# Assessing the Impact of Road Establishment on Settlement Using Remote Sensing and GIS. Northern bypass (Bweyogerere to Bwaise stretch)

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**ABSTRACT**

While determining future growing-areas of cities, monitoring city-growth in other words determining settlement changes has an important role in urban development. Introduction of essential infrastructure like roads is an important factor causing urban landuse changes. One of the important problems for developing countries is the absence of full environmental assessment and documentation of existing conditions, identification of impacts resulting from public improvements, and it stays behind urbanization movements. The Kampala Northern Bypass Highway was constructed between 2004 and 2009 and it was opened to traffic on 1st October 2009. This highway measures 21 kilometers (13 mi). The road was constructed to relieve traffic congestion within the city center, allowing cross-country traffic to bypass the city's downtown area. It stretches from Bweyogerere, approximately 13 kilometers to the east of downtown Kampala, winding through the suburbs of Naalya, Kiwaatule, Kulambiro, Kigoowa, Bukoto, Mulago, Makerere, Bwaise, Kawaala, Namungoona, and Busega. The road ends in Nateete, approximately 8 kilometers, west of the city. This project assesses the impact of road establishment on settlement by carrying out a comparative analysis for some areas around the Kampala northern bypass before and after establishment of the road. Using Standard Landsat satellite imagery produced in 2001 and 2010, land-use changes in the last 9 years for areas along the northern bypass were derived. The data was processed and analyzed using remote sensing and GIS techniques. Results show that major changes that have occurred in settlements in the last 8-10 years period have been largely contributed by the establishment of this road. Over all the results point to a decline in swamps, vegetated area, crop land and an increase in infrastructural development (built up area) like commercial buildings, residential building, roads

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background

In the face of a rapidly growing global population, increase in technological capacity, and affluence, the earth's land cover has been transformed, especially in developing countries (Meyer 1995). At the same time, social organization, attitudes and values have also undergone profound changes. In contemporary times, issues of sustainable development, pollution prevention, global environmental change and related issues of human-environment interaction have been a major concern globally.

When approaching the design of settlement as a pre-requisite aspect of safety, health, economy, convenience and amenity, one has to think the level at which such a design is to be prepared. Depending on the nature of human settlement under consideration, a number of other elements which support the well being or good functioning of the human settlement have to be considered in the planning and design process (Vancouver Declaration on Human Settlements (1976). Settlement conventionally includes its constructed facilities such as roads, enclosures, field systems, boundary banks and ditches, ponds, parks and woods, wind and water mills, manor houses, commercial facilities ,moats and churches.

There is a growing awareness that road development has major environmental impacts on settlement. Some of the major environmental impacts of road projects include damage to sensitive ecosystems, loss of productive agricultural lands, resettlement of large numbers of people, permanent disruption of local economic activities, demographic change, accelerated urbanization, and introduction of disease.(Lee, N. and Walsh, F. 1992). Since environmental impacts from road development are quite common, such projects usually call for comprehensive environmental assessment studies.

High, explosive and uncontrolled dynamic of the urban development has led to the increase of the built surfaces and to the appearance of bulk settlements. Negative action on the environment results from the lack of information on establishing a correct systematization and selection of areas for cities expansion.

Using records of remote sensing with high spatial resolution has the advantage of using updated information on areas and allows the estimation of systematic socio-economic parameters. Thus, remote sensing records (satellite images) have been used to provide tracking the extension of land cover and constructed surfaces. In this study, remote sensing and GIS have been used to study changes in characteristics of settlements as a result of establishment of the Kampala northern bypass using satellite imagery for the years 2001 and 2010. 2001 is chosen since the road had not yet been established at that time and 2010 for which the road was already established.

## 1.2 Problem statement.

Most development planners and responsible authorities have no full environmental assessment and documentation of existing conditions, identification of impacts, and a comparative examination of impacts arising from the road projects. This has made it difficult for them to know these impacts and thus making the community vulnerable to them. There is need for adequate information to study the trend of change before and after construction of roads so as to help plan, monitor, control, supervise and appraise the execution of work. Therefore this project assesses the impact of road establishment on settlement so as to help planners and authorities get a broad view of the current situation and also get a basis for assessing similar situations.

## 1.3 Aim of this project

The aim of this project is to analyze changes that have occurred in settlement as a result of establishment of the northern bypass road.

## 1.4 The specific objectives

- To prepare landcover base maps.
- To analyze the changes in settlement.

## 1.5 Significance of the study

- This study shall facilitate definition of both positive and negative significant environmental impacts on settlement.
- It can be used in suggestion of mitigation measures to enhance positive impacts and reduce negative impacts.
- Provide a basis and a reference for better decision making incase environmental assessment is to be done by the government or any other relevant authority.

## 1.6 The scope of study.

There are so many factors that influence settlement some of which include; climate, housing policies, floods, government policies, sanitation, and construction of houses. This study looks at road establishment influence on settlement with a case study of the northern bypass (Bweyogerere to Bwaise stretch) and surrounding areas . It involved extracting remote sensed satellite imagery data before and after establishment of the road, and integrating it into a GIS; ILWIS (Integrated Land and Water Information System) for processing and analysis.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.0 INTRODUCTION

This chapter contains related literature that I used for the study. It includes related research done by some authors, analysts and also relevant literature from the internet. Also basic literature was derived from magazines, journals and document archives.

## 2.1 REMOTE SENSING

The science of remote sensing comprises the analysis and interpretation of measurements of electromagnetic radiation that is reflected from or emitted by a target and observed or recorded from a vantage point by another observer or instrument that is not in contact with the target. Earth observation by remote sensing is the understanding of measurements made by airborne or satellite borne instruments of electromagnetic radiation that is reflected from or emitted by objects on the earth surface. (B.K. Ridley). The technology of remote sensing offers a practical and economical means to study vegetation cover changes and environmental changes especially over large areas (Langley *et al.* 2001; Nordberg and Evertson 2003).

An increasingly common application of remotely sensed data is for change detection. Change detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Change detection is an important process in monitoring and managing natural resources because it provides quantitative analysis of the spatial distribution of the population of interest. Change detection is useful in such diverse applications as the study of vegetation change analysis, monitoring settlements, assessment of planning as well as other environmental changes (Singh, 1989). Macleod and Congalton (1998) list four aspects of change detection which are important when monitoring natural resources; Detecting that changes have occurred, identifying the nature of the change, measuring the areal extent of the change, assessing the spatial pattern of the change.

### 2.1.1 Remote sensed Satellite imagery

Satellite Imagery technology has been improving its digital imagery capabilities. Higher resolution imagery is becoming more commonly available (Caitlin Dempsey). Information about the most prominent satellite imagery is available on websites.
Since this 1972, several generations of Landsat satellites with their Multispectral Scanners (MSS) have been providing continuous coverage of the Earth for almost 30 years. Current, Landsat satellites orbit the Earth's surface at an altitude of approximately 700 kilometers. Spatial resolution of objects on the ground surface is 79 x 56 meters. Complete coverage of the globe requires 233 orbits and occurs every 16 days. A second sensing system TM Thematic Mapper was added to Landsat satellites launched after 1982. This imaging system was upgraded to be known as the Enhanced Thematic Mapper (ETM), it records seven wavelength bands from the visible to far-infrared portions of the electromagnetic spectrum. In addition, the ground resolution of this sensor was enhanced to 30 x 20 meters. This modification allows for greatly improved clarity of imaged objects.

