Development of Vulnerability & Adaptation Framework for Dry land/Savanna Ecosystem Processes and Services

Geographic Location: Amboseli – Kilimanjaro Landscapes

Final Report submitted to the African Wildlife Foundation (Draft)

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Dedicated to Saving wildlife through sound science, local initiatives and good governance

PROJECT REPORT– June 2015.

A project implemented in partnership with the African Wildlife Foundation

Overview and Project Scope:

The African Conservation Centre (ACC) in collaboration the African Wildlife Foundation (AWF) and other partners were to implement a project called "Development of Vulnerability & Adaptation Framework for Dry Land / Savanna Ecosystem Processes and Services". The project targeted to develop a vulnerability assessment tool and outlined five major components to drive its implementation. The components were: Compiling the existing knowledge base; Stakeholder impact assessment; Mapping community perceptions on vulnerability; Land use / land cover change mapping; and Vulnerability index for ranking landscape / dry land areas.

The project aims to generate and synthesize information for better understanding of the vulnerability of the Southern Kenya and Northern landscapes. The objectives of the project were to:

- Gather information about how climate change is altering key ecosystem processes and services within the study area;
- Develop a user-friendly ecosystem process and services vulnerability and adaptation tool for conservation and development practitioners;
- Identify the means by which society can adapt to vulnerabilities in these crucial ecosystem processes and services.
- Engage practitioners / stakeholders in dialogue on shape and content of toolbox; and support landscape scale conservation planning and decision making.

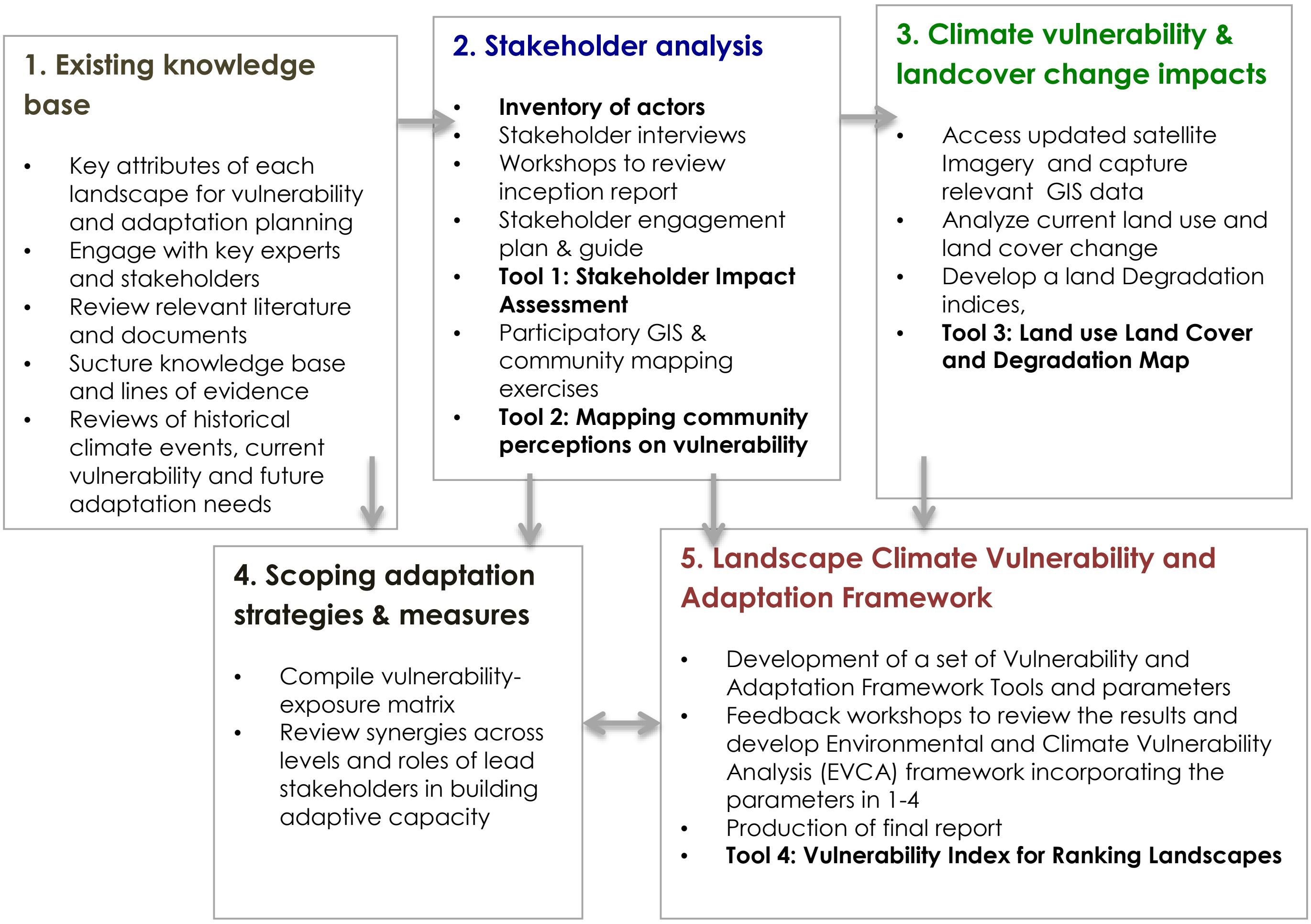
The expected outcome of the project were outlined as follows:

- Documented methodology.
- Compile relevant data inputs and formats for the study areas.
- Develop scripts or tools in support of the methodology to achieve project objectives.
- Propos adaptation interventions to respond to the vulnerabilities.
- Document results based on the tools applied in the study area.
- Outline key recommendations for further monitoring and evaluation as well as potential gaps in the process.

Development of Vulnerability & Adaptation Framework for Dry land/Savanna Ecosystem Processes and Services

Approach overview

The approach applied by ACC for the Environmental and Climate Vulnerability Analysis framework is outlined in schema below.



The African Conservation Centre (ACC) committed to undertake several activities towards meeting these objectives, by developing data and information around 4 components that would form the framework for the development of the vulnerability assessment tool:

I. STAKEHOLDER ANALYSIS - Stakeholder Assessment and on-going initiatives

ACC organized a workshop that brought together the stakeholders from Kenya and Tanzania who are already carrying out various activities and initiatives within the landscapes. A stakeholder assessment will broadly define their activities evaluate the impacts of such initiatives and identify gaps (if any) on the information/capacity required to address issues in land degradation with a view of reducing vulnerability in the landscapes.

In this regard, a workshop was held in Arusha on December 9th – 10th 2014 and a full report is attached *(Appendix 1)*.

The workshop objective was to bring the key stakeholders in the Kilimanjaro heartland and Kenya/Tanzania Borderlands region to review the progress made on the project thus far and get further input from the stakeholders in Kenya and Tanzania. The workshop specifically sought input in:

- Relevant data inputs for the study areas.
- Potential gaps in the process.
- Recommendations on further monitoring and evaluation

The study area was defined as the region that spans the Amboseli – Kilimanjaro landscape spreading from southern Kenya to northern Tanzania and is located between longitudes 35.560E and 37.950E and latitudes 1.870S and 4.750S. The study area size is about 43,748 Km2. The area hosts several national parks, ranches, forest reserves and wildlife management areas (WMAs) that include Amboseli National Park, Tarangire National Park, Lake Manyara National Park, Manyara Ranch, Saburi Ranch, West Kilimanjaro Ranch, Essimingor Forest Reserve, Monduli Forest Reserve, Burunge Wildlife Management Area, and Enduimet Wildlife Conservation Area.

The Figure 1 below shows the extent of the study area.

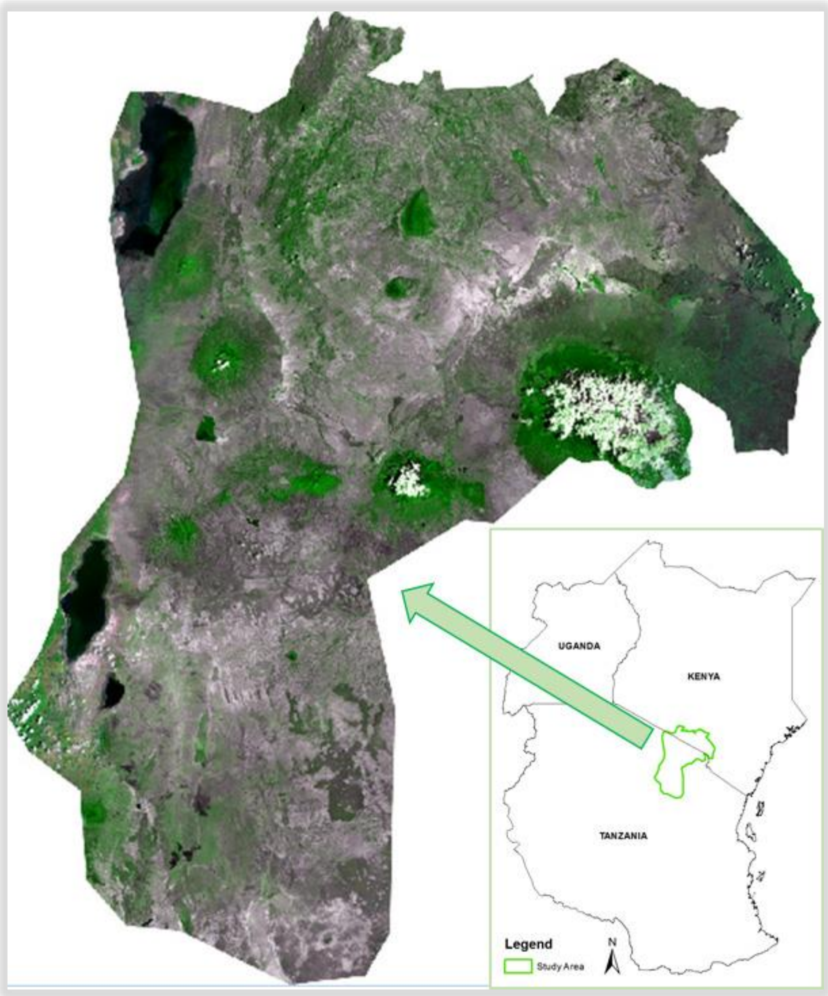


Figure 1: *Location and extent of the Study Area*

The highlights of the workshop were:

i) The exact scope of the study was redefined
ii) The institutions and individuals present indicated the range of activities they were involved in within the study area that would be relevant to the on-going project
iii) The critical datasets relevant to the project were identified together with the source of data
iv) The methodology was reviewed and the key components of the framework agreed on.

The participants held group discussions to map out and outline areas vulnerable to climate change and susceptible to degradation based on their knowledge and experience in the field. Categories for defining areas of high vulnerability were outlined as below and areas of potential high vulnerability were marked on map:

- Population and settlements
- Agriculture
- Degradation
- Development

The workshop identified other relevant on-going initiatives in the study area as follows:

i. <u>Reference to other relevant initiatives</u>

- The Nelson Mandela University on a joint project with Penn State on *Climate Change vulnerability in the Maasai Steppe (Contact person* Anna Estes)
- NTRI/TNC Maasai steppe project on *vegetation cover change in Northern Tanzania and Grass/Forest loss* – contact Alphonse. Agencies in the initiative are – Honeyguide, UCRT, WCS, TPW, Dorobo.
- AWF Redd+ project in the chyulus with 7 partners
- AWF water studies in Kimana, chyulu and Tsavo covering:
    - Boreholes and livestock/agriculture increase/abstraction
    - Tsavo river
    - Wholistic grazing in olgulului
    - Wildlife surveys with TAWIRI, KWS in 2010, 2013
    - Socio-economic studies in Amboseli and Lake Natron
    - Forest surveys and inventory in Lake Natron
    - Lease program for wildlife surveys
    - WMA programs Enduimet and Lake Natron
- ICRAF through work done by Tom Dunn has developed spectral indices and erosion indices. A manual is available with photos on how this can be replicated. Dr. Western to provide link.
- DGO Forest management with CWC-Longido corridor and WMAs
- Landuse plan in Olgulului, Enduimet and Lake Natron
- World vision with TNC and TPW in the Tarangire and Manyara area looking at:
    - Habitat loss and degradation
    - Controlling erosion
    - CCROs land tenure and landuse plan
    - Natural regeneration and fodder banks
    - Forest health assessment
- Greater Serengeti projects with TANAPA
    - Ngorogoro conservation area
    - Resource mapping and village landuse plans

    - Grassland degradation
- Water/Hydrological NASA study for Amboseli-Kilimanjaro area by African Conservation Centre and Amboseli Conservation Program. This could be expanded to cover other basins in the project area
- IPI is working in Lake Natron on water sanitation and lease study on water basin, linkages to cross border WASH initiatives, expansion and linkages for Lake Natron tourism
- IIED Climate change study in Monduli in collaboration with Govt departments
    - Capacity building
    - Action research
    - Resource management plans for Longido, Monduli, Ngorongoro
    - Policy influence
    - Cross border engagement in Narok and Kajiado
    - Hazards, water, grazing movement corridors
    - Assessments on resilience
    - Establishing of adaptation committees
- 50 years repeat photography in Amboseli Ecosystem by Amboseli Conservation Prg

ii. <u>Approaches – relevant to this project going forward</u>

- Use of participatory methods and visual tools
- Involvement of government, districts and other key agencies
- Repeat photography over time as a monitoring tool for vegetation changes. This allows for visual validation and interpretation

II. LANDUSE CHANGE IMPACTS AND CLIMATE VULNERABILTY

Mapping Land Use / Land Cover and Land Degradation in the Amboseli-Kilimanjaro landscapes

1.0 Approach and Methodology

1.1 Approach

The approach used in implementing this project entailed the following:

- Deployment of a fast, yet highly accurate, large scale, satellite based, multi-epoch land use / land cover mapping and change detection
- Deployment of a robust model that will map and simulate land degradation
- Compilation of a rich GIS database and maps
- Compilation of the final Project Report

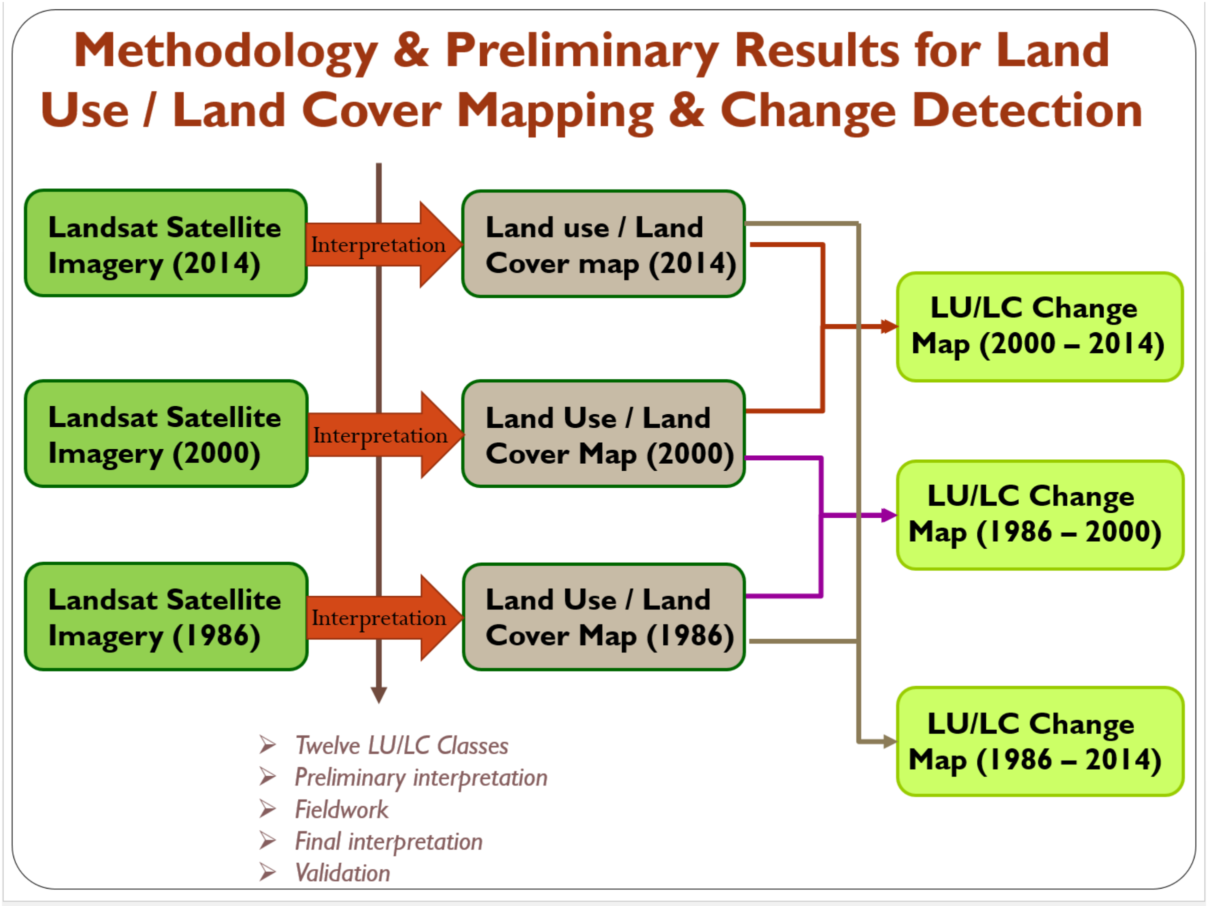
1.2 Methodology

Land use / land cover mapping and change detection

The activities that were undertaken under this task were:

- Acquisition and processing of Landsat satellite imagery covering the entire project area for the epochs of 1986 and 2014

- Preliminary image interpretation based on the land use / land cover classification categories provided in *Annex 1* of this report.
- Ground truthing fieldwork – Annex
- Final image interpretation
- Validation of land use / land cover maps
- Land use /land cover change detection
- Cartographic design and map compilation land use / land cover maps and change maps



Land degradation modelling

The activities that were undertaken under this task were:

- Acquisition of key inputs datasets (in GIS format) that are indicated in *Annex 2*.
- Processing the acquired input datasets into model-ready formats
- Executing the model

- Validating the model outputs (land degradation maps, etc)
- Cartographic design and compilation of land degradation maps

GIS database development

The activities undertaken under this task entailed the following:

- Acquisition of all requisite baseline datasets (extend of the study area, parks, wildlife management areas, topography, etc)
- Processing of all the acquired datasets into required GIS standards and formats

2.0 Outputs

2.1 Land Use / Land Cover Maps and Statistics

Land use / land cover maps covering three epochs, namely 1986, 2000 and 2014 were prepared. Statistics such as areas covered by each category of Land Use / Land Cover were also generated..

