland to Grassland	11,289.02	0.65
Woodland to Riverine Vegetation	848.65	0.05
Woodland to Urban Area	110.30	0.01
Woodland to Waterbody	174.02	0.01
TOTAL	**1,728,562.55**	100.00

Annex II: Land Cover Change Statistics from 2000-2010

Landcover Change from 2000 to 2010	Area (Ha)	%age
Bare Area to Bushland	104.34	0.01
Bare Area to Cropland Small Scale	241.42	0.01
Bare Area to Forestland	36.29	0.00
Bare Area to Grassland	273.12	0.02
Bare Area to Riverine Vegetation	8.96	0.00
Bare Area to Urban Area	124.38	0.01
Bare Area to Waterbody	174.42	0.01
Bare Area to Woodland	195.37	0.01
Bushland to Bare Area	4.88	0.00
Bushland to Cropland Plantation	4,191.51	0.24
Bushland to Cropland Small Scale	57,065.35	3.30
Bushland to Forestland	8,176.77	0.47
Bushland to Grassland	17,450.59	1.01
Bushland to Riverine Vegetation	504.81	0.03
Bushland to Urban Area	325.46	0.02
Bushland to Waterbody	315.34	0.02
Bushland to Woodland	51,828.80	3.00
Forestland to Bare Area	3.12	0.00
Forestland to Bushland	3,740.00	0.22
Forestland to Cropland Small Scale	1,300.37	0.08
Forestland to Grassland	16,196.47	0.94
Forestland to Urban Area	284.92	0.02
Forestland to Waterbody	10.37	0.00
Forestland to Woodland	13,004.79	0.75
Grassland to Bare Area	65.27	0.00
Grassland to Bushland	24,296.89	1.41
Grassland to Cropland Plantation	236.47	0.01
Grassland to Cropland Small Scale	34,308.42	1.98
Grassland to Forestland	50,348.27	2.91
Grassland to Riverine Vegetation	154.84	0.01
Grassland to Urban Area	4,556.35	0.26
Grassland to Waterbody	305.99	0.02
Grassland to Woodland	9,877.12	0.57
No Change in Bare Area	14.31	0.00
No Change in Bushland	127,456.65	7.37
No Change in Cropland Plantation	92,589.62	5.36
No Change in Cropland Small Scale	229,350.04	13.27
No Change in Forestland	95,376.31	5.52
No Change in Grassland	238,675.94	13.81
No Change in Riverine Vegetation	2,737.09	0.16
No Change in Urban Area	5,130.81	0.30
No Change in Waterbody	13,681.08	0.79

No Change in Woodland	338,639.76	19.59
Riverine Vegetation to Bushland	2,438.06	0.14
Riverine Vegetation to Cropland Plantation	264.89	0.02
Riverine Vegetation to Cropland Small Scale	483.82	0.03
Riverine Vegetation to Forestland	298.15	0.02
Riverine Vegetation to Grassland	61.15	0.00
Riverine Vegetation to Waterbody	71.58	0.00
Riverine Vegetation to Woodland	7,010.12	0.41
Waterbody to Bushland	830.11	0.05
Waterbody to Cropland Plantation	102.98	0.01
Waterbody to Cropland Small Scale	201.23	0.01
Waterbody to Forestland	39.58	0.00
Waterbody to Grassland	16.17	0.00
Waterbody to Riverine Vegetation	455.42	0.03
Waterbody to Urban Area	2.68	0.00
Waterbody to Woodland	930.25	0.05
Wetland to Bushland	32.80	0.00
Wetland to Woodland	3.37	0.00
Woodland to Bare Area	18.49	0.00
Woodland to Bushland	181,750.74	10.51
Woodland to Cropland Plantation	2,886.83	0.17
Woodland to Cropland Small Scale	36,734.48	2.13
Woodland to Forestland	12,789.85	0.74
Woodland to Grassland	31,449.52	1.82
Woodland to Riverine Vegetation	4,556.45	0.26
Woodland to Urban Area	162.09	0.01
Woodland to Waterbody	1,608.60	0.09
TOTAL	**1728562.546**	100.00

