LAND USE/LAND COVER MAPPING IN KISUMU COUNTY, KENYA

WITH TECHNICAL SUPPORT OF:

GIS LIMITED

LAND USE/LAND COVER MAPPING IN KISUMU COUNTY, KENYA

Report on Methodology and Tools

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1 INTRODUCTION

Spatial information on land use/land cover is a necessary prerequisite in planning, utilizing and management of natural resources. In the current day's context of development planning, information on land use/land cover and the changes over a period of time attain prominence because of its primary requirement for many different kinds of spatial planning and assessment, from urban planning at a local level up to regional development. Moreover, land-cover datasets are used as basic information for the assessment of renewable energy potential and to provide an overview of areas which can be considered for renewable energy project development in the future.

2 PROJECT OBJECTIVES

The main objective of the assignment is to develop shapefiles of various land cover and land use types across Kisumu County using image classification and digitization. The other objective is to digitize all the buildings footprints within Kisumu County using very high resolution satellite imagery. The data generated will serve as input for the elaboration of models of the county's energy system. A predefined Land Cover Classification scheme was used and it details information on the various land uses and land covers across Kisumu County. The specific deliverables are a shapefile of Land Use/Cover types, building footprint data and a report detailing methodology used.

3 METHODOLOGY

For the preparation of land cover maps from high resolution satellite imagery specially devised operative methodology was tested and finalized.

The land cover mapping was carried out using the proposed Land Cover Classification System (LCCS). The methodology took into account the description, characterization, classification and comparison of most land cover features identified worldwide, especially created for land cover mapping. The below flowchart describes the main phases applied in the project, for the creation of the land cover maps.

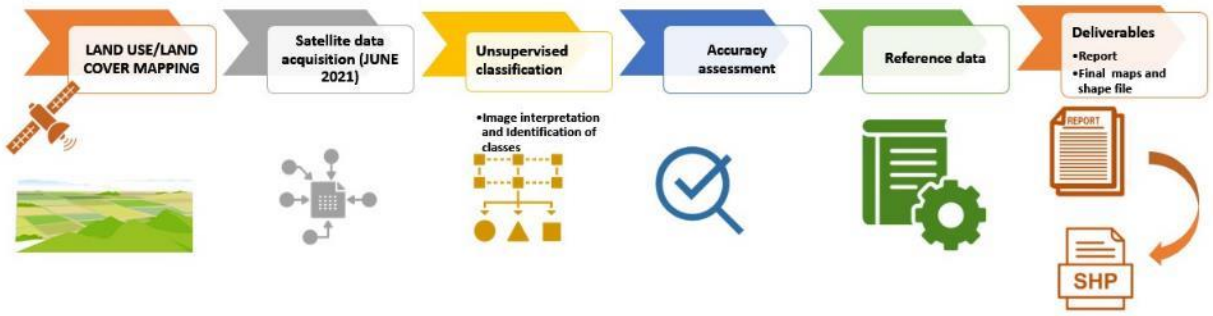


Figure 3.1 Mapping Phases

3.1 DATA ACQUISITION.

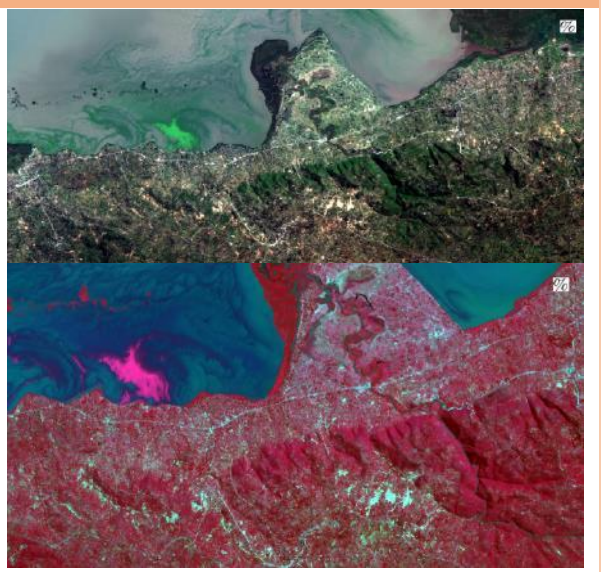
3.1.1 Existing Secondary Data

The initial step in any land cover mapping exercise is building a geospatial standardized catalogue of available secondary spatial information on land, climate, soil, topography, hydrography, infrastructure and administrative boundary. This information comes in handy when identifying various classes of the land cover during the digital image processing stage.

3.1.2 Satellite Data Selection and Purchase

Satellite Imagery selection and acquisition was then done. Planet Labs imagery data was purchased and downloaded. Planetscope Imagery was used for Land cover Mapping. Satellite data scenes were selected on the basis of the area of interest, low cloud cover percentage (≤1 %) and date of acquisition (10th June 2021). Bands 1, 2, 3, 4 of the data was acquired as shown in below table. This data has a resolution of 3m * 3 m.

Table 3.1 Satellite Image Properties

		Quick look (RGB and band combination 3,2,1 and FCC band combination 432)
Location	Kisumu County	
Sensor	HIGH RESOLUTION IMAGERY.	
Spatial Resolution.	3m x 3m 0.5m by 0.5m	
Temporal	10th JUNE 2021	
Spectral/ Radiometric Resolution.	Band 1 = Blue (0.45 - 0.52 µm) Band 2 = Green (0.52 - 0.60 µm) Band 3 = Red (0.63 - 0.69 µm) Band 4 = NIR (0.76 - 0.90 µm)	

3.2 PREPROCESSING AND MOSAICKING OF SATELLITE IMAGERY

3.2.1 Preprocessing

The data collected by sensors on satellite platforms, before being used for the analysis and interpretation need to be processed to correct errors due to the noise and distortions generated during the acquisition and transmission. Radiometric and geometric processing is the procedure to correct the errors in acquisition. Image enhancement techniques together with forming colour composites was done to enhance feature discernment in the area of interest. The satellite imagery acquired was a level 3B processed product. This means that it has already been corrected for geometric and radiometric errors. Orthorectified, scaled Top of Atmosphere Radiance (at sensor) or Surface Reflectance image product is suitable for analytic and visual applications. This product has scene-based framing and was projected to a cartographic projection.

