AN ASSESSMENT OF THE IMPACTS OF LAND USE CHANGES ON THE DUTHUNI WETLAND STREAM USING REMOTE SENSING, GIS AND SOCIAL SURVEY: A CASE STUDY IN LIMPOPO PROVINCE, SOUTH AFRICA.

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Thesis submitted in fulfilment of the requirements for the degree of Masters in Environmental Sciences in the Department of Ecology and Resource Management, School of Environmental Sciences, University of Venda

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Declaration

I, **Nephawe M** hereby declare that the thesis for the Master's degree at the University of Venda, hereby submitted by me, has not previously been submitted for a degree at this or any other University, and that it is my own work in design and execution and that all references materials contained therein has been duly acknowledged.

Signature: ___________________________ Date: ______________________________

Dedication

I dedicate this research report affectionately to my late Sister Khathutshelo Nyavhalitsheni Nephawe, "The journey continues until we meet again".

Abstract

This is a case study research that focuses on the assessment of the impacts of land use changes on the Duthuni wetland ecosystem in Limpopo Province using geospatial techniques and Social Survey. SPOT 4 satellite images which covered the time frame between 1999, 2005 to 2012, were used. The unit of analysis included different institutions such as the local municipality, farmers, the heads of the households and Chief of the Village. In this study, different methods of sampling were used in different context for selecting participants and for sample size determination. The different instruments for data collection included the questionnaires, interviews, focus group interviews and documents review. Socio-economic survey and review of documents were carried out to understand historical trends, collect ground truth and other secondary information required. Data collected from the survey were captured and analysed using the Statistical Package for Scientific Solutions (SPSS).

For quantitative analysis, Chi-Square and cross tabulation were employed in SPSS. Analysis of satellite imagery was accomplished through integrated use of ERDAS Imagine (version 2015) and ArcGIS (version 10.1) software package. The themes were identified and analysed using the content analysis based on the main research topics. The results show that the land use/ cover changes have occurred at an unprecedented rate over the years 1999 to 2012. From the year 1999 to the year 2012, the total land use/ cover conversions equal to 299.984 ha of land. The trend and spatial extent of land use/ cover changes had undergone considerable changes over the years in the study period. The major contributing factors included population increase, expansion of agriculture and lack of space to settle. The residential area was found to be the major factor contributing to land use change over the years with an increase of (102.87ha.). People residing in Duthuni village especially along the wetland ecosystem consist of the majority of female-headed households. There is no proper facilitation and mentoring in the village by the government in order to resolve social problems when it comes to land use change. Water pollution and soil erosion were found to be the major concern by wetland users such as farmers and residents. Lack of knowledge has also been identified as one of the driving factors of environmental impacts of land use change in the area. Food was the most resources with 41% which the community gets from the wetland.

Key words: *Land use change, Remote sensing/ArcGIS, ERDAS Imagine, Wetland ecosystem, Duthuni Community.*

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Signature: Scholarship Holder______________________________________ As witness

(1) ____________________________ (2)________________________

CHAPTER ONE: INTRODUCTION

1.0 Introduction

Wetland was thought to be only the habitat for hydrophytes and insects leading to downward looking of the wetland which resulted in the loss of many wetlands replaced by industries, agricultural areas and residential houses (Shi, 2013). This study aims to assess the impacts of land use cover change in wetland ecosystem using remote sensing; ArcGIS and Social survey in Duthuni wetland ecosystem. Furthermore, this chapter covers the background to the study, problem statement, research aim, specific objectives, research questions, assumption, operational definitions, justification of the study and study area descriptions.

1.1 Background to the study

The South African National Water Act 36 of 1998 defines wetlands as "land which is a transitional and aquatic system where the water table is usually at or near the surface, or land is periodically covered with shallow water, and which under normal circumstances supports or would support vegetation typically adapted to life in saturated soils". The most commonly adopted wetland definition is that of the RAMSAR convention (1971) which define wetlands as"areas of marsh, fen, peat land or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres" (Tsuji, 2012).

South African biodiversity institute report (2013) indicated that wetland makes up only 2.4% of the country's area in which 48% of wetland ecosystem types are critically endangered, over 70% of South Africa's wetland ecosystem types have no protection and only 11% are well protected. Wetlands serve as a mini-ecosystem and without such areas; populations of countless species would be threatened. Wetlands are critical natural resources that serve various purposes including environmental, hydrological and socio-economic functions. The different land use activities in wetland such as cultivation, grazing, water abstraction, extraction of natural resources among others have detrimental impacts on the wetland as it led to soil erosion, water pollution, loss of vegetation, overgrazing and other anthropogenic activities (Smith, 2013).

A study conducted by (Hove *et al*., 2013) indicated that wetland degradation has been largely a result of human activities that include overgrazing, housing development, cultivation, ground water extraction and artificial drainage among others. Land cover and land use are two main concepts related to land exploitation hence, Inglis-Smith (2006) defines land use as the way in which humans use the land whether for mixed use or development and land cover is the physical state of the land surface, including soil, topography, biota, open water and human structures. Briassoulis (2000) has stated that "land conversion or land modification are factors that lead to changes in land cover by land use hence it leads to soil erosion, loss of biodiversity, water pollution, and other environmental problems".

(Ritchie *et al*., 2015) indicated that various impacts of land use changes in wetlands ecosystem have been detected around the globe using various techniques such as visual interpretation, unsupervised classification, supervised classification, hybrid classification and rule-based classification. The social survey, remote sensing and ArcGIS were integrated to assess human impacts on wetland ecosystem and its implications on the environment in order to meet research objectives at Kissii District, Kenya (Mironga, 2004). In this study, impacts of land use change in Duthuni wetland ecosystem has been assessed based on integrating remote sensing/ GIS and social survey. The use of multiple data types, including socio-economic data and satellite data may be complementary in nature because it can improve classification accuracy and land use change dynamics in the area (Ritchie *et al*., 2015).

1.2 Problem statement

The rate of land use/cover change in Duthuni wetland is occurring at an alarming rate. Despite the importance of wetlands to humanity, Duthuni wetland has been largely degraded. Human activities that include housing development, over-exploitation of wetland resources, cultivation, road developments, power lines, groundwater extraction, overgrazing, washing clothes and vehicles among others are viewed as contributing factors to the land use/cover change in Duthuni wetland. Furthermore, the washing clothes and vehicles can lead to land use/cover change as it elevated concentrations of heavy metals in the water body affecting other land use such as agriculture.

Wetlands are important natural habitat and it is therefore necessary to map them, determine whether or not they have changed over specified time periods and quantify the changes, if any. However, various techniques have been used to study the impacts of land use cover change on wetland ecosystem changes using remote sensing/ArcGIS and other scientific methods around the globe. (Sathiya *et al*., 2010) conducted a study focused on the use of remote sensing/GIS to assess the impacts of land use related to the coastal environment. In South Africa, the study conducted by (Kotze *et al*., 2009) in Kromme River wetlands in Eastern Cape, documented the rehabilitation interventions to protect the integrity and ecosystem services of wetlands. He further presented an overview of historical land use/cover changes and the associated environmental changes over time in a selected high impact area using aerial photographs and GIS. Other studies for assessing impacts in wetland using satellite data include (Turner *et al*., 1994); (Gluck *et al*., 1996); (Jensen *et al*., 1993) and (Singh *et al*., 2010).

Furthermore, (Ritchie *et al*., 2015) indicated that various data sources may be complementary in nature, and by combining data from the various source (including ancillary data) can help to assess the impacts of land use/cover changes in a wetland ecosystem. Furthermore, the combining of social and remotely sensed data can complement indicators from ground-based sources and have the potential to improve understanding of the determinants of various land use/cover change in wetland ecosystem. The integration of remote sensing data and social data will bring many details and deep understanding of the impacts of land use/cover change in a wetland ecosystem.

There are many land use activities taking place in Duthuni wetland ecosystems such as human settlement expansion, agriculture, grazing and other anthropogenic activities. By not integrating various techniques to evaluate the impacts of land use/cover change in Duthuni wetland, the influential factors of various land use/cover changes cannot be understood. It is in view of this gap that a qualitative (social survey) and quantitative (remote sensing/ArcGIS) assessment of impacts of land use change in wetland ecosystems merits attention. Thus, this research will focus on the assessment of impacts of land use change in wetland ecosystems using remote sensing/ArcGIS and social survey.

1.3 Research aim and specific objectives

1.3.1 Research aim

This research seeks to assess the impacts of land use changes on the Duthuni wetlands ecosystem in Limpopo Province using remote sensing/GIS and social survey.

1.3.2 Specific objectives:

Specific objectives of the study focusing on Duthuni wetland are to:

- Assess the current utilization of wetland resources by the local people.
- Determine the major drivers of land use changes;
- Assess the socio-economic and environmental impacts of land use change in the study area; and
- Determine the trends and spatial extent of land use change;
- Examine the impact of the present and past land use change dynamics on the Duthuni wetland;

1.4 Research questions:

The study focusing at Duthuni wetland and seeks to provide answers to these questions:

- How are wetland resources utilized by the local people?
- What are the major drivers of land use change?
- What are the socio-economic and environmental impacts of land use change in the study area? and
- What are the trends and spatial extent of land use change?
- What are the impacts of the current and historic land use dynamics?

1.5 Hypothesis

The different human activities are the major factor contributing to the land use/ cover change in Duthuni wetland ecosystem. Remote sensing, ArcGIS and social survey can help in the characterization, identification and quantification of the land use/ cover change.

1.6 Operational definitions:

Remote sensing: Is the practice of deriving information about the Earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from Earth's surface (Cambell *et al*., 2011).

Geographic Information System (GIS): A collection of computer hardware, software, and geographic data for capturing, storing, updating, manipulating, analyzing, and displaying all forms of geographically referenced information (Brusaporci, 2015).

Land uses The way in which humans use the land- whether for mixed use or development (Inglis-Smith, 2006).

Land cover: Is the physical state of the land surface, including soil, topography, biota, open water and human structures (Inglis-Smith, 2006).

Social survey: Is a survey used to collect data on demographic characteristics and attitudes on demographic characteristics and attitudes of residents of the area (Zarina, 2007).

1.7 Justification of the study

It must be taken into consideration that Desmet, (2013) indicated that, the Duthuni wetland ecosystem categorized as critical biodiversity area category 1 (CBA1) where it is recommended that no further loss of natural habitat should occur i.e. land in this category should be maintained as natural vegetation cover as far as possible and these areas of land can act as possible biodiversity offset receiving areas. Studies conducted by (Ozesmi *et al*., 2002) have found that the use of ancillary data such as socio-economic data, soil data, and hydrological data improves classification accuracy of wetlands and other land cover classes.

The problem of not integrating various techniques such as remote sensing/GIS and social survey in detecting changes in wetland ecosystem might lead to the poor assessment of impacts of land use changes in a wetlands ecosystem. It is in view of these considerations. It is, therefore a need to assess and analyze the past, the present, trend and spatial extent at which land use change impacted the wetland ecosystems and determine wetland resources that are utilized by local people and major drivers of land use change using both remote sensing/GIS and social survey techniques.

Despite that, the fact that wetlands are also sensitive in nature, the intense degradation in the study area will have the significance impacts on wetlands ecosystem. Farming is undertaken without due consideration to sustainable land use practices, with large tracts of land being cleared for farming and infrastructural development in the wetland. It is important to intervene as soon as possible because, the different land use activities taking place in the Duthuni wetland may destroy the wetland ecosystem which includes endemic species and all the benefits of the wetland ecosystem will be lost.

1.8 Study area

1.8.1 Study Sites Description

The area of study is situated South-East of Thohoyandou. Thohoyandou falls under Vhembe District in the northern region of Limpopo Province. Vhembe district is comprised of four municipalities, which are, Musina, Makhado, Mutale, and Thulamela municipality. The study area is located at Duthuni village on the farm Beuster 253-mt under Thulamela municipality and is approximately 15km South-East of Thohoyandou. It lies between the latitude of 22º58’03.8” South and between the longitudes 030°23’54.3” East. The study area is also situated in the middle of the R543 and R544 (Punda Maria road). Subsistence farming is dominant in the study area where maize and vegetables are produced. The map (figure 1.1) represents a study area below:

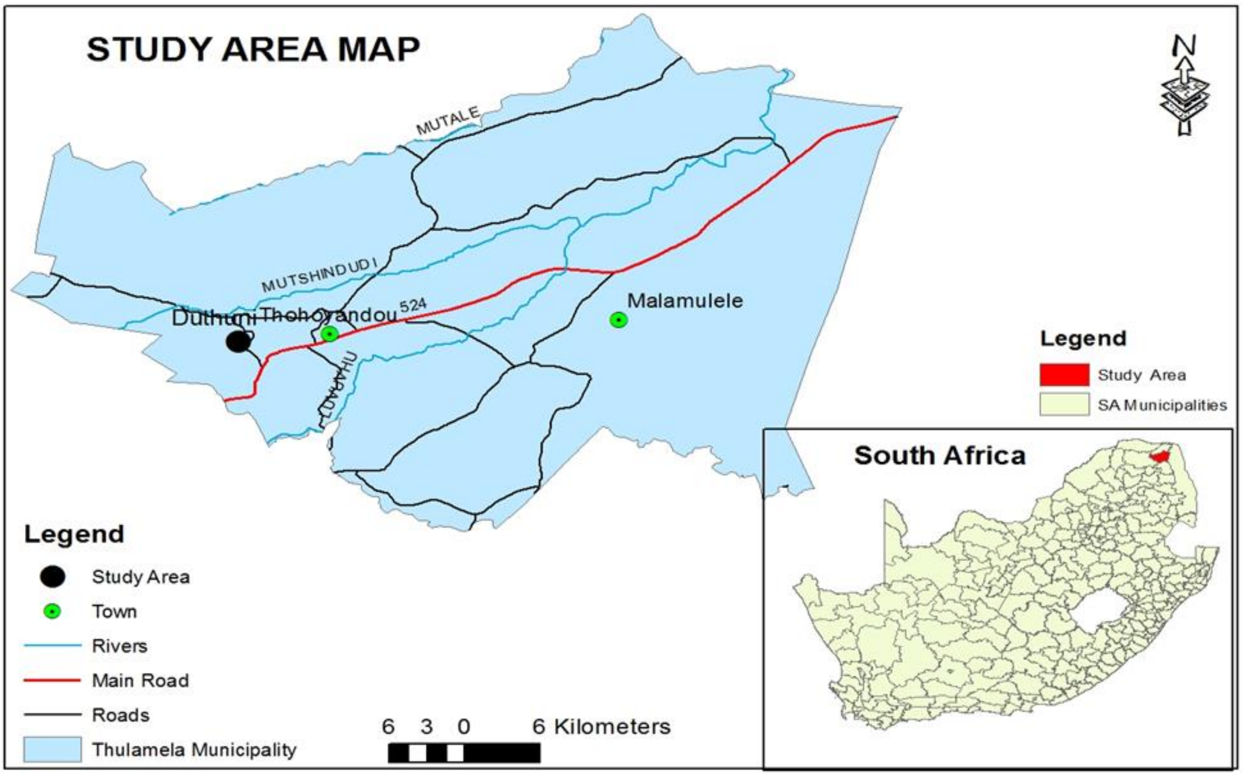

Figure 1.1: Map of Limpopo province representing the study Area

1.8.2 Vegetation and Landscape features

The study area lies along the Soutpansberg mountain range and most of the slopes are 32^0 to 45^0. The topography of the east-west ridges of the mountain tends to change drastically over a short distance and these tend to bring orographic rain on the southern ridge and the effects of shadow on the northern ridges. The mountain ridges have arranged themselves from the low to high mountains, with the highest mountains found in the west and splitting into increasing number of lower mountain ridges towards the east.

Another feature is the tall shrubland with few trees to moderately dense low woodland on the deep sandy uplands with silver terminalia *(Terminalia sericea)*, Large-fruited Bush willow (*Combretum zeyheri)*. Dense thickets to open savannas abound in the bottomlands with *Acacia nigrescens*, Knob Thorn *(Dichrostachys cinerea)*. At seep lines where convex topography changes to concave, dense fringe of silver terminalia (*Terminalia sericea)* occurs, with (Gum Grass) *Eragrostis gummiflua* in the undergrowth, with the Altitude 250-700m (Mucina and Rutherford, 2006).

1.8.3 Geology and Pedology

The Duthuni wetland area is underlain by Precambrian basalts of the Sibasa Formation of the Soutpansberg Group to the north and leucocratic biotite gneiss, leucocratic granite and pegmatite, grey biotite gneiss and migmatite of the Sand River Gneiss of the Central Zone of the Limpopo Belt to the south (Rubidge, 2015). The soil in the area of study has high permeability, moderate porosity, fine texture and agents such as wind and rainfall can wash the soil away. The study area is characterized by loamy (reddish brown) soil which can support the different land use and vegetation.