Urban mapping using Landsat imagery include spectral mixing of diverse land cover components within pixels, spectral confusion with other land cover features (Guindon, Zhang, Dillabaugh, 2004; Lu, Weng 2006). Therefore, it is most desirable to set the remote sensing images to obtain good results prior to classification. For this purpose different image processing techniques provided by the software can be employed. One of spectral enhancement techniques is principal component analysis. It enhances the spectral discrimination among reflectance of different features (Kaiser et. al. 2008). Modification of the original bands in digital image classification has also shown to improve land use land cover classification accuracy (KC, 2009).

The digital image processing is largely concerned with four basic operations; image restoration, image enhancement, image classification and image transformation (Eastman,1999). This is the process of applying primary corrections to the raw satellite image inorder to improve on the visual quality of the image (radiometric character correction) and to orient the image to its correct ground position (geometric correction). Image enhancement is predominantly concerned with the modification of images so as to improve their visual quality.image transformation refers to the derivation of new imagery as a result of some mathematical treatment of the raw image bands.

Digital image classification is the popular and challenging approach of remotely sensed image analysis process. In the process pixels in the image are sorted to obtain meaningful information of the real world as derived in the thematic maps bearing the information such as land cover type; vegetation type, built up areas. (Matinfar, 2007). Although there are different classification systems in existence throughout the world, they are generally not comparable one to another and also there is no single internationally accepted land cover classification system (Latham, 2001). Therefore, determination of land cover classification system is decided considering the purpose of the study and usually it varies according to different research projects (Tateishi, 2002).

There are two general classification approaches: supervised and unsupervised. In the supervised approach the useful information categories are defined and examined for their spectral separability where in the unsupervised approach, spectrally separable classes are determined and defined relative to their informational utility to form a supervised classification scheme (Kaiser et. al. 2008). Supervised classification uses the independent information from spectral reflectance to define training data for determining classification categories (Ratanopad and Kainz, 2006). In classification process, supervised classification has been widely used in remote sensing applications (Yüksel, Akay, Gundogan, 2008).

Additionally, supervised classification has different sub classification methods which are named as parallelepiped, maximum likelihood, minimum distances and Fisher classifier methods. These methods are named as Hard Classifier. The maximum likelihood classification is the most common supervised classification method used with remote sensing image data (Richards 1995) because it labels all pixels in an image. This classifier is based on Bayesian probability theory (IDRISI Klimanjaro Guide 2004).

### 2.1.2 Use of remote sensing in mapping change in settlement

Settlement is the main place for people to live in. Their appearance and inner structure can be used to present the living standard of the rural people in material and culture. Satellite remote sensing provides technology for studying the distribution of settlements. The methodologies of extracting settlements from satellite remote sensing include visual interpretation, classification, extraction based on knowledge discovering. The visual interpretation was used to extract the settlements in urban and town level in the triangle area of Yangtse river (J.F.He and D.F.Zhuang, 2006),the industrial land of Tangshan city (H.Y.Pan et al., 2007), and the settlements in urban and town level in Changsu city inChina from Landsat TM/ETM images (R.H.Ma et al.,2004).

Y.Zha et al.,2003 in his study discovered that accurate result can be obtained by using the visual interpretation, which will consume a lot of labors and time. The classification method was used to extract the settlements above town level in Shanghai (X.W.Li et al.,2003), and in the triangle area of Zhujiang river from Landsat TM/ETM (W.P.Hu et al.,2003). The conventional classification method is not good for extracting settlements from the satellite remote sensing images with high spatial resolution. The method of extraction based on knowledge discovering was used to extract settlements in Fuqing city (C.J.Yang and C.H.Zhou, 2000), and Wuxi city in China.

Settlements extracted from Landsat TM/ETM mainly are limited to the settlements in urban and town level, because of the limitation of its spatial resolution. The satellite images with high spatial resolution such as SPOT, IKONOS and QUICKBIRD images were used to obtain urban objects (G.J.Wen et al.,2003), urban building density and floor area. The inner structure characteristics of the rural settlement are rarely discussed. It is expensive to study the inner structure characteristics of the rural settlement by using conventional investigation technology in field. Acquiring the information for rural settlement timely and accurately has an important significance for construction and development of rural areas. The development of remote sensing technology provides advanced means of the acquirement of the information of settlement area. The study of extracting rural settlement information from Quickbird images in Xindu district, Chengdu City, P.R.of China was discussed here

Changes in land cover and in the way people use the land have become recognized over the last 15 years as important global environmental changes in their own right (Turner, 2002). To understand how Land change affects and interacts with global earth systems, information is needed on what changes occur, where and when they occur, the rates at which they occur, and the social and physical forces that drive those changes (Lambin, 1997). The information needs for such a synthesis are diverse. Remote sensing has an important contribution to make in documenting the actual change in land use/land cover on regional and global scales from the mid-1970s (Lambin et al., 2003).

Adejuwon and Jeje (1973), in an earlier study mapped landcover/landuse associations in the Ife area using 1:40,000 panchromatic aerial photographs. Land use/cover studies using satellite image in this region (such as Salami, 1999; Salami et al., 1999) are a recent phenomenon. Likewise, Salami and Akinyede (2006) conducted land use/cover change studies in the region using data from Landsat satellite imagery of December, 1986 and the newly operational NigeriaSat-1 satellite imagery of December 2004. Amamoo et al. (1998) used satellite image for the same region but their concern was to differentiate between built-up and non built-up land use for population census base map revision.

In recent decades, remotely sensed data have been widely used to provide the land use/cover information such as degradation level of forests and wetlands, rate of urbanization and other human-induced changes (Alrababah, Alhamad, 2006). Moreover, the advent of widely available and less expensive Landsat imagery has permitted the development of highly accurate land cover map products (Goetz, et. al., 2009).

The urban dynamics model driven by Geographic Information Systems (GIS) as well as remote sensing data proved to be useful for identifying urban growth and land use/cover tendencies that enable local planning authorities to recognize and manage city growth according to the environmental carrying capacity, present and envisaged infrastructure availability (Alameida et. al. 2005) as well as socioeconomic considerations.

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Many applications (like Thenkabail et al., 2006) in settlement monitoring require frequent Coverage of the same area. This can be maximized by using data from multiple sensors. However, since data from these sensors are acquired in multiple resolutions (spatial, spectral, radiometric), multiple bandwidth, and in varying conditions, they need to be harmonized and Synthesized before being used (Thenkabail et al., 2004). This helps normalize for sensor Characteristics such as pixel sizes, radiometry, spectral domain, and time of acquisitions, as well as for scales. Also, inter-sensor relationships (Thenkabail, 2004) helps establish seamless monitoring of phenomenon across landscape.