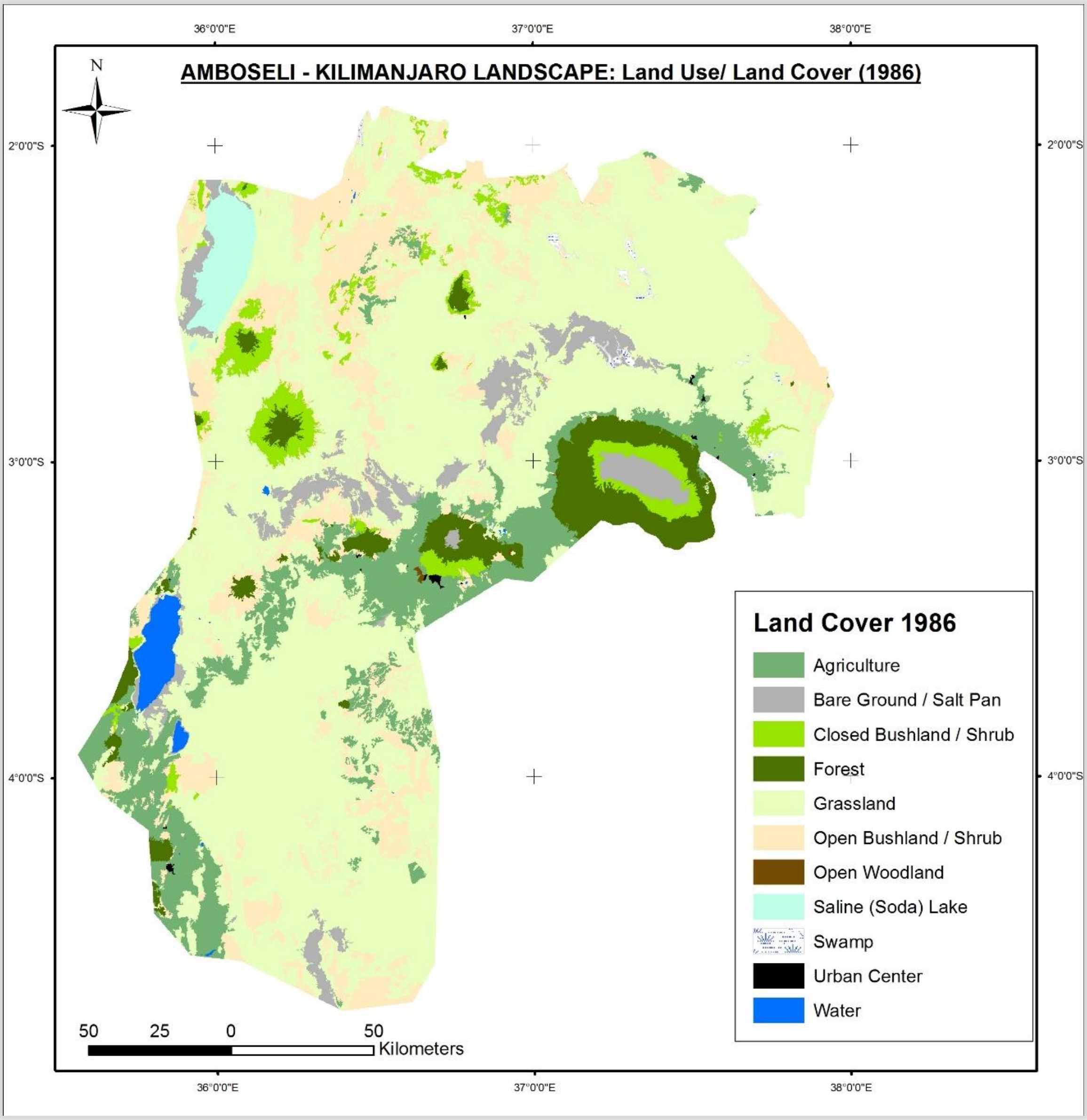


Figure 2a: *Land Use / Land Cover Map of 1986*

Table 1: Area of Land Use / Land Cover Categories in 1986

LU/LC Category	Area (Sq. Km)	Percentage (%)
Water	458.805	1.048717638
Grassland	25179.586	57.55446421
Swamp	146.286	0.334374535
Forest	2250.364	5.143789667
Open Woodland	13.695	0.031303469
Closed Woodland	1.372	0.003136061
Open Bushland / Shrub	6445.519	14.73290278
Closed Bushland / Shrub	1678.164	3.835878393
Agriculture	4760.715	10.88184695
Urban Centre	32.116	0.073409435
Bare Ground / Salt Pan	2095.602	4.79004104
Saline (Soda) Lake	686.921	1.570135828
TOTAL AREA	**43749.14**	**100**

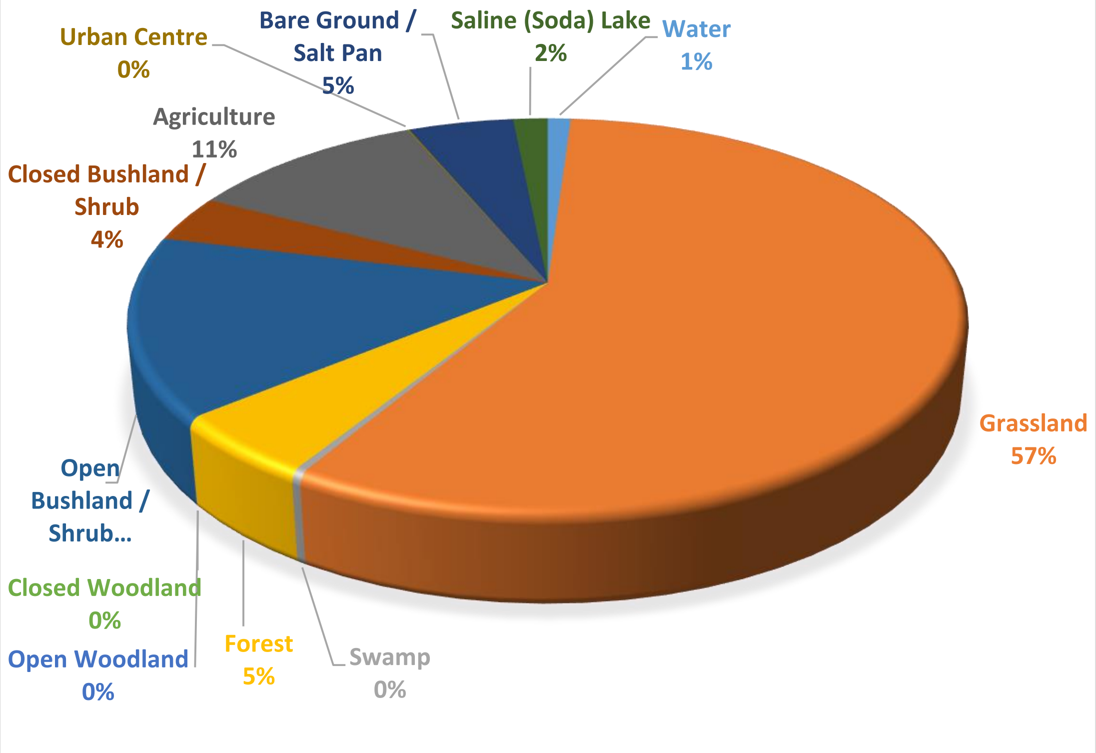


***Figure 2b**: Distribution of Land Use / Land Cover in 1986*

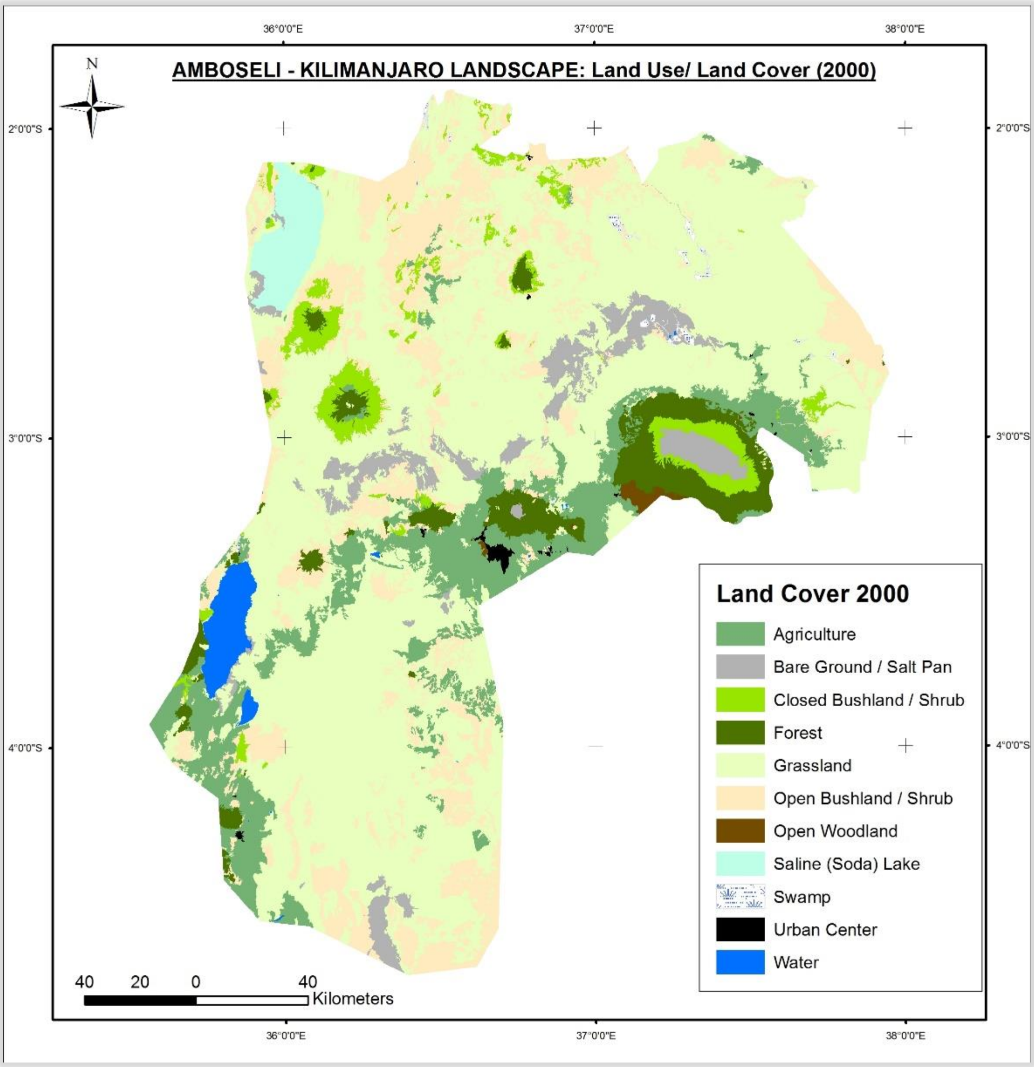


Figure 3: *Land Use / Land Cover Map of 2000*

Table 2: Area of Land Use / Land Cover Categories in 2000

LU/LC Category	Area (Sq. Km)	Percentage (%)
Water	618.21	1.413079561
Grassland	24613.258	56.25999548
Swamp	143.965	0.329069408
Forest	2029.47	4.638880925
Open Woodland	113.035	0.258370858
Closed Woodland	0.746	0.001705177
Open Bushland / Shrub	7099.881	16.22862252
Closed Bushland / Shrub	1564.497	3.576064337
Agriculture	4718.932	10.78634503
Urban Centre	89.625	0.204861221
Bare Ground / Salt Pan	1943.605	4.44261416
Saline (Soda) Lake	813.905	1.860391323
TOTAL AREA	**43749.129**	**100**

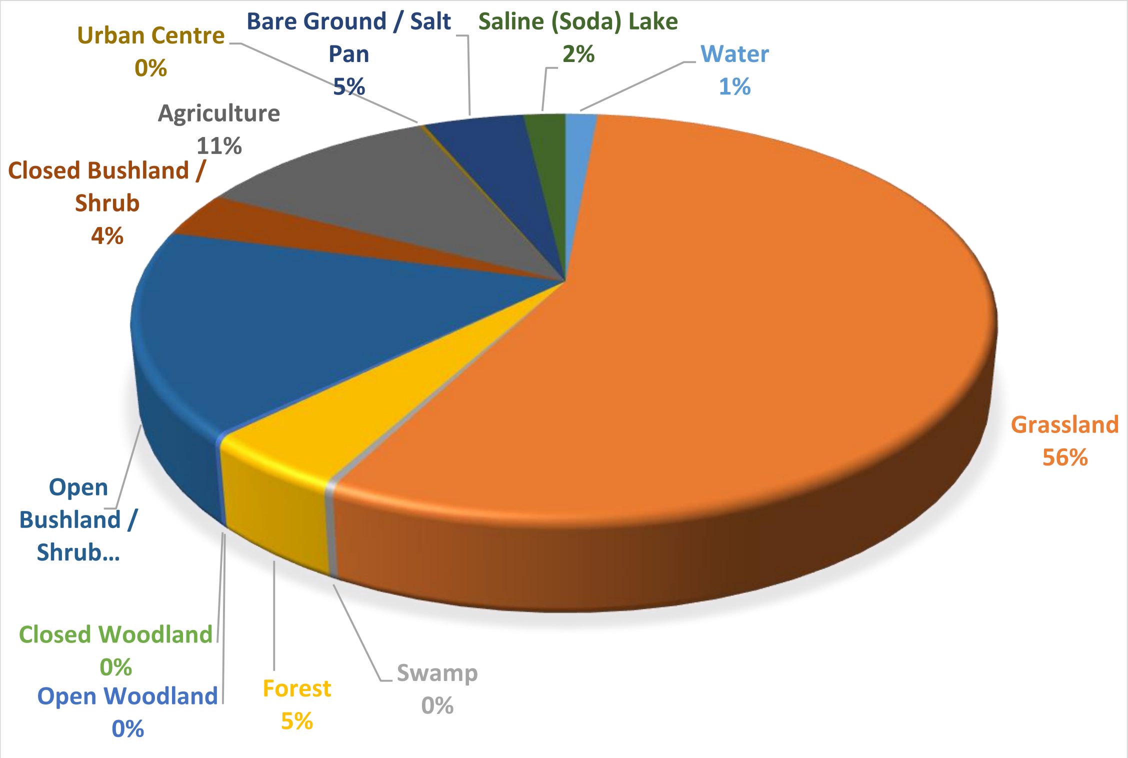


Figure 3b: *Distribution of Land Use / Land Cover in 2000*

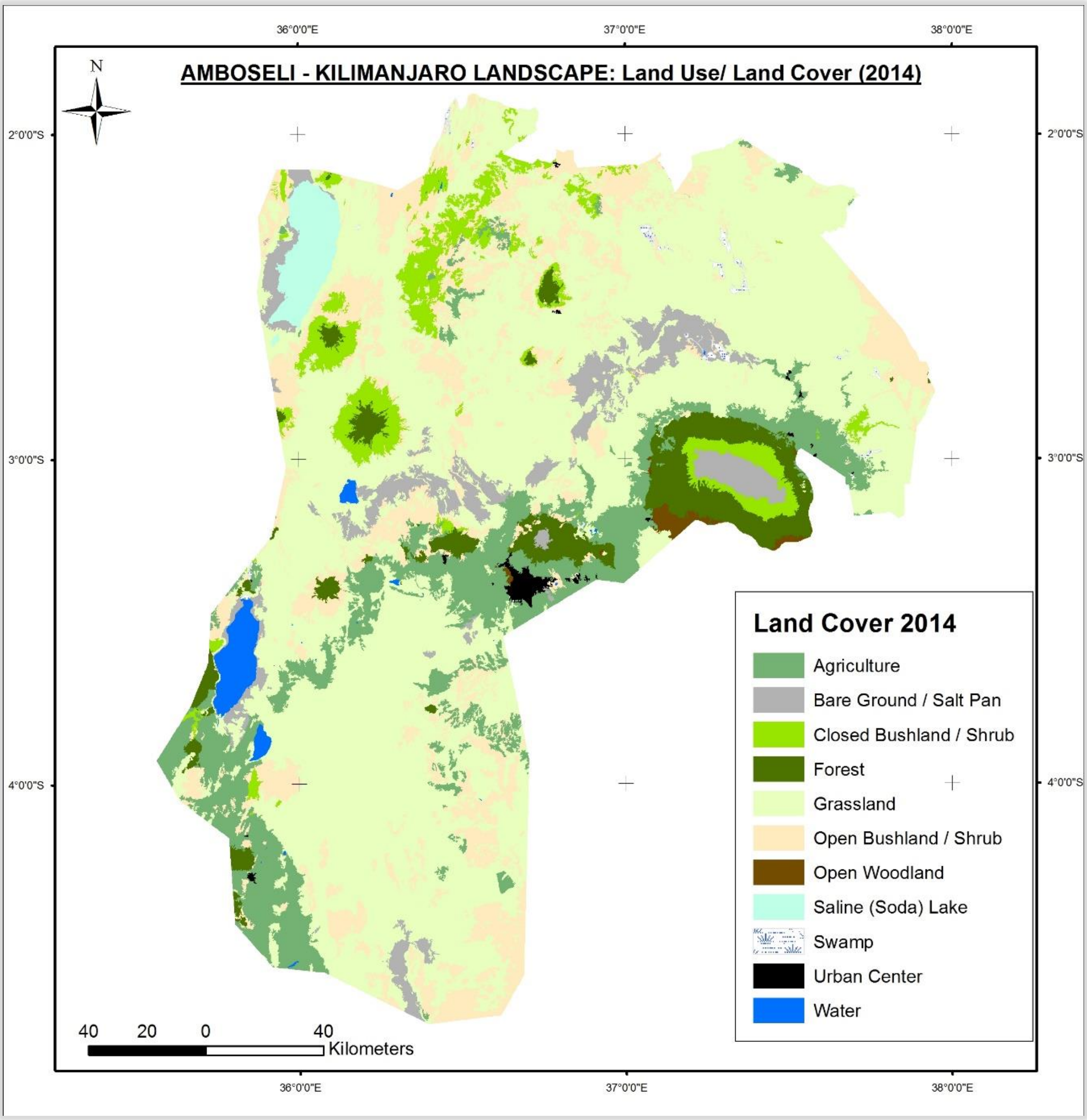


Figure 4a: *Land Use / Land Cover Map of 2014*

Table 3: Area of Land Use / Land Cover Categories in 2014

LU/LC Category	**Area (Sq. Km)**	**Percentage (%)**
Water	472.145	1.07920426
Grassland	25598.895	58.51261061
Swamp	64.399	0.147199854
Forest	2920.787	6.676181624
Open Woodland	147.941	0.338155773
Closed Woodland	1.372	0.003136046
Open Bushland / Shrub	6293.026	14.38426853
Closed Bushland / Shrub	1027.539	2.348694715
Agriculture	4300.906	9.830785197
Urban Centre	172.967	0.39535889
Bare Ground / Salt Pan	2127.319	4.862514116
Saline (Soda) Lake	623.44	1.42502643
TOTAL AREA	**43749.364**	**100**

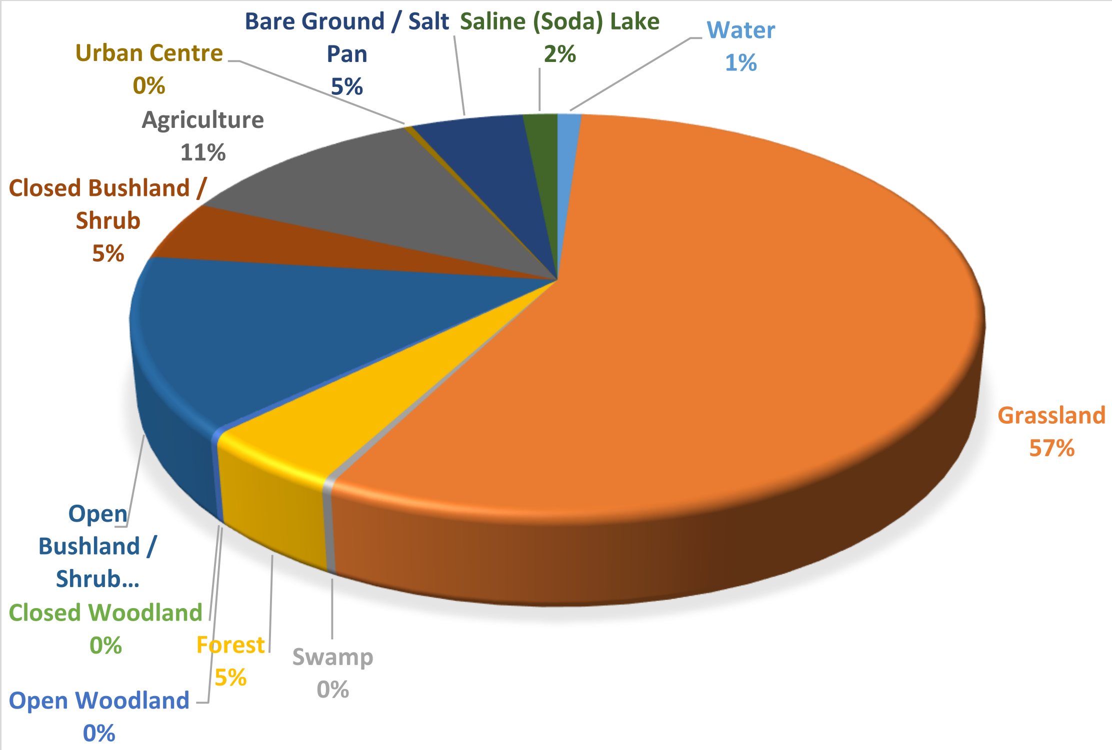


Figure 4b: *Distribution of Land Use / Land Cover in 2014*

2.2 Land Use / Land Cover Change

Short-term and long-term land use / land cover change detection was conducted as follows: 1986 – 2000, 2000 – 2014 (short-term) and 1986 – 2014 (long-term). Maps showing the major Land use / land cover changes (contiguous land parcels greater than 10 Km^2) were generated as shown in *Figures 5.2a, 5.2b and 5.2c*. Statistics such as areas of land parcels that transitioned from one category to another and those that remained unchanged were computed. Land use / land cover change maps were also generated.