1.8.4 Population and Human settlement

The human populations in the study area are rapidly expanding towards the buffer zone of wetland, causing the massive destruction of wetland. The human settlement around the area is nucleated and the people that are found at Duthuni are Tshivenda-speaking people. The community is ruled under the traditional leadership and local communities rely heavily on natural resources from wetland for shelter, food, energy, local economic development, and livelihoods sustenance.

1.9 Dissertation outline

The study is organized into six chapters:

- ***Chapter 1*** has been to; introduce the background of the study, problem statement, research aim, specific objectives, research questions, assumption, operational definition, justification of the study and study area descriptions.
- ***Chapter 2:*** This chapter reviews existing literature in relation to the land use/ cover issues
- ***Chapter 3:*** Explains the research design, research methodology, sampling size, data collection instrument and methods of data analysis
- ***Chapter 4:*** Presents the major research findings and interpretation of the results.
- ***Chapter 5***: Focuses on the discussions of the results in relation to both research questions and existing knowledge.
- ***Chapter 6:*** Relate the findings to the objectives of the study. The chapter also covers the conclusions of the findings and recommendations respectively.

CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

This chapter reviews existing core literature in relation to the major causes of land use/cover change in wetlands ecosystem around the globe, significant functions and values of wetland ecosystem and Impacts of land use change in wetland ecosystem. The various methods that have been used to detect land use/cover changes in wetlands and its effectiveness are discussed.

2.1 Characteristics of wetlands

(Ellery *et al.*, 2009) indicated that wetlands form at the interfaces between terrestrial and aquatic environment, and between groundwater and surface water system. Furthermore, he indicated that scientifically wetlands have been overlooked since they are neither terrestrial nor aquatic, nor determined solely by groundwater or surface water (fluvial) process. Kotze 2009, indicated that wetland occur in diverse settings ranging from the broad, flat coastal plain, heads of streams, on floodplains along rivers, and in the downstream. Human manipulations of natural systems often accelerate natural processes of change such as (erosion by gullying, river avulsion, or eutrophication), and may in extreme cases lead to complete character and process metamorphosis, forcing a system to an alternative development pathway on which former natural characteristics and processes (and the former natural dynamic) cannot reinstated (Ellery *et al.*, 2009).

2.2 Significant functions and values of wetlands ecosystem

2.2.1 Erosion control by wetland vegetation

Wetlands are amongst the most productive ecosystems of the Earth (Emerton and Bos, 2004). According to (Asibor, 2009), the major difference between wetland function and wetland value is that the wetland functions if properties that wetlands naturally provides while wetland values are properties that are valuable to humans. Soil erosion in wetland ecosystem not only involves the loss of fertile topsoil and reduction of soil productivity, but is also coupled with serious off-site impacts related to increased mobilisation of sediment and delivery to rivers, causing siltation and pollution of South Africa's water resource SANBI, 2013). The wetland vegetation plays a major role in reducing the hazard of erosion by binding the soil with its roots and protecting the soil surface with its leaves and stems. The slower the water travels the lower the erosive power of the water (Traynor *et al*., 2010).

Wetland vegetation is generally good at controlling erosion by reducing wave and current energy, which is caused by the resistance of wetland plants to the water which slows it down. Furthermore, soil erosion strongly affects the health of wetland and the whole ecosystem of the area (SANBI *et al*., 2013). The ability of wetlands to slow down the velocity of flowing water, as well to absorb some of the water within the system, the peaks of floods is often reduced. With the implication that instead of all the water flowing down the wetland in one big flood event. Some of water held back to be released later, so that same volume of water runs down the wetland over a lengthier period of time. This decreases the peak of the flood while preventing or attenuating potential flooding events (Collins, 2005).

2.2.2 Harvesting of wild food and provisions of medicines

Wetland and estuarine ecosystems in South Africa are under considerably greater threat than river ecosystems. Of the 114,000 wetlands mapped and evaluated in South Africa, the majority are already completely lost, due in part to agriculture, timber plantations, mining and urban development. Some 19,500 tonnes of medicinal plant material is removed annually from South African wetlands (Mander *et al*., 2007). According to (Turpie *et al*., 2010) stated that most of the rural community in South Africa source medicines and wild food in the wetlands ecosystem and some areas water lilies like *Zantedeschia aethiopica* are grown by people along wetlands to provide a significant source of food. 28 million South Africans use about 19,500 tons of medicinal plant material and wetlands of the Eastern Cape and Kwazulu Natal yield the river pumpkin (*Gunnera perpensa)*, which is used to ease child birth and treat kidney and bladder infection. *Eucomis comosa*, (slender pineapple flower), is used to treat rheumatism. The honey *disa polygonoides* is found along the eastern coastline from the Eastern Cape to Southern Mozambique and used to restore the voice after an illness (SANBI, 2013).

2.2.3 Valuable land for cultivation

(Frenken *et al*., 2002) indicated that, the use of wetlands for agriculture has increased over the years as the poor see it as an opportunity to cultivate during the dry season to earn more income and further reduce poverty and food insecurity. Wetlands are often drained so that plants not adapted to the waterlogged conditions can be grown and this has important environmental impacts, requiring that the cultivation of wetlands be well controlled (Kotze, 2002). (Mulatu *et. al*., 2015) indicated that the analysis of socio-economic impacts of wetland cultivation in South- Bench in Southwest Ethiopia shows that most of the households benefited from wetland cultivation through growing different crops.

Collins, 2005) indicated that wetland soils are potentially productive, but the anaerobic conditions associated with wetlands exclude most commonly grown crops, except for those specially adapted, such as coco yam (*Colocasia esculenta*) and rice. The study concludes that farming around Eriti wetland is profitable and thus recommends that farmers should be encouraged to cultivate fruity vegetable, rice and cassava to maximize their profit (Agatha *et al*., 2015).

2.2.4 Harvesting of raw materials

Wetland plants have been used for thousands of years, providing valued materials for products such as mats, baskets, and paper, produced from papyrus, which is sedge (Traynor *et al*., 2010). In South Africa for example, many types of foods harvested from wetlands which includes bullfrogs, cane rats and they are popularly eaten in many areas. Wetland plants have been used for thousands of years, providing valued materials for products such as mats, baskets, and paper, produced from papyrus, which is sedge (SANBI, 2013). In South Africa, wetland plants have been used for long period of time and is continued to be harvested for different reasons or purposes including, subsistence and commercial purposes. There are several plant species which are suitable and are used extensively for making handcrafts in South Africa, such as the rush *Juncus krausii* (iNcema), and the sedges *Cyperus latifolius* (Ikhwane) and *C. textilis* (iMisis) is used for construction purposes e.g. houses (Kotze *et al*., 2002). Some of the wetland plants are used for medicinal purposes. For example, *Acorus calamus* is one of which is used to treat epilepsy, asthma and improve memory power (Panda and Misra, 2011).

2.2.5 Livestock grazing

Wetlands, especially temporarily and seasonally waterlogged areas may provide very valuable grazing-lands for domestic and wild grazers and this is particularly so in the early growing season and during droughts when grazing reserves are low in the surrounding veld (rangeland) but the wetlands continue to produce a lot of grazing. Utilization needs to be sustainable if the wetland is to maintain its value for grazing and with dry land pastures; wetlands are only able to sustain a certain amount of animal grazing (Kotze, 2002).

(Collins, 2005) indicated that grazing may have both positive and negative effects on the benefits of wetlands and some wetlands erode easily if they are disturbed by trampling and grazing. Furthermore (Collins, 2005) indicated that utilizing the wetlands, sustainability is required if the wetland is to maintain its value for grazing. As with dry land pastures, wetlands are only able to sustain a certain amount of grazing, where particular care is required in wetlands where the erosion hazard is high. (Palmer *et al*., 2002) indicated that commercial farmers in South Africa rely on wetland ecosystem for providing grazing resources during the dry season.

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2.2.6 Water purification

Wetland provide water for bathing, washing clothes, consumption and in other communities it helps them to save time and money from buying water in another area (Turpie *et al*., 2010). The wetlands around the Klip River in Southern Johannesburg have been cleaning the water released by gold mines there for the past 100 years, along with more recent industrial and urban pollution (SANBI, 2013). In 1990, it was shown that without the Cangaree swamp in

South Carolina, the area would need 5 million dollar waste water treatment plant (U.S. Environmental Protection Agency, 2005).

Wetlands are natural filters, helping to purify water by trapping pollutants for example sediments, excess nutrients most importantly (nitrogen and phosphorus), heavy metals, disease-causing bacteria and viruses as well as synthesized organic pollutants e.g. pesticides. Water leaving a wetland most often is cleaner than the water which enters it. Wetlands are able to purify water efficiently by slowing down the flow of water resulting in sediment carried towards the water to be deposited. This also results in the trapping of other pollutants (e.g. phosphorus) which are attached to soil particles. Surface water is spread out over a wide area, facilitating exchanges between soil and water (Collins, 2005).

Furthermore (Collins, 2005) indicated that there are various chemical processes taking place in wetlands that remove pollutants from the water. For example, they provide a suitable place for de-nitrification because anaerobic and aerobic soil zones are found close together. However, an abundant organic matter in wetland soils provides suitable surfaces for catching some of the pollutants such as heavy metal. Also, wetland micro-organisms aided in decomposing man-made organic pollutants, such as pesticides. (Kotze, 2000) regard wetlands as natural filters, helping to purify water by trapping pollutants, they do this by removing the sediment, excess nutrients such as nitrogen and phosphorus, heavy metals, disease-causing bacteria and viruses and synthesized organic pollutants such as pesticides. (Barbier *et al*., (1997) also confirmed that wetlands in Uganda near Kampala are conserved because they purify water.

2.3 Major causes of land use/cover change in wetlands ecosystem around the globe

2.3.1 Increase of human population

The increase in an area's population would mean an increase in the interactions and therefore ecosystem changes (Mutyavaviri, 2006). The study conducted by Hove *et al*., (2013) using socio-economic data to detect wetland degradation in Magwenzi wetland found that human population has increased significantly by more than 100% around 1980 to 2010. Furthermore, the study revealed that human population growth increase pressure on limited wetland resources as households continuously exploit wetland ecosystem to meet the demands of the growing household size. Bali wetland has been affected due to development of hotels and expansion of human settlement over 22 years of observation (Wsandi *et al*., 2006).

The analysis of remote sensing and GIS techniques shows that the major changes of land use/cover change in Chennai coastal was due to rapid population and industrial growth in the coastal belt (Santhiya *et al*., 2010). The analysis of socio-economic data shows that the rapid and unprecedented population increase and unplanned informal housing has led to wetland encroachment and destruction in Kampala city (Byaruhanga *et al*., 2012). Schuyt, (2005) indicated that the development of human settlement along riverine and wetland areas due to the suitability for farming and easy availability of water for cultivation has caused human population migration to the wetlands ecosystem. Turpie, (2010) indicated that the increase of population in Mfuleni informal human settlement has led to the dwellers to be the main users of wetland areas.

2.3.2 Agriculture and industrial activities

The socio-economic data shows that the cultivation has been reported to be contributing factors to the impacts on wetland ecosystems because agricultural expansion increases the yields and the response to population growth, create an increase demand for agricultural land. The clearance of land had direct impacts on Magwenzi wetland biodiversity and various tree, grass and animal species were affected by farming (Hove *et al*., 2013). The analysis of social survey has revealed that a large number of farmers in wetland areas do not take environmental effects of agriculture into account due to the ignorance of wetland functions, values and magnitude of their effects on wetlands ecosystem (Mironga, 2004).

The analysis of social survey and GIS were integrated to assess the effects of land use change to the quality of urban wetlands. The analysis showed that both methods complement each other as both results revealed that 13.4 % of the wetland has been lost either by cultivation and recreational activities. These activities have had detrimental effects to the wetland biodiversity (Murungweni, 2013). The remote sensing and GIS data revealed that the average water depth of Hokar Sar wetland has reduced significantly, wetland has attained eutrophication condition and the overall ecosystem of the wetland has been found to be degraded because of the conversion and encroachment of wetland area into agricultural land by the local farmers (Akhtar *et al*. 2011).

A study conducted at Mfuleni (Turpie *et al*., 2010) reveal that agriculture was practiced on the wetland itself affecting its ecosystem. Agricultural activities in wetland have led to introduction of alien species in the area resulting in the alteration of wetland ecosystem functions. The conversion of wetland to other land uses such as crop production in Victoria wetlands was due to high demand of land to produce food for local people to meet their basic needs (Musamba *et al*., 2011). Chinnai coastal area has been affected due to fertilizers plant, refineries, petroleum products and tryes manufacturing leading untreated effluents containing heavy materials and toxic chemicals affecting coastal and marine ecology and affected the sensitive ecological area for birds migrating habitat (Santhiya *et al*., 2010).

2.3.3 Heavy grazing

Study conducted by (Hove *et al*., 2013) shows that the total size of herd that graze on the wetland has increased and reducing land cover and altering wetland ecosystem interactions leading to soil compaction, overgrazing on the wetland and hydrological effects. Furthermore, the study found that the animal tracks are causing habitat fragmentation which significantly alters some species interaction in the wetland as their ecological niche is disturbed. The effects of livestock grazing on species composition have been found to ultimately affect the structure and function of wetland vegetation. Furthermore, stock grazing is however frequently accompanied by deleterious impacts such as soil infiltration, nutrient enrichment and bacterial contamination from dung and urine (Jansen, 2003). The analysis revealed that heavy grazing pressure in Kamiesberg uplands wetlands has contributed to the decline in the abundance of indigenous perennial grasses.

(Ausden *et al*., 2005) investigated the effects of cattle grazing on tall-herb fen vegetation in England and found that grazing reduced the biomass of Cosmopolitan common reed (*Phragmites australis)* and increased stem densities of the grass Great Manna Grass (*Glyceria maxima)*, resulting in a shift of dominance from *phragmite*s to *Glyceria*. Such effects can have influence on bird populations, communities and species diversity by making a wetland less suitable for reed –dwelling species and more attractive to grass frequenting species. Livestock access to wetland area can adversely affect wetland biodiversity; reduce vegetation biomass, change plant composition, and deposit faeces and urine directly into water. Extensive stock trampling can also transport wetland material, resulting in increased fluxes of sediment and organic material entering streams (Hughes, 2013).

The Remote Sensing/GIS and social data has shown to be instrumental to assess the impact of wetland resources utilization as observation from the satellite images indicates progressive depletion of wetland size as seen from changes in biomass cover on the floodplain drained by Simiyu river and its tributaries. Furthermore, the analysis revealed that, there is progressive degradation of land resources in the Simiyu basin that the bare ground increased from 11.4% in 1985 to 37% in 2005 presumably due to increased density of livestock (Mwakalila, 2006).

2.3.4 Overexploitation and over-harvesting of wetland resources

(Traynor *et al*., 2010) indicated that wetlands in arid or semi-arid areas such as the Northern Cape are especially important resources because they supply grazing and crops during the long dry season. Furthermore, the study revealed that at the same time, they are increasingly under threat due to over-exploitation leading to land use change of wetlands. Overexploitation of wetland resources is a major threat to the sustainability of the Nyando wetland due to the use of destructive fishing techniques, degradation of the wetland environment and invasion by alien species (Morrison *et al*., 2012). Other wetland macrophytes threatened by overexploitation in wetland ecosystems include *Sesbania sesban* (Asao) and *Pycreus nitidus* (Se) these species are known to be used as building materials (Masese *et al*., 2012). (Morrison *et al*., 2012) stated that pressure on wetland resources has increased in recent years with the expansion of human settlements and farmlands and this has led to competition among mutually exclusive wetland uses. Wetlands are one of the most productive areas on the earth and known to attract many different groups of users and stakeholders who seek to access their resources. Wetland plants can be harvested sustainably for weaving of traditional and tourist craft (SANBI, 2013).

2.3.5 Infrastructure development and urbanization

Urban sprawl and infrastructure development is the major contributing factor on the wetland degradation. Infrastructure development involves both human settlement expansion as well as the expansion of transport networks (Murungweni, 2015). Furthermore, (Murungweni, 2015) indicated that wetlands resources are threatened as people built infrastructures such as residential houses within the wetlands result in the loss of biodiversity and degradation of the wetland. Housing development usually negatively impacts wetlands from both the surface and underground perspectives. In Lagos, Nigeria, it was identified that wetlands are being affected by the construction activities occurring in the City. It emerged that construction activities result in the alteration of water quality, indirect modification of the hydrological system and loss of habitat (Ajibola *et al*., 2012).

The analysis revealed that property development was the single most destroyers of wetlands in the Bungoma Municipality through drainage, dredging deposition of fill material, diking and damming, construction, air and water pollution, changing nutrient levels and release of toxic chemicals (Rodgers, 2013). Development in urban and rural areas now is the cause of more than 60% of national wetland loss. The construction of roads across streams and wetlands can also cause hydrologic changes that extend a significant distance upstream and/or downstream (Kotze *et al*., 2009).