3.2.2 Mosaicking

The images acquired in the Geo-TiFF format were be exported as multiple files according to the overall bounding box of selection (Kisumu County Boundary). Edge-matching procedure was then done. This creates an overlapping area between each tile ready for mosaicking of the individual tiles together. A mosaic merges multiple existing raster datasets into one raster dataset (below figure). A mosaic is useful when two or more adjacent raster datasets need to be merged into one entity. Envi software seamless Mosaic workflow was used. This workflow lets you apply color balancing and edge feathering to create a high-quality mosaic.

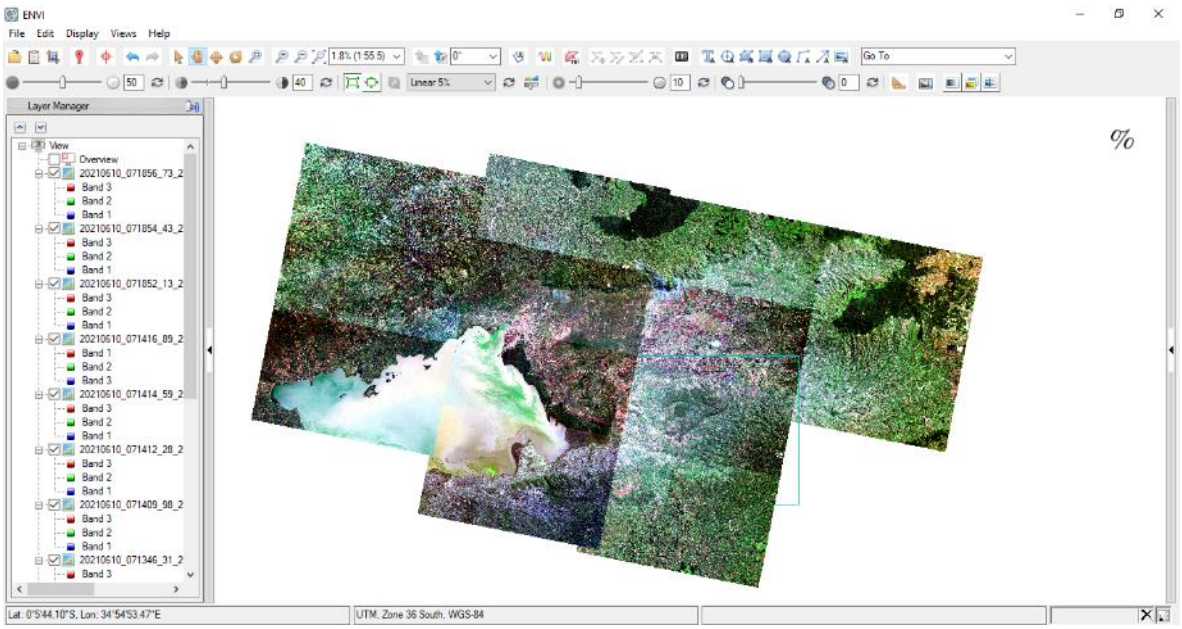


Image 3.1 Image mosaicking procedure to create a one covering the entire Kisumu County.

3.3 SELECTION AND DEFINITION OF LAND COVER CLASSES

A clear and a precise definition of cover classes is important in any type of land use mapping exercise. Classes can overlap and sometimes can be difficult to differentiate and classify. As Specified in the terms of referenced below classification scheme was be used for the land cover mapping exercise.

The proposed classification scheme consisted of 8 land use/land cover classes. However, in this study, the 32 classes were aggregated into the proposed 8 classes which can be distinguished with high confidence in high resolution satellite imagery. This was done, in with reference to ground truth data collected.

Table 3.2 Land Cover Classes

LAND COVER.	DESCRIPTION.
Forest cover	
	Area covered chiefly with scattered trees and undergrowth, in natural and modified landscapes
Shrubs	
	Woody perennial plants with persistent and woody stems and without any defined main stem being less than 5 m tall. The shrub foliage can be either evergreen or deciduous.

Herbaceous vegetation	
	Plants without persistent stems or shoots above ground and lacking definite firm structure (tree and shrub cover would be expected to be less than 10%).
Herbaceous wetland	
	Lands with a permanent mixture of water and herbaceous or woody vegetation. The vegetation can be present in either salt, brackish, or fresh water.
Cultivated and managed vegetation/agriculture (cropland)	
	Lands covered with temporary crops followed by harvest and a bare soil period (e.g. Single and multiple cropping systems). Perennial woody crops was classified as the appropriate forest or shrub land cover type.

Permanent water bodies, lakes, reservoirs, rivers	
	Can be either fresh or salt-water bodies.

3.4 IMAGE CLASSIFICATION

Standard Image classification workflow in ENVI was then be run on the imagery. Image classification is the extraction of meaningful information from images; mainly from digital images by means of digital image processing techniques. The process of sorting pixels into a number of data categories based on their data file values and reducing images to information classes. In this process spatial pattern recognition, the decision rules are based on the geometric shape, size, texture, and patterns of pixels or objects derived from them over a prescribed neighborhood. In order to take advantage of and make good use of remote sensing data to develop land cover, extracting meaningful information from the imagery is very important. During the image classification the following interpretation factors were considered: Tone, Shape, Size: Pattern: Texture: Shadow of the features of the imagery to assist in identification of the land covers

Unsupervised classification workflow procedures in ENVI software were run using ISODATA algorithm and using 31 classes as a reference. *Unsupervised Classification* is a technique for classifying land cover features in a digital image. In the unsupervised approach, the dominant spectral response patterns that occur within a satellite image are extracted and the desired information classes are identified through collection of ground truth data – by using reference ground truth data and visits to the site in the image.