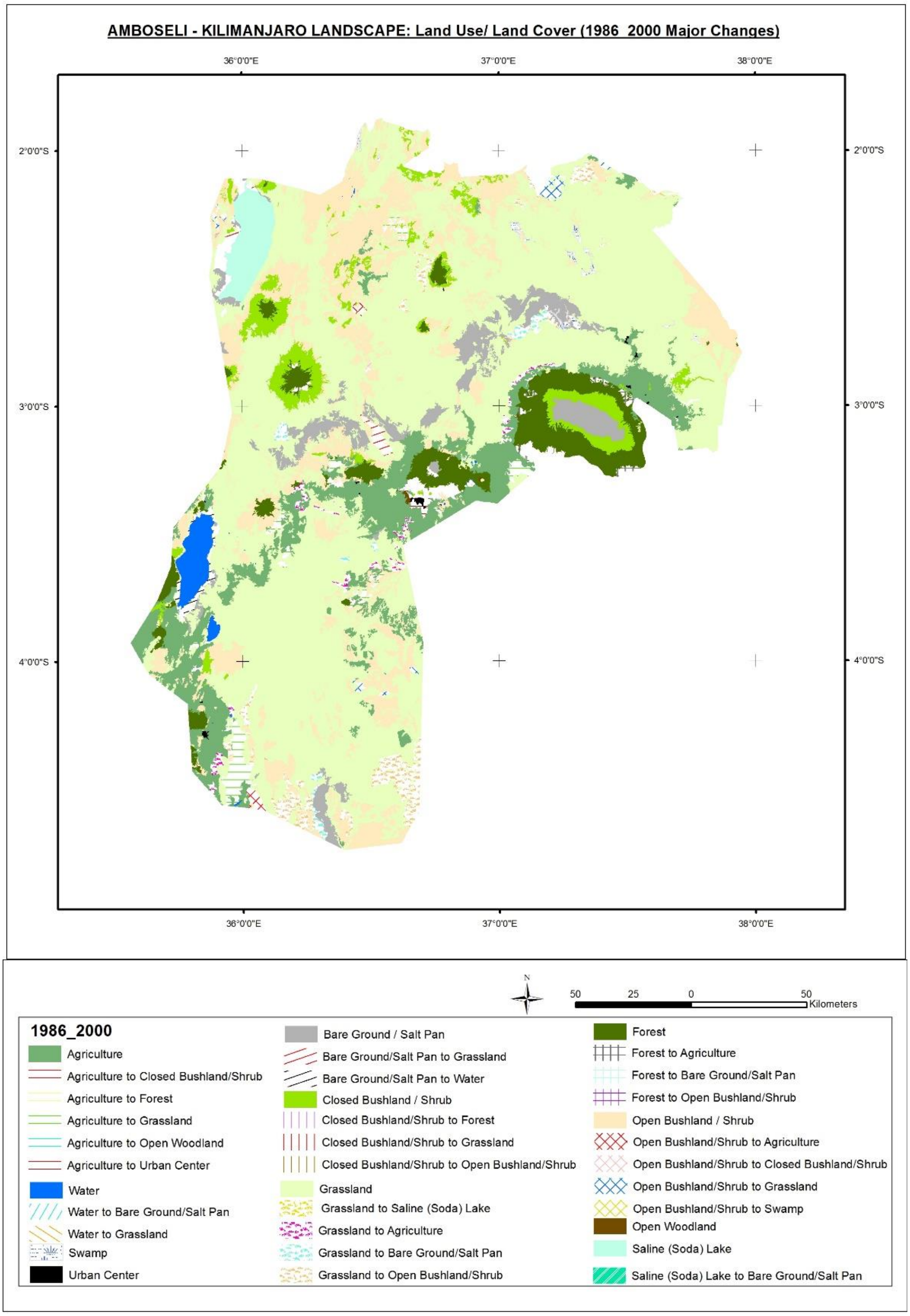


Figure 5.2a: *Map showing areas where major land use/land cover changes (above 10 Km2) occurred between 1986 – 2000*

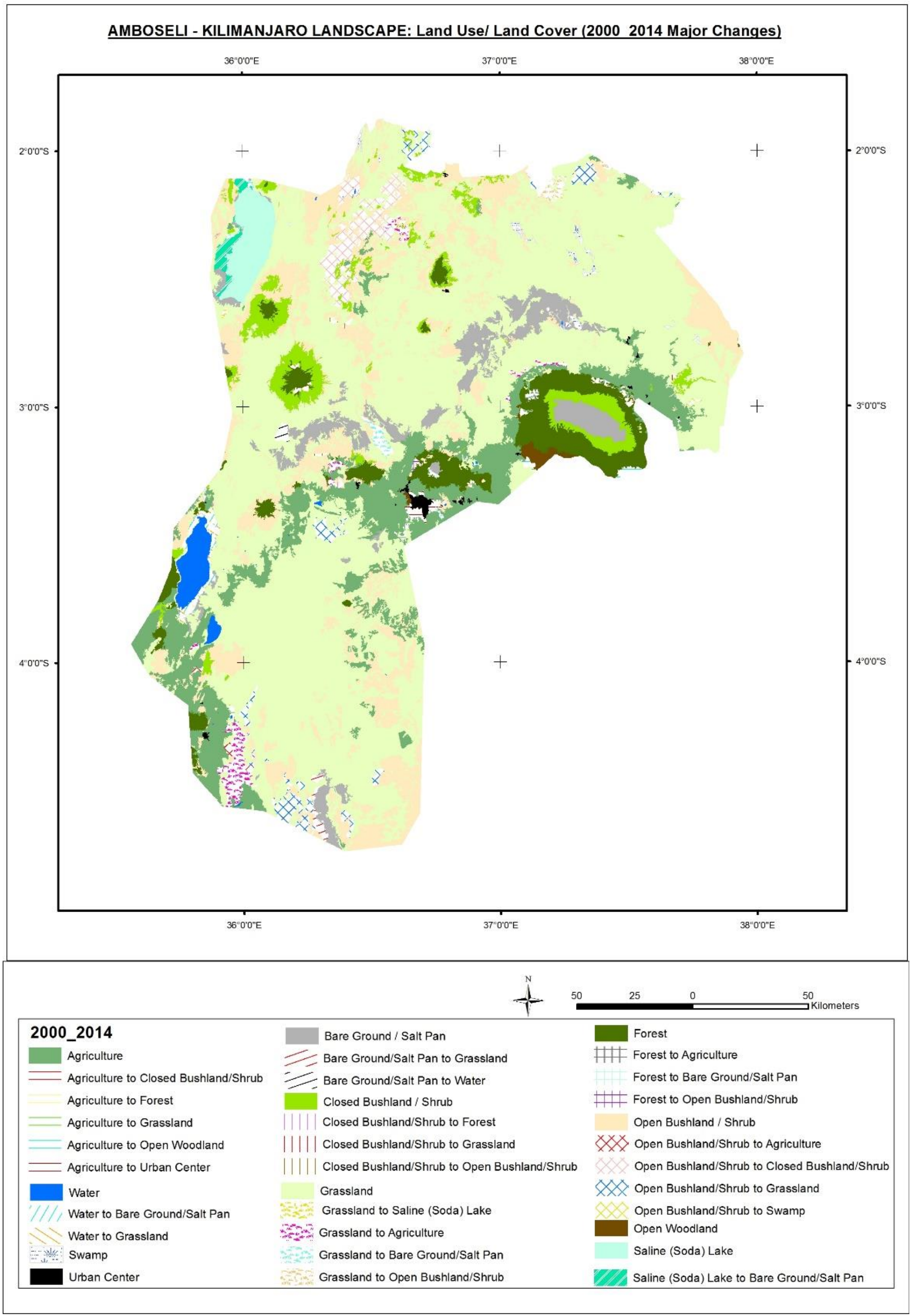


Figure 5.2b: *Map showing areas where major land use/land cover changes (above 10 Km2) occurred between 2000 – 2014*

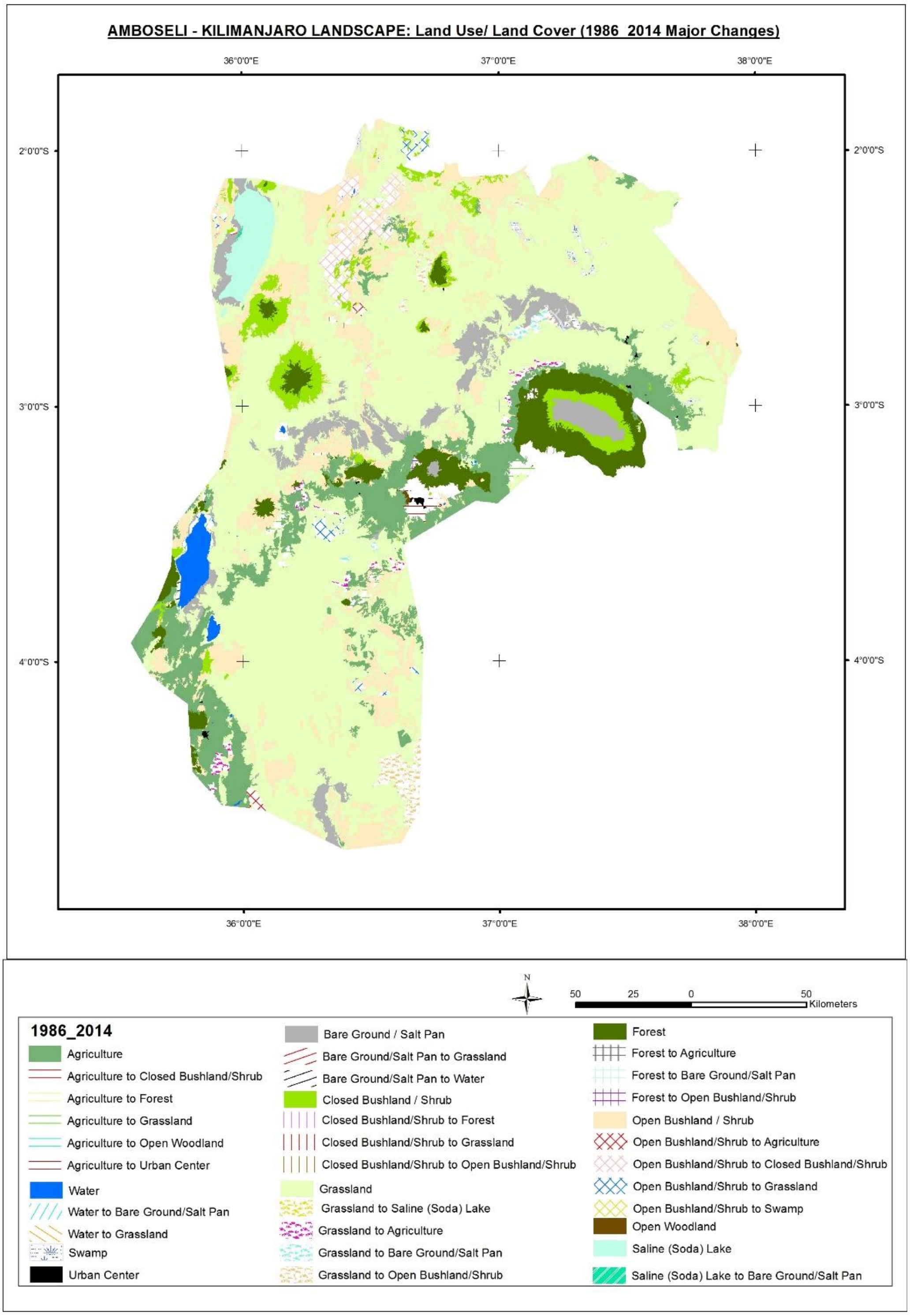


Figure 5.2c: *Map showing areas where major land use/land cover changes (above 10 Km2) occurred between 1986 – 2014*

2.2.1 Short-term changes (1986 – 2000 and 2000 – 2014 Periods)

The short-term (1986 – 2000 and 2000 – 2014) land use / land cover trends in the Amboseli-Kilimanjaro landscape are summarized in Figure 5.2.1a and Table 4.

Overall, whereas there were notable land use / land cover transitions between various categories, these did not significantly alter the overall total areas in the categories. The specific land use / land cover transitions are discussed in Sections 5.2.1.1 and 5.2.1.2. Throughout the three epochs, grasslands (over 24,600 Km^2) remained the most dominant, followed by open bushlands / shrublands (over 6,200 Km^2), agriculture (4,300 Km^2), forests (over 2000 Km2), bare areas / salt pans (over 1900 Km^2) and closed bushlands / shrublands (over 1,000 Km2).

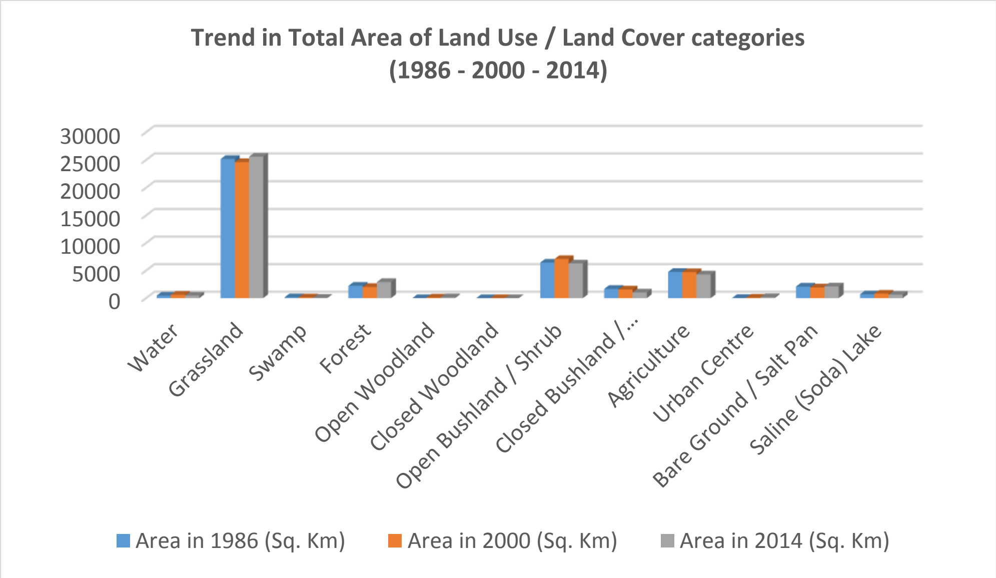


Figure 5.2.1a: *Trend in total area of land use / land cover categories from 1986 to 2014*

Table 4: Trend in Total Area of Land Use / Land Cover Categories in 1986, 2000 and 2014

LU/LC Category	**Area in 1986 (Sq. Km)**	**Area in 2000 (Sq. Km)**	**Area in 2014 (Sq. Km)**
Water	458.805	618.21	472.145
Grassland	25179.586	24613.258	25598.895
Swamp	146.286	143.965	64.399
Forest	2250.364	2029.47	2920.787
Open Woodland	13.695	113.035	147.941

Closed Woodland	1.372	0.746	1.372
Open Bushland / Shrub	6445.519	7099.881	6293.026
Closed Bushland / Shrub	1678.164	1564.497	1027.539
Agriculture	4760.715	4718.932	4300.906
Urban Centre	32.116	89.625	172.967
Bare Ground / Salt Pan	2095.602	1943.605	2127.319
Saline (Soda) Lake	686.921	813.905	623.44

5.2.1.1 1986 to 2000 Period

During the period 1986 – 2000, the Amboseli-Kilimanjaro landscape experienced the following key changes:

i. There was a significant loss of grasslands to other land use / land cover categories (nearly 1,400 Km^2) against a gain of about 800 Km^2 from other land use / land cover categories (*Figure 5.2.1b*). Grasslands were mostly lost to open bushlands / shrublands (about 700 Km^2), bare ground / salt pan (about 100 Km^2) and forest (about 80 Km^2), *(Figure 5.2.1c)*
ii. There was a gain in area under Open Bushland / Shrubland (about 900 Km^2) from other land use / land cover categories against a loss of about 200 Km^2 to other land use / land cover categories (*Figure 5.2.1a*). The most significant gain was made from Grassland (nearly 700 Km^2) while the key loss was to Agriculture (about 50 Km^2) (*Figure 5.2.1d*)
iii. Closed Bushland / Shrubland mainly suffered loss (about 200 Km^2) to other land use / land cover categories (*Figure 5.2.1a*). This loss was mainly to Agriculture (about 135 Km^2) (*Figure 5.2.1e*)
iv. The area under agriculture remained relatively the same – gaining about 700 Km^2 and losing about 700 Km^2 from other land use / land cover categories. (*Figure 5.2.1a*). Gains were notably made from Closed Bushland / Shrubland (about 130 Km^2), Open Bushland / Shrubland (about 40 Km^2) and Forest (about 100 Km^2). The major loses were to Agriculture (about 280 Km^2) and to Urban Centres (about 60 Km^2) (*Figure 5.2.1f*)

v. Forests mostly suffered loss (close to 250 Km^2) *(Figure 5.2.1a)* with key beneficiaries being Open Woodland (about 100 Km^2), Agriculture (about 95 Km^2), Closed Bushland / Shrubland (about 10 Km^2) and Open Bushland / Shrubland (about 10 Km^2) (*Figure 5.2.1g*)

vi. Areas under Bare Ground decreased by about 300 Km^2 (*Figure 5x*) and increased by about 200 Km^2 (*Figure 5.2.1a*). Saline (Soda) Lake (about 130 Km^2) and Water (about 90 Km^2) were the notable beneficiaries from the Bare Ground. Increament were realized from Grasslands (about 80 Km^2) (*Figure 5.2.1h*).

vii. Urban Centres expanded by about 60 Km^2 (*Figure 5.2.1a*) with key contributors to this expansion being Agricultural land (about 48 Km^2) and Closed Bushland / Shrubland that contributed about 8 Km^2 (*Figure 5.2.1i*).