## 2.2 Geographical information systems (GIS)

Geographical Information System (GIS) are computer systems that can store, integrate, analyze and display spatial data (João & Fonseca, 1996). The first systems evolved in the late sixties, and by mid seventies they had been used for environmental impact assessment EIA. Special attributes of the GIS are very important for the analysis of environmental issues, since most of them are spatial by nature, and no other computerized system can handle them properly (Schaller, 1990). In recent years two important developments have helped in reduce the complexity of spatial analysis. In the last decade, due to the evolution of computer technology, and especially their graphic capabilities, GIS has become more user friendly and powerful. In addition the availability and quality of digital spatial data sets improved, to the level where they are now adequate for routine analysis (Batty, 1993).

GIS are rapidly becoming a key technology for the automated capture, management, analysis and presentation of location- referred data all over the world (Ottens, 1992, p.27). This ability to store and retrieve data about special aspects of the earth and the way people live on it and the potential to use these data in models of environmental and socioeconomic impacts in order to learn more about the possible outcomes of natural trends, planning decisions or disaster is not only very important for industrialized countries but also for the developing world (Burrough, 1992, p.17).

Glickman (1994) used GIS to compare proximity-based measurements and risk-based measurements of settlement equity in an analysis of industrial hazards in Pittsburgh and surrounding Allegheny County, Pennsylvania. To measure settlement equity based on people's proximity to facilities, he divided the county's industrial facilities into two types: (1) those that may pose chronic hazards, and (2) those that may pose acute hazards. He constructed circles with radii of one-half mile, one mile, and two miles around each chronic hazard and each acute hazard facility. Then, for each radius, the county was divided into two parts, the area within the circles and the area outside of all circles. The combined area within the circles became the “close-proximity region.” The proportion of nonwhite residents and poor residents inside and outside of the close-proximity region was then estimated.

More recently, simultaneous information management with respect to the important factors in road planning and rapid impact assessment of the roads has been possible by using GIS capabilities (Naghdi and Babapour, 2009; Pentek et al, 2005; Gumus et al, 2007). Using of all environmental and influenced layers includes slope, soils type, geology, hydrography, aspect, and trees volume m3 per hectare, tree type and elevation in forest road planning in tradition methods can create enormous data and subsequently create a complicated situation when using and decision making (Ezzati et al, 2009).

### 2.2. 1 ILWIS

ILWIS is an acronym for the Integrated Land and Water Information System. It is a Geographic Information System (GIS) with image processing capabilities. ILWIS has been developed by the International Institute for Aerospace Survey and Earth Sciences, Enscheda the Netherlands. For more than a decade, since 1985, the software has undergone major improvements. As a GIS package, ILWIS allows you to input, manage, analyze and present geographical data. From the data you can generate information on the spatial and temporal patterns and processes on the earth surface.

ILWIS (Integrated Land and Water Information System) is also a remote sensing and GIS software which integrates image, vector and thematic data in one unique and powerful package on the desktop. ILWIS delivers a wide range of features including import/export, digitalizing, editing, analysis and display of data, as well as production of quality maps. ILWIS software is renowned for its functionality, user-friendliness and low cost, and has established a wide user community over the years of its development.

## CHAPTER THREE

## METHODOLOGY

### 3.0 Introduction

This chapter explains the procedures that were followed to achieve the specific objectives, the tools and soft wares used with the different approaches applied to the different data which were available for the study. It involved getting, relating and integrating necessary primary data and secondary data about the study area.

### 3.1 Softwares used

ILWIS 3.0 (Integrated Land and Water Information System) which is a GIS (Geographic information system), was used for satellite image processing and classification of the images that facilitated analysis. The study area (kampala northern bypass and surrounding areas) was delineated out using this software from co-ordinates.

Microsoft office was used for presentation of the project.

### 3.2 Instruments and Tools used

Hand held GPS was used for picking co-ordinates of points. A digital camera for taking photographs required to enhance this study.

### 3.3 Data collection

This involved getting necessary primary data and secondary data. Primary data (co-ordinates, photographs) was collected using handheld global positioning system (GPS) and digital camera during physical ground truthing.

Secondary data was inform of satellite images. It was also obtained from available literature about various issues that have been discussed and written related to this study.

Satellite images (Landsat Enhanced Thematic Mapper plus) were obtained from the Global land cover Facility (GLCF) and United States National Aeronautical and Space Administration (NASA) Websites.

| sensor | Number of bands available | Bands used | Year of acquisition |
|---|---|---|---|
| L 5 ETM+ | 7 | 3 | 2010 |
| L 7 ETM+ | 7 | 3 | 2001 |

Table 1; description of satellite imagery used for this study.

### 3.4 Ground truthing

The data collected during this exercise were co-ordinates of few points using GPS, which were picked in relation to a particular feature (classes) so as to help in image classification, that is developing signature from the training pixels. This was necessary to identify the features on ground. Co-ordinates of features are presented in table 3.

Some scenes were taken using a digital camera so as to observe the characteristic of the road in relation to settlement.

Identification of the variables needed to assess settlement change was done. The variables consist of socioeconomic and environmental information that are elements of settlement. The essential variables considered for this study include;