3.5 BUILDING FOOTPRINT DIGITIZATION.

A standard on screen digitizing of features from the imagery was carried out on QGIS software. The following were the guidelines for digitizing:

a) An ergonomic work environment was maintained to ensure maximum efficiency.

b) Expected output standards, procedures and responsibilities were clearly defined. This included examples features to be digitized (All Building Footprints); comfortable viewing scales; and feature styles specifications including colours and line work.

c) The satellite image was divided into smaller blocks so as to reduce duplication, and define production outcomes.

d) Feature Layers were clearly defined at the start: layers created; coordinate system configured; metadata populated; and appropriate feature colour and line type defined.

e) An appropriate zoom scale of the satellite image was set. This was to ensure that relative accuracy of buildings is maintained to same standard, since the zoom scale affects the interpretability of feature edges. The zoom level was set higher than the anticipated production scale of the building footprint.

f) The smallest features to be digitized should represent a minimum of 3 pixels.

g) Building roofs were digitized as closed polygons, and if the displacement of the building is large, the polygon was moved to the base of the feature.

h) Where the displacement was large due to tall features, an adjustment that included, a translation, rotation and scaling was required.

i) The high-resolution 50cm imagery allowed for accurate digitization of buildings partially covered by trees.

j) Post digitizing squaring of the buildings was done. This ensured that for a given building, each building corner was orthogonally connected.

k) Adequate breaks were implemented for the GIS Expert Assistants during digitizing to avoid fatigue that could reduce digitizing accuracy.

l) The digitized output was reviewed at the end of each section, within the block and in relation to the bigger scene to ensure conformance.

m) Once the block was approved, the data was integrated with other blocks and all metadata updated.

n) All work was saved in duplicate, ready for final output production and sharing.

3.6 SATELLITE IMAGE INTERPRETATION AND IDENTIFICATION OF GENERATED LAND COVER CLASSES

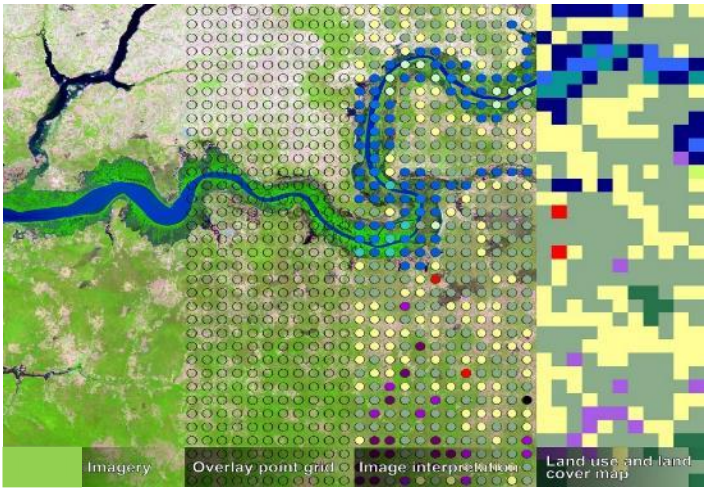
3.7 Image Interpretation and Identification

Identification of the generated classes from unsupervised classification was done here using combination of visual interpretation, existing ground truth data and field surveys. The combination of firsthand knowledge of the landscapes and reliance on multiple dimensions of information inherent in the high-resolution imagery is a powerful approach to producing accurate land cover maps. Mapping land cover from satellite images requires special skills and detailed local knowledge about the area of interest — including its physical, biological and human components. Planet labs satellite images contain a detailed record of features on the Earth's surface.

Drawing upon training, field experience, geographic knowledge, an acute power of observation and patience, image analysts were able to identify the land use and land cover classes. They relied on the basic elements of image interpretation: shape, size, pattern, color, tone, texture, shadows, geographic context, and association. The time of year when each image was acquired was also an important factor in identifying the land cover classes. The land cover class identification process was facilitated through the use of interpretation guidelines, which included written and illustrated definitions of all of the land use and land cover classes.

3.8 Field Survey/Validation

Stratified random sampling was done to generate a number of points per class that was visited to verify the land cover class. This was done during field survey using hand held GPS devices to navigate to the various points.



Steps in identifying land use and land cover classes;

- *Selecting imagery;*
- *Overlaying a stratified grid of points;*
- *Interpreting and attributing, and*
- *Making land use/land cover map.*

Image 3.2 Field Verification/Ground Truthing at Muhoroni and Kisian, Kisumu County

4 ACCURACY ASSESSMENT

After unsupervised classification and image interpretation the generated land cover classes was assessed to find if each group was classified correctly. This involves identifying the percentage of pixels in the original training areas that were correctly classified versus the pixels misclassified. The contingency type of accuracy assessment was applied. The result is a contingency table of error matrix showing accuracy level in percentages. Accuracy assessments determine the quality of the information derived from remotely sensed data. The outcome of accuracy assessment was presented in a table that reveals accuracy for each cover category and for all categories as a whole.

In order to ensure credibility of the generated land cover datasets, accuracy assessment should be considered as a mandatory step in a geospatial map production. A field data collection campaign was organized in to gather the ground truth samples for assessing the accuracy of the land cover dataset.

Samples were identified a priori based on a stratified sampling scheme, but the remoteness and inaccessibility of many areas and the extent of the Areas Of Interest, made this approach impractical. To complement this approach other verified secondary data and higher resolution google earth imagery were used to identify various classes for the reference points. In total, 1280 samples were used for the accuracy assessment. For each sample, we entered two attributes: the land cover class code with the actual data collected in the field (the reference ground truth information) and an attribute generated by the overlay with the generated land cover dataset.

The table was analyzed and was used to generate the confusion matrix statistics. As the land cover dataset presents two levels of classifications, two individual confusion matrixes was calculated.

5 POST PROCESSING

This involved converting the raster land cover map to a vector layer (shapefile). Attributes for the shapefile were edited using the provided coded template as reference and similar classes were merged ready for export.