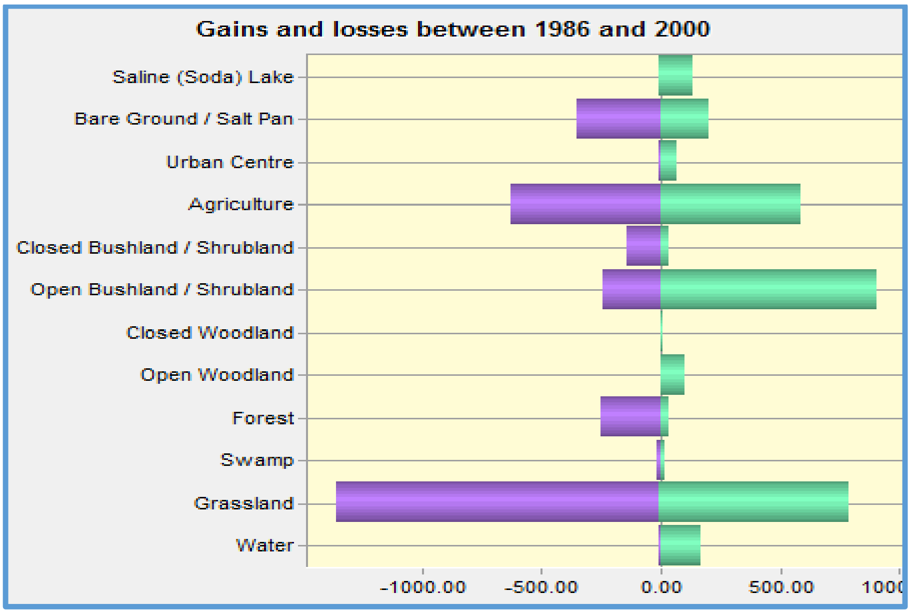


***Figure 5..2.1b:** Overall gains and losses in land use / land cover between 1986 and 2000*

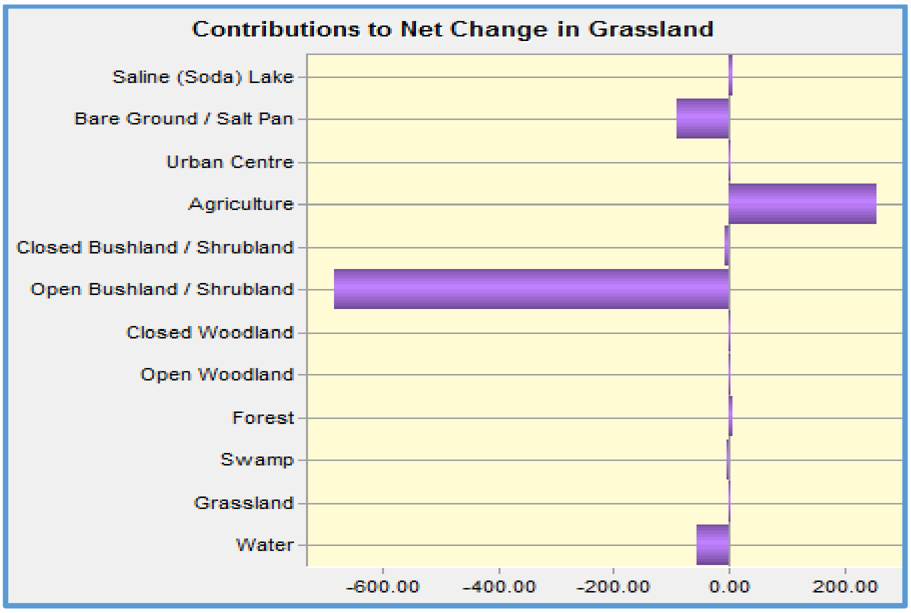


Figure 5.2.1c: *Contributions to net change in Grasslands between 1986 and 2000*

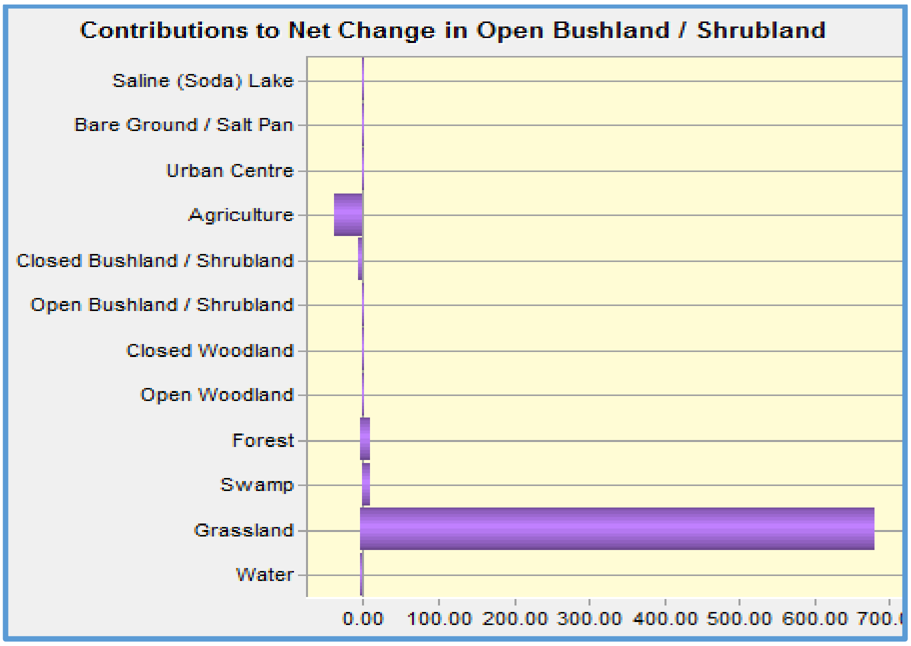


Figure 5.2.1d: *Contributions to net change in Open Bushland / Shrubland between 1986 and 2000*

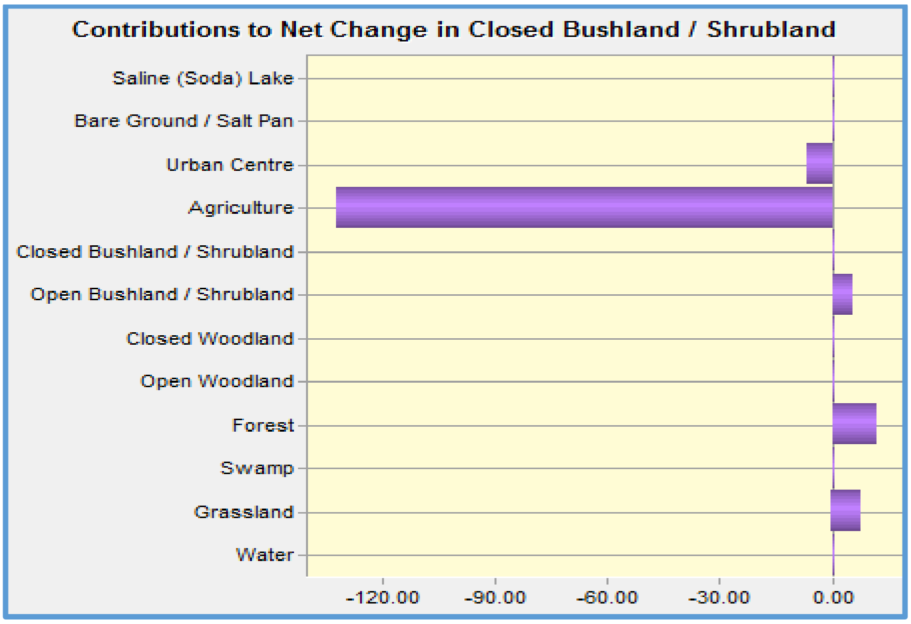


Figure 5.2.1e: *Contributions to net change in Closed Bushland / Shrubland between 1986 and 2000*

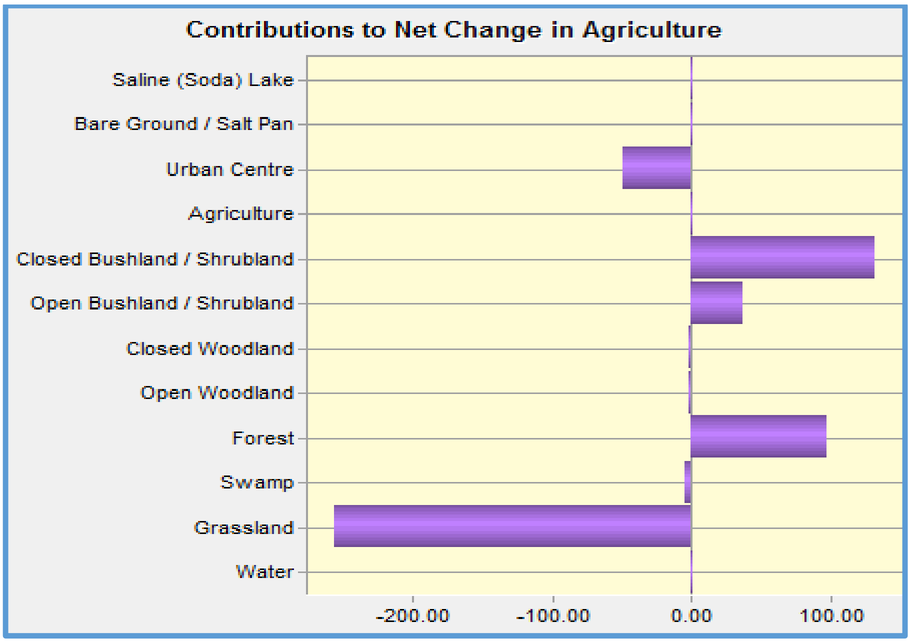


Figure 5.2.1f: *Contributions to net change in Agriculture between 1986 and 2000*

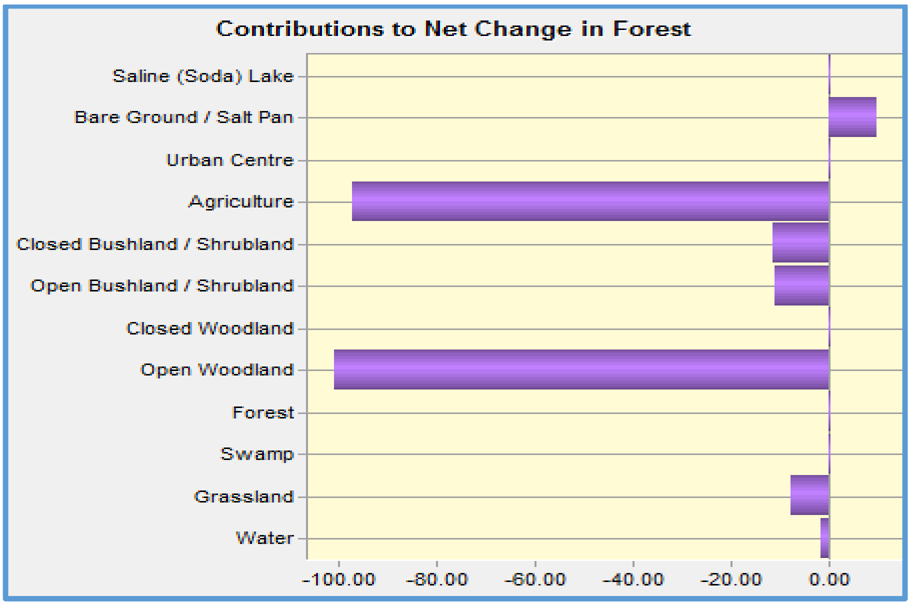


Figure 5.2.1g: *Contributions to net change in Forest between 1986 and 2000*

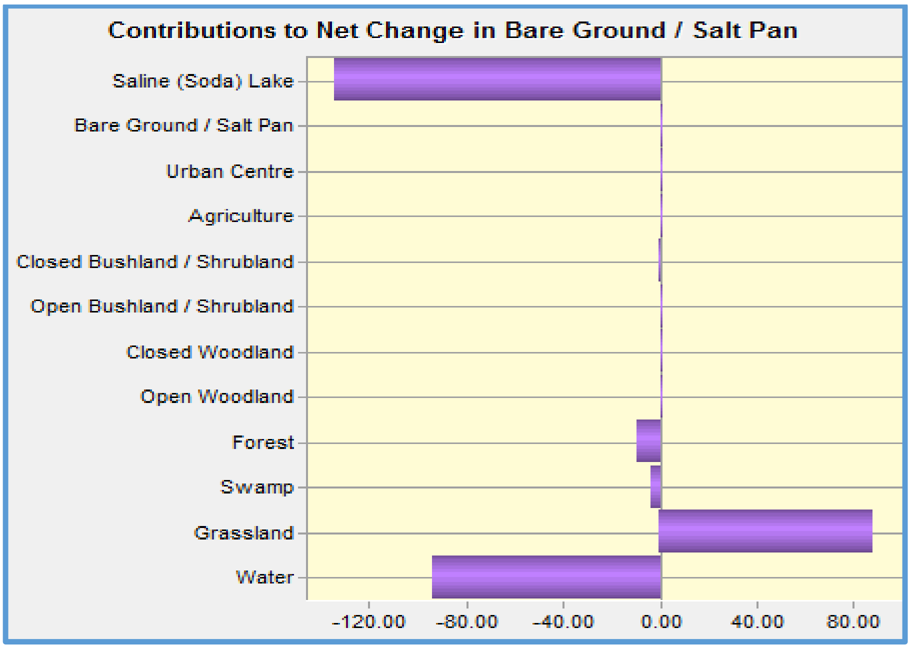


Figure 5.2.1h: *Contributions to net change in Bare Ground / Salt Pan between 1986 and 2000*

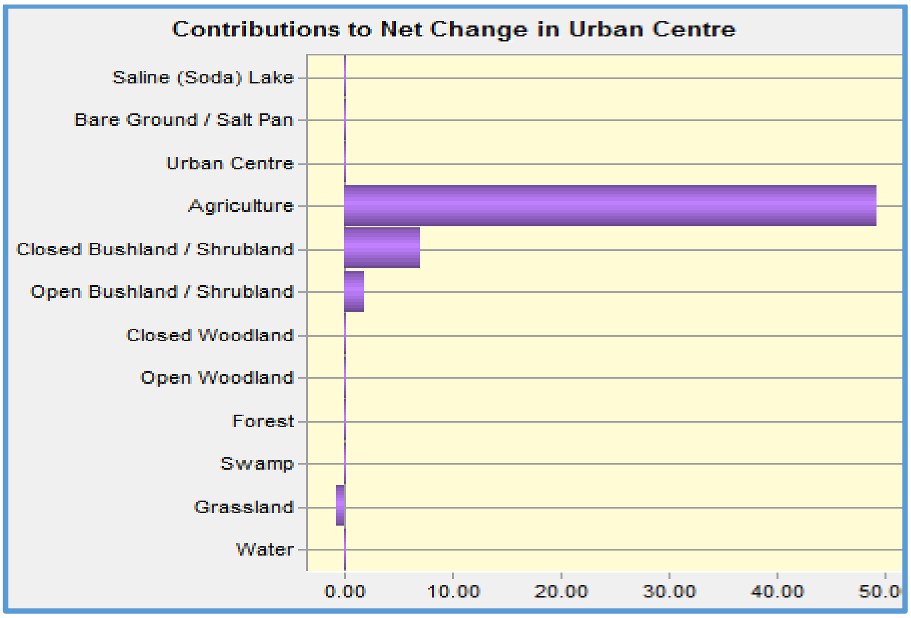


Figure 5.2.1i: *Contributions to net change in Urban Centres between 1986 and 2000*

5.2.1.2 2000 to 2014 Period

During the period 2000 – 2014, the Amboseli-Kilimanjaro landscape experienced the following key changes:

i. There was a significant loss of grasslands to other land use / land cover categories (nearly 600 Km^2) against a gain of about 550 Km^2 from other land use / land cover categories (*Figure 5.2.1j*). Grasslands were mostly lost to agriculture (about 300 Km^2) and bare ground / salt pan (about 50 Km^2) *(Figure 5.2.1k)*

ii. The area under Open Bushland / Shrubland suffered a loss of about 400 Km^2 against a gain of only 150 Km^2 (*Figure 5.2.1j*). The most significant loss was to Grassland (nearly 270 Km^2) and agriculture (nearly 40 Km^2) while the key gains were made from Forest (about 20 Km^2) (*Figure 5.2.1l*).

iii. The was no significant gain or loss in Closed Bushland / Shrubland (*Figure 5.2.1j*) with gain being a megre 9 Km^2 from Agriculture and lost 13 Km^2 to Forest and 6 Km^2 to Grassland (*Figure 5.2.1m*)

iv. The area under agriculture gained about 400 Km^2 and lost about 275 Km^2 from other land use / land cover categories. (*Figure 5.2.1j*). The main gain was from Grassland (about 330 Km^2) and Open Bushland / Shrubland (about 50 Km^2). The loses were to Agriculture (about 80 Km^2), to Forest (about 50 Km^2) and to Open Woodland (about 40 Km^2) (*Figure 5.2.1n*).

v. Forests gained over 150 Km^2 and lost about 80 Km^2 *(Figure 5.2.1j).* Forests benefitted from Agriculture (about 40 Km^2), Closed Bushland / Shrubland (about 15 Km^2) and Grassland about 8 Km^2). The loss was to Open Bushland / Shrubland (about 10 Km^2) and Bare Ground / Salt Pan (about 8 Km^2) (*Figure 5.2.1p*)

vi. Areas under Bare Ground increased by about 350 Km^2 and decreased by about 100 Km^2 (*Figure 5.2.1j*). The bare Ground benefited from Saline (Soda) Lake (about 130 Km^2), Water (about 75 Km^2) and Grassland (about 35 Km^2) (*Figure 5.2.1q*).

vii. Urban Centres expanded by about 80 Km^2 (*Figure 5.2.1j*) with key contributors to this expansion being Agricultural land (about 70 Km^2) and Grassland that contributed about 4 Km^2 (*Figure 5.2.1r*).