- Vegetated areas / grassland
- Built up areas
- Bare ground
- Swamp

### 3.5 Steps followed while using the satellite images

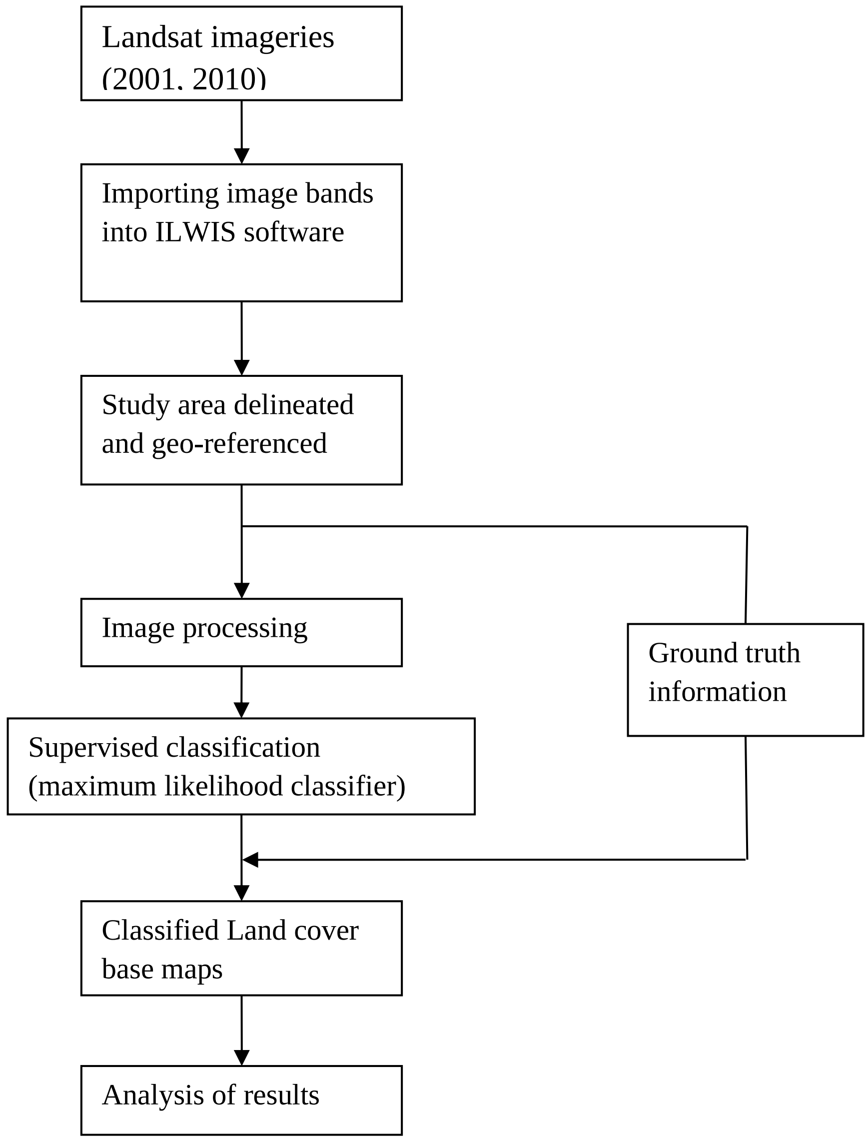



Figure 1; showing flow diagram for the methodology

### 3.6 Data preparation

Satellite imageries of the years 2001 and 2010 containing the study area were obtained. Different bands (1, 2,3,4,5 6 and 7) of the images were imported to ILWIS software so as to start processing the images.

The next step was to delineate the study area from the images. In ILWIS, the image windowing dialogue box under the reformat menu was used to delineate the study area. It was important to know the minimum and maximum X, Y geographic co-ordinates so as to clearly extract out the boundary of the study area.

Also row/column positions can be used to delineate a given area.

| | | |
|---|---|---|
| Filename | For example; 2001 band 1 | |
| File type | Binary | |
| Minimum | X=449314.3 | Y=37312.5 |
| Maximum | X=461991.2 | Y=42249.9 |
| Rows | 132 | |
| Columns | 419 | |
| Data type | Byte | |
| Reference system | UTM 36N | |
| Reference units | meters | |
| Unit distance | 1.000 | |
| Minimum value | 0 | |
| Maximum value | 255 | |
| Resolution | 2001= 30m<br><br>2010= 30m | |

Table 2; showing data used to delineate the study area

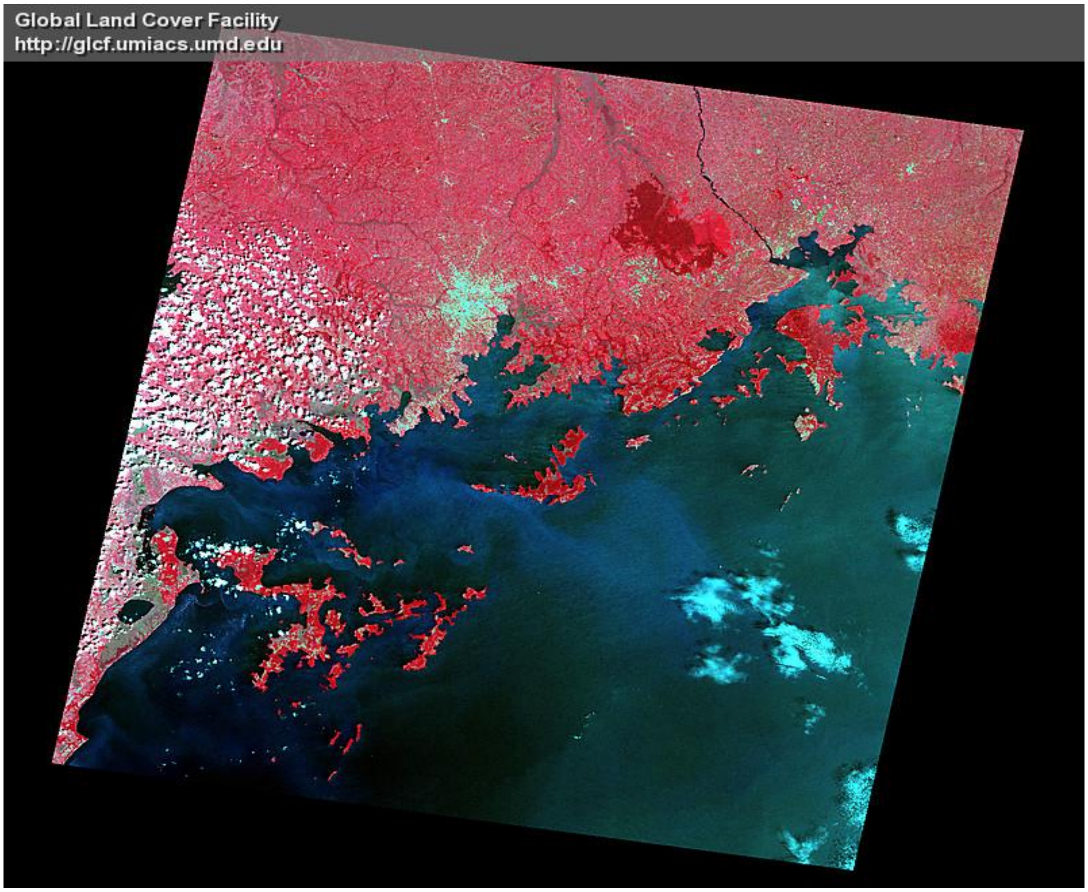
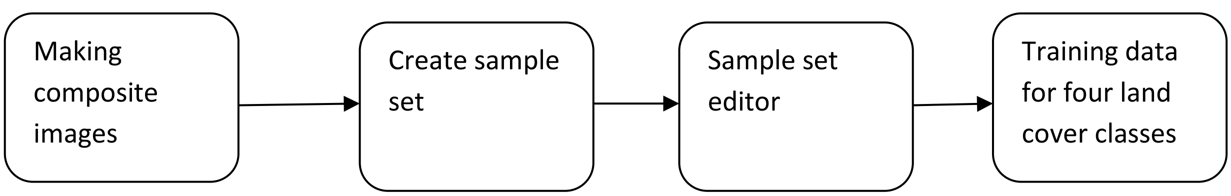



Figure 2; showing a true color composite image containing the study area.

The following procedure (image processing) was followed in ILWIS software so as to achieve image classification for 2001 and 2010 satellite imagery.




### 3. 6.1 Making composite images

The color composite was created for each year considered, by combining 3 raster (bands/maps). This is because ILWIS uses three bands at a time to make a composite.

One band was displayed in shades of red, one in shades of green and one in shades of blue. A color composite gives visual impression of 3 raster bands. Putting the three bands together in one color map gave a better visual impression of the reality on the ground, than by displaying one band at a time. To make the composite, operations option was selected from the menu bar followed by image processing and selecting color composite and this brought the dialogue box below;

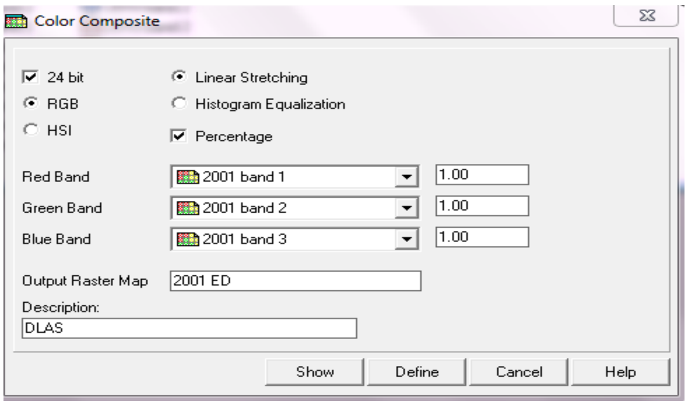



Figure 3; showing ILWIS tool for making color composite.