Table 5.1 Land Cover Codes

LAND COVER CLASS	LAND COVER CODE(GRID CODE)
Forest Cover	1
Shrubs	2
Herbaceous Vegetation	3
Herbaceous Wetland	4
Bare/Spare Vegetation	5
Cropland	6
Permanent Water Body	7
Urban/Built Up	8

6 RESULTS

6.1 Land Use and Land Cover Types

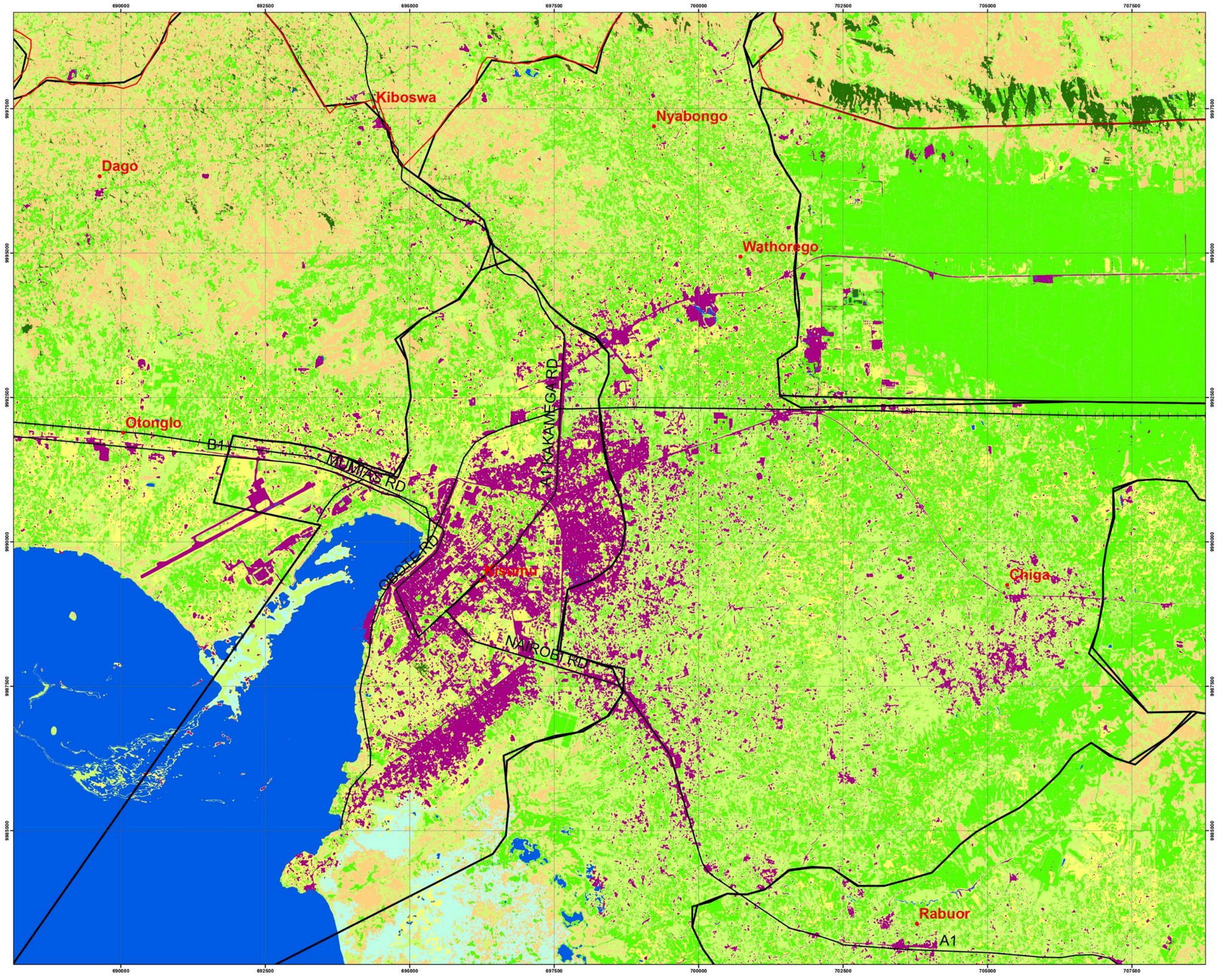
The aim of this project was to undertake land use/land cover mapping and produce an updated land cover/land use map for Kisumu County. A classification system, proposed by ICLEI comprising 8 classes was used for this purpose.

The land use/land cover analysis were undertaken in ENVI software, and QGIS an open source, GIS-based platform. Below table and maps shows percentage coverage for each land cover class.

Table 6.1 Percentage Coverage of Land Cover Classes

LAND COVER CLASS	LAND COVER CODE	Area in sq. km AREA IN SQ. KM
Forest Cover	1	20.687
Shrubs	2	428.887
Herbaceous Vegetation	3	548.147
Herbaceous Wetland	4	38.279
Bare/Spare Vegetation	5	237.666
Cropland	6	763.135
Permanent Water Body	7	588.994
Urban/Built Up	8	49.445 20.650 (Buildings)
	TOTAL	2675.2

LAND USE AND LAND COVER OF KISUMU COUNTY - KISUMU CENTRAL SUB COUNTY



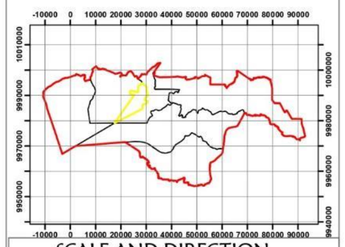
LAND USE AND LAND COVER MAPPING OF KISUMU COUNTY

LEGEND

Sub-County
Road
Railway
Town

LAND USE AND LAND COVER

- Forest Cover
- Shrubs
- Herbaceous Vegetation
- Herberceous Wetland
- Bare/Sparse Vegetation
- Cultivated/Agricuture (cropland
- Permanent Water Body
- Urban/Built Up



SCALE AND DIRECTION

1:1,100,624

Kilometers
0 25 50 100

DATA SOURCES

Survey of Kenya
Kenya Roads Board
Satellite Imagery

DATUM

Geographic Coordinate System:GCS
Datum: WGS_1984
Prime Meridian: Greenwich
Angular Unit: Degree