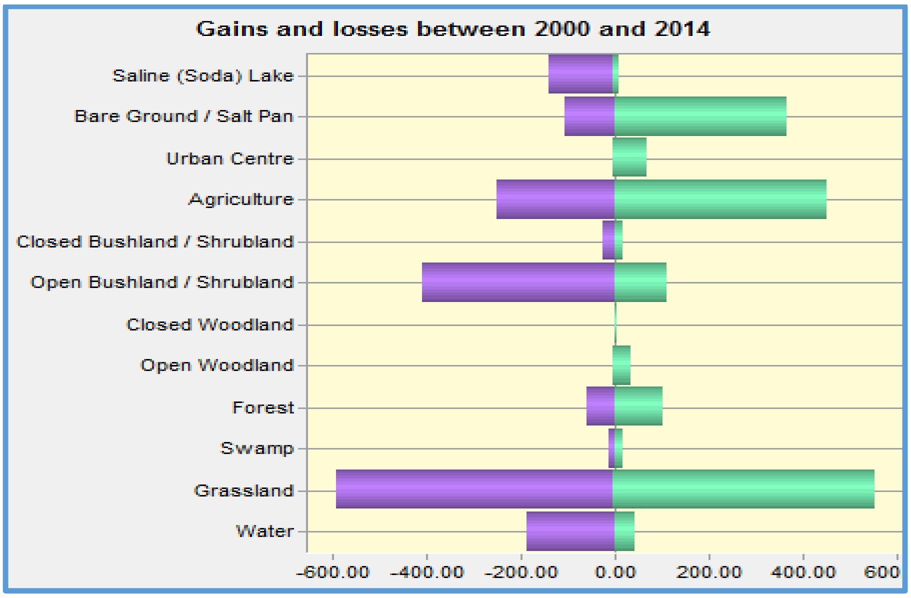


Figure 5.2.1j: *Overall gains and losses in land use / land cover between 2000 and 2014*

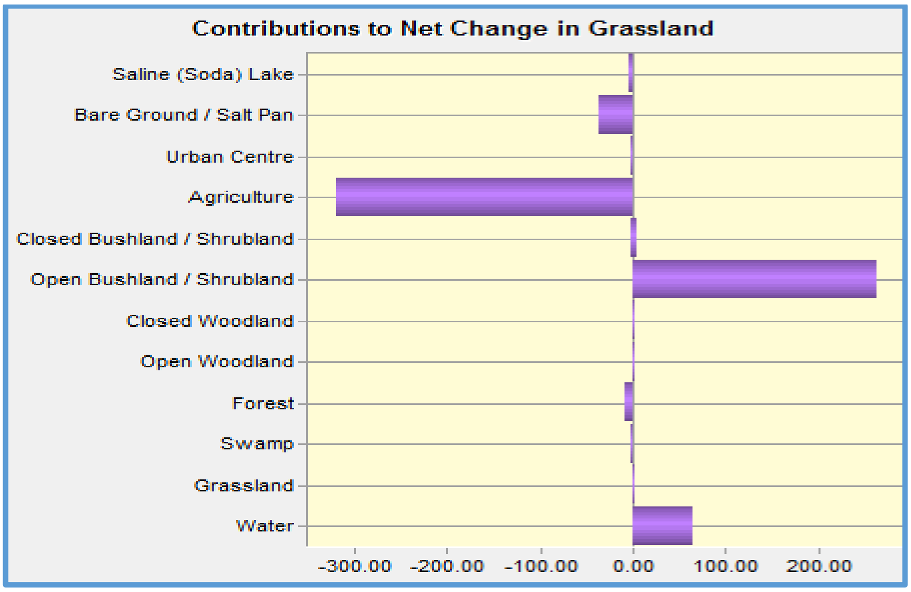


Figure 5.2.1k: *Contributions to net change in Grassland between 2000 and 2014*

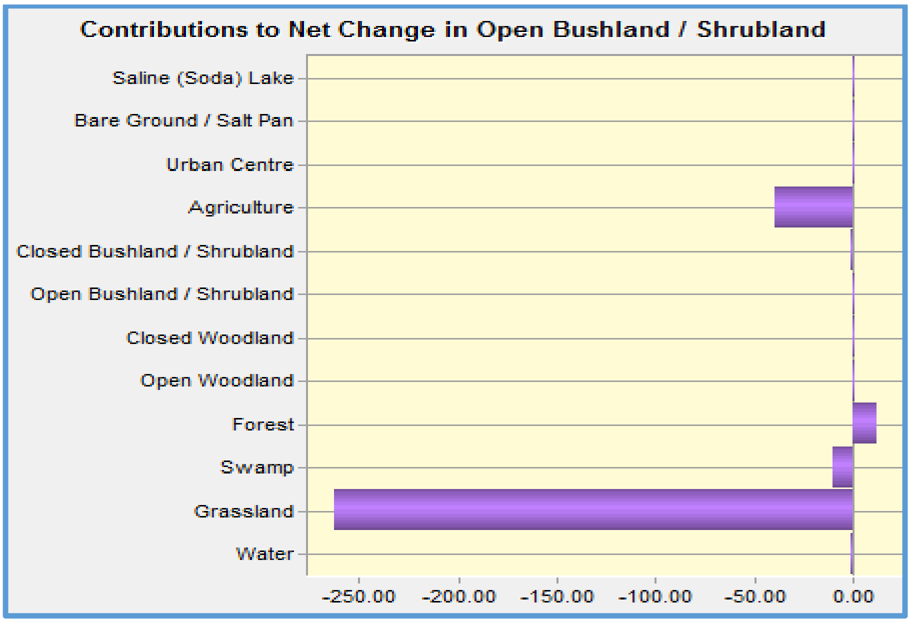


Figure 5.2.1l: *Contributions to net change in Open Bushland /Shrubland between 2000 and 2014*

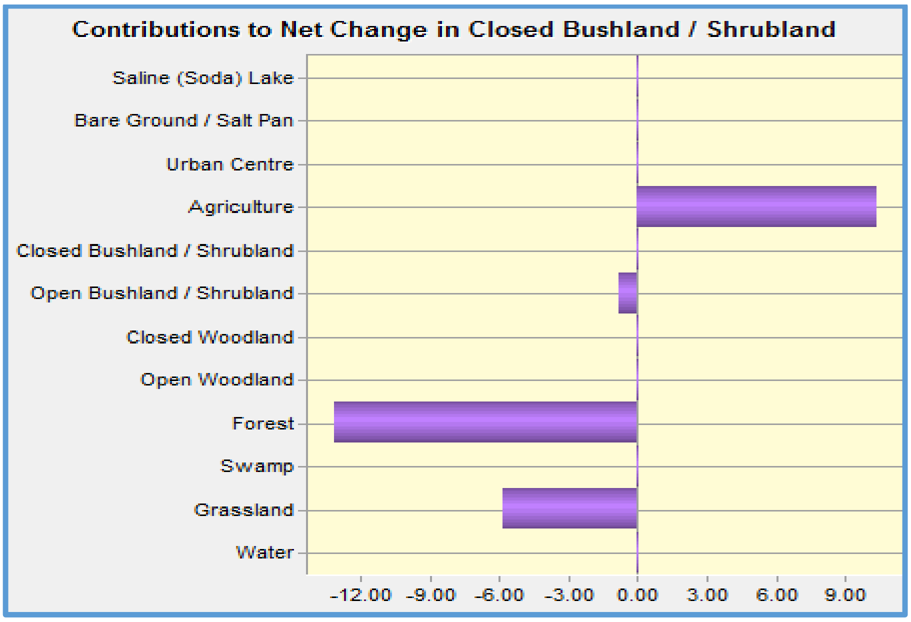


Figure 5.2.1m: *Contributions to net change in Closed Bushland / Shrubland between 2000 and 2014*

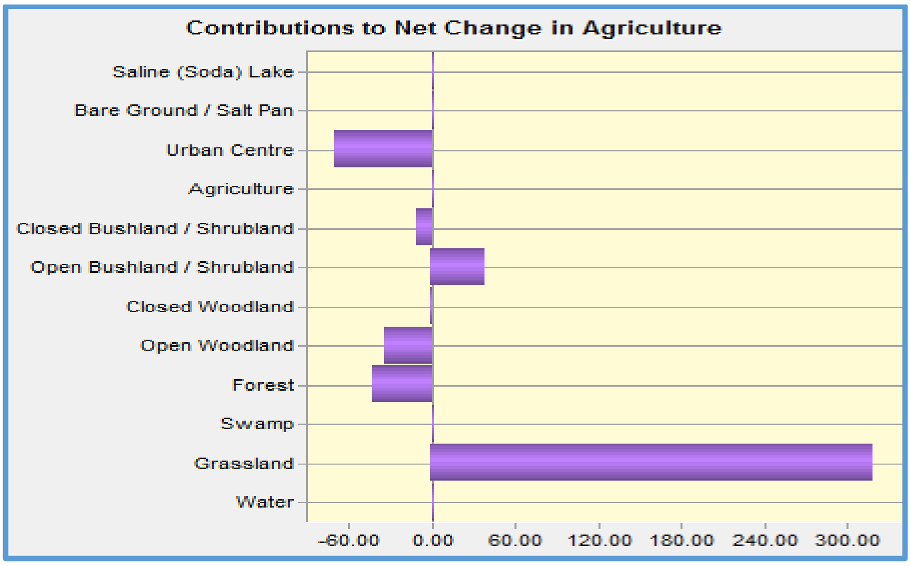


Figure 5.2.1n: *Contributions to net change in Agriculture between 2000 and 2014*

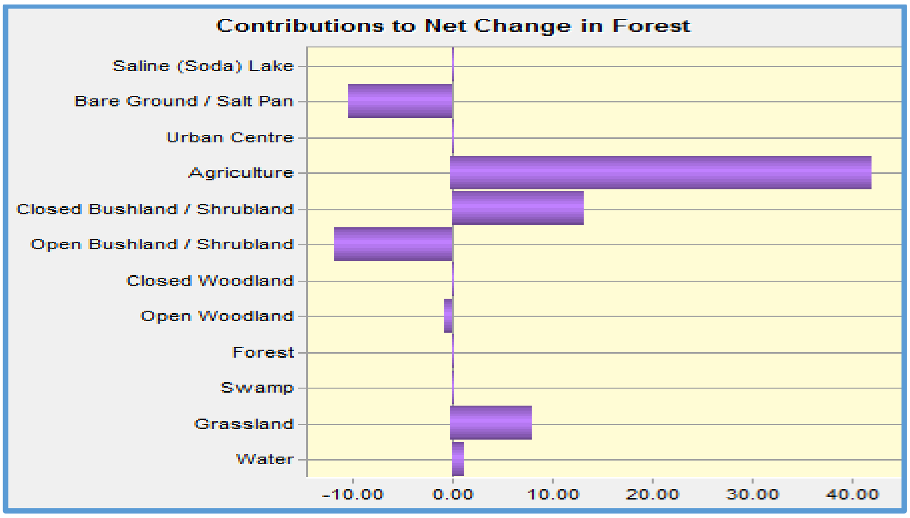


Figure 5.2.1p: *Contributions to net change in Forest between 2000 and 2014*

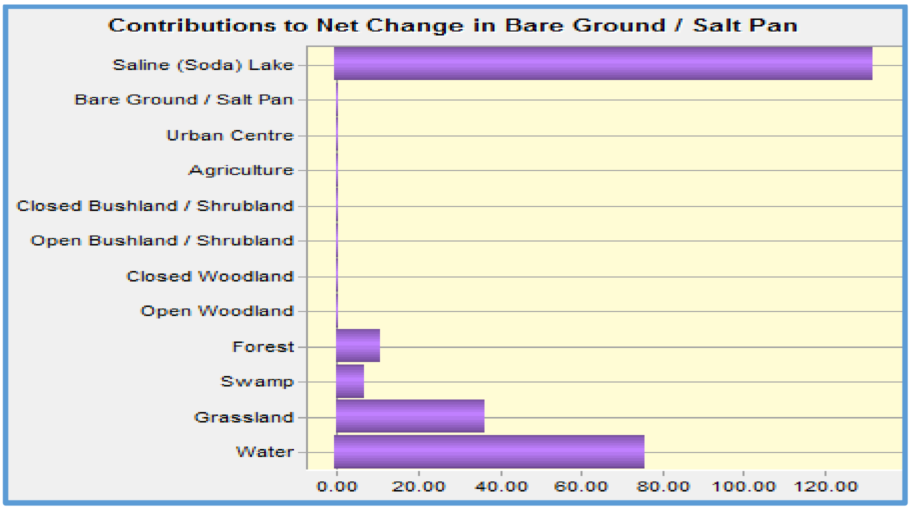


Figure 5.2.1q: *Contributions to net change in Bare Ground / Salt Pan between 2000 and 2014*

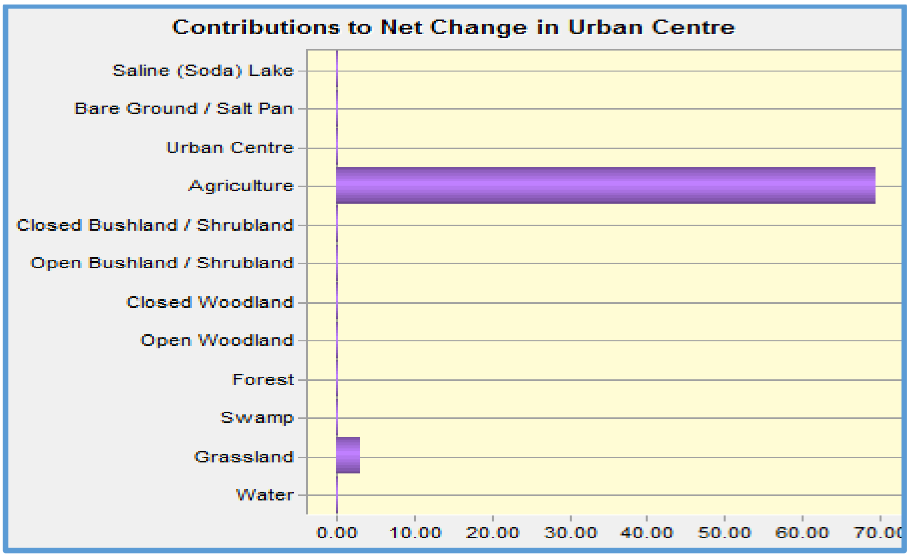


Figure 5.2.1r: *Contributions to net change in Urban Centres between 2000 and 2014*

2.2.2 Long-term changes (1986 – 2014 Period)

During the period 1986 – 2014, the Amboseli-Kilimanjaro landscape experienced the following key changes:

i. There was a significant loss of grasslands to other land use / land cover categories (nearly 900 Km^2) against a gain of about 300 Km^2 from other land use / land cover categories (*Figure 5.2.2a*). Grasslands were mostly lost to open bushland / shrubland (over 400 Km^2), bare ground / salt pan (close to 100 Km^2) and agriculture (about 80 Km^2) *(Figure 5.2.2.b)*

ii. There was a gain in area under Open Bushland / Shrubland (over 500 Km^2) from other land use / land cover categories against a loss of about 150 Km^2 to other land use / land cover categories (*Figure 5.2.2a*). The most significant gain was made from Grassland (over 400 Km^2) while the key loss was to Agriculture (about 80 Km^2) (*Figure 5.2.2c*)

iii. Closed Bushland / Shrubland mainly suffered loss (about 140 Km^2) to other land use / land cover categories (*Figure 5.2.2a*). This loss was mainly to Agriculture (about 100 Km^2) (*Figure 5.2.2d*)

iv. There was a gain in area under agriculture (about 500 Km^2) from other land use / land cover categories against a loss of over 300 Km^2 to other land use / land cover categories (*Figure 5.2.2a*). Gains were notably made from Closed Bushland / Shrubland (about 60 Km^2), Open Bushland / Shrubland (about 100 Km^2) and Grassland (about 80 Km^2). Urban centres however took away about 120 Km^2 from land previously under agriculture (*Figure 5.2.2e*)

v. Forests mostly suffered loss (close to 200 Km^2) *(Figure 5.2.2a)* with key beneficiaries being Open Woodland (about 140 Km^2), Agriculture (about 30 Km^2), and Open Bushland / Shrubland (about 25 Km^2) (*Figure 5.2.2f*)

vi. Areas under Bare Ground increased by about 150 Km^2 (*Figure 5.2.2a*) with notable increments being realized from Grassland (close to 90 Km^2) and Water (about 13 Km^2) (*Figure 5.2.2g*).

vii. Urban Centres expanded by about 150 Km^2 (*Figure 5.2.2a*) with key contributors to this expansion being Agricultural land (about 110 Km^2) and Closed Bushland / Shrubland that contributed about 10 Km^2 (*Figure 5.2.2h*)

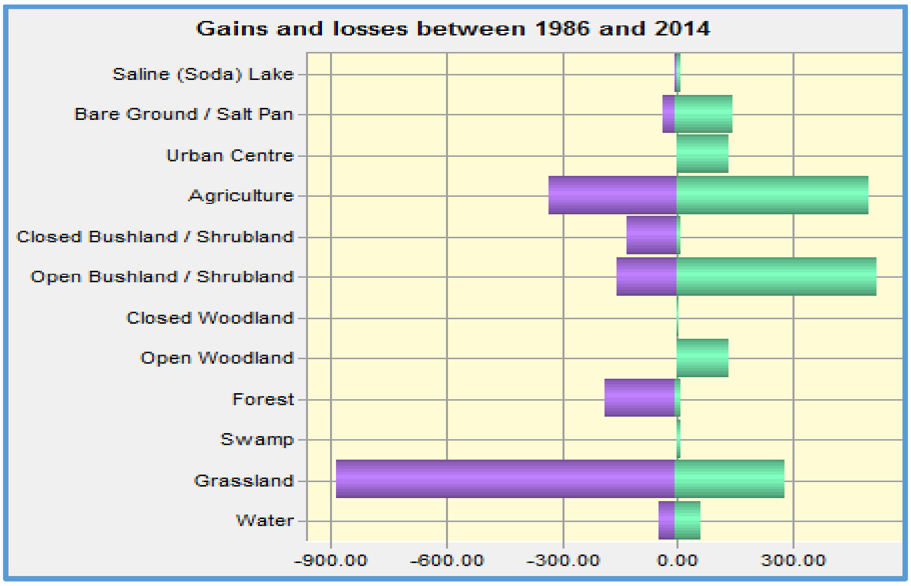


Figure 5.2.2a: *Overall gains and losses in land use / land cover between 1986 and 2014*

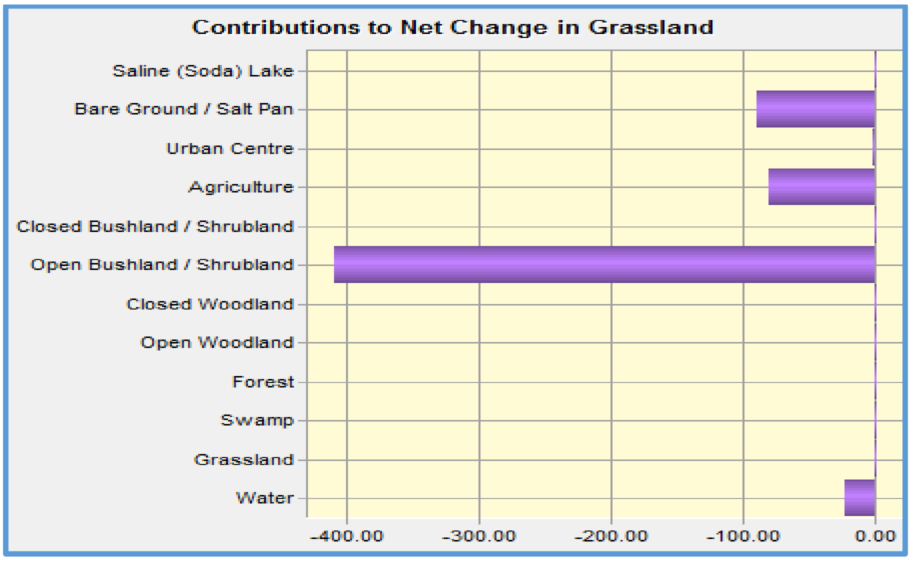


Figure 5.2.2b: *Contributions to net change in Grasslands between 1986 and 2014*

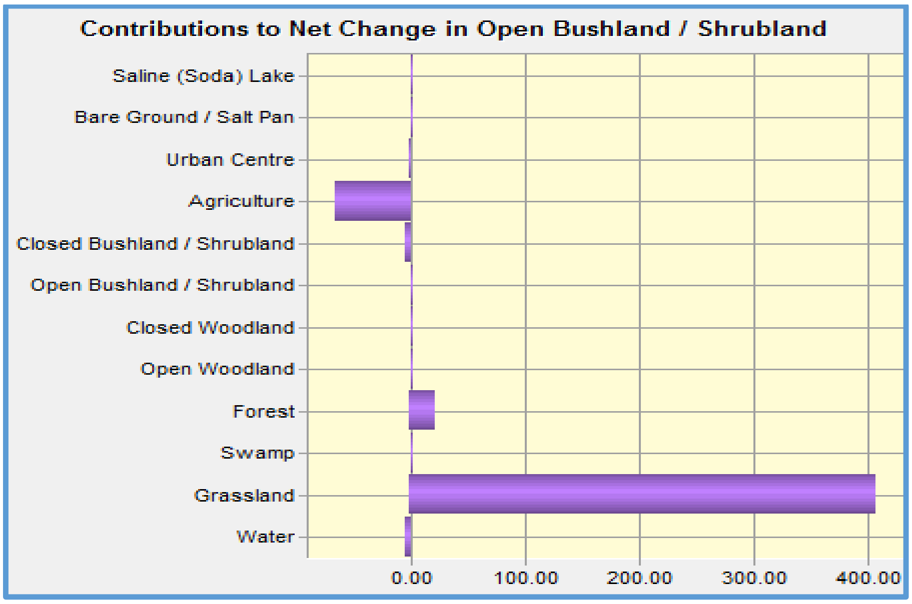


Figure 5.2.2c: *Contributions to net change in Open Bushland / Shrubland between 1986 and 2014*