### 3.6.2 Creating a Sample set

A sample set was created before sampling/training pixels. Therefore it was required for performing multi-spectral image classification since it stores the locations of sampled pixels and the assigned class names.There are other procedures like clustering that can be followed to achieve image classification, though I used creating a sample set for this study.

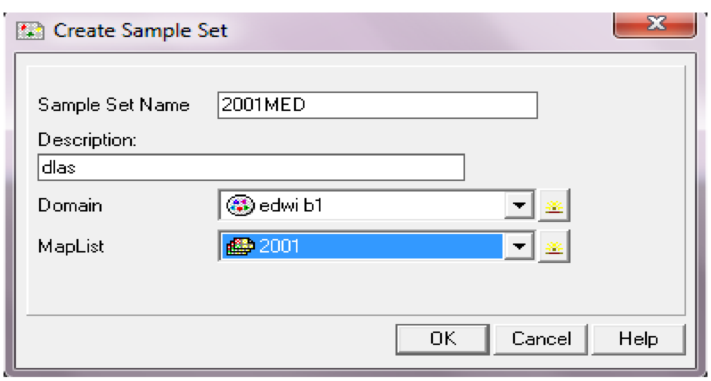



Figure 4; showing ILWIS tool for creating sample set

### 3.6.3 Sample set editor / training pixels

During sampling, class names for the four land cover were assigned to groups of pixels with similar spectral values that are supposed to represent a known feature on the ground. The sample pixels are also called training pixels. I double-clicked a pixel and chose a class name from the list, or one can enter a new class name, or select multiple pixels, press the right mouse button and select Edit from the context-sensitive menu. In a small dialog box that appears, choose a class name from the list or enter a new class name.

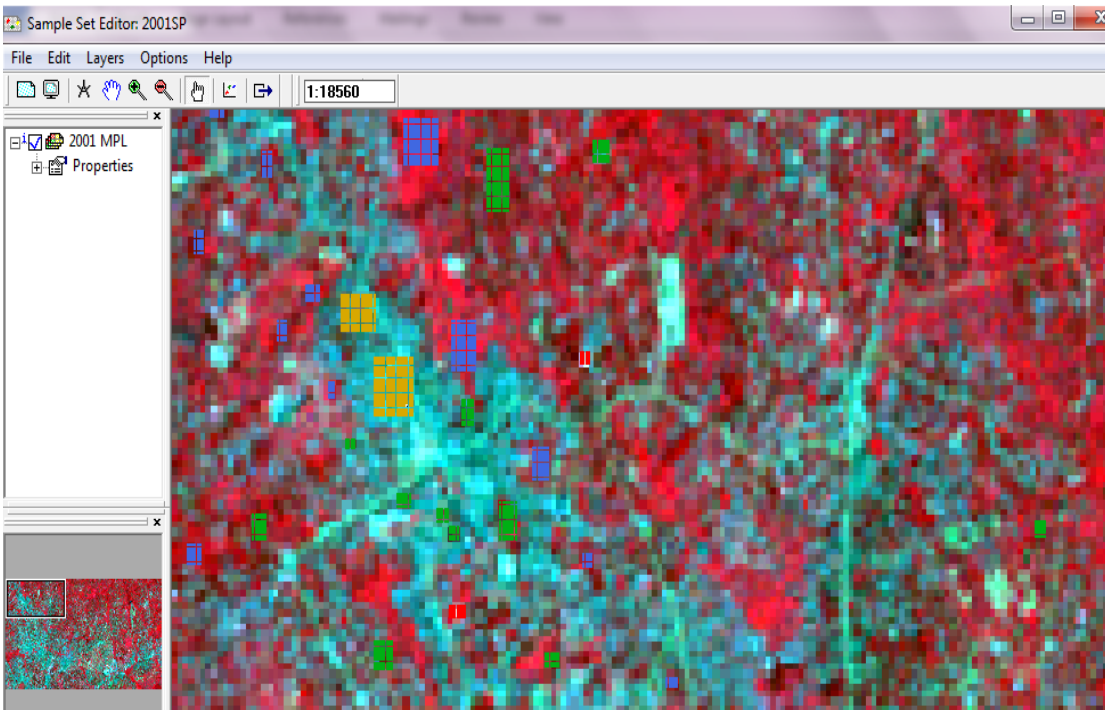



Figure 5; showing a raster image containing the developed signatures of the training data for the four land cover classes.

### 3.7 Landcover / Image classification

In the classification dialogue box, the name of the sample set created was entered and maximum likelihood classifier chosen as per the classification type (supervised classification) proposed. The name of the output raster map and description were required to retrieve desired output.

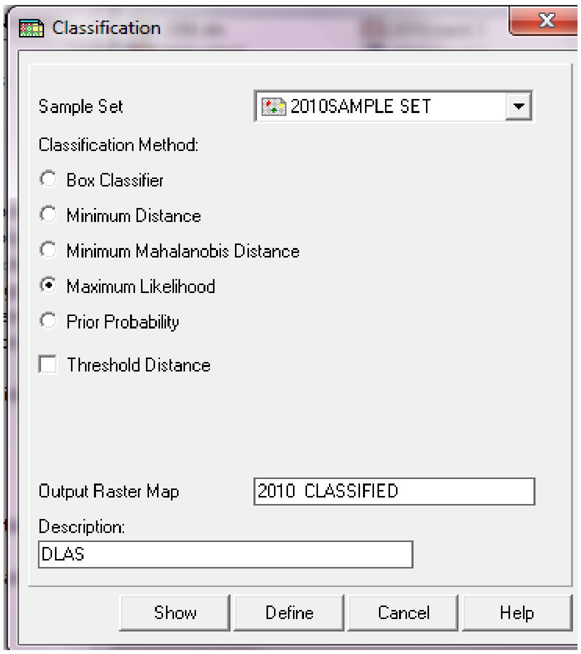



Figure 6; showing classification using maximum likelihood classifier

The classified land cover base maps for the two years 2001 and 2010 contained four land cover classes that is; built up area, swamp, grass land and bare land. The obtained google earth satellite imagery and ground truthing data were used in the sampling of pixels so as to make sure that the land cover classes correspond to their position on map as on ground.

This operation facilitated the accuracy assessment of the Landcover base maps.

| point | Easting | northing | description |
|---|---|---|---|
| 1 | 461382.4 | 38808.6 | Flyover to bweyogerere |
| 2 | 461219.6 | 39308.8 | Road centre line |
| 3 | 461085.8 | 37779.6 | Road cenre line |
| 4 | 461151.1 | 39989.7 | swamp |
| 5 | 461291.8 | 38775.8 | grassland |
| 6 | 461583.6 | 39060.7 | Builtup area |
| 7 | 461548.7 | 39158.9 | Built up area |
| 8 | 461412.5 | 39234.8 | Grass land |
| 9 | 461391.7 | 39129.3 | swamp |
| 10 | 461293.6 | 39180.6 | swamp |
| 11 | 461096.8 | 40172.5 | grassland |
| 12 | 460748.8 | 40502.9 | Fly over to namugongo |
| 13 | 460732.6 | 40373.8 | Bare ground |
| 14 | 464532.5 | 40576.7 | Built up area |
| 15 | 460630.6 | 40367.5 | Grass land |
| 16 | 460456.7 | 36756.7 | swamp |
| 17 | 456172.7 | 36.7357 | Grass land |
| 18 | 454410.09 | 35736.62 | Built up area |
| 19 | 452667.16 | 34946.67 | Built up area |

Table 3; showing data got from ground truth field work

# CHAPTER FOUR

# RESULTS ANALYSIS AND DISCUSSION

## 4.0 INTRODUCTION

This chapter contains analysis of the results from classified images ( land cover maps) and it also contains discussion of the results.