Urban development and intensive agriculture in wetlands areas are the major threat to the health, productivity and biodiversity of the wetland ecosystem. Furthermore, some urban agglomerations are seen as the more responsible for changes in land cover in wetlands as the results of urban expansion which lead to ecological damage within the wetland ecosystems (Wu, 2006) and (Lubowski *et al*., 2006).

2.4 Effects of different land use activities on wetland ecosystem

2.4.1 Mining impact

Ecological impacts of mines are diverse, and are both direct and indirect. The extent, intensity and duration of these vary with mining type and size of the mineral deposit. The effects of mining increase the loss of habitats and impair the quality, functionality and delivery of ecosystem services. Key impacts include alterations to the water table, a decline in the functioning and quality of aboveground natural ecosystems at the mine and its surrounding areas, and visible changes to the scenery by mine dumps, slime dams and open pits (Zeitsman, 2011). (Rogers, 2004) indicated that mining activities has got large chemical impacts especially coal and gold mining industries contribute to the sediment load in South Africa Rivers and wetlands. He further indicated that water-borne sediments entering a wetland may have many impacts affecting wetland vertebrate fauna through its effects on feeding efficiency and breeding success. The preliminary analysis has revealed that the establishment and development of the Witwatersrand urban area has affected Klip River wetland due to rise in the concentrations of several heavy metals and phosphorus in the discharged water, which is reflected in increasing concentrations in the peat (McCarthy *et al*., 2006).

(SAEO, 2012) indicated that the impacts of mining include pollution of ground water systems, disruption of land forms and disturbances to local plant and animal communities. Mine dumps are often susceptible to alien plant infestations (due to decline in ecosystem resilience), and thus serve as source centres for dispersal to surrounding areas. (Adcock, 1984) indicated that wetlands impacted by acid mine drainage are those surrounding the gold fields of the Witwatersrand and carrying run-off from the coal mines to the east of Johannesburg.

A recent study conducted by (Naicker *et al*., 2003) confirmed that the ground water in Johannesburg area, South Africa is heavily contaminated and acidified because of mines tailings dumps. (Christianen *et al*., 2011) indicated that land use changes in tropical regions such as mining activity not only affect freshwater and terrestrial ecosystems but also have a strong impact on coastal marine ecosystems. (Camp *et al*. 1981) indicated that wetlands that are mined for peat are significantly modified, often being transformed into open water habitat. Phosphate mining has resulted in the loss of thousands of acres of wetlands in central Florida (Mitsch and Gosselink, 1993). Acid drainage from active and abandoned mines causes extensive ecological damages and the acidity and the high metal concentrations alter the biotic community composition that can result in mortality (Lacki *et al*., 1992).

The impact of mining on wetlands ecosystem widely depends on the method of mining adopted, the geo-mining conditions of the area in question, the size and duration of the mining operations. In contrast to underground mining, open-cast mining usually results in extensive damage on the wetlands. These will affect the wetlands in a number of ways and concentrations of people in a particular locality may result in the increasing of the demand for public facilities; damage to property, crops and livestock; disturbance of existing landscape; dereliction of land; felling of trees; pollution of both ground water and surface water and many more similar effects on the natural environment (Allister *et al*., 2009).

2.4.2 Loss of biodiversity and habitat

(Liu *et al*., 2004) indicated that the loss and fragmentation of wetlands as a result of agricultural development over 50 years has impacted wetland communities and its biodiversity. Wetlands mammals are more threatened than terrestrial mammals due to human intervention within the wetlands ecosystem (Buhrmann *e.t al*., 2002). Human activities currently dominate all ecosystem functions in South Africa leading to the continued decline of species and loss of biodiversity in a wetland ecosystem. The conversion of wetland ecosystems due to various land use such as human settlement, agriculture and development is the most significant causes of biodiversity loss in South Africa (Kotze, 2002).

2.4.3 Water pollution

In eastern South Africa, 50% of the wetlands have been lost or degraded as a result of modification by subsistence agriculture (SANBI, 2013). (Kotze *et al*., 2009) indicated that urbanization, industrialization, and population growth have aggravated the significance of water pollution as a threat to the persistence of South Africa's wetland resources and the wide range of water borne pollutants are nutrients, acidic compounds, sediments, salts, heavy metals, and biocides are considered most significant in terms of their impact on wetlands and biota.

2.4.4 Effects on Streamflow regulation

Road crossings may greatly modify water flow patterns in wetlands, and the building structures in a wetland result in serious gully erosion, detracting from the ecological and hydrological values of the wetland (Kotze, 2002). Normal sedimentation rates in coastal wetlands are necessary to reduce land subsidence. Channelization and channel modification alter in stream water temperature and diminish habitat suitable for fish and wildlife (USEPA, 1993a). Changes in land cover can lead to significant changes in leaf area index, evapotranspiration, soil moisture content and infiltration capacity surface and subsurface flow regimes including base flow contributions to streams and recharge, surface roughness as well as soil erosion through complex interactions among vegetation, soils, geology, terrain and climate processes. Furthermore, land use modifications can also affect flood frequency and magnitude. Land use changes such as urbanization, deforestation, and reforestation continue to affect groundwater-surface water interactions including percolation or recharge, groundwater contributions to streams, and soil moisture as well as water availability influencing ecosystem services (Hundecha *et al*. 2004). Deforestation changes the hydrological, geomorphological, and biochemical states of streams by decreasing evapotranspiration on the land surface and increasing runoff, river discharge, erosion and sediment fluxes from the land surface (Coe *et al.*, 2011).

2.4.5 Over – grazing

Most cattle use on public lands occurs during the hot season when cattle seek cooler areas while foraging, such as riparian wetlands. Therefore, riparian wetland sedges and riparian wetland vegetation frequently become over grazed. Reduced height of sedges and other species comprising riparian wetlands not only reduces replenishment rates for organic material, but it has other adverse effects as well. Wildlife frequently suffers when riparian wetlands are over grazed, e.g., reduced cover for sage hen chicks and less food for wildlife (Corning, 2002).

2.4.6 Roads and bridges constructions

Study conducted by (Yisha, 2013) found that roads and bridges are frequently constructed across wetlands since people thought wetlands have low land value in Canaan valley wetland leading wetland near the Windwood Fly-in Resort airport to decrease since 1992. Roads can impede movement of certain species or result in increased mortality for animals crossing them. Borrow pits (used to provide fill for road construction) that are adjacent to wetlands can degrade water quality through sedimentation and increase turbidity in the wetland (Irwin, 1994). Roads and bridges are frequently constructed across wetlands and is often considered to be more cost effective to build roads or bridges across wetlands than around them (Winter, 1988). Roads can also disrupt habitat continuity, driving out more sensitive, interior species, and providing habitat for harder opportunistic edge and non-native species. The maintenance and use of roads contribute many chemicals into the surrounding wetlands and rock salt used for roads can damage or kill vegetation and aquatic life (Zentner, 1994).

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY

3.0 Introduction

This chapter details the methodology employed in conducting the study using a remote sensing, ArcGIS and social survey approach and it aims to describe the research design, ethical considerations and overall research methodology, detailed procedures of sampling and sampling size, methods of data collection and methods of data analysis.

3.1 Research design

The research design is the procedure and conditions for data collection and analysis to combine the relevance of data with the purpose of the research (Kothari, 2004). This study adopted the descriptive research design using both quantitative and quantitative data and change detection method. A quantitative technique was used for describing statistically the association of various variables on the social survey and remote sensing/ArcGIS, while qualitative technique explored the opinions and attitudes about the issues in the research. This is a case study research with the aim of assessing the impacts of land use changes on Duthuni wetland ecosystems. In order to answer research questions adequately, different data from various sources was collected by means of the social survey (questionnaires, field survey, observation and key informants) and remote sensing/GIS (satellite images and maps). The collected data was analyzed using various techniques tools such as ERDAS imagine (version, 2015) and Arc GIS 10.1 software in order to detect land use changes/cover over different periods in the study area.

3.2. Ethical considerations

During data collection in the study area, the ethical issues were taken into consideration. The researcher first got permission to collect data from the chief of the village. The researcher also explained to participants what the research was about and they were told that they had the right not to participate or withdraw to participate at any time. All participants were also told that they are not going to be identified by their names and their information will be kept confidential.

3.3 Research Methodology

The methods of data collection in the study include both qualitative and quantitative techniques. This is a case study research where both qualitative and quantitative techniques were combined and adopted because both methods complement each other (see figure 3.1 refers). These methods have been used to increase the accuracy of findings and the level of confidence in this research. The quantitative technique was used statistically to describe different results and qualitative technique was used to explore the knowledge regarding the impact of land use changes in the study area. In this case, a triangulation mixed methods approach were used as a method of collecting both quantitative and qualitative data, analyzing the results, compared and interpreted them.

Invakova *et al*., (2007) defined mixed methods research as "a procedure for collecting, analyzing and "mixing" both qualitative and quantitative data at some stage of the research process within a single study to understand a research problem more completely". In this case, data was mixed, integrated and interpreted to provide more comprehensive evidence and better (stronger) inferences. The other reason of using the mixed method in this study as described it is because it eliminates different kinds of bias, describes the true nature of the subject being investigated and improves various forms of validity or quality criteria. The below methodology was used:

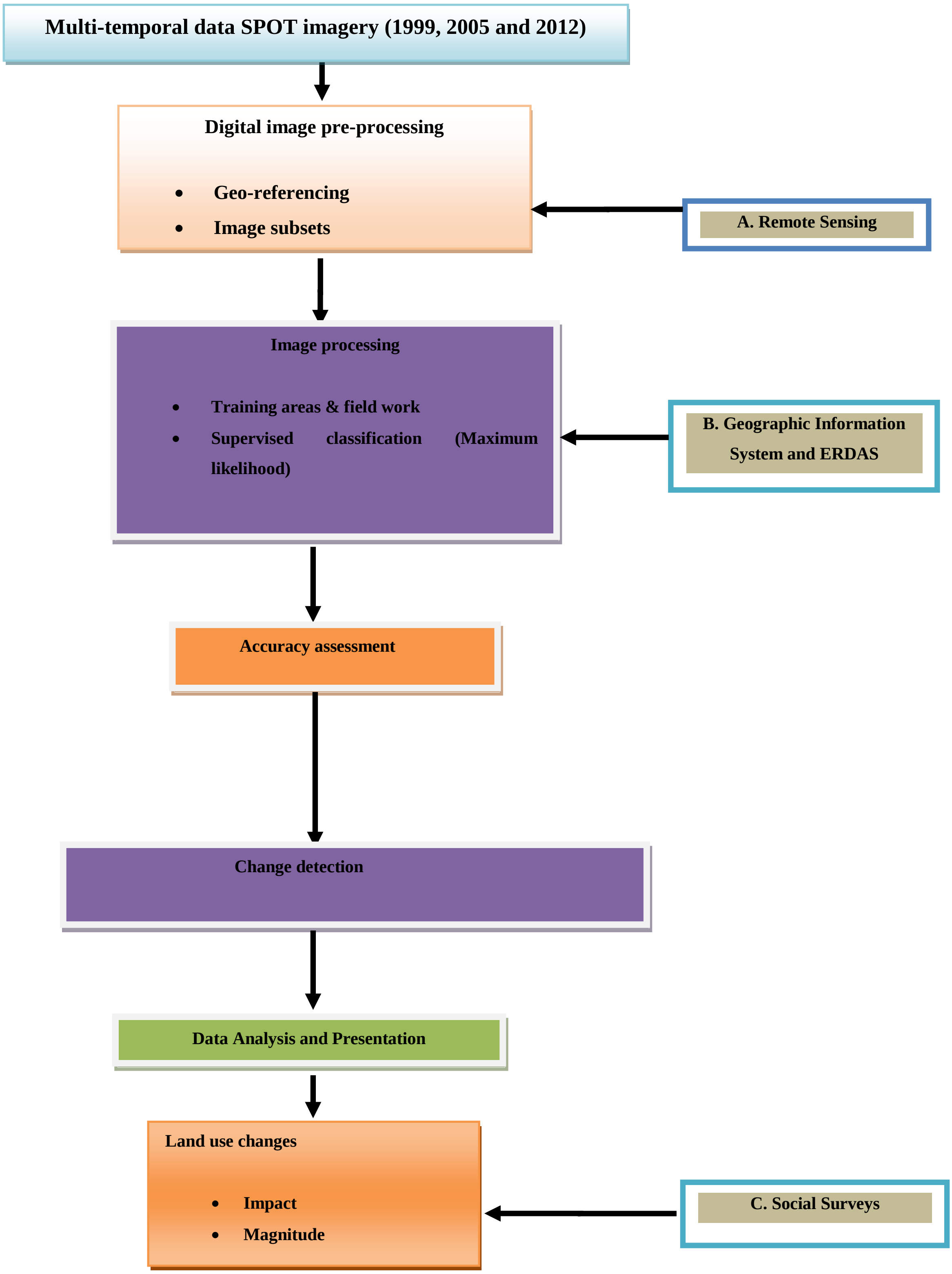

Figure 3.1: Research methodology

3.3.1 Method of sampling and sampling size

There are different methods of sampling such as random sampling, stratified sampling, convenience sampling and random sampling. In this case, a random sampling was chosen as the best sampling method for this study because every member of the population in the study area had an equal chance of being included in the sample. Random sampling also known as probability sampling, is that method of drawing a portion, or a sample, of a population so that each member of the population has an equal chance of being selected (Monette *et al*., 2005). In this research, out of 225 households, 150 were sampled which represents the population of the study area. This means that not all the households were part of the sampling for the purpose of reducing time and cost.

Households who have been dwelling in the study area were randomly selected based on the fact that they have witnessed land modification. Farmers were selected based on the fact that they have been farming in the area for a long time and have seen changes on land use/ land cover change over the years. The Chief and Municipality were selected because they have valid and accurate information regarding land use changes in the study area. The respondents were randomly selected based on their backgrounds of the area. Satellite images from different years were selected and sampled to get detailed information about the wetlands in the study area. The below table 3.1 and 3.2, represents the sampling methods used for satellite data and social survey data respectively.

Table 3.1: Satellite data sampling method

Research objectives	Sources of information	Sampling methods	Data analysis
Examine the impact of the present and past land use change dynamics on the wetland;	• Satellite images (SPOT imagery) ➢ Field observation	• Supervised image classification ➢ Maps and satellite images	• Satellite SPOT imagery using GIS and Erdas software from 1999 to 2012
Determine the trends and spatial extent of land use change;	• Satellite images (SPOT imagery) ➢ Field observation	• Supervised image classification ➢ Maps and satellite images	• Satellite SPOT imagery using GIS and Erdas software

Table 3.2: Social survey sampling method

Research objectives	Sources of information	Sampling methods	Sampling size and data analysis
Examine the impact of the present and past land use change dynamics on the wetland;	• Social survey (questionnaires) • Key informants • Field observation	• Random sampling	• 150 Households • Content analysis
Determine the trends and spatial extent of land use change	• Social survey (questionnaires) • Key informants • Field observation	• Random sampling	• 150 Households • Content analysis
Determine the major drivers of land use change	• Social survey (questionnaires) • Key informants • Field observation	• Random sampling	• 150 Households • Content analysis
Assess the environmental and socio-economic impacts of land use change on wetland ecosystem	• Social survey (questionnaires) • Key informants • Field observation	• Random sampling	• 150 Households • Content analysis
Assess the current utilization of wetland resources by the local people.	• Social survey (questionnaires) • Key informants • Field observation	• Random sampling	• 150 Households • Content analysis

3.3.2 Social survey data collection

The social survey deals with subjective data that are produced by the thoughts of respondents or interviewers and its aim is to understand the importance which respondents attach to their environment (Welman *et al*., 2005). Primary data collections in the study area were done in the form of distributing questionnaires to the various households, various key informants, and field observation. The reason for conducting the social survey was to complement remote sensing data. The social survey was crucial to meet research objectives which are to assess the environmental and socio-economic impacts of land use change in the study area; determine the major drivers of land use changes, assess the current utilization of wetland resources by the local people and examine the impact of the present and land use change dynamics on the wetland ecosystem.

- **Questionnaires**

Questionnaires were designed to cover a wide range of information needed to answer research objectives and questions. Questionnaires contained the language that respondents understand. The questionnaires comprised of semi- structured and structured questions. The main reason for using such questionnaires is because semi-structured questionnaires comprised of questions which were prearranged with open-ended questions to allow respondents to write their own opinions whereas structured questionnaires comprised of closed-ended questions of which the information is quantifiable. Questionnaires were distributed to a sampled 150 households with the help of the research assistance to assist where respondents didn't understand.

- **Key informants**

The questionnaires were distributed to the key informants such as farmers, chief of the village and government officials. It was important to identify various key informants to avoid results that are one-sided or biased. The key informants were carefully chosen by the researcher bearing in mind that they have knowledge, understanding and provide insight on the nature of problems and give recommendations for solutions concerning the impact of land use changes in the wetland ecosystem.