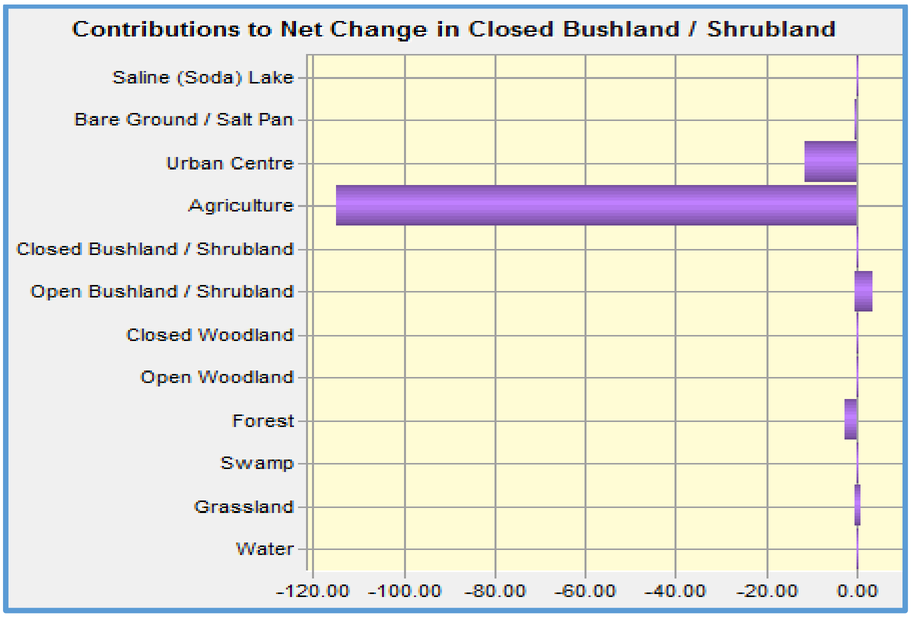


Figure 5.2.2d: *Contributions to net change in Closed Bushland / Shrubland between 1986 and 2014*

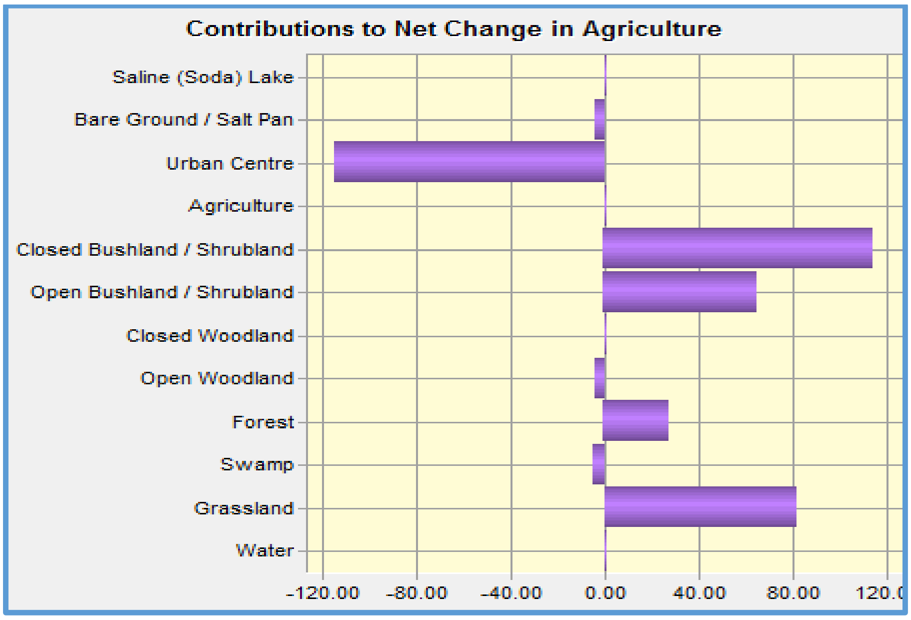


Figure 5.2.2e: *Contributions to net change in Agriculture between 1986 and 2014*

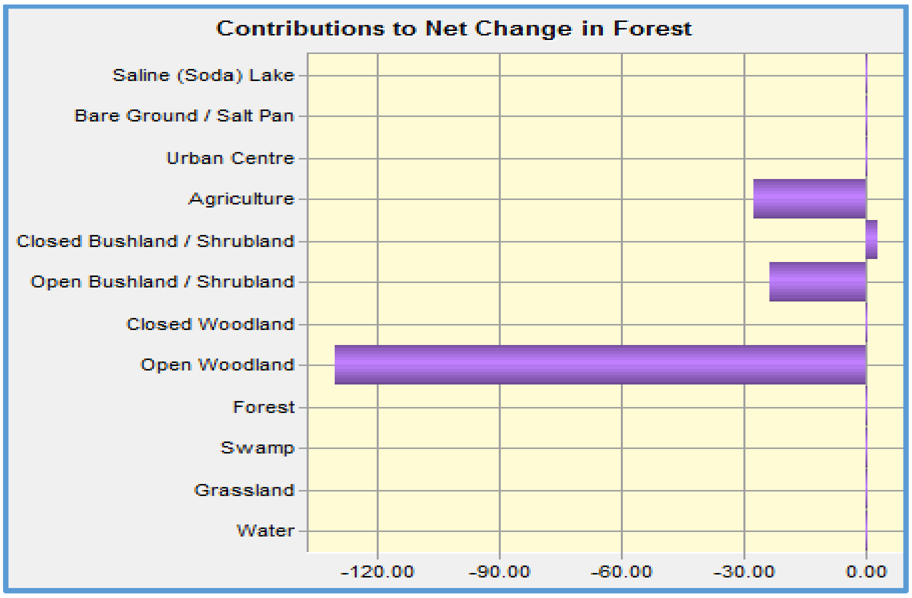


Figure 5.2.2f: *Contributions to net change in Forest between 1986 and 2014*

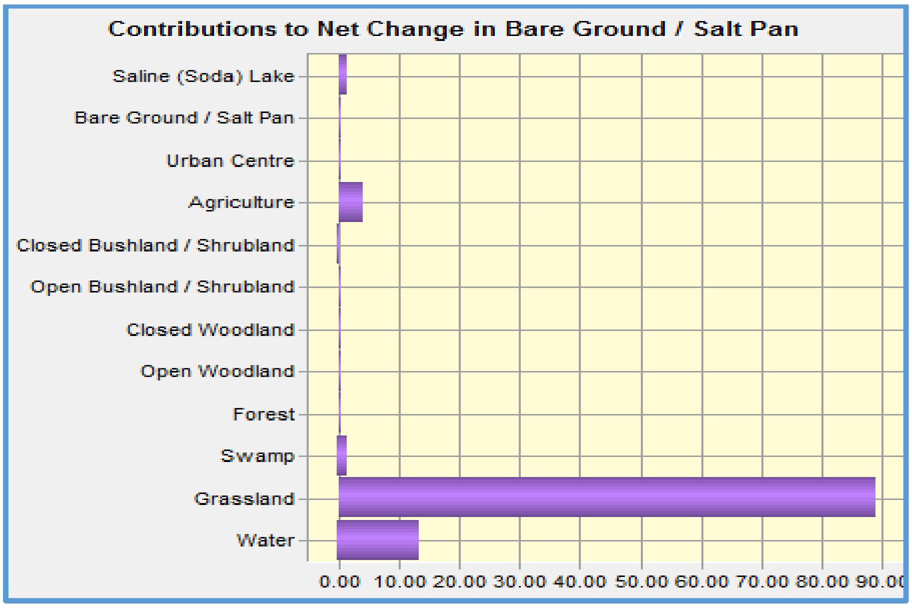


Figure 5.2.2g: *Contributions to net change in Bare Ground / Salt Pan between 1986 and 2014*

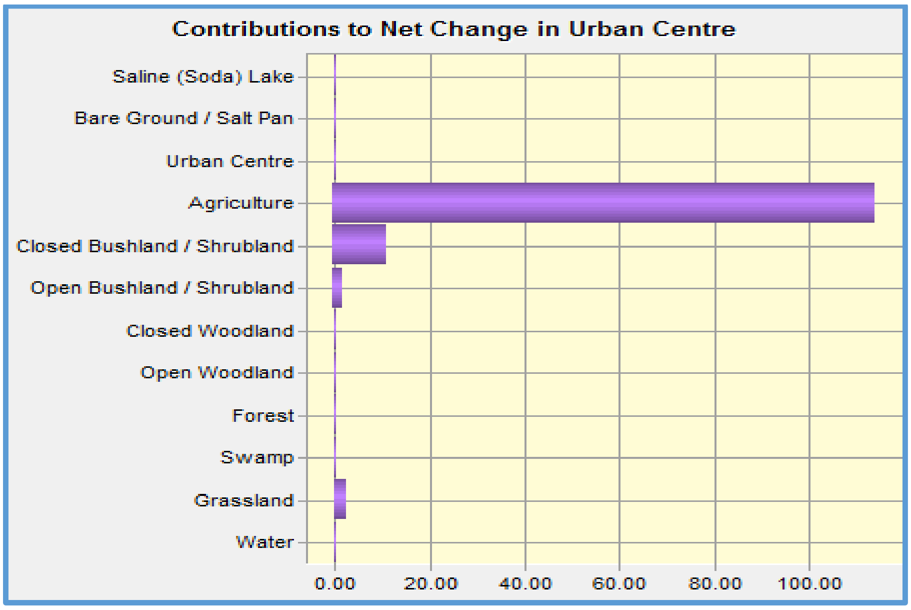
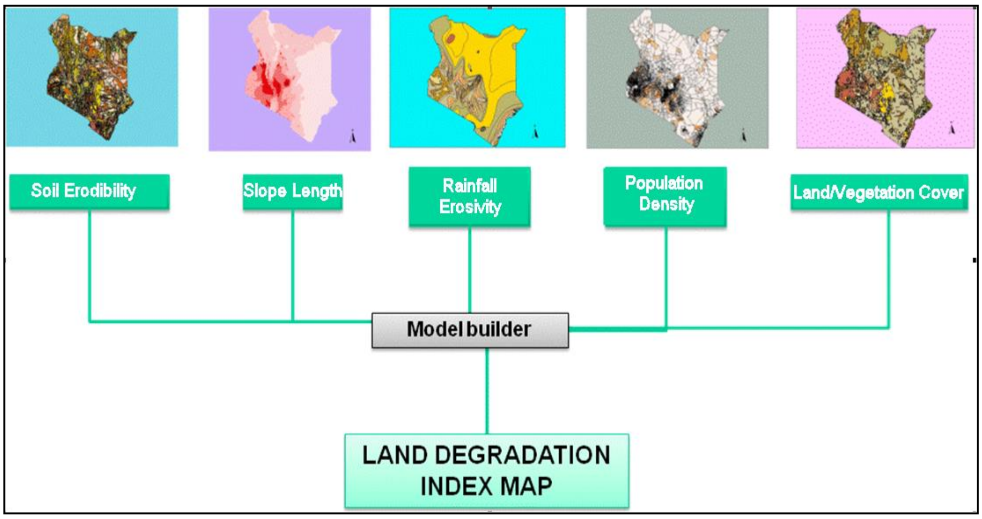
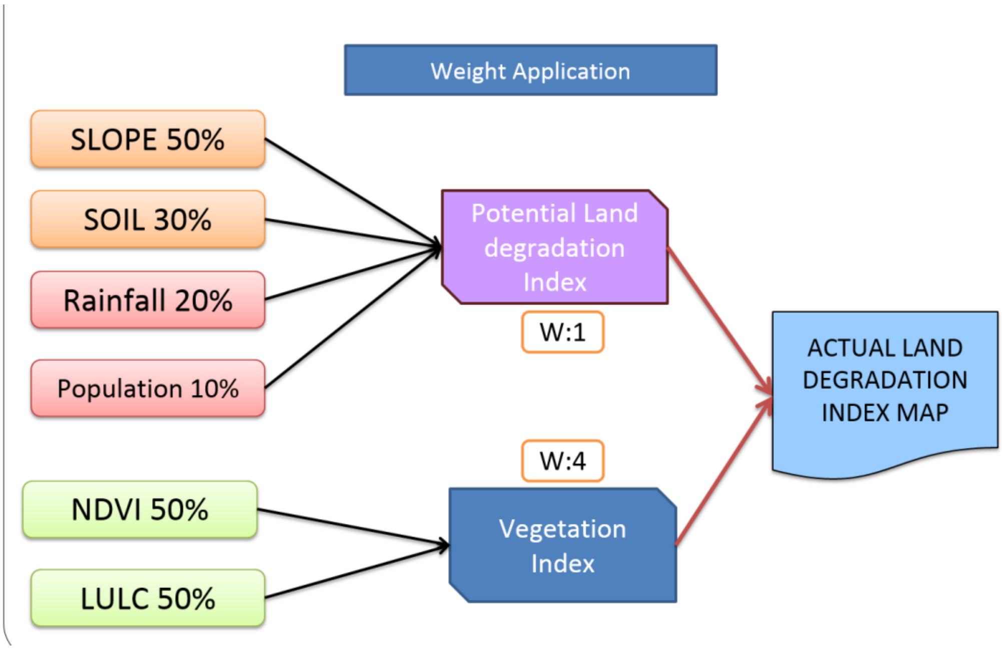


Figure 5.2.2h: *Contributions to net change in Urban Centres between 1986 and 2014*

2.3 Land Degradation Maps and Statistics

ACC proposed to develop a degradation index map for the study areas, using the parameters developed for IGAD countries. This index will measure the degradation potential of the area with a view to identify hot spots of potential vulnerability to climatic changes. The parameters use variable weights that can be adjusted based on the actual information on the ground. This component is pending but is almost complete. However the various data layers that are the inputs to the degradation index are outlined in the diagram below of the land degradation model.





5.3.1 Potential and Actual Land Degradation Index Maps

Two land degradation maps (potential & actual degradation maps) and statistics were produced for the entire Amboseli-Kilimanjaro Landscape. The maps and statistics are shown here below.

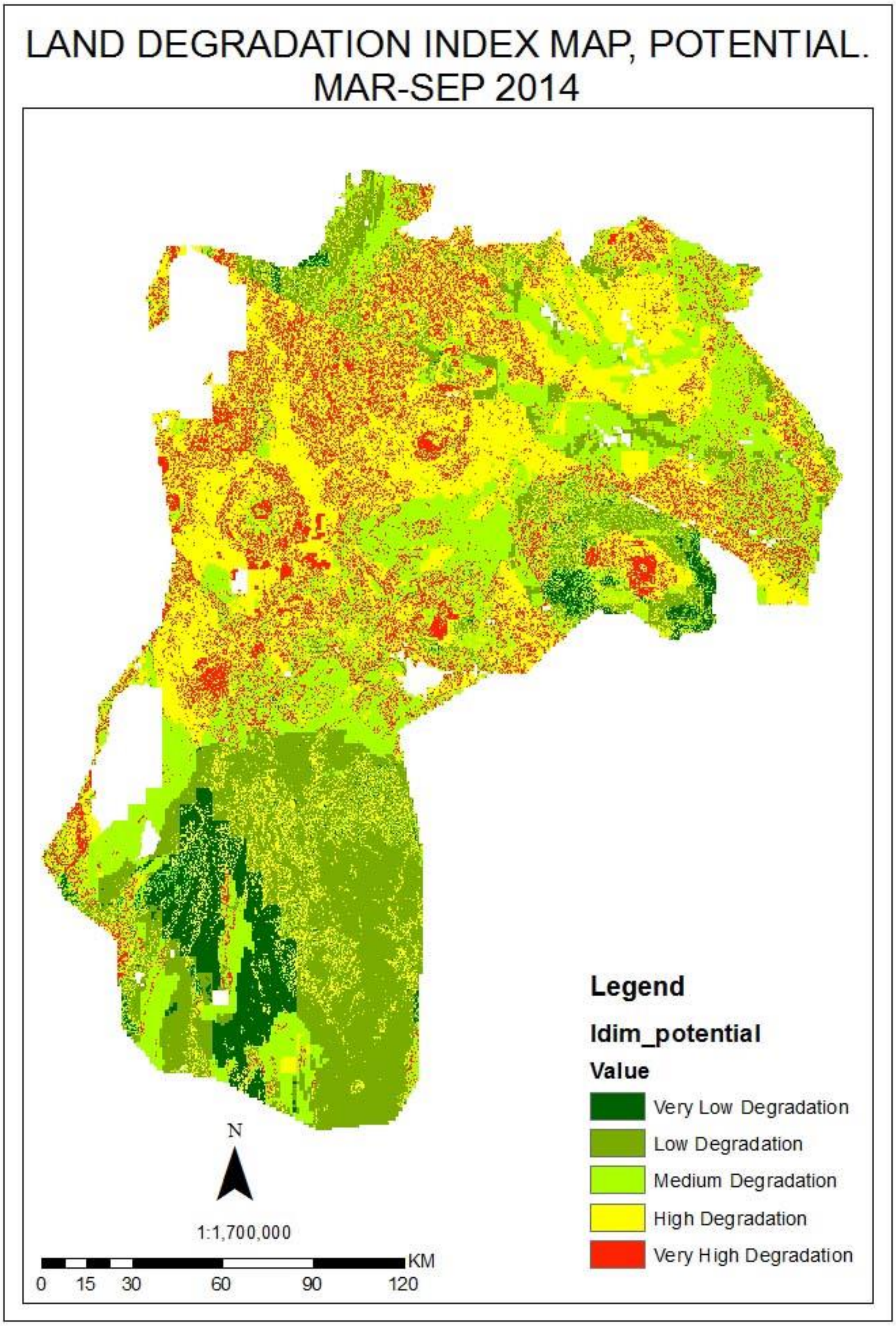


Figure 5.3.1a: *Potential land degradation index map for the period March – September 2014*

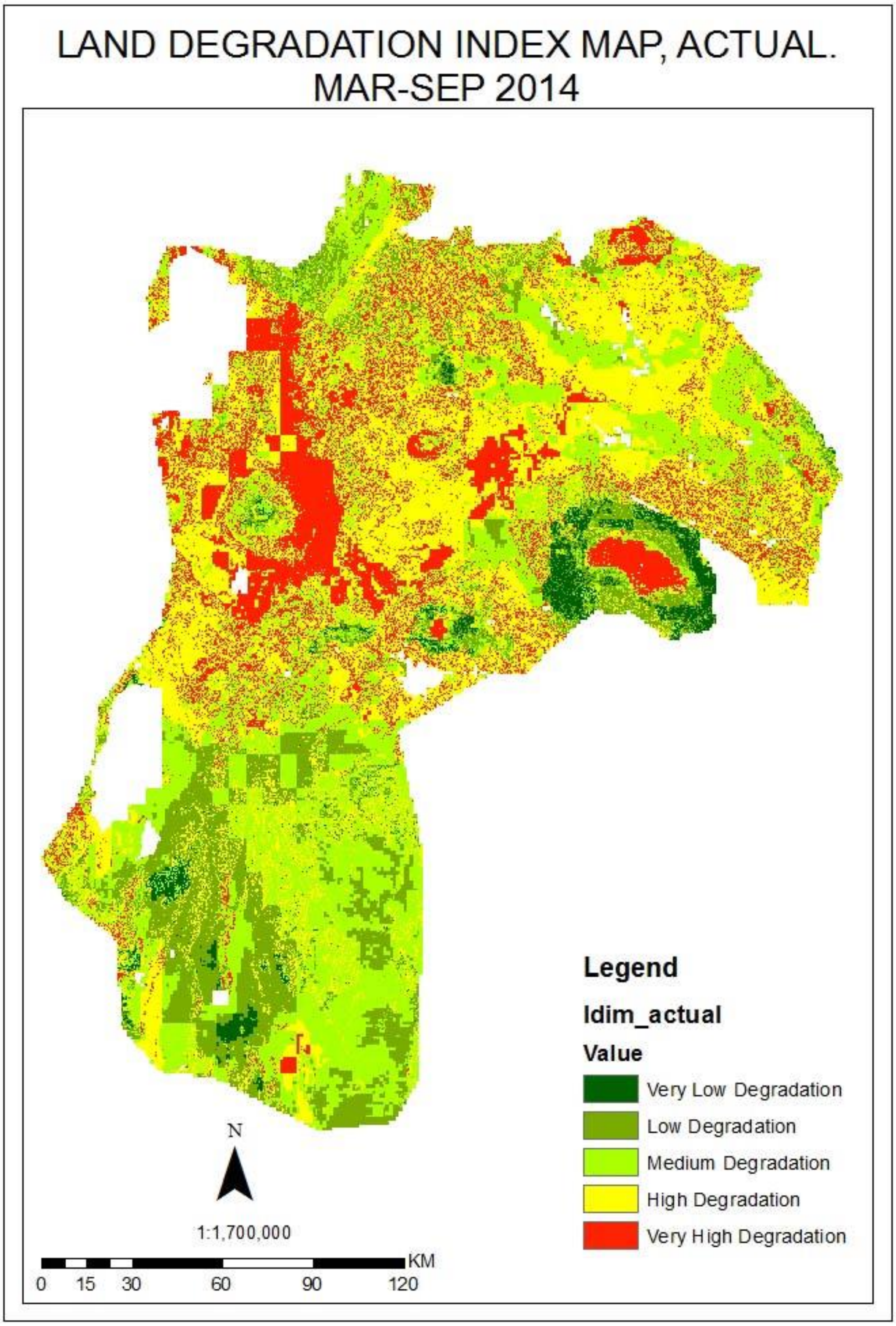


Figure 5.3.1b: *Actual land degradation index map for the period March – September 2014*

5.3.2 Land Degradation Statistics

Land degradation statistics were computed based on the Actual Land Degradation Index Map. These statistics are presented here below in *Figures 5.3.2a and 5.3.2b*.