CLIENT

ICLEI Local Governments for Sustainability

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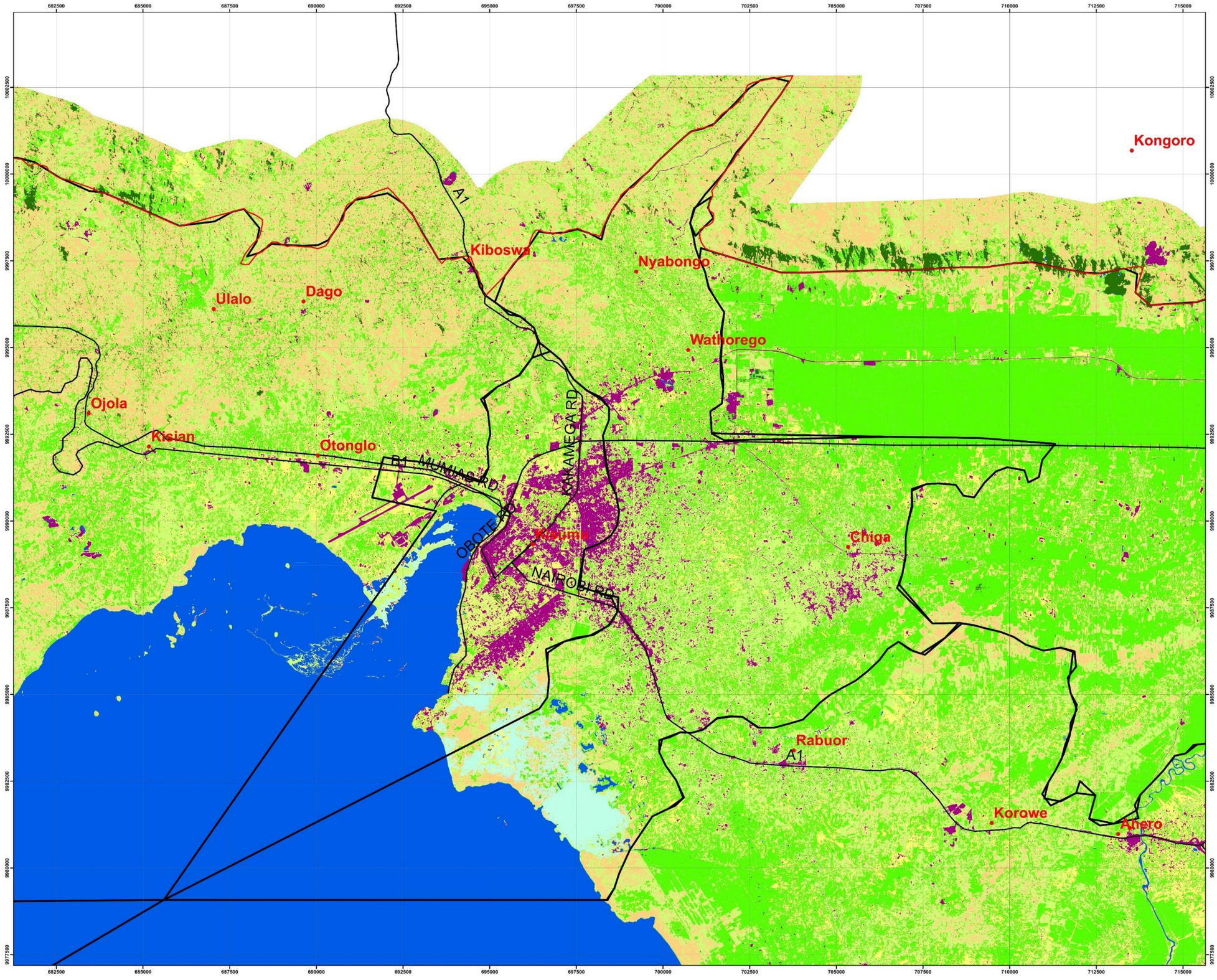
LAND USE AND LAND COVER OF KISUMU COUNTY - KISUMU EAST SUB COUNTY



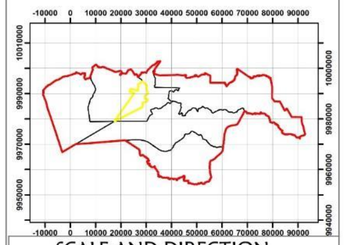
LAND USE AND LAND COVER MAPPING OF KISUMU COUNTY

LEGEND

- Sub-County
- Road
- Railway
- Town

LAND USE AND LAND COVER

- Forest Cover
- Shrubs
- Herbaceous Vegetation
- Herberceous Wetland
- Bare/Sparse Vegetation
- Cultivated/Agricuture (cropland
- Permanent Water Body
- Urban/Built Up