- **Field survey/observation**

The main purpose of the field survey/observations was to observe what is actually taking place in order to complement the specific objectives of the study which are to examine the impact of the present and land use change dynamics on the wetland; determine the trends and spatial extent of land use change; determine the major drivers of land use change; assess the current utilization of wetland resources by the local people; assess the environmental and socio-economic impacts of land use change. It was crucial to conduct a field survey to observe the magnitude of the impact of land use change. Field survey and observations were done to locate training area for supervised classification and also verified how closely the classification map agrees with the ground truthing actual field situation. GPS points of different locations together with their respective cover classes were recorded and verified in the field for the purpose of accuracy assessment.

3.3.3 Remote sensing and GIS data collection

In this study SPOT 4 imagery was used with the swath width of 60 km x 60 km to 80 km at a nadir in order to collect the required data from satellite imagery. Multi-temporal images were ordered at SANSA. SPOT 4 images of 1999, 2005 and 2012 were used covering the scene of the study area because there was no recent one available. 1999, 2005 and 2012 images were geo-rectified and all were radiometrically corrected and cloud free, therefore the images did not have errors arising from fluctuations in orbital and platform attitudes of the satellites. Images were selected due to their availability and the acquired dates are as follows: 08 august 1999 with the K/J reference (***135/396***), 31 October 2005 with the K/J reference (135/396) and 5 November 2012 with the K/J reference (135/396).

During digital image pre-processing, imagery for 1999, 2005 and 2012 was imported to the ERDAS imagine version 2015 and geo-referenced. Google earth image was used as a base image. A minimum of 25 ground control points was used. Road junctions and dams were used as ground control points. In this study, UTM projection was used as it is a commonly used and preferred projected coordinate system. WGS 1984 datum was used because it is the reference coordinate system used by the Global Positioning System. Three Imageries were subset using ERDAS imagine software 2015 and distinctive landmarks in both images were identified to ensure that coverage overlaps spatially. The geostatistical analyst in ERDAS imagines was used to create subsets of sample points for training and accuracy assessment.

Image classification is the process of assigning pixels to classes and usually, each pixel is treated as an individual unit composed of values in several spectral bands. This study used supervised image classification process where it can be defined informally as the process of using samples of known identity to classify pixels of unknown identity (Cambell B *et al*., 2011). Signature creation was performed on all 3 images using ERDAS imagine. Polygons were created around the points for the creation of signatures from which the classification would be made. 5 signature classes were created using the signature editor of ERDAS and this process was performed on all three images. The created signature classes covered the wetland and adjacent area.

The created signatures are as follows:

Water: All open bodies of water including streams and wetland

Healthy vegetation: All vegetation which is healthy

Dry vegetation: All vegetation which is dry

Bare soil: All cultivated area including roads and all degraded area

Residential area: An area where there is permanent concentration of people, buildings & man- made structures

Maximum likelihood was used as one of the best specific algorithm methods for supervised classification in this study. The maximum-likelihood algorithm assumes that the statistics for each class in each band are normally distributed and calculate the probability that a given pixel belongs to a specific class (Cambell *et al*., 2011). Trotter (1998) indicates that a band combination of red, blue and green (RGB) is the good combination because it displays images in standard colour composites and visual interpretation for land use and vegetation mapping which are often used in the tropics. In this study, SPOT 4 images displayed a band combination 1, 2 and 3 (Red, blue, green) for the purpose of visual interpretation for land use. SPOT 4 (Four) images of the different years (1999, 2005 and 2012) were used in order to reflect the true wetland conditions.

After classification completed it was important to determine the accuracy of the final images. Accuracy assessment compares two sources of information, one based on analysis of remote sense data and another based on a different source of information assumed to be accurate (Cambell *et al*., 2011). This study adapted the error matrix accuracy method. A random stratified sampling method using geostatistical analyst in ERDAS was used. In order to increase accuracy, the classified imagery for 1999, 2005 and 2012 was overlaid with SPOT 5 image for the purpose of accuracy assessment of the study area. It was crucial to compare the classified images with known points in order to achieve verification and accuracy of land cover for the classified imagery. Singh (1989) defined change detection as the process of identifying differences in the state of an object or phenomenon by observing it at different times. Cambell *et al*., (2011) defined change detection as an assessment of changes in the type or condition of the surface features. In this study, post-classification change detection technique was applied to detect the trends and spatial extent of land use change, determine major drivers of land use change, examine the present and past land use change dynamics and environmental, socio-economic impacts of land use change in the study area. This method consists only of comparing the ‘‘from’’ class and ‘‘to’’ class for each pixel or segment. Therefore, change information was extracted to determine how much change has resulted from different land covers over time.

Munyati (2000), Ramsey and Laine (1997) indicated that post classification has been commonly applied for wetland studies to determine the total area of wetland change and to identify specific locations of such changes and this method is the easiest change detection analysis technique based on the classifications. Change detection was done from 1999-2005 and 2012 imagery to get information of changes in land use and land cover in the study area. The land use change detection method was carried out using Post classification cross-tabulation in ERDAS imagine software and Microsoft office excel 2010. The final land use land cover maps were imported and produced in Arc GIS 10.1 software.

3.4 Data analysis methods

Data analysis includes the description of how collected data will be analyzed and concluded (Bless *et al*., 2007). The analyses of data in this study involve the data collected using the questionnaires, key informants, field survey/observation, remote sensing/GIS. Below presents the methods of data analysis adopted in this study.

- **Questionnaires**

Data obtained from questionnaires was captured in Microsoft excel and analyzed using Statistical Package for the Scientific Solution (SPSS). Data were presented by means of graphs, graphic statistics, and frequencies tables.

- **Key informants**

Interview data were collected through the voice recorder and notes. Content analysis was adopted to analyze the results collected from the interviews.

- **Field survey and field observation**

Data from field observation was analyzed using the Arc- GIS (version 10.1) and ERDAS software. This data was presented using the process of supervised image classification.

- **Remote sensing and GIS**

Imagery change analysis was carried out using Arc-GIS (version 10.1) software package and ERDAS (2015). This was done with the creation of image processing, signature classes, change detection and accuracy assessment. Data were presented by means of graphs, graphic statistics and frequencies table. Some data were presented using Microsoft Excel spread sheet (tabular output of results).

3.5 Summary

This chapter reveals and describes the logic behind research methods and techniques used in the study. The research methodology aims to describe the research design and methods of data collection, and detailed procedures for sampling participants and the methods of data analysis. This is a case study research in which triangulation of research methods including both qualitative and quantitative data collection, sampling and analysis strategies are adopted. The study unit of analysis comprise of the individuals, groups and institutions. Data gathering process involved multiple sources and techniques. This includes the use of remote sensing/ ArcGIS, document reviews, field observation and questionnaires.

CHAPTER FOUR: DATA PRESENTATION AND INTERPRETATION

4.0 Introduction

In this chapter, the captured data from the qualitative and quantitative techniques is presented, analyzed and interpreted respectively. In this study, data was analyzed using both the qualitative and quantitative methods and data were also linked to empirical evidence to obtain comprehensive data in accordance with the research aim. At this point in time, one must take a closer look at both methods of analysis. Firstly, the results are presented in the form of tables, bar charts, and land use/cover (LULC) change maps. Next, each theme has an empirical data that attempts to explain the findings which are specific to the research questions.

Furthermore, the analysis has been divided thematically according to the five research objectives namely: Examine the impacts of the current and historic land use dynamics on the wetland ecosystem; determine the trends and spatial extent of land use change; determine the major drivers of land use change in the study area; Assess the socio-economic and environmental impacts of land use change in the study area; Assess the current utilization of wetland resources by the local people.The research also covers various aspects of challenges encountered by Chief of the village, farmers, and community residing adjacent to the wetland ecosystem in the study area. The impacts of the current and historic land use dynamics were presented first on the Duthuni wetland ecosystem.

4.1 Examination of the impacts of current and historic land use dynamics

The findings of the past and present land use/cover changes acquired from remote sensing/GIS and the social survey is presented below with discussion based on the empirical evidence that attempts to explain the findings.

4.1.1 Imagery classification results using Remote Sensing/GIS technique

The criterion which was used to select satellite images was adopted from (Munyati, 1997). The approach was to select satellite imagery which can extract enough information for the study. In this case, dry season (August) images were chosen because the wetland system stands out from the surrounding dry land then, permits differentiation of a larger number of land cover classes than on wet season images. In the (wet season summer), the surrounding land also has green vegetation and is moist. The wetland system is at its weakest in the dry season and it was anticipated that any trends in wetlands quality and size could best be detected. For the land use change classification, SPOT 4 images were used. The results of land use/cover status of images are presented below:

4.1.1.1 Image classification of 1999

For the classification of 1999 image, a satellite image of 08 August 1999 was used. Table 4.1 below, shows the land use/cover for the year 1999. In this classification, healthy vegetation land-use/cover class was found to be a major land use/cover consisting of 181.507 hectares of total land. The reason why Duthuni wetland in 1999 (Fig. 4.1) was dominated by healthy vegetation class, is because there was low human population and low agricultural activities that took place in the wetland and associated resources. When the population is low, human impacts on the wetland and its natural resources is very limited.

Bare soil was covered by 37.564 hectares compared to residential land cover with 156.643 hectares. Water covered 15.590 hectares compared to dry vegetation with 149.184 hectares. From change detection analysis, it can be concluded that the level of area degraded by the community was small (Fig 4.1). This can be supported by the IPAT model which states that population growth and overpopulation plays a pivotal role in causing environmental deterioration. Therefore, in this case of Duthuni wetland, the low population in 1999 contributed to less or minimal environmental impacts within the wetland ecosystem. The total study area was 540.489 hectares. All this information is presented in (table: 4.1). Figure 4.1, represent land use/cover change of the year 1999 and the classified map is presented in (figure: 4.2). The overall classification accuracy assessment report was found to be 94% (table: 4.2).

Table 4.1: Land use/cover change (1999) in hectares

Class	Total area/hectare	Area in (%)
Bare soil	37.564	6.950
Water	15.590	2.884
Dry vegetation	149.184	27.601
Residential	156.643	28.981
Healthy vegetation	181.507	33.581
Total	**540.489**	**100%**

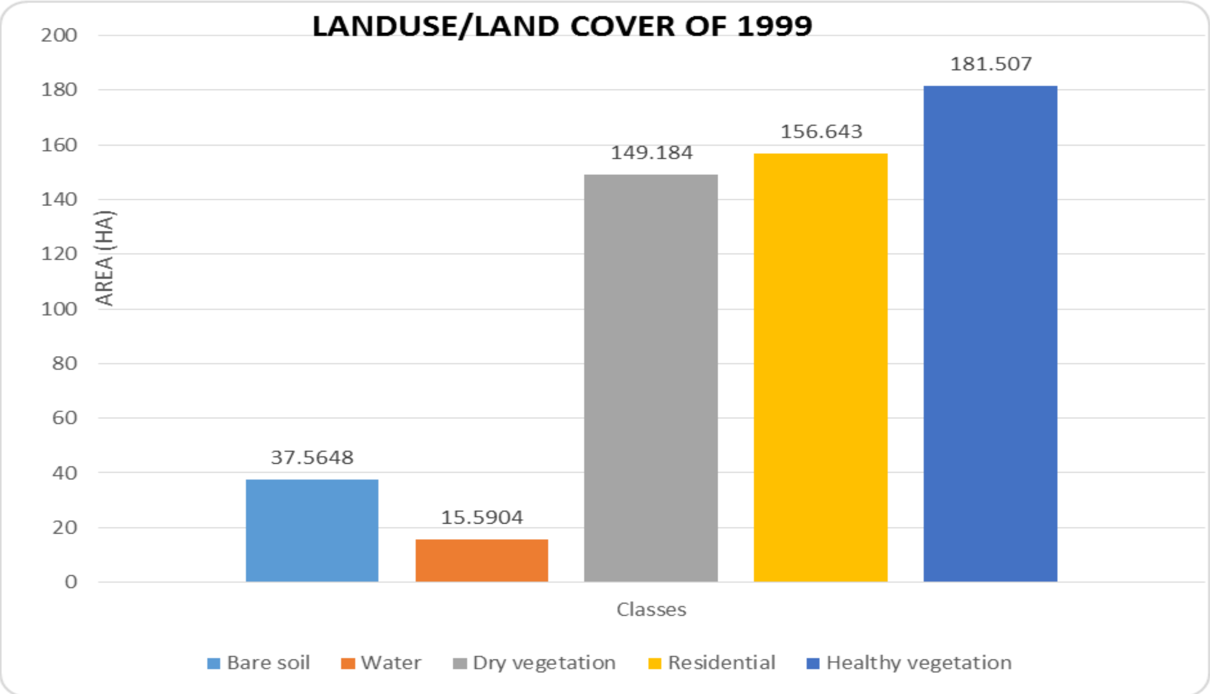

Figure 4.1: Land use/cover classes (1999) hectares

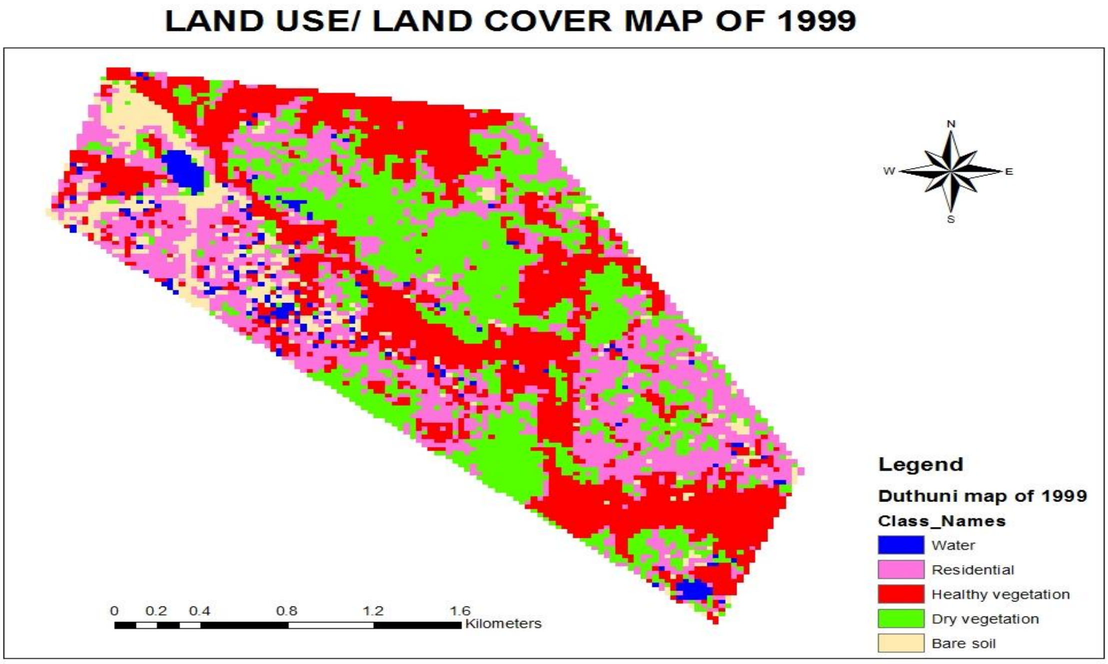

Figure 4.2: Land use/cover map (1999)

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File: e:/spot images/SPOT4_136_396_08_August_1999/classified
User Name: NWUUser
Date : Thu Sep 03 14:37:34 2015

Table 4.2: Land use/cover class (1999)

	Reference data				
	Reference total	Classified total	Number correct	Producer's accuracy (%)	User's accuracy (%)
Bare soil	2	3	2	100.00%	66.67%
Water	1	1	1	100.00%	100.00%
Dry vegetation	15	14	14	93.33%	100.00%
Residential	16	15	14	87.50%	93.33%
Healthy vegetation	16	17	16	100.00%	94.12%
Totals	**50**	**50**	**47**		

```
Overall accuracy = 47/50 = 94.00%
Overall Kappa = 0.9153= 91.53%
```

The overall accuracy is found to be **94.00%** and overall kappa was **91.53%** this means that many pixels were classified correctly.

4.1.1.2 Image classification of 2005

For the classification of 2005 image, a satellite image of 31 October 2005 was used. Table 4.3 shows the land use/cover for the year 2005.The land use cover data of 2005 was compared with data of 1999 respectively. Bare soil was decline to 25.688 hectares compared to 1999 bare soil which covered 37.564 hectares and the total area of land use/cover was covered by 555.875 hectares. Dry vegetation increased to 212.129 hectares compared to the dry vegetation of 1999 which was 149.184 hectares. This is due to decrease of healthy vegetation to 116.002 hectares compared to the year 1999 which was 181.507 hectares and also decline of water in the wetland area to 11.694 hectares compared to water of 1999 which was 15.590 hectares.