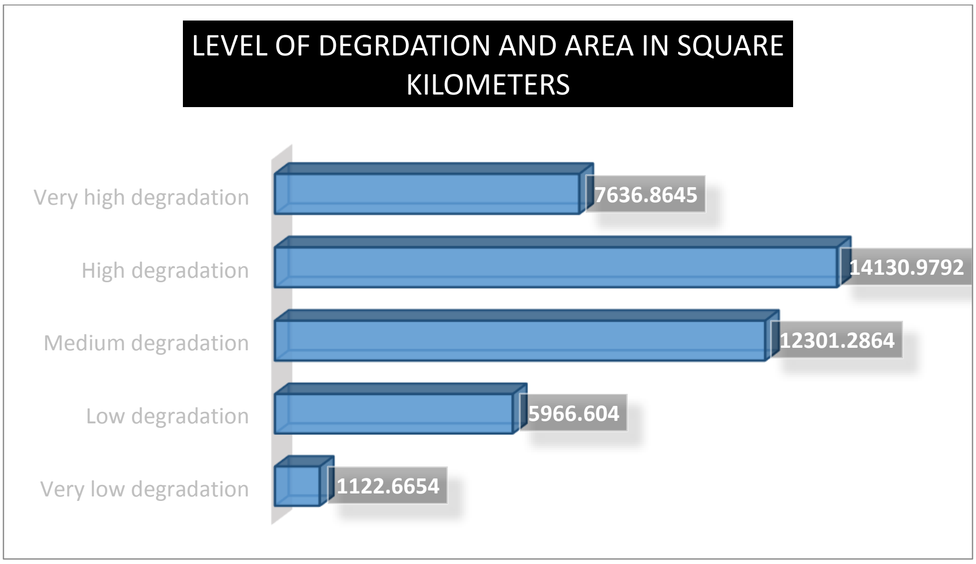


Figure 5.3.2a: *Levels of land degradation and their associated areas (in Square Kilometers)*

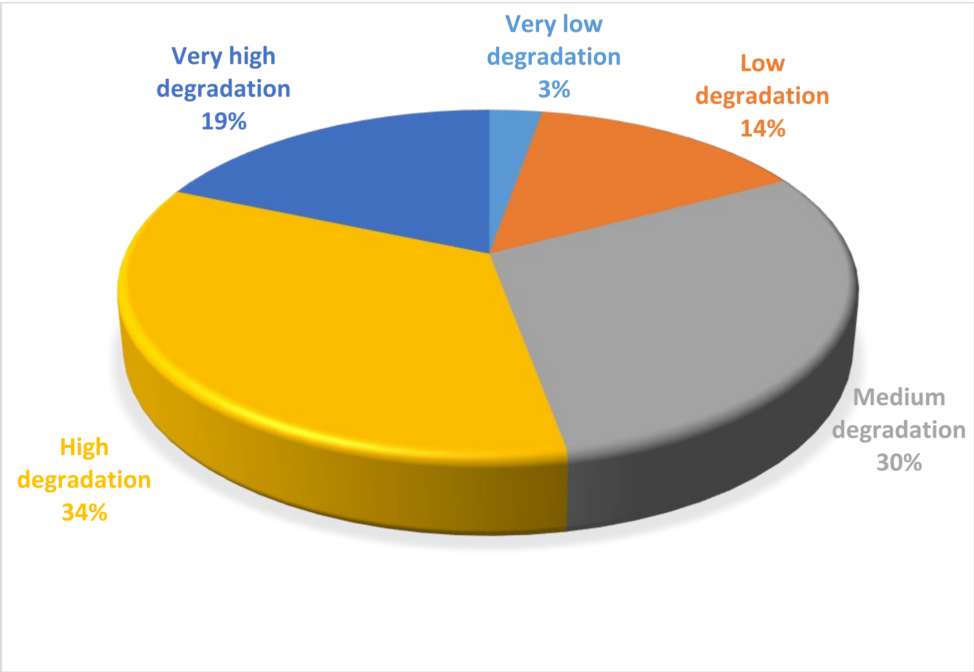


Figure 5.3.2b: *Levels of land degradation and their associated percentages*

From the statistics, the dominant level of degradation in the Amboseli – Kilimanjaro landscape is the high degraded areas witnessed over a total area of 14,131 Km^2 (34%). This is followed by 12,301 Km^2 (30%) of medium degraded areas, 7,637 Km^2 (19%) of very high degraded areas, 5,967 Km^2 (14%) of low degraded areas and 1,123 Km^2 (3%) of very low degraded areas.

2.4 Analysis of Land Use / Land Cover Changes and Land Degradation

Spatial analyses were conducted to determine if there was any relationship between the land use / land cover changes and the land degradation levels mapped within the Amboseli – Kilimanjaro Landscape. The findings are illustrated here below by way of maps and statistics.

As shown in *Table 5* and *Figure 5.4*, the key areas affected by high to very high land degradation levels are those that were Grassland in 1986 and remained so in 2014 (10,270.5 Km^2) followed by areas that remained under bare ground / salt pans in 1986 and 2014 (1611.128 Km^2), areas that remained under agriculture in 1986 and 2014 (1602.7 Km^2), areas that remained under open bushland / shrubs in 1986 and 2014 (1055.48 Km^2), and areas that remained under closed bushland / shrubs in 1986 and 2014 (417.062 Km^2).

Table 5

Reconciliation of Land Ddegradation and Land Use / Land Cover Change (1986-2014)	**Area in Sq. Km**
High degradation and No Change in Agriculture	1355.995
High degradation and No Change in Bare Ground/Salt Pan	488.405
High degradation and No Change in Closed Bushland/Shrub	218.213
High degradation and No Change in Forest	143.42
High degradation and No Change in Grassland	8043.451
High degradation and No Change in Open Bushland/Shrub	650.495
High degradation and Open Bushland/Shrub to Closed Bushland/Shrub	103.141
Very high degradation and No Change in Agriculture	246.681
Very high degradation and No Change in Bare Ground / Salt Pan	1122.723
Very high degradation and No Change in Closed Bushland/Shrub	198.849
Very high degradation and No Change in Grassland	2227.02
Very high degradation and No Change in Open Bushland/Shrub	404.985

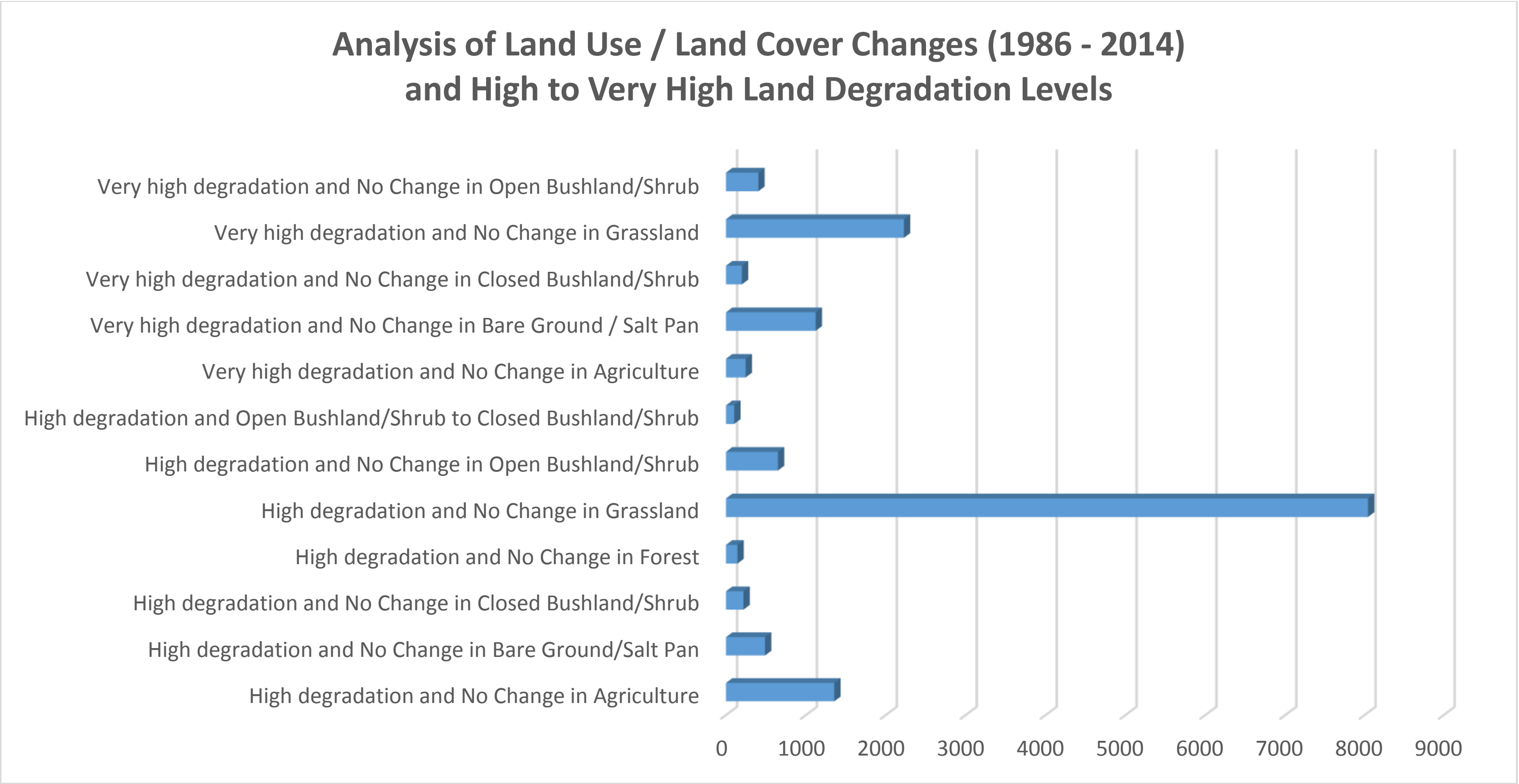


Figure 5.4: *Analysis of major land use / land cover changes and high to very high land degradation levels in the Study area*

III. Mapping community perception on vulnerability

A documentation and mapping of the perceptions of vulnerability by the host communities in the two countries was undertaken. This assessment involves participatory mapping exercises to highlight communities' knowledge, attitudes and perceptions on long term changes, their causes and responses to the changes. The tool developed focused on three main questions;

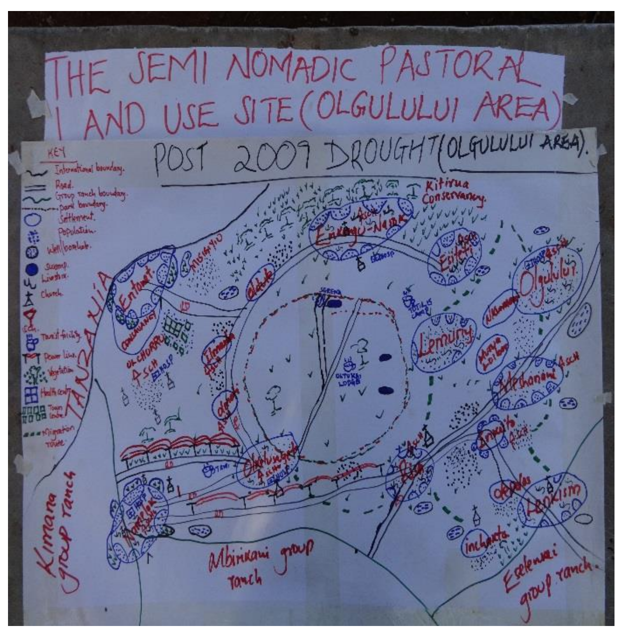
i. What do communities view as drivers of climate variability and change?
ii. To what extent do these perceptions match scientific assessments?
iii. What are their drought/flood coping strategies and how effective are they?

Focus group discussions were applied comprising of opinion leaders, experts from varied occupations, gender, government representatives and different ethnic communities. The groups started by sketching: three maps starting with historic maps of free ranging system, then concentration period and lastly the sedentarization period. Discussions followed on causes of the perceived range resources trends: wet and dry season grazing areas, swamps, medicinal plants/firewood, migratory corridors, livestock trends, individual household trends.

The following was achieved through this exercise:

- Mapping of the pastoral resource patches and their change dynamics over the last 30 years in the study areas.
- Identifying causes of the perceived changes and their implications on the use value of pastoral resource patches in the study area.
- Assessing the effects of land use changes on pastoral household herd size and mobility patterns in the study area.

Below are samples of Maps generated by Focus Group Discussions



The process of mapping community perceptions was undertaken in the targeted areas in Amboseli-Kilimanjaro heartland. Below is a summary of the results and a fhe full report is available in Appendix 2

Village		Land use site	Current Livelihood
Kenya	**Namelok**	Semi nomadic	Cultivation
	Eselenkei	Nomadic	Pastoralism
	Kimana	Sedentary	Businesses/cultivation
	Rombo	Semi nomadic	Cultivation
	Maili tisa	Semi nomadic	Businesses/pastoralism
	Ngatataek	Semi nomadic	Businesses/pastoralism
Tanzania	**Longido**	Nomadic	Pastoralism
	Oldonyo sampu	Sedentary	Cultivation
	Enkikaret	Nomadic	Pastoralism
	Esilalei	Semi nomadic	Pastoralism
	Burunge	Sedentary	Cultivation
	Ketumbeine	Nomadic	Pastoralism
	Merughoi	Nomadic	Pastoralism

Village		Main land uses in different time periods		
		Free range (1967-1976)	**Concentration period (1977-1987)**	**Sedentarization (1988 onwards)**
Kenya	Namelok	Nomadic	semi nomadic	Agro pastoralism
	Eselenkei	Nomadic	Nomadic	Nomadic
	Kimana	Nomadic	semi nomadic	Agro pastoralism
	Rombo	Nomadic	Nomadic	Agro pastoralism
	Maili tisa	Nomadic	Nomadic	semi nomadic
	Ngatataek	Nomadic	Nomadic	Semi nomadic
Tanzania	Longido	Nomadic	Nomadic	semi nomadic
	Oldonyo sampu	Nomadic	Nomadic	Cultivation
	Enkikaret	Nomadic	Nomadic	Nomadic
	Esilalei	Nomadic	Nomadic	semi nomadic
	Burunge	Nomadic	Agro pastoralist	Agro pastoralist
	Ketumbeine	Nomadic	Nomadic	Nomadic
	Merughoi	Nomadic	Nomadic	Nomadic

	Village	Wet and dry season grazing areas extent			General trend
		Free range (1967-1976)	Concentration period (1977-1987)	Sedentarization (1988 onwards)	
Kenya	Namelok	100%	> 50%	< 20%	Decreased
	Eselenkei	100%	> 80%	> 50 %	Decreased
	Kimana	> 80 %	< 50%	< 5%	Decreased
	Rombo	100%	> 50%	< 20%	Decreased
	Maili tisa	100%	>50 %	< 20%	Decreased
	Ngatataek	100%	>50 %	< 20%	Decreased
Tanzania	Longido	100%	> 80%	> 50 %	Decreased
	Oldonyo sampu	< 50 %	< 20%	< 5 %	Decreased
	Enkikaret	100%	>80 %	> 50 %	Decreased
	Esilalei	100%	> 80 %	> 50 %	Decreased
	Burunge	< 50%	< 20%	< 5%	Decreased
	Ketumbeine	100%	> 80%	> 50 %	Decreased
	Merughoi	100%	> 80%	> 50 %	Decreased

	Village	Migratory corridors/sites extent			General trend
		Free range (1967-1976)	Concentration period (1977-1987)	Sedentarization (1988 onwards)	
Kenya	Namelok	100%	> 20%	< 5%	Decreased
	Eselenkei	100%	> 80%	> 50 %	Moderate
	Kimana	> 80 %	< 50%	0%	Decreased
	Rombo	100%	> 20%	< 5%	Decreased
	Maili tisa	100%	> 20 %	< 5%	Decreased
	Ngatataek	100%	>20 %	< 5%	Decreased
Tanzania	Longido	100%	> 80%	> 50 %	Moderate
	Oldonyo sampu	< 50 %	< 5%	0%	Decreased
	Enkikaret	100%	>80 %	> 50 %	Moderate
	Esilalei	100%	> 80 %	> 50 %	Moderate
	Burunge	< 50%	< 5%	0%	Decreased
	Ketumbeine	100%	> 80%	> 50 %	Moderate
	Merughoi	100%	> 80%	> 50 %	Moderate

Perceived changes	Causes of perceived changes in Land use sites (Ranked in order)		
	Nomadic land use sites	**Semi nomadic land use**	**Sedentary land use sites**
Livestock number decrease	Frequent drought Land degradation Loss of land productivity Reduced rainfall	Population increase Loss of land productivity Loss of kinship relations Changing land use	Restricted movement Cutting down of trees Cultivation Lack of herding labour
Household herd size decrease	Frequent drought Poverty Reduced rainfall Reduced pastures Loss of land productivity	Reduced rainfall Poverty Reduced grazing area Overstocking	Cultivation Reduced grazing areas Reduced pastures Increased settlement Restricted movement
Pastures/trees/habitats decrease	Frequent droughts Reduced rainfall Poor land use planning Poor governance Climate change	changing land use Overgrazing Reduced rainfall climate change	land use change Population increase subdivision & fragmentation Infrastructure development
Changing pastoral mobility	Restricted movement Reduced pastures Land degradation Loss of traditional culture	Changing land use Cultivation Reduced pastures Reduced household herd size	Land subdivision & fragmentation Restricted movement Cultivation
Human wildlife conflict increase	Habitat encroachment Government policies Increase in number Population increase	Increase in settlement Habitat destruction Increase in wildlife Government policies	Increase dryland farming Habitat encroachment Climate change Reduced pastures
Drought increase	Land degradation Loss of land productivity Reduced rainfall Loss of grazing land	Reduced grazing land Reduced rainfall Reduced land cover Land degradation	Cultivation Reduced tree cover Reduced rainfall Land degradation
Reduced rain days, distribution and amount	Climate change Natural factors Loss of trees Pollution	Changing land use Natural factors Climate change	Tree cutting Reduced cover Cultivation

Response to perceived long term changes in Land use sites (Ranked in order)		
Nomadic	**Semi nomadic**	**Sedentary**
Grazing management schemes	Diversification	Diversification
Informed land use planning	Educating children	Planting trees
Educating children	Looking for employment	Destalking
Diversification	Planting trees	Land zonation
Improving livestock breeds	Improving livestock breeds	agricultural intensification
Rain water harvesting	Informed land use planning	
Resource conservation		

IV. Vulnerability Index for ranking landscapes/dry land areas

The final critical component of the project is to undertake a consultative process to syntehsize all the above parameters and develop a possible Vulnerability index that can be used as a tool to assess vulnerability of any savannah landscape. This will be done through a stakeholder feedback workshop to ensure that we have the relevant input from the government, non-government and community groups in the Amboseli and Kilimanjaro landscapes. This workshop will be hosted and organised by AWF

This vulnerability index can then be periodically updated with new parameters and applied with slight variations to suit individual landscapes.