Annex III: Land Cover Change Statistics from 2010-2015

Landcover change from 2010 to 2015	Area (Ha)	%age
Bare Area to Cropland Small Scale	4.88	0.82
Bare Area to Grassland	15.15	0.00
Bare Area to Waterbody	0.73	0.00
Bare Area to Woodland	3.21	0.00
Bushland to Bare Area	245.16	0.01
Bushland to Cropland Plantation	2,612.59	0.15
Bushland to Cropland Small Scale	36,328.77	2.10
Bushland to Forestland	946.57	0.05
Bushland to Grassland	27,470.46	1.59
Bushland to Riverine Vegetation	39.29	0.00
Bushland to Urban Area	617.26	0.04
Bushland to Waterbody	351.65	0.02
Bushland to Woodland	46,842.89	2.71
Cropland Plantation to Bare Area	24.13	0.00
Cropland Plantation to Bushland	19,261.67	1.11
Cropland Plantation to Cropland Small Scale	483.91	0.03
Cropland Plantation to Forestland	480.00	0.03
Cropland Plantation to Grassland	60.53	0.00
Cropland Plantation to Riverine Vegetation	766.92	0.04
Cropland Plantation to Urban Area	240.16	0.01
Cropland Plantation to Waterbody	217.93	0.01
Cropland Plantation to Woodland	3,976.66	0.23
Cropland Small Scale to Bare Area	1,253.66	0.07
Cropland Small Scale to Bushland	22,869.07	1.32
Cropland Small Scale to Cropland Plantation	13,854.78	0.80
Cropland Small Scale to Forestland	2,564.98	0.15
Cropland Small Scale to Grassland	7,552.77	0.44
Cropland Small Scale to Riverine Vegetation	1,023.78	0.06
Cropland Small Scale to Urban Area	931.98	0.05
Cropland Small Scale to Waterbody	1,122.25	0.06
Cropland Small Scale to Woodland	36,408.37	2.11
Forestland to Bare Area	24.80	0.00
Forestland to Bushland	1,617.72	0.09
Forestland to Cropland Plantation	75.20	0.00
Forestland to Cropland Small Scale	8,613.12	0.50
Forestland to Grassland	40,884.73	2.37
Forestland to Urban Area	246.04	0.01
Forestland to Waterbody	12.71	0.00
Forestland to Woodland	3,672.71	0.21
Grassland to Bare Area	352.07	0.02
Grassland to Bushland	12,084.49	0.70
Grassland to Cropland Plantation	90.07	0.01