SCALE AND DIRECTION

1:1,100,624

Kilometers 0 25 50 100

DATA SOURCES

Survey of Kenya
Kenya Roads Board
Satellite Imagery

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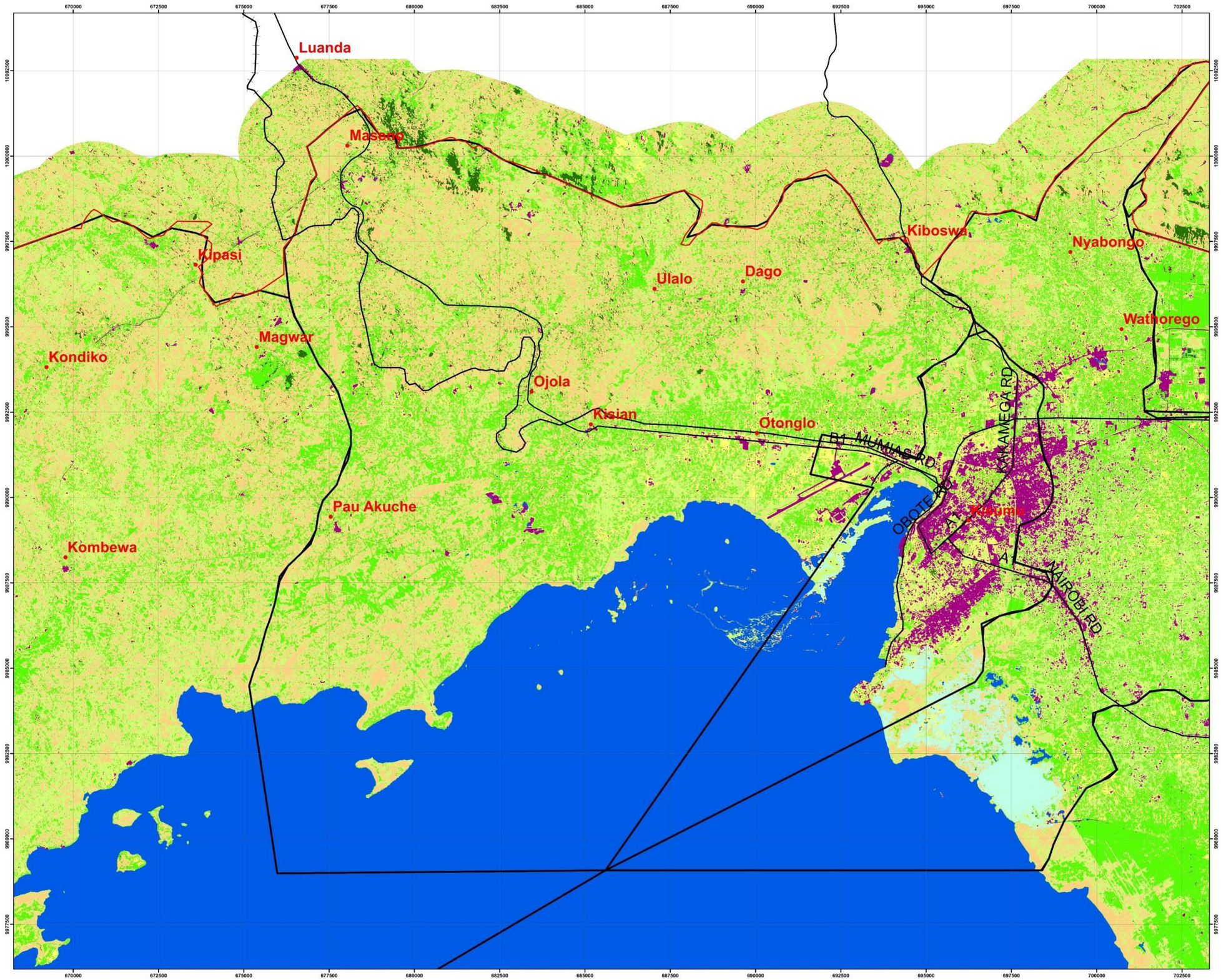
LAND USE AND LAND COVER OF KISUMU COUNTY - KISUMU WEST SUB COUNTY

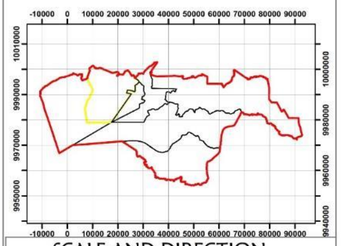


LAND USE AND LAND COVER MAPPING OF KISUMU COUNTY

LEGEND

Sub-County
Road
Railway
Town

LAND USE AND LAND COVER
- Forest Cover
- Shrubs
- Herbaceous Vegetation
- Herberceous Wetland
- Bare/Sparse Vegetation
- Cultivated/Agricuture (cropland
- Permanent Water Body
- Urban/Built Up



SCALE AND DIRECTION

1:1,100,624

0 25 50 Kilometers 100

DATA SOURCES

Survey of Kenya
Kenya Roads Board
Satellite Imagery

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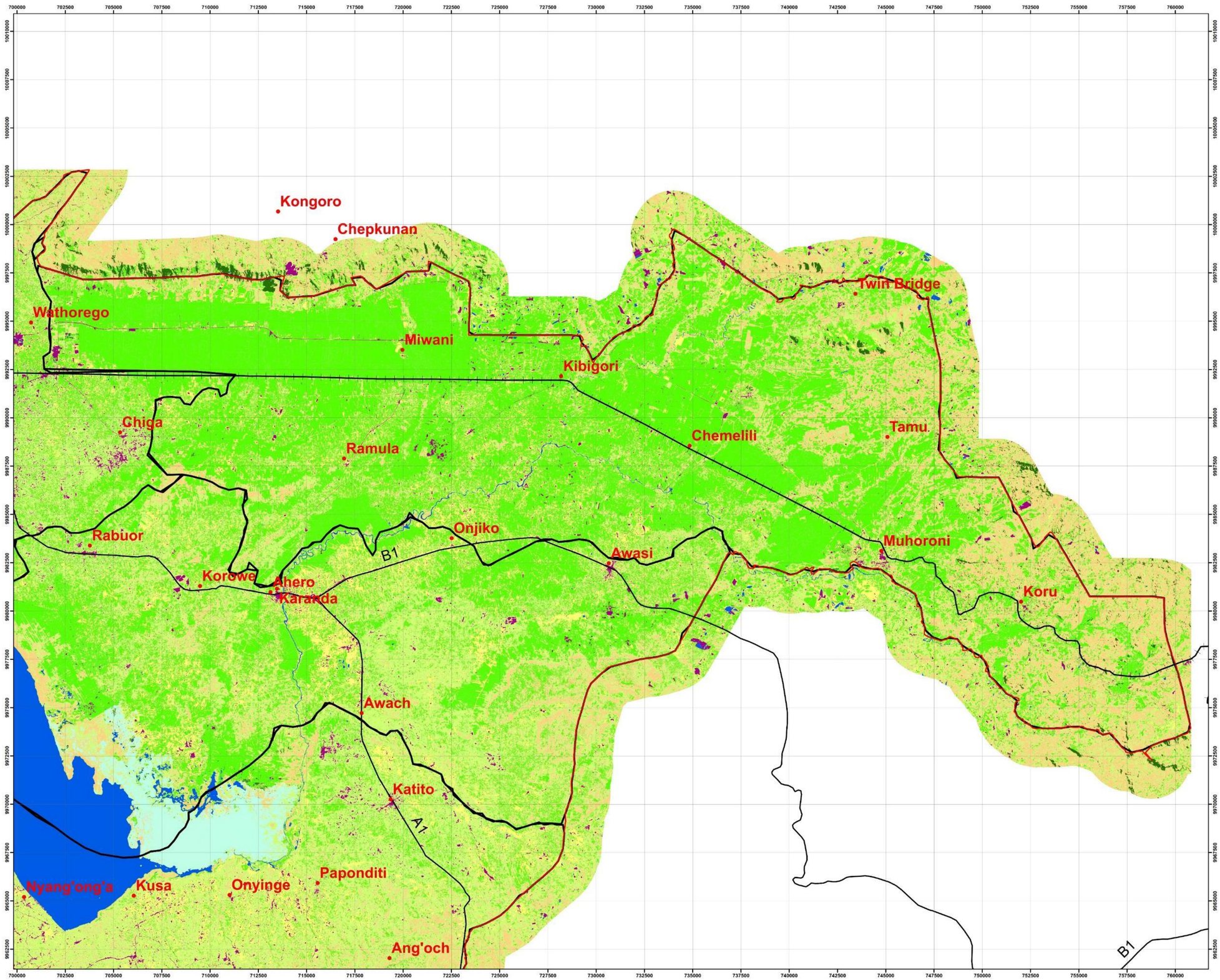
LAND USE AND LAND COVER OF KISUMU COUNTY - MUHORONI SUB COUNTY