In accordance with the trends from the past, the residential land expanded again from 1999 to 2005 by 190.362 hectares compared to the year 1999 which was 156.643 hectares. Change detection analysis for 2005 image indicated the drastic increase in anthropogenic activities with a decline in the healthy vegetation cover in the wetland area. Healthy vegetation decreased due to higher demand of land use activities which impacted wetland ecosystem leading to soil erosion, loss of biodiversity, water pollution, overgrazing, agricultural activities and high demand for residential space. Table 4.3 and figure 4.3, represent land use/cover change of the year 2005 and the classified map is presented in (figure: 4.4). The overall classification accuracy assessment report was found to be 88% (table: 4.4).

Table 4.3: Land use/cover class (2005)

Land use/cover	Area (ha)	Area in (%)
Bare soil	25.688	4.621
Water	11.694	2.103
Dry vegetation	212.129	38.161
Residential	190.362	34.245
Healthy vegetation	116.002	20.868
Total	**555.875**	**100%**

Figure 4.3: Land use/cover classes (2005)

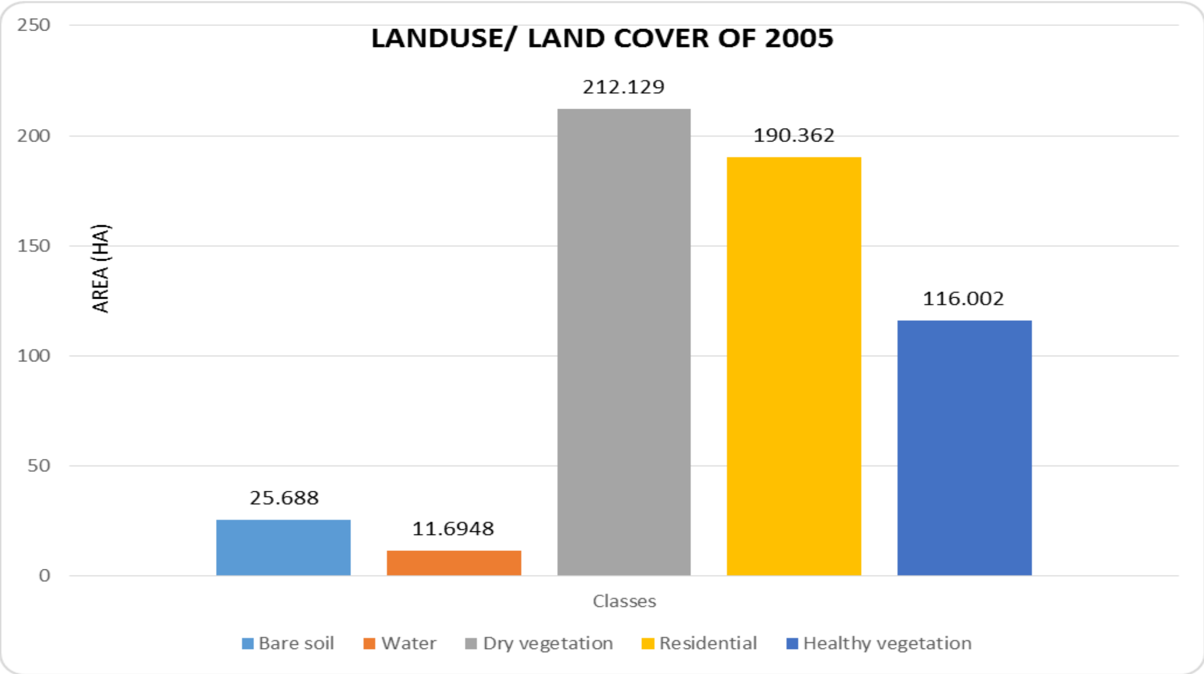

Figure 4.3: Land use/cover classes (2005) in hectares

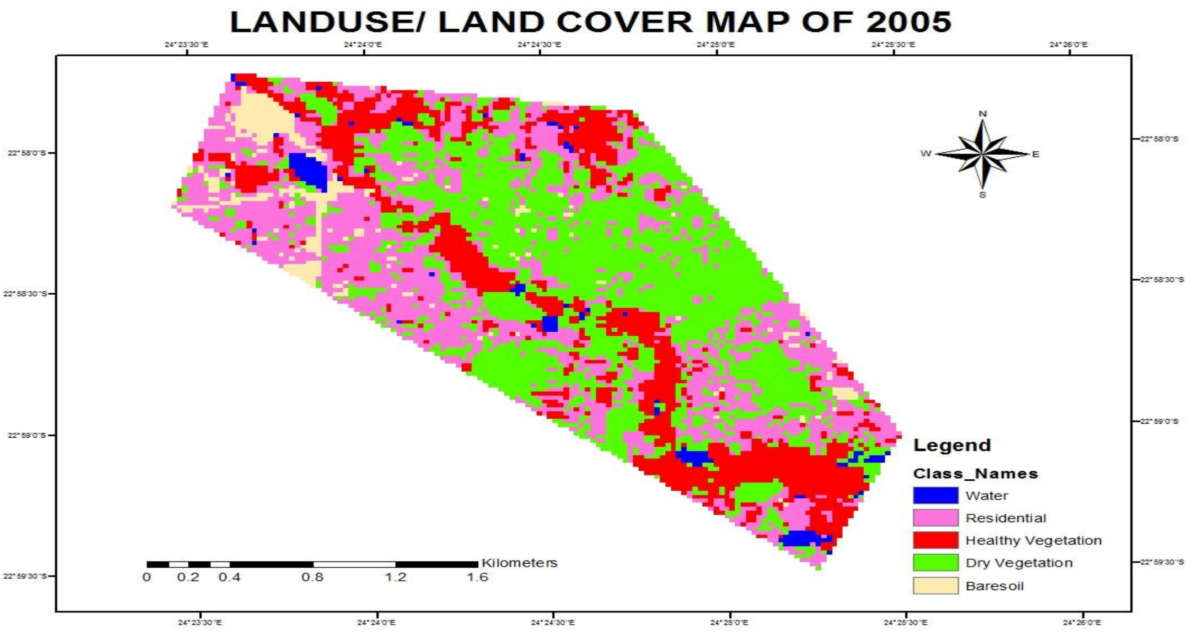

Figure 4.4: Land uses/cover map (2005)

CLASSIFICATION ACCURACY ASSESSMENT REPORT

Image File : e:/spot Images/SPOT4_135_396_31_october_2005/classified
User Name : NWUUser
Date : Thu Sep 03 17:16:09 2015

Table 4.4: Land use/cover class (2005)

	Reference data				
Class	Reference total	Classified total	Number correct	Producer's accuracy (%)	User's accuracy (%)
Bare soil	2	2	2	100.00%	100.00%
Water	1	1	1	100.00%	100.00%
Dry veg	19	19	16	84.21%	84.21%
Residential	18	17	16	88.89%	94.12%
Healthy veg	10	11	9	90.00%	81.82%
Totals	**50**	**50**	**44**		

```
Overall accuracy = 44/50 = 88.00%

Overall Kappa = 0.8254 = 82.54%
```

The overall accuracy was found to be **88.00%** and overall kappa was **82.54%**, this simply shows that many pixels were classified correctly. If this was not the case, the overall accuracy classification would be unacceptably low.

4.1.1.3 Image classification of 2012

For the classification of 2012 image, a satellite image of 05 November 2012 was used. Table 4.5 shows the land use/cover for the year 2012. It was also noted that residential land use/cover was still increasing with 225.734 hectares compared to the previous years. Change detection analysis indicates by the year 2012, Duthuni wetland experienced a drastic change in terms of land use/cover pattern. It has been detected that the residential areas and agricultural areas played a pivotal role in wetland transformation throughout the period of the study. As the population size increased, environmental impacts also increased due to the creation of various land use activities such as human settlement area and agricultural sites. Water has declined to 9.0432 hectares compared to previous years due to an increase of land use activities. Dry vegetation declines to 150.106 hectares compared to 2005 which was 212.129 hectares this is due to increase of human settlement area and expansion of the agricultural sites.

Healthy vegetation increases to 161.28 hectares compared to 116.002 hectares of the year 2005. Bare soil also declines by 23.2128 hectares. All this information is presented in table 4.5 below representing land us/cover of the year 2012. Figure 4.5, represent land use/cover change of the year 2012 and the classified map is presented in (figure: 4.6). The classification accuracy assessment report was also presented in (table: 4.6) below respectively:

Table 4.5: Land use/cover class (2012)

Land use/cover	Area (ha)	Area in (%)
Bare soil	23.2128	4.076
Water	9.0432	**1.588**
Dry veg	150.106	26.363
Residential	225.734	39.645
Healthy veg	161.28	28.325
Total	**569.376**	**100%**

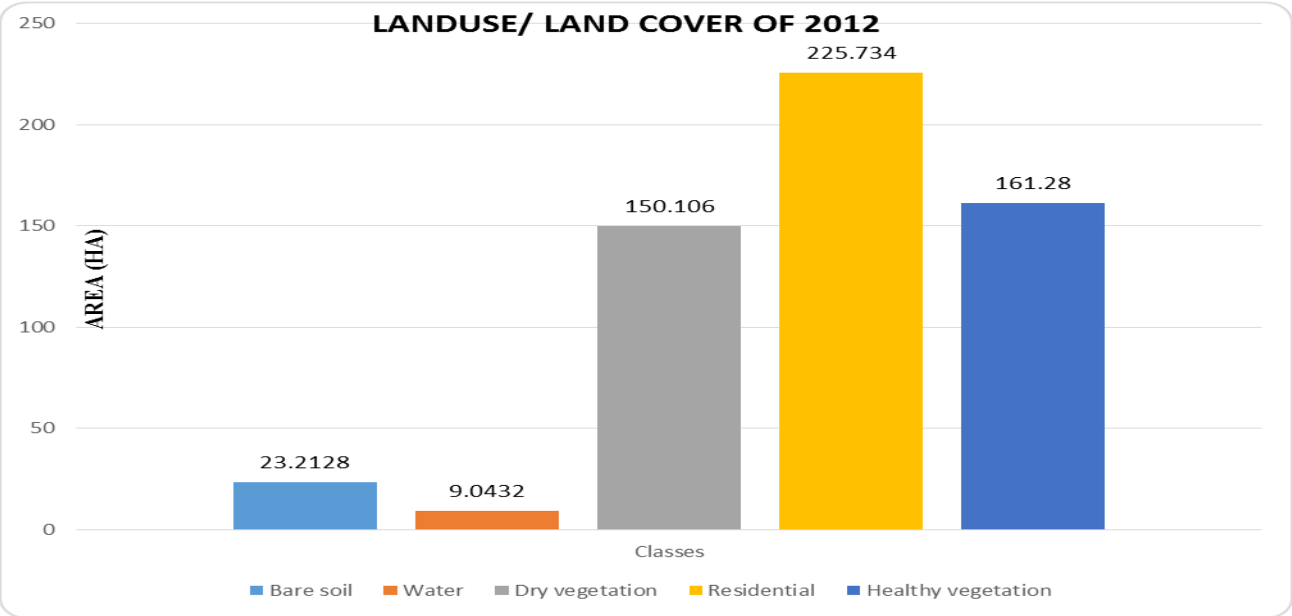

Figure 4.5: Land use/ cover classes (2012) in hectares

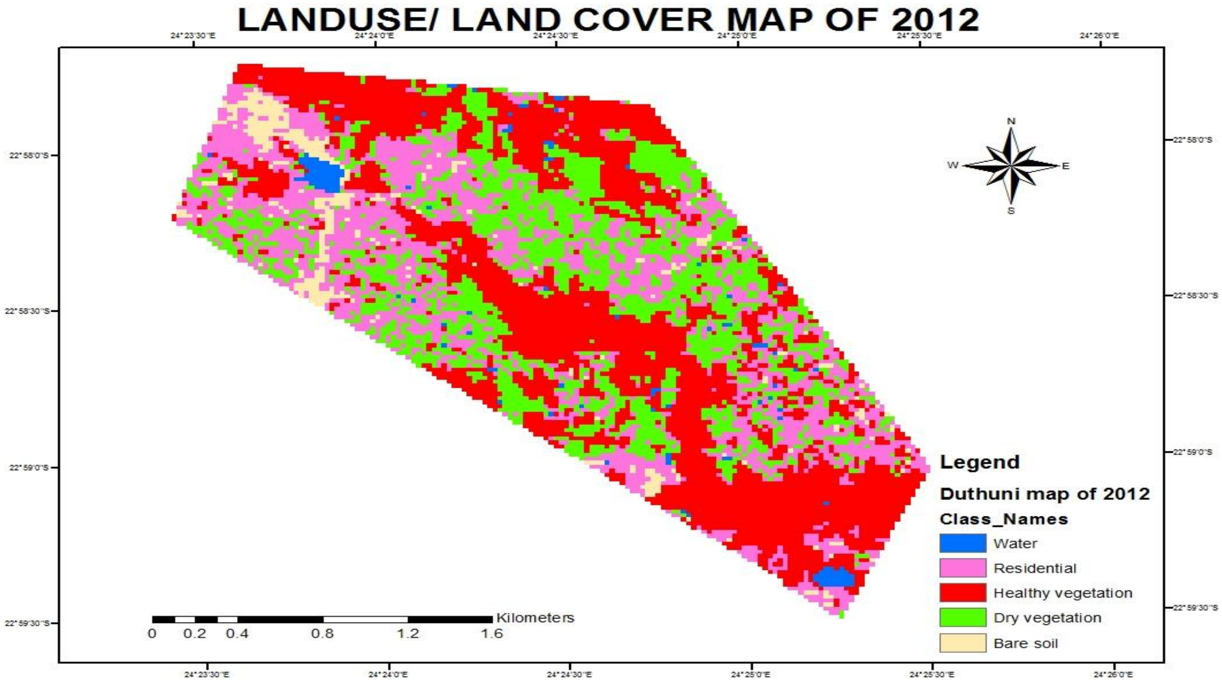

Figure 4.6: Land uses/ cover map (2012)

CLASSIFICATION ACCURACY ASSESSMENT REPORT

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Image File  : e:/spot images/ SPOT4_135_396_05_November_ 2012/classified
User Name   : NWUUser
Date        :  Fri Sep 04 10:02:52 2015
```

Table 4.6: Land use/cover class (2012)

	Reference data				
	Reference total	Classified total	Number correct	Producer's accuracy (%)	User's accuracy (%)
Bare soil	4	2	2	50.0%	100.0%
Water	1	1	1	100.0%	100.0%
Dry veg	12	13	12	100.0%	92.31%
Residential	12	14	11	91.67%	78.57%
Healthy veg	21	20	19	90.48%	95.0%
Totals	**50**	**50**	**45**		