Grassland to Cropland Small Scale	40,557.59	2.35
Grassland to Forestland	13,653.80	0.79
Grassland to Riverine Vegetation	113.04	0.01
Grassland to Urban Area	63.61	0.00
Grassland to Waterbody	52.81	0.00
Grassland to Woodland	9,181.30	0.53
No Change in Bare Area	82.07	0.00
No Change in Bushland	225,198.13	13.03
No Change in Cropland Plantation	74,757.55	4.32
No Change in Cropland Small Scale	272,110.81	15.74
No Change in Forestland	111,914.12	6.47
No Change in Grassland	227,979.20	13.19
No Change in Riverine Vegetation	7,328.41	0.42
No Change in Urban Area	10,057.50	0.58
No Change in Waterbody	15,746.73	0.91
No Change in Woodland	286,535.07	16.58
Riverine Vegetation to Bushland	173.36	0.01
Riverine Vegetation to Cropland Plantation	68.30	0.00
Riverine Vegetation to Cropland Small Scale	1.03	0.00
Riverine Vegetation to Waterbody	3.40	0.00
Riverine Vegetation to Woodland	845.16	0.05
Urban Area to Bushland	76.42	0.00
Urban Area to Cropland Plantation	67.86	0.00
Urban Area to Cropland Small Scale	111.94	0.01
Urban Area to Forestland	31.47	0.00
Urban Area to Grassland	159.61	0.01
Urban Area to Waterbody	2.08	0.00
Urban Area to Woodland	80.85	0.00
Waterbody to Bare Area	90.41	0.01
Waterbody to Bushland	176.32	0.01
Waterbody to Cropland Plantation	116.73	0.01
Waterbody to Cropland Small Scale	19.96	0.00
Waterbody to Forestland	2.15	0.00
Waterbody to Grassland	4.57	0.00
Waterbody to Woodland	9.72	0.00
Woodland to Bare Area	1.29	0.00
Woodland to Bushland	104,950.51	6.07
Woodland to Cropland Plantation	2,602.13	0.15
Woodland to Cropland Small Scale	12,894.32	0.75
Woodland to Forestland	4,654.57	0.27
Woodland to Grassland	8,596.27	0.50
Woodland to Riverine Vegetation	451.86	0.03
Woodland to Urban Area	201.43	0.01
Woodland to Waterbody	591.31	0.03
TOTAL	**1,728,562.55**	100.00

Annex IV: Land Cover Change Statistics from 1990-2015

Landcover Change from 1990 to 2015	Area (Ha)	%age
Bare Area to Bushland	165.58	0.01
Bare Area to Cropland Plantation	30.64	0.00
Bare Area to Cropland Small Scale	567.87	0.03
Bare Area to Forestland	161.49	0.01
Bare Area to Grassland	148.42	0.01
Bare Area to Riverine Vegetation	6.65	0.00
Bare Area to Urban Area	329.77	0.02
Bare Area to Waterbody	27.88	0.00
Bare Area to Woodland	207.44	0.01
Bushland to Bare Area	329.91	0.02
Bushland to Cropland Plantation	10,341.54	0.60
Bushland to Cropland Small Scale	74,477.47	4.31
Bushland to Forestland	2,786.17	0.16
Bushland to Grassland	16,750.67	0.97
Bushland to Riverine Vegetation	225.49	0.01
Bushland to Urban Area	1,346.17	0.08
Bushland to Waterbody	393.64	0.02
Bushland to Woodland	71,763.35	4.15
Cropland Plantation to Bare Area	24.13	0.00
Cropland Plantation to Bushland	18,622.51	1.08
Cropland Plantation to Cropland Small Scale	458.35	0.03
Cropland Plantation to Forestland	431.38	0.02
Cropland Plantation to Grassland	25.12	0.00
Cropland Plantation to Riverine Vegetation	603.01	0.03
Cropland Plantation to Urban Area	198.52	0.01
Cropland Plantation to Waterbody	188.89	0.01
Cropland Plantation to Woodland	2,663.57	0.15
Cropland Small Scale to Bare Area	519.88	0.03
Cropland Small Scale to Bushland	12,346.67	0.71
Cropland Small Scale to Cropland Plantation	11,657.74	0.67
Cropland Small Scale to Forestland	278.39	0.02
Cropland Small Scale to Grassland	1,942.59	0.11
Cropland Small Scale to Riverine Vegetation	834.71	0.05
Cropland Small Scale to Urban Area	770.42	0.04
Cropland Small Scale to Waterbody	761.35	0.04
Cropland Small Scale to Woodland	17,667.86	1.02
Forestland to Bare Area	7.35	0.00
Forestland to Bushland	4,300.46	0.25
Forestland to Cropland Plantation	259.92	0.02
Forestland to Cropland Small Scale	3,105.62	0.18
Forestland to Grassland	14,596.26	0.84
Forestland to Riverine Vegetation	30.00	0.00