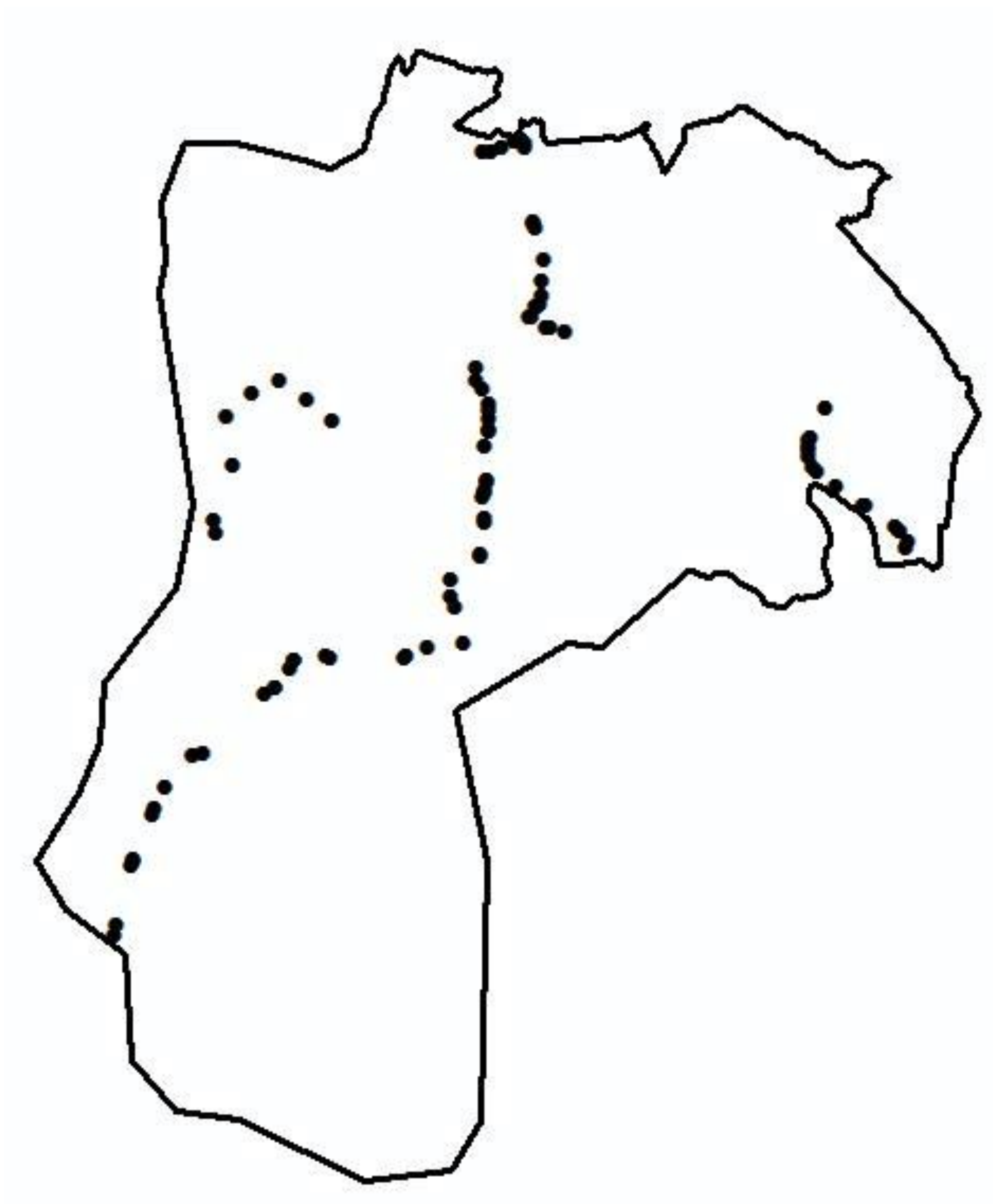
Annex 1

Land Use / Land Cover Categories used by the Project to undertake Mapping

ID	Class	Description
1	Water	Standing water present >11 months; deep lakes or rivers
2	Grassland	Open land containing sparse to dense cover of herbaceous vegetation (<20% bush or tree cover)
3	Swamp	Vegetated lands (herbaceous) inundated with water present at or near the surface
4	Forest	Vegetated land with tree canopy cover greater than 80% and height greater than 5 meters, often including densely vegetated under story
5	Open Woodland	Vegetated land with tree canopy cover between 20 - 80% and height greater than 5 meters, relatively open under story
6	Closed Woodland	Vegetated land with tree canopy cover greater than 80% and height greater than 5 meters, relatively open under story
7	Open Bushland/ Shrub	Vegetated land with shrub/bush canopy cover between 20 - 80% and height less than 5 meters
8	Closed Bushland/ Shrub	Vegetated land with shrub/bush canopy cover greater than 80% and height less than 5 meters
9	Agriculture	Open and cultivated agricultural land and shambas
10	Urban Center	Impervious surface such as roads, airport runways, commercial development, and high density residential
11	Bare Ground / Salt Pan	Non-vegetated land-cover including dirt and/or salt deposits
12	Saline (soda) Lake	Shallow lake covered >80% in a sodium carbonate brine during the dry seasons

Annex 2

Coverage of Field Points sampled during Ground Truthing Fieldwork

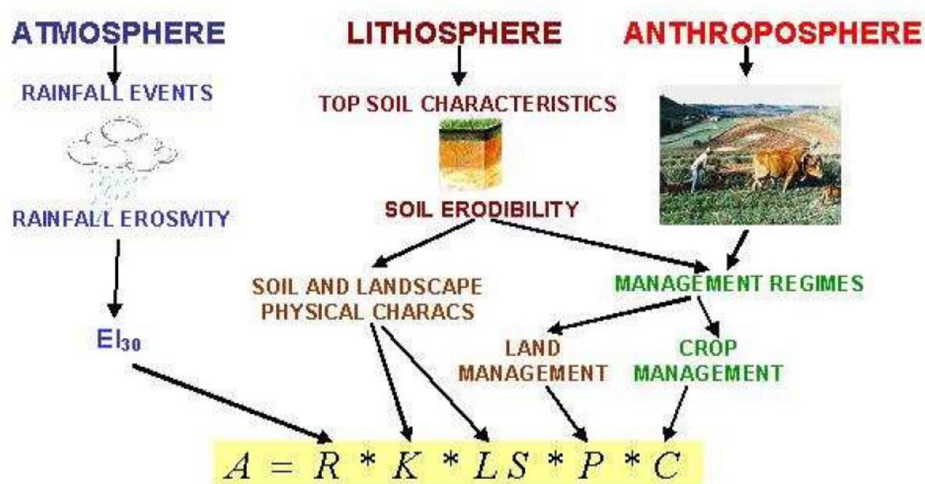


Annex 3

Description of Land Degradation Methodology

Based on the LD definition adopted for the work, the (Revised) Universal Soil Loss Equation (USLE and RUSLE) empirical model for estimating soil loss was used to guide causal indicator selection. The model provided an estimate of the long-term average annual soil loss from segments of arable land under various cropping conditions. The model is presented in Figure 2 and the factors briefly introduced below.

Figure 2: Factors controlling soil erosion by water, as considered by the Universal Soil Loss Equation (in ton/ha/yr).



The equation is presented in the form

A = R x K x L x S x C x P

where:

A is the spatial average soil loss in t/ha·yr

R is the rainfall runoff erosivity factor in MJ.mm/ha·h·yr

K is the soil erodibility factor in t/ha per unit R

L is the slope length factor

S is the steepness factor

C is the cover management factor

P is the support practice factor

Although (R) USLE was originally developed for sub-slope scale soil conservation purposes, the model has gained acceptance in regional-scale applications for the following reasons:

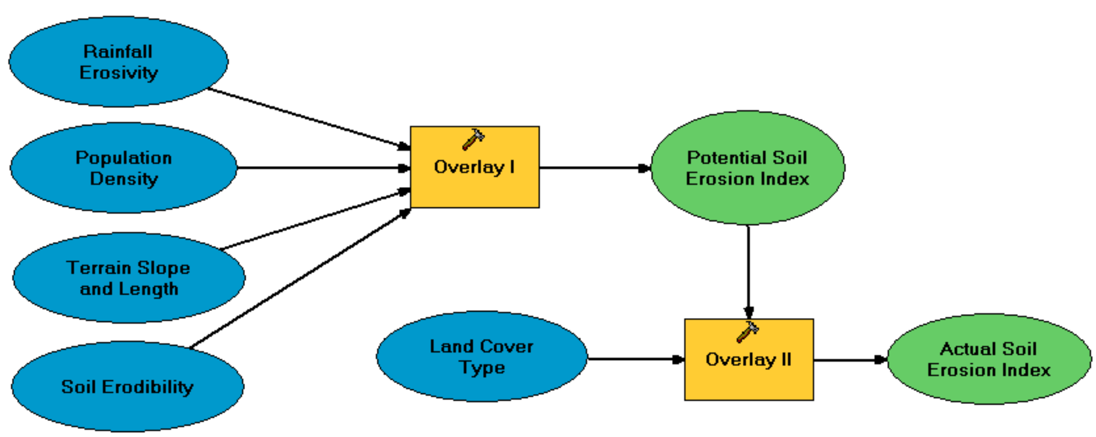
- RUSLE distils soil erosion into a set of measurable primary soil-erosion factors that facilitates the input data accessibility over larger areas
- The factor-based nature of RUSLE allows easy analysis of the role of individual factors in contributing to the estimated erosion rate
- RUSLE has a simple mathematical form facilitating the handling of large datasets using GIS.

This approach had the potential to provide a rational physical basis to combine factors which can be derived from coarse scale GIS, and overcome the difficulties about weighting and inter-correlation which are encountered in purely factor based assessments. Principal Component Analysis (PCA) and correlation analysis was applied on the factors to assess inter-correlation and duplication of information. An important aspect was the need to develop a model, which was used for validation at fine scales, and for region-wide forecasting at a coarse scale, so that cross-scale reconciliation was as explicit as possible.

An overlay mathematical analysis in a geographical information system (GIS) as a factor-based assessment of risk was used. Input factors were combined to estimate different categories of (potential and) actual soil erosion risk. Potential risk excluded vegetation factors, and so identified land at risk, while actual risk includes the vegetation factor to indicate whether the potential was being realised. The approach focuses on medium-term averages (seasonal) or cumulative impact rather than individual events.

The final data processing was performed in the ArcGIS ModelBuilder and a global scheme was presented as in Figure 4. Each of the input layers (e.g. Rainfall Erosivity, Soil Erodibility, Slope Length etc) was the result of pre-processing (sub-model) as explained under the different Products under this Service. These intermediate products were then combined using Map Algebra to obtain the final products.

Figure 4 : Service 1 Processing chain



Data was combined and modelled using the "Analytic Hierarchy Process", a decision-making framework used for multi-criteria decision analysis (Saaty, 2001). Weights were assigned to the criteria according to their relative importance, using a pair-wise preference matrix which was a measure to express the relative preference among the factors.

1.1.1 Input Data Layers

Five input data layers were required to compute the principal products. However, most of these input data were computed from two or more other data layers, which are described in the other sections below:

1. **Vegetation cover type and condition**

   This data indicated the vegetation cover and its condition in the area under consideration at a given time. It was derived from existing land cover data, satellite images (1 km SPOT VGT data and 300 m GlobCover data) and fieldwork. The data spatially covered the IGAD region. It was produced biannually as one of the major input data layers to the model.

2. **Rainfall erosivity**

   Rainfall intensity indicates the amount of rainfall per given time span in mm/time. It shows the variability of the intensity and also indicates the potential erosive capacity of rainfall. The data was computed biannually for the whole IGAD region coarse scale of 25km. The source of the data was mainly meteorological satellite precipitation estimation (TRMM) which was validated using ground stations readings.

3. **Soil erodibility**

   Soil erodibility data is a composite indicator derived from soil mineralogy and texture. The data covered the whole IGAD region and it was computed once for the whole region. It was a relatively static parameter once computed, unless more reliable soil profile data becomes available. The main sources of this data layer were soil sample analyses available at national soil laboratories of the IGAD countries. A regional soil map was also available from FAO – Harmonised World Soil Database (HWSD).

4. **Topography (Slope and slope length)**

   Slope was computed from the corrected SRTM (Shuttle Radar Topographic Mission) at a resolution of 90 m. For modelling purposes the outcome was resampled to correspond with the other input data layers. The data covered the whole IGAD region.

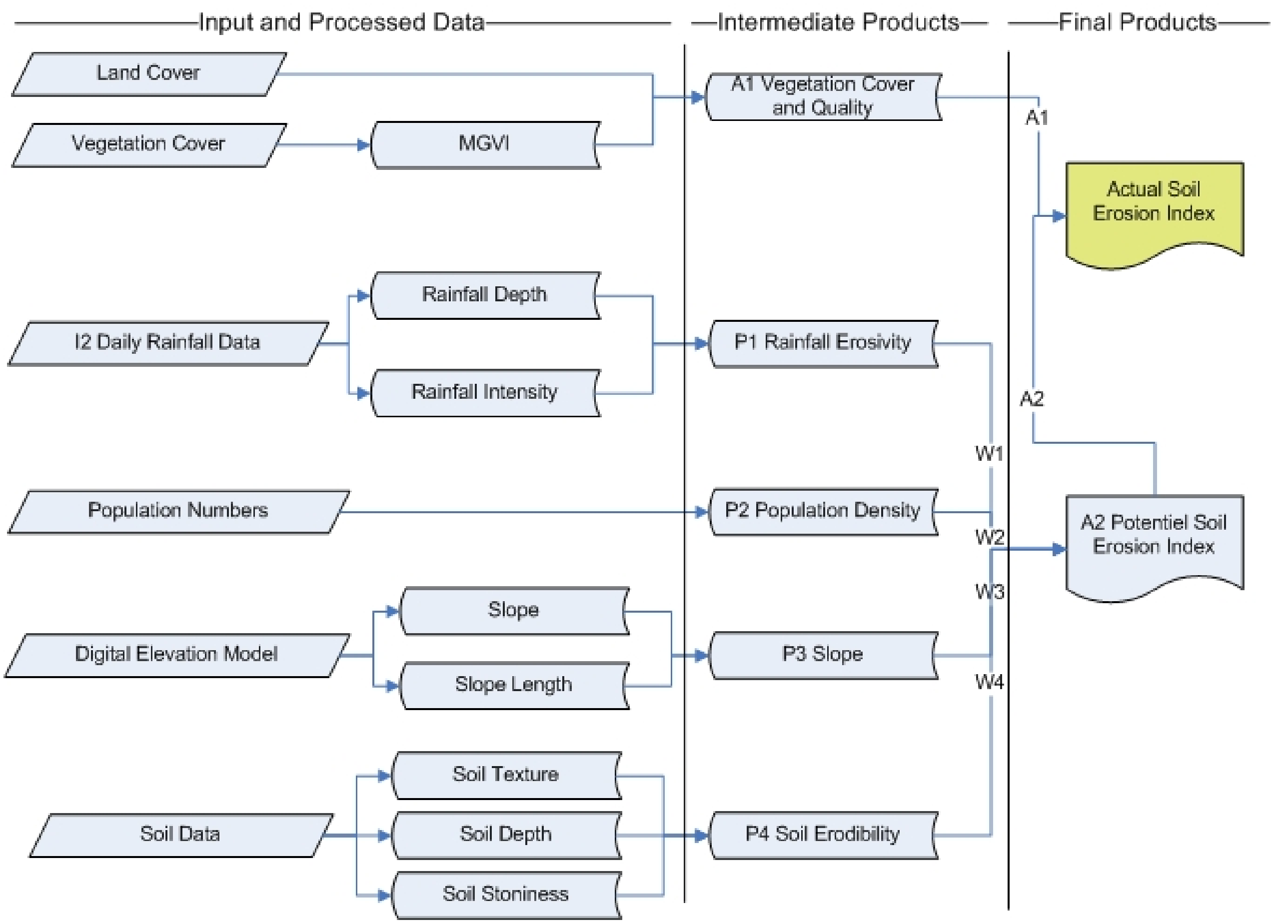
5. **Population density**

   Population pressure was the major socio-economic variable that is continuously increasing at an alarming rate in the region. Population density was obtained from the Landscan data source, which is considered the most up-to-date continuous population dataset. Different rating values was defined for each population density class.

1.1.2 Processing

The generalized processing tree for the Service 1 is presented in Figure . The input data (I1 to I6) is presented at the left and includes the raw data sources and processed data which were used to create the Intermediate products. Finally the Intermediate products are combined to compute the Potential and Actual Soil Erosion Index, using Map Algebra. The actual processing chains are presented under each product, and this section only describes the processing of the Potential and Actual Soil Erosion indices.

Figure 5: Summarised processing chain of soil erosion modelling



The five appropriate criteria for soil erosion analysis are defined from the literature review and were computed as intermediate products (P1-P5). These were then combined using Map Algebra, whereby each pixel for each factor was added using a weighting factor (WP1-WP4 and WA1-WA2). The basic pre-requisite for the assessment was thus the determination of weights and rating values representing the relative importance of factors and their categories. The importance of classes was determined before assigning weights to the layers, and a suitable rating scale for each factor was defined from literature and from the actual data, based on their impact on erosion risks.

APPENDICES

Appendix 1: ***Report on Stakeholders workshop – Arusha, 2014***

Annex 2: ***Report on mapping community perceptions***