```
Overall accuracy = 45/50 = 90.0%
Overall Kappa = 0.8569 = 85.69%
```

The overall accuracy was found to be **90.0%** and overall kappa was **85.69%** and this means that many pixels were classified correctly. This study discovered that the overall accuracy assessment was above 90% on average which indicate that most of the pixels were classified correctly

4.1.2 Results of Social survey techniques regarding the current and historic impacts on land use/cover change dynamics in the study area.

It was important to conduct this type of survey to get more information regarding the assessment of the impacts of current and historic land use dynamics in Duthuni wetland ecosystem.

4.1.2.1 Duration of stay and land cover changes over the years

Table 4.7 clearly demonstrates the land cover change which has occurred in Duthuni over the past years. All the respondents (100%) who settled in the area for less than five years indicated that the land cover was dominated by human settlement. Of the seventy (70) people who indicated that they settled in the area 11-20 years ago, 77.1% indicated that the land was predominantly natural vegetation and 20% said it was a human settlement, whilst only 2.9% said the area was used for agricultural/cultivation purpose. 77% of those who settled more than 20 years ago indicated that the land cover was predominantly natural vegetation with wetland; 11.4% said it was mainly human settlement; 8.6% said it was grass and 2.9% said it was agricultural land. It was observed during data collection that human settlement and agriculture are one of the contributing factors affecting the wetland.

Table 4.7: Duration of stay and land cover changes

			Q9_Land cover				Total
			cultivated land	natural forest	settlement	grass	
Q8_Duration of stay	less than 5years	Count	0	0	2	0	2
		% within Q8_Duration of stay	0.0%	0.0%	100.0%	0.0%	100.0%
		% within Q9_Land cover	0.0%	0.0%	7.1%	0.0%	1.3%
	5-10years	Count	4	0	4	0	8
		% within Q8_Duration of stay	50.0%	0.0%	50.0%	0.0%	100.0%
		% within Q9_Land cover	50.0%	0.0%	14.3%	0.0%	5.3%
	11-20years	Count	2	54	14	0	70
		% within Q8_Duration of stay	2.9%	77.1%	20.0%	0.0%	100.0%
		% within Q9_Land cover	25.0%	50.0%	50.0%	0.0%	46.7%
	more than 20years	Count	2	54	8	6	70
		% within Q8_Duration of stay	2.9%	77.1%	11.4%	8.6%	100.0%
		% within Q9_Land cover	25.0%	50.0%	28.6%	100.0%	46.7%
Total		Count	8	108	28	6	150
		% within Q8_Duration of stay	5.3%	72.0%	18.7%	4.0%	100.0%
		% within Q9_Land cover	100.0%	100.0%	100.0%	100.0%	100.0%

4.1.2.2 Duration of stay and changes in population

All the respondents who settled in the area within the last 5 years indicated that the human population was high before they settled (Table 4.8). For those who settled in the last 5 to 10 years, 75% said it was high and the other 25% said it was low. For those who settled in the last 11-20 years, 74.3% indicated that it was low; 14.3% indicated that it was moderate and 11.4% indicated that it was high. 71.4% of populations who has settled for more than 20 years indicated that population was low and 28.6% said it was moderate This finding agrees with the change detection analyses which indicated that during 1999, human population was too low in Duthuni and it was also verified by photographs (Plate 4.1-4.4) and confirmed by Chief and the farmers who utilize wetland ecosystem for subsistence farming.

Table 4.8: Duration of stay and changes in resident's population

			Q11_ human Population			Total
			Low	moderate	high	
Q8_Duration of stay	less than 5years	Count	0	0	2	2
		% within Q8_Duration of stay	0.0%	0.0%	100.0%	100.0%
		% within Q11_Population	0.0%	0.0%	12.5%	1.3%
	5-10years	Count	2	0	6	8
		% within Q8_Duration of stay	25.0%	0.0%	75.0%	100.0%
		% within Q11_ Population	1.9%	0.0%	37.5%	5.3%
	11-20years	Count	52	10	8	70
		% within Q8_Duration of stay	74.3%	14.3%	11.4%	100.0%
		% within Q11_ Population	50.0%	33.3%	50.0%	46.7%
	more than 20years	Count	50	20	0	70
		% within Q8_Duration of stay	71.4%	28.6%	0.0%	100.0%
		% within Q11_ Population	48.1%	66.7%	0.0%	46.7%
Total		Count	104	30	16	150
		% within Q8_Duration of stay	69.3%	20.0%	10.7%	100.0%
		% within Q11_ Population	100.0%	100.0%	100.0%	100.0%

4.1.2.3 Change in land cover/use and its previous state

93% of the respondents indicated that they had noticed land use/cover changes in the area. The majority (75.7%) of the respondents indicated that the land was dominated by natural vegetation before; 10% said it was human settlement; 5.7% said it was a wetland; another 5.7% said it was cultivated land and 2.9% said it was grass. Of those who indicated that there has been any change in land use/ cover status, 80% indicated that the area was a wetland and 20% said it was a human settlement refers to table 4.9 below:

Table 4.9: Change in land cover/use and its previous state

			13B					Total
			cultivated land	natural vegetation	wetland	settlement	grass	
Q13A_Cover changes	yes	Count	8	106	8	14	4	140
		% within Q13A_Cover changes	5.70%	75.70%	5.70%	10.00%	2.90%	100.00%
		% within 13B	100.00%	100.00%	50.00%	87.50%	100.00%	93.30%
	no	Count	0	0	8	2	0	10
		% within Q13A_Cover changes	0.00%	0.00%	80.00%	20.00%	0.00%	100.00%
		% within 13B	0.00%	0.00%	50.00%	12.50%	0.00%	6.70%
Total		Count	8	106	16	16	4	150
		% within Q13A_Cover changes	5.30%	70.70%	10.70%	10.70%	2.70%	100.00%
		% within 13B	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

4.1.2.4 Changes in land used for agriculture over time

According to the survey findings, the land that was used for agriculture has been decreased compared to previous years due to an increase in human population in the area and this was also confirmed by farmers and government officials during an interview that the land use for agriculture has decreased compared to previous years. This finding is consistency with the finding from remote sensing/GIS analysis, where human settlement was higher than agricultural land use/cover changes. The results show that 77% of the respondents indicated that the land being used for agriculture has generally decreased, 67.9% indicated that it has decreased over the past 5 to 10 years; 19.6% said in the past 11-20 years; 8.9% said less than 5 years back and 3.6% said in more than 20 years ago. It is important to note that those who noted that the land usage in agriculture was increasing, they pointed out to the period 0 to 10 years back (90.3%), (53.3% + 40%). Of the 146 people who responded to both questions, only 4 indicated that the land use in agriculture had remained unchanged and all of them pointed to the period 0 to 10 years back refers to table 4.10 and Figure 4.7 below and figure 4.7 for cross tabulation of changes in land used for agriculture over time.

Table 4.10: Changes in land used for agriculture over time

			Q24B				Total
			less than 5years	5-10years	11-20years	more than 20yeras	
Q24A	Increased	Count	16	12	2	0	30
		% within Q24A	53.3%	40.0%	6.7%	0.0%	100.0%
		% within Q24B	57.1%	13.3%	8.3%	0.0%	20.5%
	Decrease	Count	10	76	22	4	112
		% within Q24A	8.9%	67.9%	19.6%	3.6%	100.0%
		% within Q24B	35.7%	84.4%	91.7%	100.0%	76.7%
	remain unchanged	Count	2	2	0	0	4
		% within Q24A	50.0%	50.0%	0.0%	0.0%	100.0%
		% within Q24B	7.1%	2.2%	0.0%	0.0%	2.7%
Total		Count	28	90	24	4	146
		% within Q24A	19.2%	61.6%	16.4%	2.7%	100.0%
		% within Q24B	100.0%	100.0%	100.0%	100.0%	100.0%

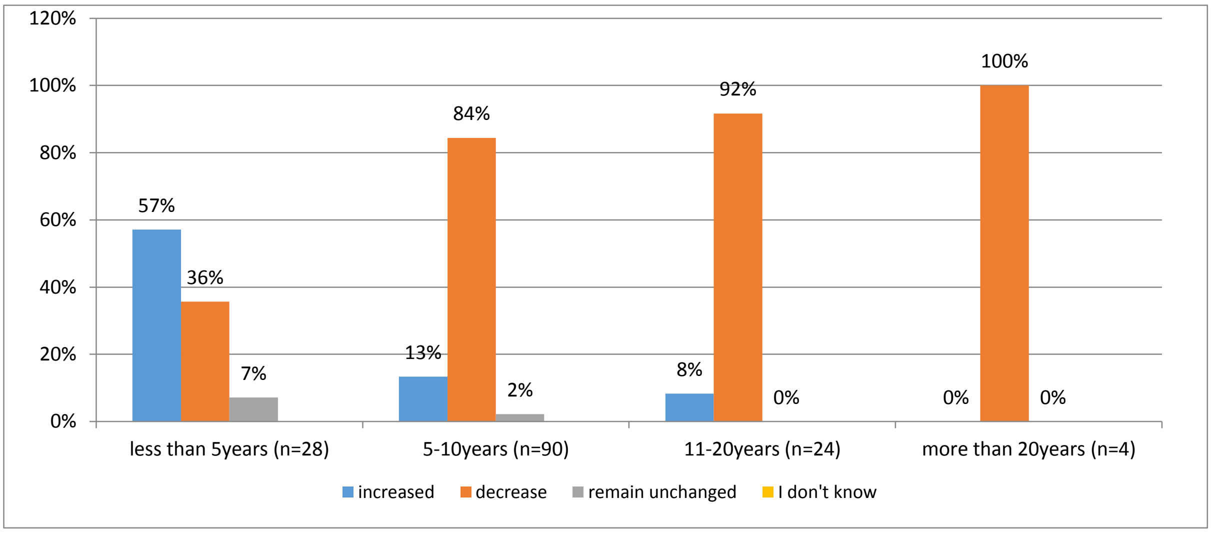

Figure 4.7: Cross tabulation of Changes in land used for agriculture over time

4.1.2.4 Land use changes for human settlement over time

The land used for human settlement had increased over time. 99% of the respondents indicated that the land used for human settlement had increased over time and with the major increase having occurred in the periods of 5 to 10 years back (47.3%) and 11 to 20 years back (43.2%). This is illustrated in Table 4.11.

Table 4.11: Land use change/cover for human settlement over time

			Q26B			
			less than 5years	5-10years	11-20years	Total
Q26A	Increased	Count	14	70	64	148
		% within Q26A	9.5%	47.3%	43.2%	100.0%
		% within Q26B	87.5%	100.0%	100.0%	98.7%
	remain unchanged	Count	2	0	0	2
		% within Q26A	100.0%	0.0%	0.0%	100.0%
		% within Q26B	12.5%	0.0%	0.0%	1.3%
Total		Count	16	70	64	150
		% within Q26A	10.7%	46.7%	42.7%	100.0%
		% within Q26B	100.0%	100.0%	100.0%	100.0%

4.1.2.5 The results of agriculture, grazing land, and residential land use change

Figure 4.9 below shows that residential land has increased when compared to both agricultural land and grazing land, with 99% of the villagers indicating that it has increased compared to 20% for Agriculture and 8% for grazing land. It also shows that agricultural land had decreased tremendously compared to grazing land and residential land. This was due to the convertion of agricultural land into the residential human settlement. Grazing land was not found to be a major threat to the wetland ecosystem.

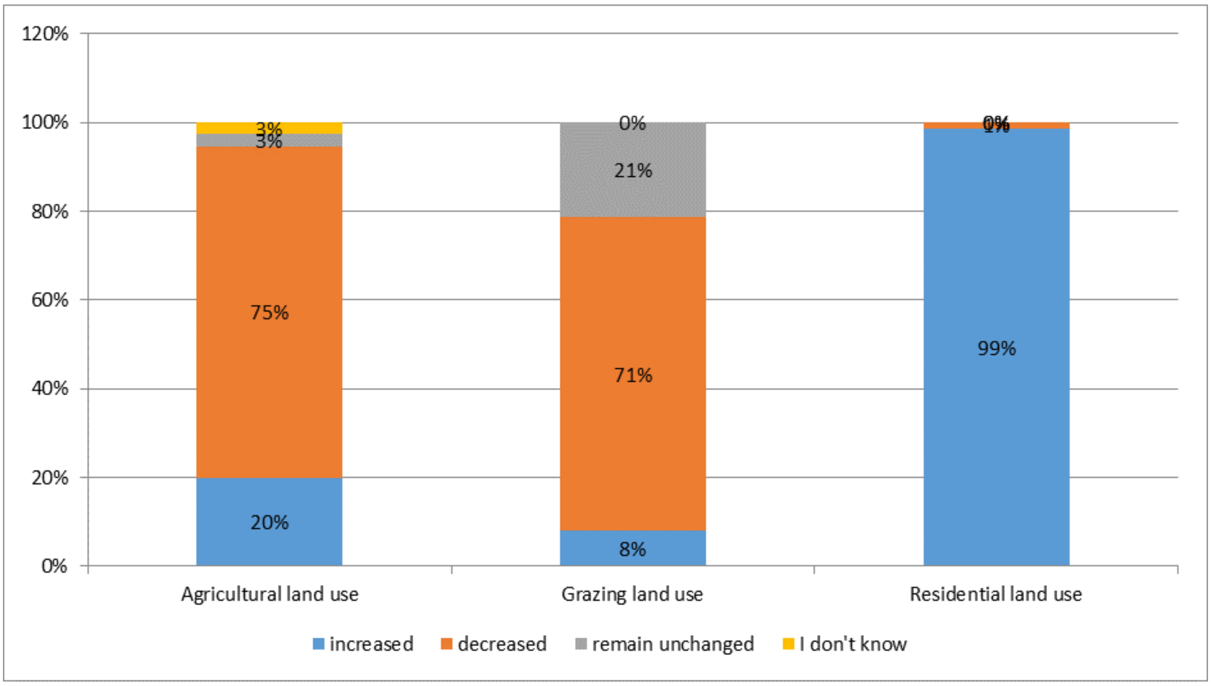

Figure 4.8: Land use/cover changes over the area

4.2 Trends and spatial extent of land use changes