LAND USE AND LAND COVER MAPPING OF KISUMU COUNTY

LEGEND

Sub-County
Road
Railway
Town

LAND USE AND LAND COVER

- Forest Cover
- Shrubs
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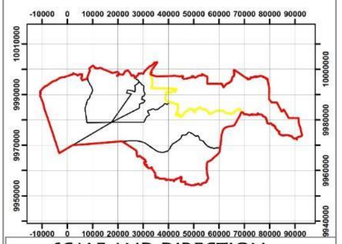

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1:1,100,624

Kilometers 0 25 50 100

DATA SOURCES

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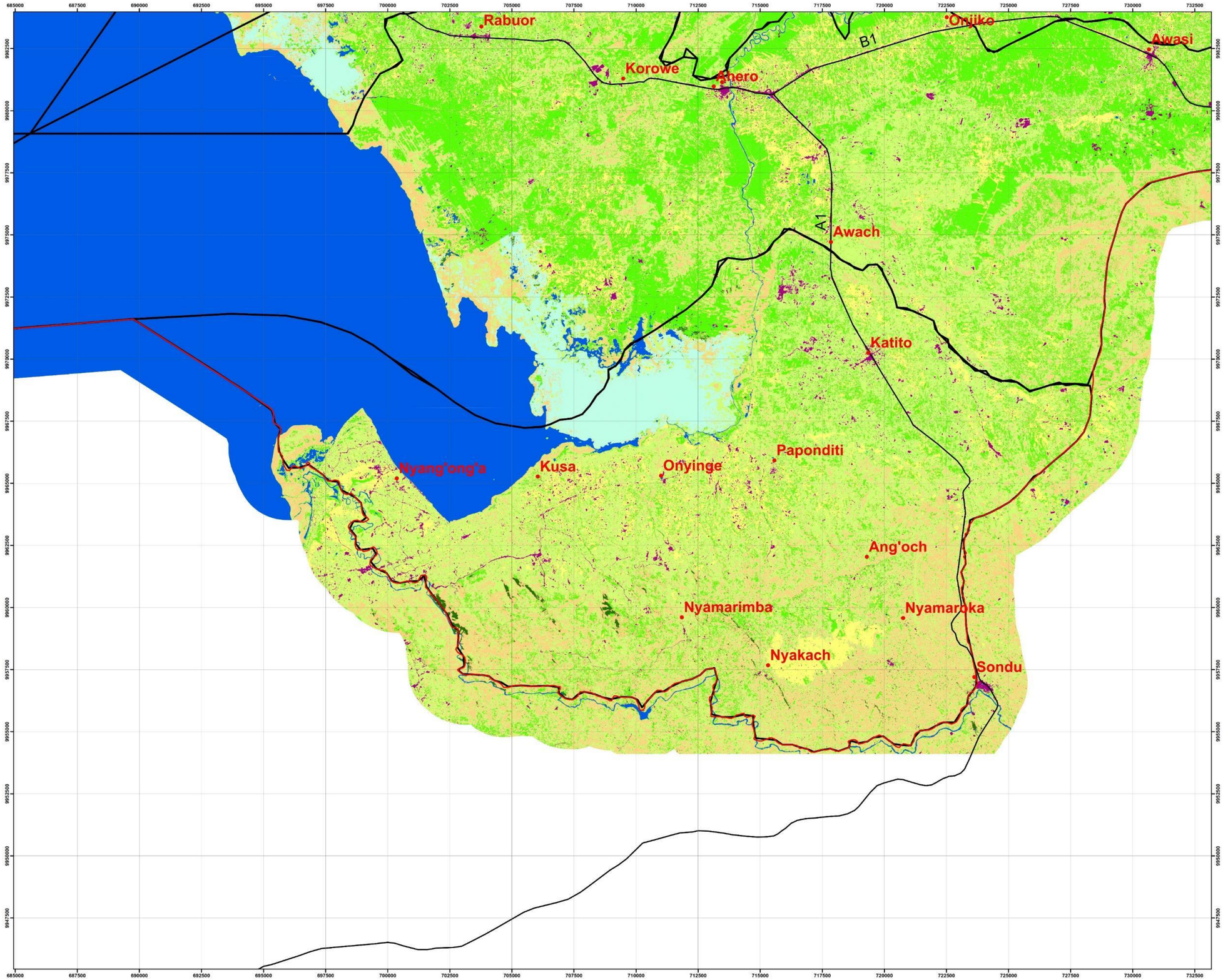
LAND USE AND LAND COVER OF KISUMU COUNTY - NYAKACH SUB COUNTY



LAND USE AND LAND COVER MAPPING OF KISUMU COUNTY

LEGEND

Sub-County
Road
Railway
Town

LAND USE AND LAND COVER
- Forest Cover
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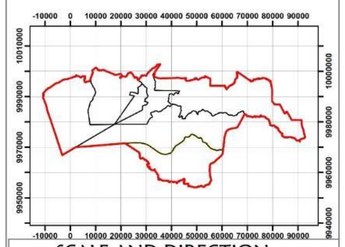

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Kilometers
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JULY, 2021

6.2 Building Area Coverage.

The area covered by building area coverage in Kisumu was estimated from the interpretation of the unsupervised classification results. The Built-up area from the classification resulted consisted of 2 subclasses. Based on further analysis of the two subclasses, class 2 was identified to have clearly covered buildings only, and Class 1 had an overlap of buildings and other elements forming the built-up area, like asphalt road networks. Editing was done to remove the linear features representing the road network. The analysis derived that the building area coverage in Kisumu County is approximately 20.65 square kilometers.