## 4.1 RESULTS

This includes presentation of results from creating color composites and image classification. Here below are the color composites of the imported satellite image bands containing the study area.

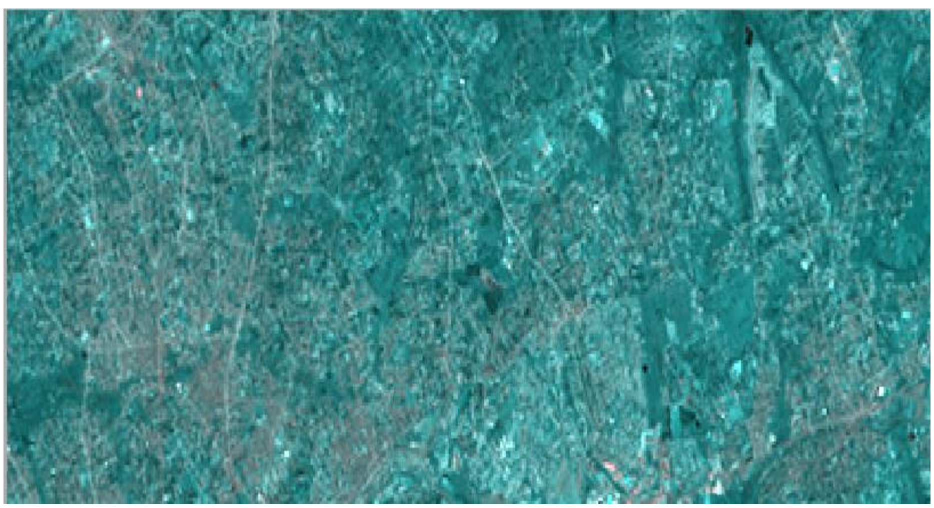


Figure 7; showing color composite for the study area the year 2001

The figure above doesnot contain the road since at the time it was not constructed. Therefore it is to be used for comparative assessment with the year 2010 for which the road was already established.

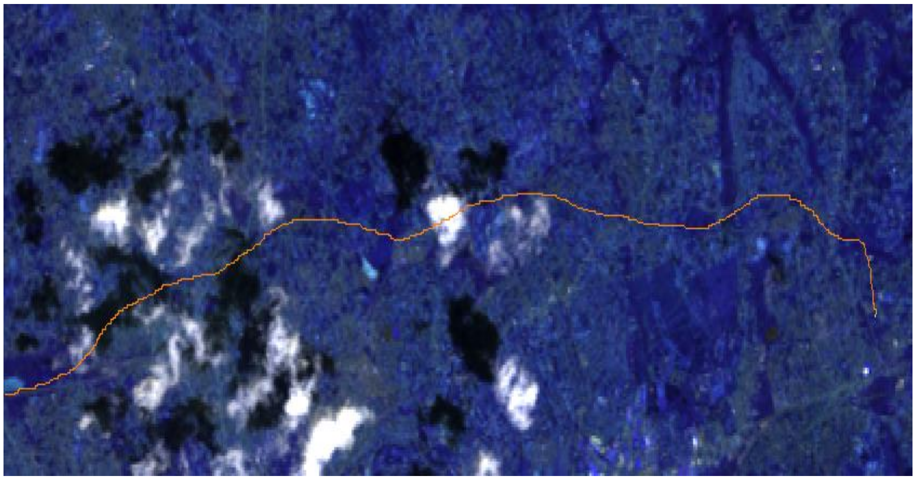


Figure 8; showing color composite for the study area containing the road 2010.

When you observe the color composites(figure 7 and figure 10) carefully, you see that cloud cover has affected a part of the 2010 image. Therefore, a number of co-ordinates for points affected by cloud cover were written from the georeferenced image and used to identify the classess they obstruct during ground truthing and observation of google earth satellite imagery. It was found out that much of those areas are densily built up areas of which some are slums that have seriously enchroached on the swamp.

Results for the image classification for the four classess ( builtup area, swamp, bare ground, grass land) using related ground truth data and google earth imagery are shown below;