4.2.1 Results of Trends and spatial extent of land use changes (Remote sensing/GIS)

The changes that have occurred in land use/cover in Duthuni for the last 13 years are shown in land use/cover maps of 1999, 2005 and 2012 (See fig 4.9 and Table 4.12). The analysis shows that the major changes are present in the residential areas due to the rapid increase in population in the area. It was observed that residential increased from 156.643 hectares

(1999), 190.362 hectares (2005) and 225.734 hectares in (2012). The total changes for the residential area were found to be changed by 102.87 hectares. Water covering an area about 15.590 hectares in (1999), 11.694 hectares in (2005) and has been decreased in 2012 to 9.0432 hectares. The total changes in bare soil were found to be transformed to 15.64 hectares. Healthy vegetation was 181.50 hectares in (1999), 116.002 hectares in (2005) and surprisingly was increased in (2012) to 161.28 hectares due to the high amount of rainfall received in the year 2012. The total changes in healthy vegetation were 82.774 hectares, which is a negative change between years 1999 to 2012. In 1999 dry vegetation was 149.184 hectares and increased to 212.129 hectares in (2005) and surprisingly decreased in (2012) to 150.106 hectares.

Table 4.12: The area per land use type for years 1999, 2005 and 2012

Land cover types	1999		2005		2012		**Total changes**
	Hectare	**Percent**	**hectare**	**percent**	**Hectare**	**Percent**	
Bare soil	37.564	6.95	25.688	4.62	23.2128	4.08	**15.64**
Water	15.590	2.88	11.694	2.10	9.0432	1.59	**6.575**
Dry vegetation	149.184	27.60	212.129	38.16	150.106	26.36	**92.125**
Residential	156.643	28.98	190.362	34.25	225.734	39.65	**102.87**
Healthy vegetation	181.507	33.58	116.002	20.87	161.28	28.33	**82.774**

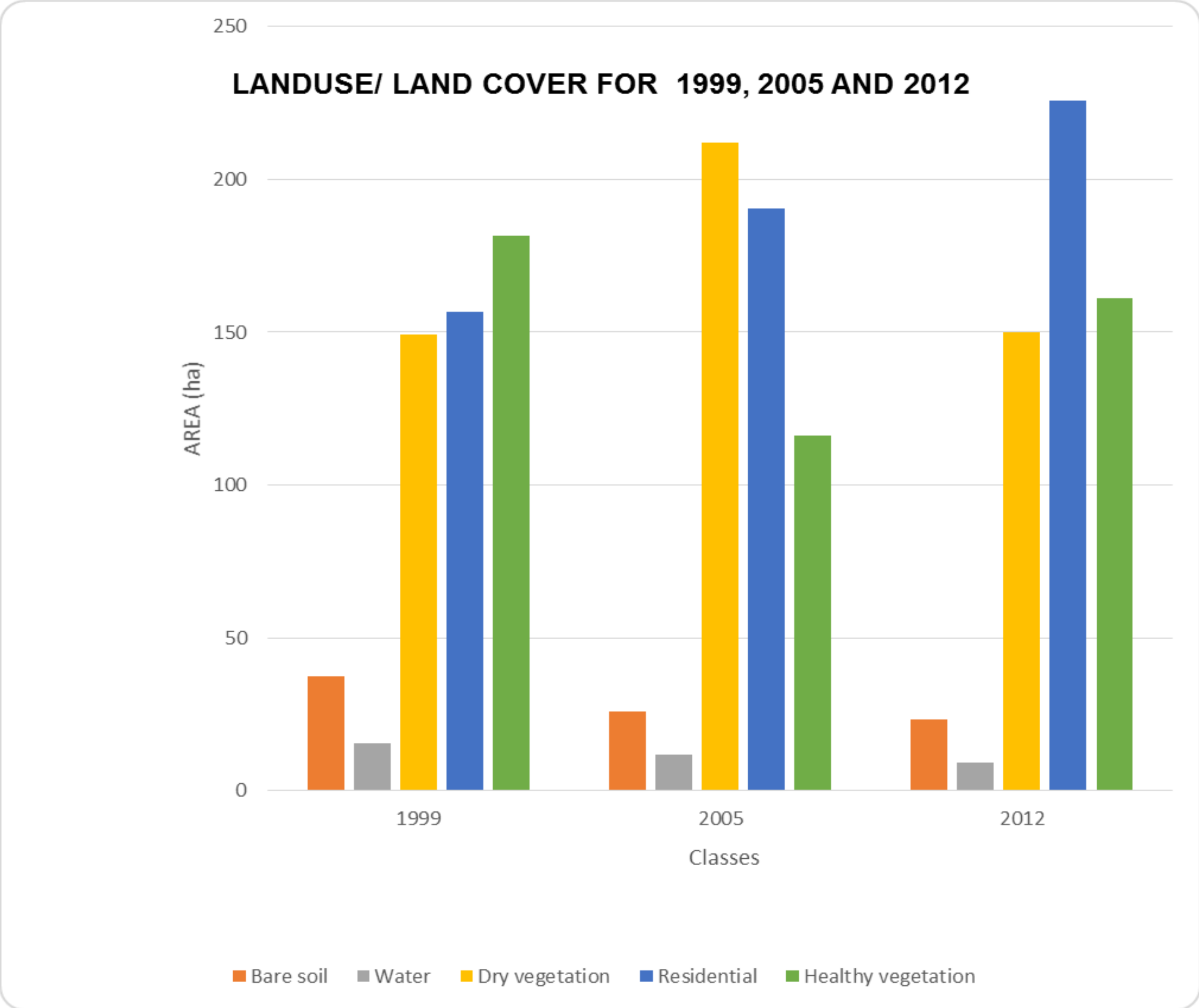

Figure 4.9: Comparison of the land use/cover in Duthuni wetland (1999, 2005 and 2012)

4.2.2 Results of Trends and spatial extent of land use changes using social survey

4.2.2.1 Frequency and percentage of land use/cover change over the years

The frequency of land use/cover changes over the years is represented in a graph below (figure 4.10). This result shows that major changes in land use have occurred in the last 5 to 10 years and the least changes occurred in more than 20 years back. This finding is consistency with the findings of remote sensing/GIS in this study.

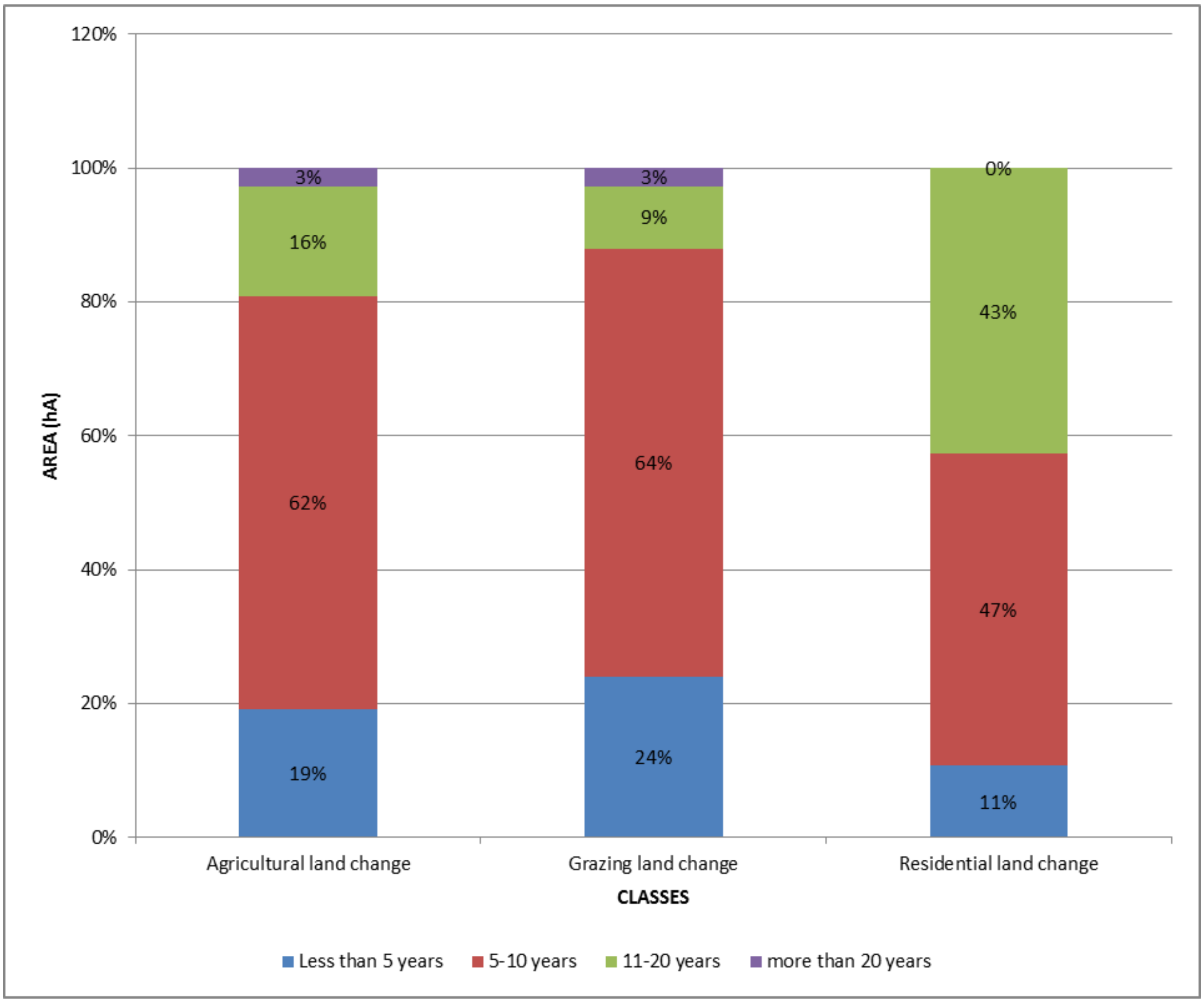

Figure 4.10: Frequency and percentage of the land use/cover changes over the years

4.3 Major drivers of land use changes in the wetland

The findings indicated that residential is the major driver of the land use change in Duthuni wetland ecosystem which consist of 70.55% followed by agricultural land use consist of 15.93%. The utilization of wetland resources which consist of 11.95% has contributed to the transformation of wetland because of the needs to access water for various use such as thatch grass, extraction of soil for brick laying and harvesting food from the wetland ecosystem. 1.57% of responded indicated that they settle in the area because is their ancestral land. Figure **4.11** and plates **4.1 to 4.5** can confirm that the Duthuni wetland ecosystem has been disturbed due to anthropogenic activities and other various factors. All these factors have contributed to soil erosion, water pollution, overgrazing, loss of wetland area and habitat loss.

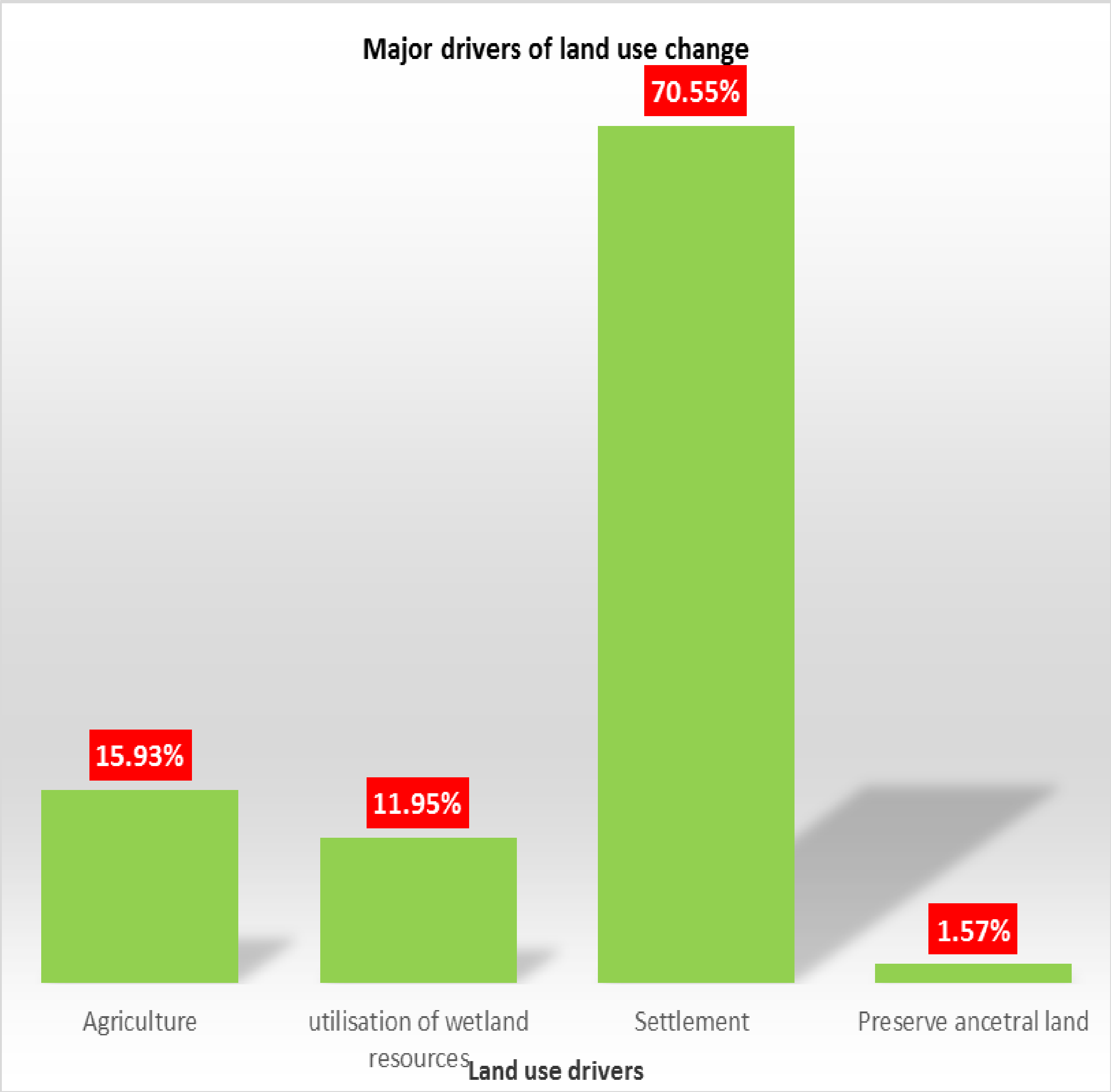

Figure 4.11: Major drivers of land use change in the wetland

Plate 4.1: Land use activities in Duthuni wetland

Plate 4.2: Expansion of human settlement towards the wetland ecosystem in Duthuni

Plate 4.3: Agricultural activities and expansion of human settlement towards wetland

Plate 4.4: Agricultural activities in the wetland

4.4 Assessment of socio-economic and environmental impacts of land use change

4.4.1. Household characteristics

The results of the household characteristics indicated that that 94 households out of 150 which is (62.7%) represent the age group from 46 years and above from the greatest percentage of the respondents and 40 (26.7%) represents 36-45 years age group whilst 26-35 years age group is the least represented with 16 (10.7%) of the entire sample. out of the 68% of the interviewed community members were females and 32 % were males.

In addition, the analysis indicated that 62.5% of the male participants were married; 25% were divorced and 8.3% were widowed. 35.3% of the females were widowed; 33.3% were married; 27.5% were never married and 3.9% were divorced. The 70.7% of the participants were unemployed; 16.0% were self-employed and only 13.3% of the respondents were formally employed. It also shows that only the employed and self-employed reached the R5000-00+ per month in income and that the majority of the villagers who earned less that R1000-00 per month were within the unemployed category (84.4%).

4.4.2 socio-economic impacts of land use/cover change in Duthuni wetland

From the above household characteristics, one can deduce that the rate of unemployment rate and low income of respondents has contributed to a massive change of wetland ecosystem in Duthuni village because the majority of the population depends on the wetland resources for their likelihood. The farmer's results show that farmers were growing vegetables and maize in order to secure their food shortage and also income generation so that they can sustain themselves. The results also indicated that major drivers for wetland utilization were due to a shortage of subsistence food because of the increase of population.

The respondents indicated that cultivating on the wetland has got the positive benefit because it resolves some of their socio-economic problems such as shortage of subsistence food and cost needed to be used. The respondents also indicated that they receive various resources from the wetland that help them for their livelihood. During the focus group, farmers indicated that various land use activities such as vegetation clearing, roads development, washing cars and laundry have impacted the wetland negatively.

4.4.3 The local perception and knowledge on environmental impacts in wetland

4.4.3.1 Role played by the wetland

When asked if they knew whether the wetland around them plays an important ecosystem role, 57.3% of the respondents indicated that they did not know and 42.7% indicated that they know (see table 4.13 below).

Table 4.13: Role played by the wetland

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	64	42.7	42.7	42.7
	No	86	57.3	57.3	100.0
	Total	150	100.0	100.0	

4.4.3.2 Educational level and knowledge on environmental impacts of different land uses on Wetland

Out of the 150 respondents from the village 76 (50.7%) have no formal education; 42 (28%) have a secondary education; 22 (14.7%) have tertiary education and 10 (6.7%) have primary education. Based on this, it is clear that most of the participants were predominantly uneducated. Lack of knowledge was identified as one of the contributing factors on wetland destruction. A high level of education is usually associated with better understanding of land use change within their area. Cross tabulation regarding the relationship between the level of education and environmental impacts in the study area is presented in table 4.14, figure 4.12 and 4.13 respectively.

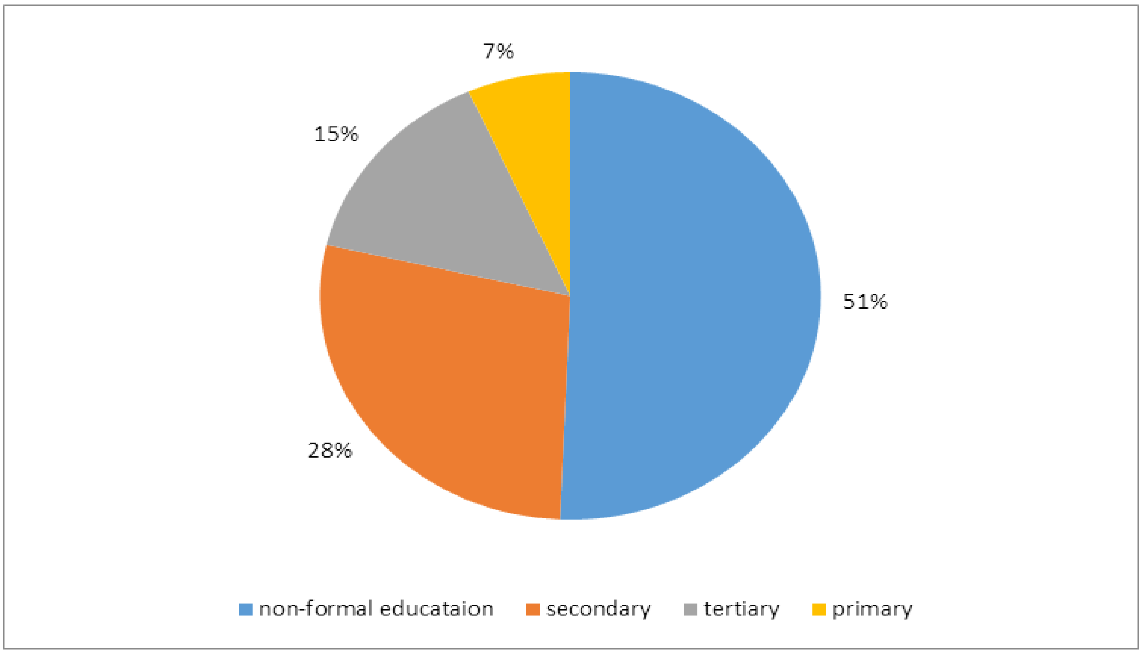

Figure 4.12: Education level of the participants (%)

Table 4.14: Q6. Education level * Question 30A. Knowledge of environmental impacts of different land uses on wetlands

			Q30A		Total
			Yes	no	
Q6_Edu Level	non-formal education	Count	8	68	76
		% within Q6_Edu Level	10.5%	89.5%	100.0%
		% within Q30A	22.2%	59.6%	50.7%
	primary	Count	2	8	10
		% within Q6_Edu Level	20.0%	80.0%	100.0%
		% within Q30A	5.6%	7.0%	6.7%
	secondary	Count	16	26	42
		% within Q6_Edu Level	38.1%	61.9%	100.0%
		% within Q30A	44.4%	22.8%	28.0%
	tertiary	Count	10	12	22
		% within Q6_Edu Level	45.5%	54.5%	100.0%
		% within Q30A	27.8%	10.5%	14.7%
Total		Count	36	114	150
		% within Q6_Edu Level	24.0%	76.0%	100.0%
		% within Q30A	100.0%	100.0%	100.0%

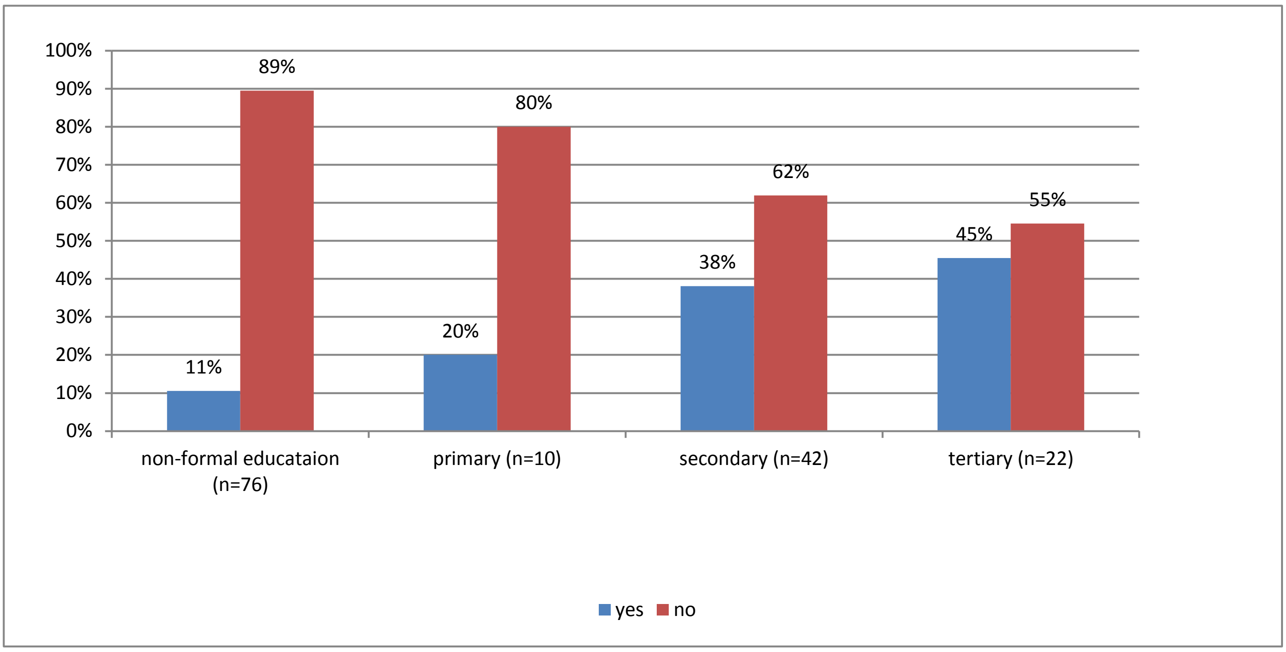

Figure 4.13 Educational levels Versus Knowledge on environmental impacts of different land uses on wetlands

A Chi-Square test was also done to understand the differences between Educational level versus knowledge on environmental impacts of different land uses on wetlands and table below present Chi-Square test results.

Table 4.15: Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.778[a]	3	.000
Likelihood Ratio	18.032	3	.000
Linear-by-Linear Association	17.382	1	.000
N of Valid Cases	150		

a. 1 cells (12.5%) have expected count less than 5. The minimum expected count is 2.40.