From the heads up digitization of the high resolution 50cm imagery. Building footprint for the entire county was obtained. Analysis of the digitized buildings gave an area of 30.71 square kilometers.

The difference in the results is because of the spatial resolution of the datasets used. i.e. 50cm resolution imagery vs the 3meter resolution imagery. The level of detail captured in the higher resolution imagery is higher and precise. It is recommended to use the results from the higher resolution data be used.

6.3 Sugarcane and Rice Area Coverage.

The area covered cropland was further analyzed to deduce the area under Sugarcane and Rice. This analysis was done on the subclasses within the cropland land cover class to extract approximate area coverage of rice and sugarcane farmlands within Kisumu County. The analysis was guided by historical data gathered through literature review that indicated the sugar belt zone and the Rice irrigation zones within Kisumu County. The identified sugarbelt zone is within Muhoroni. Koru, Chemilil, Miwani and Kibos area, while the Rice irrigation zones are within Ahero, and West Kano. Observations made during the ground truthing and verification exercise confirms the identified zones. Based on the analysis of cropland subclasses, the sugarcane plantations and rice irrigations cover approximately 264.14 square kilometres and 72.34 square kilometres respectively.

6.4 Metadata

Data describing the contents of the database for generated data was prepared in MS Excel format, to preserve information for future users of the database. The following parameters were included:

Data format: Shapefile

Coordinate system Used: GCS WGS84

Image used for land cover map: 3m Planet Imagery

7 ANNEX: COMMENTS BY VARIOUS STAKEHOLDERS AND THE RESPONSES.

- ***Which projected coordinate system can be used for the study area?***
- *WGS84 UTM ZONE 36S.*

- ***In the buildings layer, in the "type" field, there are some records with type "buildings", but the others do not have any type at all.***
- *All the features in the buildings layer are buildings.*

- ***Is there any kind of generalization that has been done for these layers, especially the land-covers, or these layers are the raw output data from the classification process?***
- *Generalization done was based on the proposed Land cover classification system in the terms of reference*

- ***Are there any other details about the croplands (type of crops at least)?***
- *This wasn't part of the scope of work to map the different types of croplands; however we managed to approximate the area under sugarcane and rice. The major crops in the area are Sugarcane, Rice, Maize,* Beans, sweet potatoes, sorghum, and cassava.

- ***Adding to Annette's point about the buildings, I have double-checked the buildings with an aerial ESRI basemap. I am not sure about these buildings' locations.***
- *The buildings were digitized from 50 cm resolution satellite imagery.*
  Local arc1960 DATUM was used, that is why there was a slight shift as noted by Annette. However projection has been done and the data will be made available.
- ***The land cover Shapefile does not have a class name column; that should be added.***
- *The class name has been coded no 1 to 8 using the grid code column in the attribute table as explained in the report.*

- **The new method for obtaining building footprints is not described in the report yet, but I assume it will be in the next version.**
- The new method -heads up digitization will be explained in the updated version of the report.
- **About the building layer:**
  why are there two layers, Kisumu buildings and Shauri Moyo buildings?
- As per discussions in the previous meeting I was to send sample data of the building footprints. ShauriMoyo is the sample that was ready by the end of the same day. **What is the unit of the area in the building layer?**
- The data provided will be in GCS WGS84 coordinate systems.
- **The total building area is now around 30 km² (if the unit is m²), with the old method it was around 20 m², it would be good if the report would explain how that difference can occur between the two methods**
- The difference in the results is because of the spatial resolution of the datasets used. i.e. 50cm resolution imagery vs the 3 meter resolution imagery. The level of detail captured in the higher resolution imagery is higher and precise. It is recommended to use the results from the higher resolution data.
- **It seems that the layers Kisumu buildings (pink) and the original one showing everything (orange) are shifted to each other. See my first screenshot: in the upper left part the large pink buildings are more left than the orange area which most probably is depicting the same buildings (I filtered for urban/built up area here).**
- We used Local Datum arc1960 to do the mapping for the building. EPSG CODE 4210.That is why there is slight displacement. In the two layers. If you go to properties options and set the CRS EPSG 4210 will fix the issue. However reprojected data will be provided with correct coordinate system.

- **In addition it seems that there are buildings everywhere, also in the rural areas (see my second screenshot). Are these really buildings or something else and if they are buildings is it possible to install PV on them?**
- I can confirm to you the distribution of buildings is spread over the entire county representing the nature of human settlement. They are all buildings it is possible to install PV on them.

- **I'm suggesting once more that the consultant ensure that the final report capture approximated areas covered by two major crops in Kisumu County (Sugarcane & Rice) in Sq. Km because unlike other crops, they are grown in large scale and have high potential for energy production. Bagasse from sugarcane is already being used by sugar factories for power generation and other companies using for industrial briquettes production.**
- *This wasn't part of the scope of work to map the different types of croplands; however we managed to approximate the area under sugarcane and rice.*

- **We are unable to query the different categories of Land use. [When data (shapefiles) is loaded in GIS software it appears general with only one symbology being depicted from it],**
- **From the attribute table we can't get the exact description of different Land cover and Land uses.**
- **The submitted data also lacks metadata of the same [more information about the different classes of land cover] - this cannot be seen when the same data is loaded in GIS software and queried.**

- *The land cover classes have been coded no 1 to 8 using the grid code column in the attribute table as explained in the report.*

- ***The data set submitted concerning the buildings could be of importance only if Toponymes [Names of Specific Buildings] were also deployed for specific buildings which can assist in orienting the Kisumu County.***
- *This wasn't in the scope of our work.*