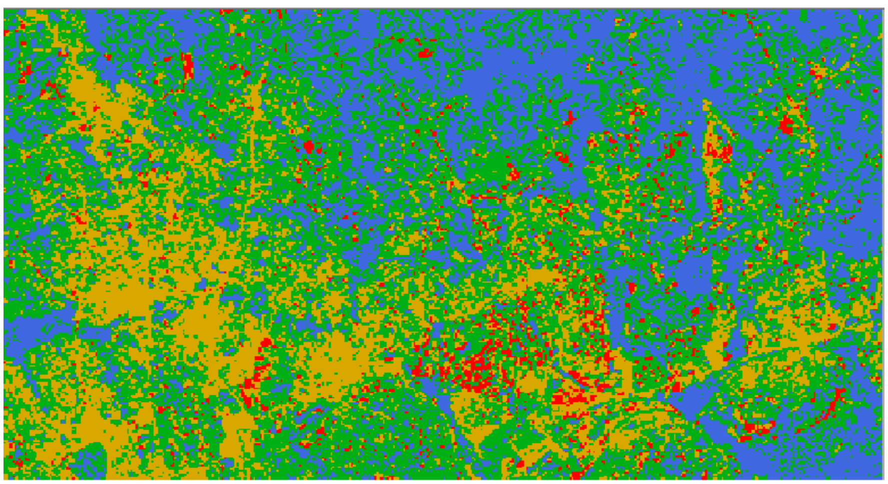


Figure 9; showing classified image (land cover base map) for 2001

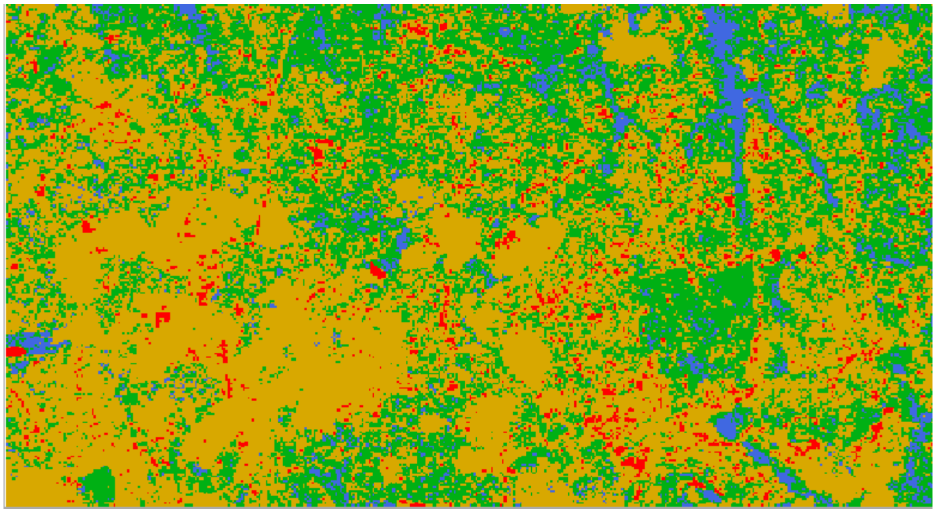


Figure 10; showing classified image (land cover map) for 2010

**Legend;**

Bare ground

Grass land

Built up area

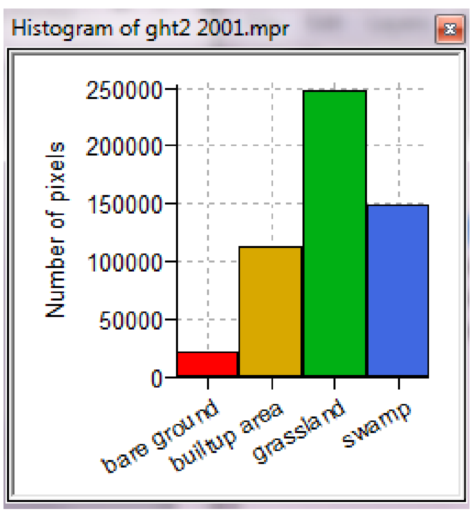
Swamp

## 4.2 ANALYSIS

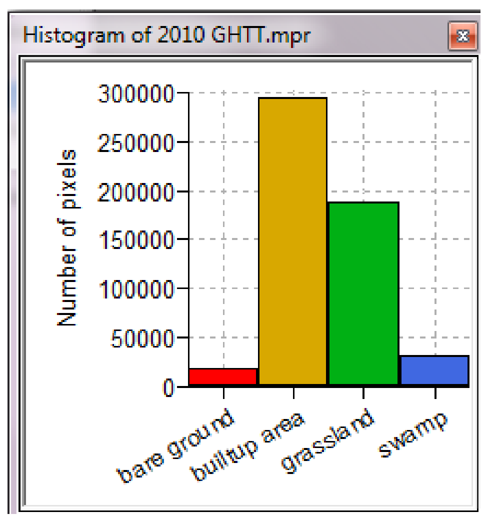
### 4.2.1 Visual analysis

Visual analysis of the result of images classified (figure 9 and figure 10) was done so as to come up with comparable solid discussions, conclusions and recommendations.With a basis on the colors in the legend and the classes they represent, it can be seen that grassland, swamp and bare ground was more before the establishment of the road in 2001 than in 2010 after which we see that built-up area has taken up much of the area. The built up area is comprised of residential, commercial, institutional and transportation land use. These have taken up much of the area in the areas along the northern bypass.

This is illustrated in the histograms figure 11 below;




(a) 2001




(b) 2010

Figure 11; showing histograms of land cover classes for 2010 and 2010

Using figure 10 to analyze built-up areas in Landsat 5 ETM+ image of 2010, It is understood through this image that the impact continues due to the attraction to the areas as a result of the benefits associated with the road. It is also seen that the built up area alongside the road greatly increased in the left side of figure 10 this was in the parts of Bwaise, mulago, makerere, bukoto and kigoowa to the previous years. Also when the two land cover maps (figure 9 and figure 10) were observed, the swamp/wetland area reduced so much and yet it was among the classes taking the biggest area in the year 2001.

### 4.2.2 Calculation of the change in class area

The extent of area taken up by the classes was calculated from pixels in ILWIS. The classes and their corresponding area is shown in the figures 12 and 13 for 2001 and 2010 respectively.