Forestland to Urban Area	665.34	0.04
Forestland to Waterbody	30.29	0.00
Forestland to Woodland	10,260.13	0.59
Grassland to Bare Area	352.69	0.02
Grassland to Bushland	19,209.89	1.11
Grassland to Cropland Plantation	363.16	0.02
Grassland to Cropland Small Scale	66,417.26	3.84
Grassland to Forestland	22,950.84	1.33
Grassland to Riverine Vegetation	224.24	0.01
Grassland to Urban Area	3,808.18	0.22
Grassland to Waterbody	543.62	0.03
Grassland to Woodland	10,300.55	0.60
No Change in Bare Area	67.62	0.00
No Change in Bushland	71,570.88	4.14
No Change in Cropland Plantation	59,400.74	3.44
No Change in Cropland Small Scale	145,817.71	8.44
No Change in Forestland	102,789.04	5.95
No Change in Grassland	225,722.50	13.06
No Change in Riverine Vegetation	3,909.61	0.23
No Change in Urban Area	3,124.91	0.18
No Change in Waterbody	13,704.20	0.79
No Change in Woodland	267,963.36	15.50
Riverine Vegetation to Bare Area	0.51	0.00
Riverine Vegetation to Bushland	4,154.02	0.24
Riverine Vegetation to Cropland Plantation	454.78	0.03
Riverine Vegetation to Cropland Small Scale	466.59	0.03
Riverine Vegetation to Forestland	151.00	0.01
Riverine Vegetation to Grassland	21.63	0.00
Riverine Vegetation to Waterbody	115.03	0.01
Riverine Vegetation to Woodland	6,322.23	0.37
Urban Area to Bushland	50.86	0.00
Urban Area to Cropland Plantation	66.75	0.00
Urban Area to Cropland Small Scale	35.60	0.00
Urban Area to Forestland	3.41	0.00
Urban Area to Grassland	14.59	0.00
Urban Area to Woodland	46.19	0.00
Waterbody to Bushland	164.09	0.01
Waterbody to Cropland Plantation	172.84	0.01
Waterbody to Cropland Small Scale	137.27	0.01
Waterbody to Forestland	28.27	0.00
Waterbody to Riverine Vegetation	2.75	0.00
Waterbody to Urban Area	0.76	0.00
Waterbody to Woodland	346.14	0.02
Wetland to Bushland	181.47	0.01
Wetland to Waterbody	290.18	0.02
Wetland to Woodland	3.37	0.00

Woodland to Bare Area	770.05	0.04
Woodland to Bushland	255,636.35	14.79
Woodland to Cropland Plantation	11,493.72	0.66
Woodland to Cropland Small Scale	79,667.40	4.61
Woodland to Forestland	4,650.68	0.27
Woodland to Grassland	53,536.18	3.10
Woodland to Riverine Vegetation	3,888.93	0.22
Woodland to Urban Area	2,112.06	0.12
Woodland to Waterbody	2,025.26	0.12
TOTAL	**1,728,562.55**	100.00

Annex V: Field Verification Form

POINT NAME/NUMBER	
AREA LOCAL NAME	
OBSERVER	
DATE	
TIME	

ACCESSIBILITY		
	VERY GOOD	
	GOOD	
	MEDIUM	
	BAD	

COORDINATES IN DD	**X**	**Y**	**ELEVATION**

PHOTOS			
		NORTH	
	WEST		EAST
		SOUTH	
FROM A DISTANCE			

Land Use		Land Use	
Cropland		Natural Forest	
Plantation Cropland		Plantation Forest	
Open Grassland		Wetland	
Closed Grassland		Bare Area	
Open Shrubland		Built Up Area	
Closed Shrubland		Woodland	

Vegetation Type	
Montane Grassland	
Sour Bushveld	
Lowveld Busveld	
Lebombo Bushveld	

COMMENTS
North:
East:
West:

South:

Reference

Loffler, .P. and Linda. (2005). Swaziland Tree Atlas including selected shrubs and climbers, Capture Press, Pretoria, South Africa