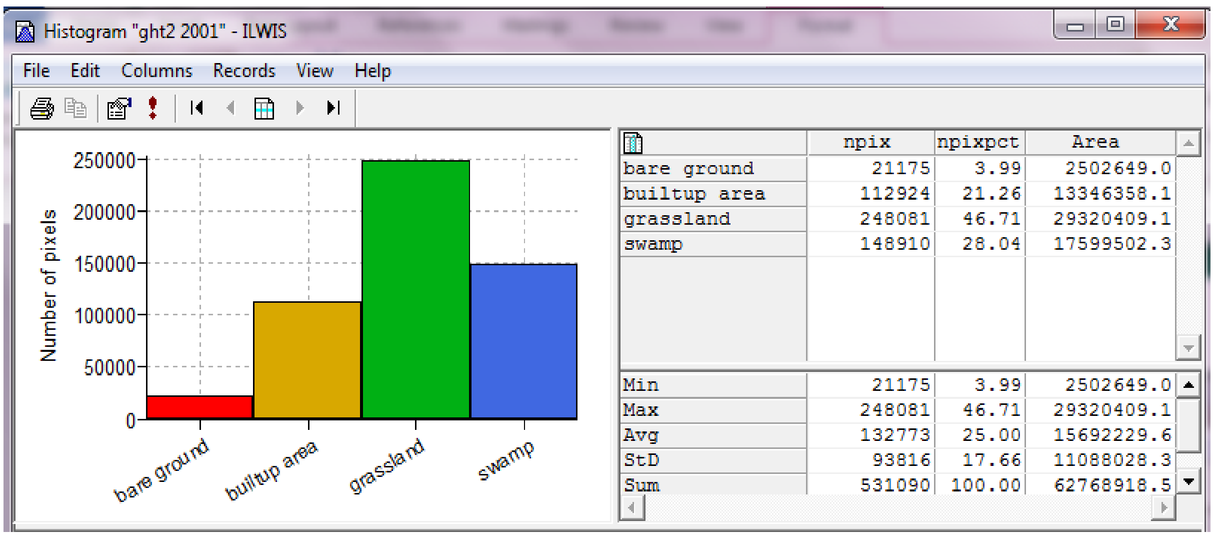



Figure 12; showing pixel area ($m^2$) of the classes 2001

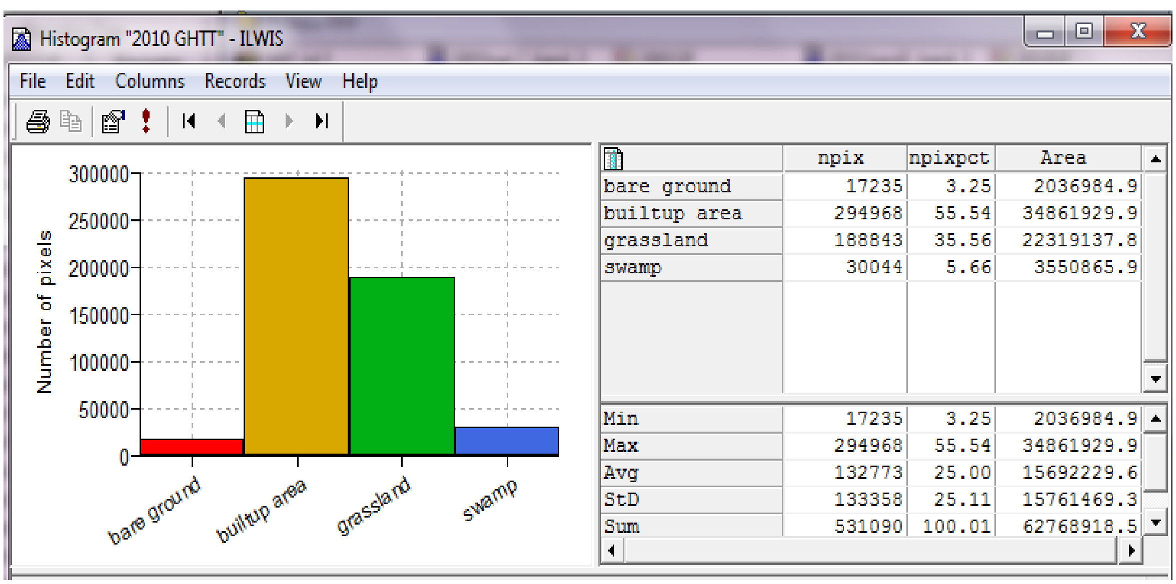



Figure 13 showing pixel area ($m^2$ ) of the classes 2010.

The areas for the classes were given in meters squared from ILWIS and were converted to hectares for better presentation;

| **Classes** | **Area in hectares** | | **Change in hectares** | | **Percentage change(%)** |
|---|---|---|---|---|---|
| | **2001** | **2010** | + | - | |
| Built up area | **1334.64** | **3486.19** | **2151.55** | | **+ 34.3** |
| grassland | **2932.04** | **2231.91** | | **700.13** | **- 11.2** |
| Swamp | **1759.95** | **355.09** | | **1404.86** | **- 22.4** |
| Bare ground | **250.26** | **203.69** | | **46.57** | **-7.4** |
| **total** | **6276.89** | **6276.89** | | | |

Table 4; showing change in area for different classes for the years 2001 and 2010

As seen from calculations in the above table, it is logical that built up area has increased by over 34% at the expense of the grassland, swamps and bare ground. One of the reasons for the serious reduction of the swamp area is that the land acquired for construction of the northern bypass was to a big extent wetland. Documented literature provides that, the failure of government to meet the high compensation fees for acquisition of land for the original plan led to it opting for cheap land that is swampy.Also increased urbanization has led to emergence of squatters in the swampy areas. One of the photographs taken shows a clip of how people are living in the swamp.

Figure 14; A natural spring flowing from foundations of structures next to the Northern Bypass.

## 4.3 DISCUSSION

To a big extent, an increase in built up area is an indicator of economic development. Studies generally show an increase in the square footage of development because of a new transportation facility constructed in an area. From my findings, increased property values (and related tax revenue) are resulting from development on land parcels served by a new transportation facility. This is why we see real estate companies developing structures along the Northern bypass. Also people tend to reside near this new transport facility due to the increased employment prospects.

In spite of the frameworks in place, the results not only reveal that the study area experienced some significant changes in its environments, but the region remains an ecosystem under stress. This is because of the extent to which the grass land and wetland have been depleted. Figure 9 shows a big coverage for grassland and swamp classesand yet we see their coverage seriously reducing in figure 10. This also shows that flora and fauna habitats are at sufferance.

The nature and extent of this change showed some variations across time and space. The changes attributed to socioeconomic and environmental variables reflect also a host of other factors. Over all the results point to a decline in swamps, vegetated area, crop land and an increase in infrastructural development like commercial buildings,residential building, roads. Other interesting findings touch on an impending population explosion in the area especially in the areas of Kisaasi, Kalerwe and Bwaise with concern of the growth rate that shows concentration of human settlements in the suburbs along the northern by pass. The trend for house hold population for some of the areas along the northern by pass is shown in the table below;

| **Area** | **House hold population.** | |
|---|---|---|
| | **2010** | **2001** |
| Bweyogerere | 1867 | 766 |
| Naalya | 2607 | 667 |
| Kisaasi | 1350 | 600 |
| Kalerwe | 1890 | 686 |
| Bwaise | 2907 | 1025 |

Table 6 showing population for some of the study areas.

When Table 6 showing population information of the study area is examined, it is seen that the population of the areas has increased to a number that is multiplied by 3 between 2001 – 2010years. In addition to this, while the amount of the built-up areas was about 1123.9 in 2001, it is 3106.2 hectares in 2010 as shown in table 4. In this stage, it is seen that the aerial growing factor of the settling areas increased 2.5 times.

That the population growth and physical growth of the study area has a close rational, does not indicate that the study area has a regular development scheme. Because, while the housing areas increased, the residual naked areas did not increase at the same rate. On the contrary, the bare ground areas as well as the agricultural (grass lands) areas were transferred into housing areas.

As a result of increasing pressure on land due to the increase in population, many residential and commercial buildings of all kinds have been erected though they have increased at the expense of agricultural activities. At some points of the road, houses, shops, markets are even encroaching on the road reserves.

This trend is gradually turning regions along the northern bypass into areas that need adequate simulation monitoring. This will not only threaten the carrying capacity of the current monitoring structure but it poses enormous challenges for both environmental and natural resource managers in the region if not confronted with the urgency it deserves.

Given the location of northern Bypass, findings indicate that flooding risk and degrading the wetland/swamp system are key impacts of the Scheme. Direct negative impacts include soil erosion, scouring of the landscape due to opening of borrow pits, inadequate revegetation, increased sediment loads to wetland system, and occupational safety hazards.

However, positive impacts from road establishment and development have occurred and indeed justify this scheme. Secondary beneficial impacts include improved accessibility, reduced public transport costs, road safety, improved access to social services, improved local economies and induced development. Other benefits include stimulation and development of roadside economic activities, increased social mobility and access to social services especially health.

# CHAPTER FIVE; CONCLUSION AND RECOMMENDATION

## 5.1 CONCLUSION

The use of satellite images and ground truthing collectively were very important in accuracy assessment of the impact of establishment of the road since it enabled the researcher to know the characteristic of the place in image classification. Using remotely sensed satellite imagery and GIS modeling facilitated vivid analysis of the spatial distribution of settlement change involving land cover classification.

This report serves as an essential tool for the design of geo-spatial decision support systems for land managers, urban planning and physical planning managers in the assessment of environmental impacts of development in areas.

## 5.2 RECOMMENDATIONS

For more effective use of the remote sensing data, landuse managers should be aware of the limitations and advantages of satellite data and should choose from their available landuse mapping options accordingly.

In monitoring areas that have a rapid changing characteristic, analyzing broad areas using remote sensing and GIS technics is far more easy and fast than the classical surveying methods. Urban growing areas should be channeled under the control of local authorities, using GIS and Remote Sensing techniques especially in planning stages and monitoring urban areas.

Techniques for improving the classification of landcover with remote sensing data should include the use of appropriate digital data. In order to achieve this task, selection of the most proper satellite image, band combination, and the classifier are very important. Additionally, the image processing is important and different stages of it such as filtering of bands and principal component analysis should be done.

Consultation is important for both urban and rural locations. It enables road project proponents to identify potential impacts as well as local sources of information and knowledge, to highlight community concerns about the effects of road changes on lifestyles and welfare, and to encourage participation in the development of workable solutions.

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