Because .000 < .05 (in table 4.15), this does represent a statistically significant relationship between the two variables (level of education and response to question 30(A) on participants' knowledge on environmental impacts of practicing different land uses on the wetland) in the above crosstab. A total of 27.8% (22.2% + 5.6%) of the respondents who had non-formal education to primary school education indicate that they were not aware of the environmental impacts contributing to wetland destruction which does not compare to 72.2% (44.4% + 27.8%) of those who indicated that they were aware of the environmental impacts and had attained secondary to tertiary level education. This difference was large enough to be statistically significant.

4.4.3.3 Major environmental impacts on the wetland

Figure 4.14 shows that the Community feels that water pollution is the major impact of land use change on the wetland with 65.33% followed by soil erosion (12%). A land use change shows 10.67% loss of habitat and biodiversity due to land use/cover activities. The results show that 1.33% impacts of overgrazing over the wetland area. Farmers confirmed that they are receiving dirty water from upstream containing pollutants such as pumpers and waste clothes. During field observation, pit toilets were observed in the wetland and the respondents indicated that they dig another hole when it is full. This shows that wetland might be contaminated due to spillages. Through field observation, it was confirmed that the stream contains the above-mentioned pollutants which have resulted in 65.33% of the water pollution (Fig 4.14).

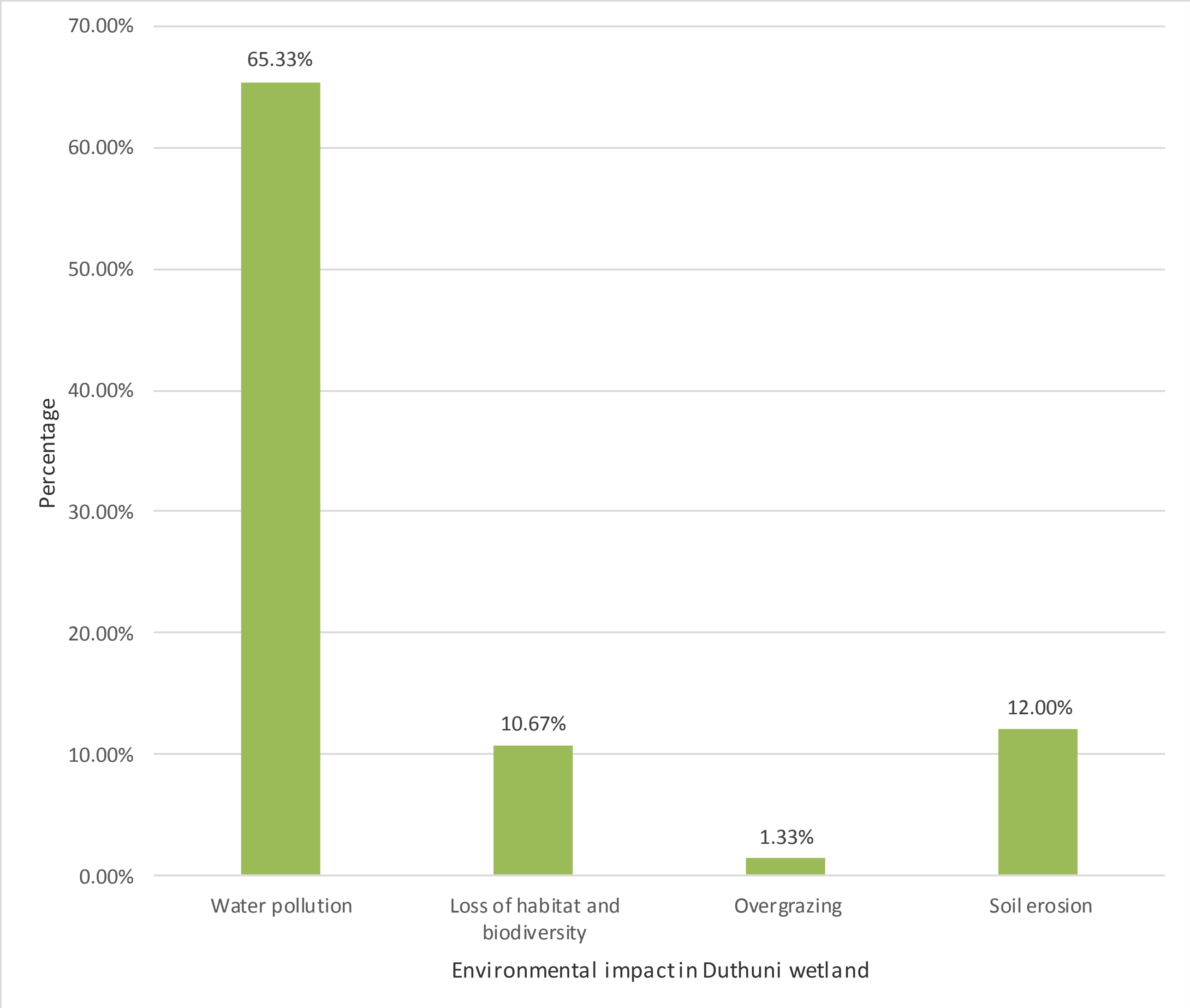

Figure 4.14: Major impacts on the wetland ecosystem

4.5 The current utilisation of wetland resources by the local people

Several environmental issues were observed during series of field visits in order to understand the current utilisation of wetland resources by the local people.

4.5.1 Percentage of people who utilized wetland resources

When respondents were asked if they practiced anything on the wetland, 57.3 percent of the respondents indicated they did not whilst the other 42.7% indicated that they did practice, as shown in table 4.16 below:

Table 4.16: Percentage of people who utilized wetland resources

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Yes	64	42.7	42.7	42.7
	No	86	57.3	57.3	100.0
	Total	150	100.0	100.0	

The 42.7% of the responded who indicated that they practiced some activities on the wetland, 94% indicated that they practiced agricultural related activities; and only 6% practiced fishing (3%) and washing (3%) refer to table 4.17, figure 4.16 and plate 4.5 respectively.

Table: 4.17 Human activities on the wetland

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	agricultural activities	60	40.0	93.8	93.8
	Fishing	2	1.3	3.1	96.9
	Washing	2	1.3	3.1	100.0
	Total	64	42.7	100.0	
Missing	System	86	57.3		
Total		150	100.0		

Plate 4.5: Women washing in the wetland

4.5.1 Resources Communities get from the wetland

Majority of the respondents said it was necessary to access the wetland because it provides means of getting fodder for household consumptions. For a range of resources the community gets from the wetland, food is the most common resource derived by the community from the wetland. Forty-one percent of the respondents indicated that they get food from the wetland; 18.67% named handcraft production and 14.67% indicated construction material. Medicines; water for drinking and irrigation all had below 10% popularity (see Figure 4.15). However, key informants mentioned that the frequency and amount of collected wetland resources is more than what the wetland can support.

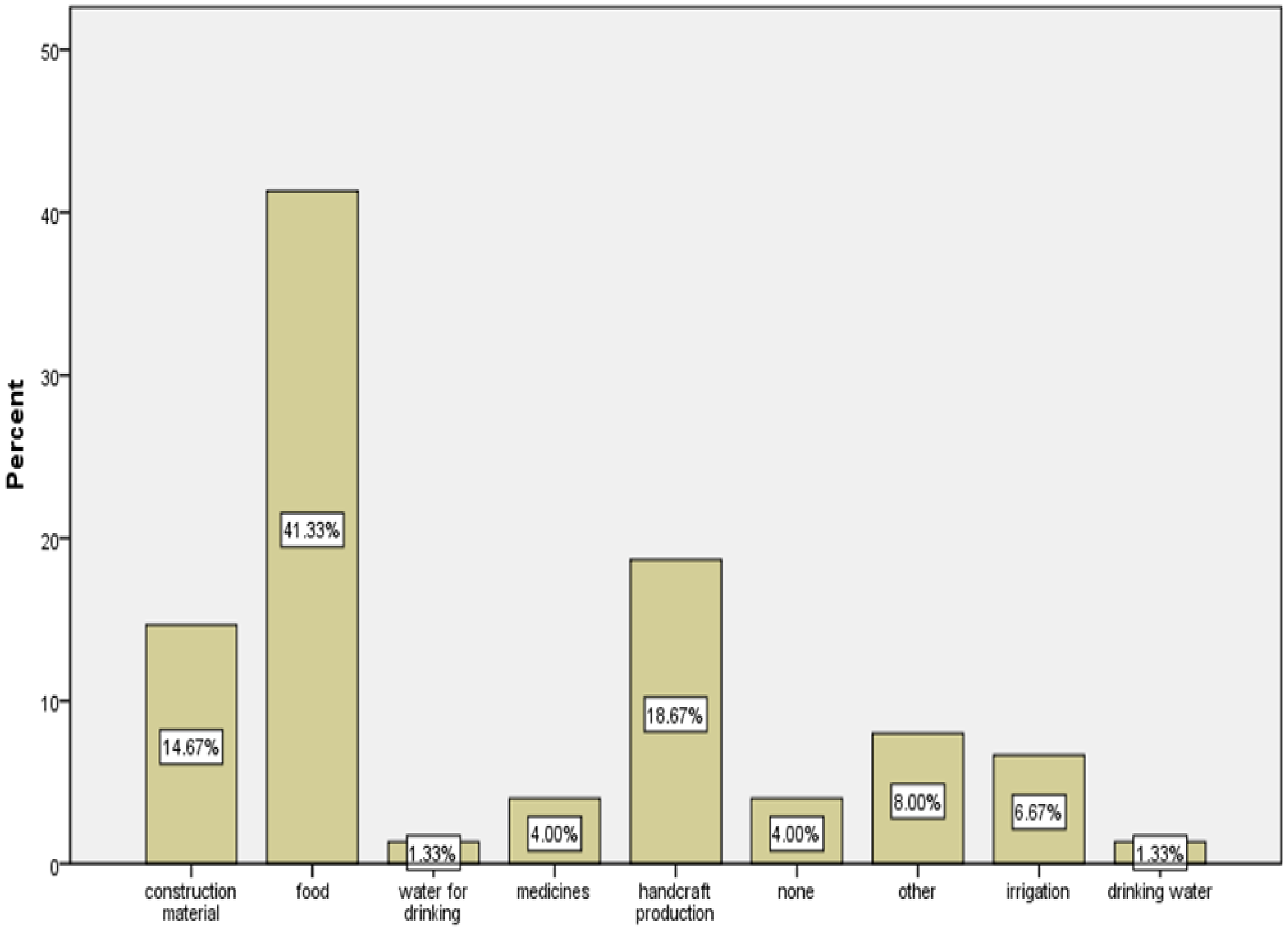

Figure 4.15: Resources Communities get from the Duthuni wetland

4.6 Summary

Various methods were used to analyze the data collected in Duthuni wetland. In carrying out this research, remote sensing/GIS and social survey techniques were used to analyze the data and found to complement each other. The expansion of population into a wetland area, agricultural activities, and utilization of wetland resources by the community was found to be the main causes of land use/cover change in Duthuni wetland during the study periods. The above findings will be discussed in detail in the next chapter.

CHAPTER FIVE: DISCUSSION OF THE FINDING

5.0 Introduction

In the previous chapter, the research findings were presented and interpreted. This chapter focuses on the discussions of the results presented in the previous chapter in relation to both research questions and existing knowledge. The discussions include the aspects of the impact of the past and present land use change dynamics on the wetland. It further determines the trends and spatial extent of land use change and determines the major drivers of land use changes. In addition, the chapter discusses the assessment of the environmental, socio-economic impacts of land use change on wetland ecosystem in the study area. Furthermore, the assessments of the current utilization of wetland resources by the local people are dealt with later on in this chapter. In each theme, major findings are related to the literature to assess whether such findings are consistent with the literature or not.

5.1 Examination of the impact of the past and present land use change dynamics on the wetland.

This theme will cover two different results which were acquired using remote sensing/GIS and social survey. It was important to use these two different methods as it complements each other in order to examine the past and present land use change dynamics.

5.1.1 Impact of the present and past land use change dynamics on the wetland using remote sensing/ GIS technique.

The area under major land use/cover categories was analyzed for the year 1999, 2005 and 2012 respectively. Land use/cover has been categorized into 5 different classes that are bare soil, water bodies, residential/human settlement area, dry vegetation and healthy vegetation. It was discovered that from 1999 to 2012, post-classification change detection technique showed that there was a change in different land use/cover in Duthuni wetland ecosystem. The land use/covers examined were:

5.1.1.1 Change in bare soil

This type of land is widely found along the wetland going down the stream where agricultural activities were practiced. Results show that there was degradation on bare soil for the 13 years of study (1999 to 2012) with total changes of 15.64 hectares in the overall area of study. The various land use activities such as the expansion of human settlement area, cultivation, and anthropogenic activities within the wetland have exposed an area to erosion. As a result, if unsustainable land use activities take place where there is a high risk of erosion then the likelihood is high that this will contribute to erosion. The land cover changes on bare soil in Duthuni wetland was expected due to the various land uses practiced in the area. Previous research indicates that more than 70% of South Africa including wetland areas is affected by varying intensities of soil erosion (Kotze *et al*., 2009). The increase in cultivations of seasonal crops such as spinach, cabbage, maize and loss of biodiversity in the adjacent area of the wetland in Duthuni has led to serious erosion problems such as low water table, modification of natural habitat biodiversity loss.

The finding of this research is concur the analysis of (Masese *et al*., 2012) who indicated that Nyando wetland in kenya has been affected by soil erosion because of the flooding and poor farming practices which have led to heavy siltation and the silt deposited in the wetland. (Mazvimavi, 2002) indicated that soils in cultivation areas are susceptible to erosion and this may be particularly serious in vulnerable areas such as steep slopes or near stream. Results of the similar studies by Butt *et al*., 2015 found that the increased soil erosion in the bare soil in Pakistan was due to rapid deforestation in the adjacent of the wetland area which removed the vegetation cover from the land and rendered it barren and exposed.

5.1.1.2 Change of water bodies

Water covering an area of about 15.590 hectares in 1999, 11.694 hectares in 2005 and 9.0432 hectares by 2012 with total changes of 6.575 hectares in the overall area during the study period. The loss of water in Duthuni village was due to anthropogenic activities which were observed such as dumping of domestic solid waste, the reclaimed for development activities such as the building of roads and houses, burning of wetland vegetation, over-exploitation of wetland resources such as handcraft production, water for consumption, medicines and construction material. (Santhiya *et al*., 2010) found that waterlogged area was transformed due to the human activities like residential areas and infrastructure development in Chennai coastal area. This study agrees with earlier findings of (Malatu, 20015), as they reported that drainage of wetlands was one of the contributing factors for the decline in water supply in Illuababora zone.

5.1.1.3 Change of residential/human settlement area

The residential area was 156.643 hectares 1999, 190.362 hectares 2005 and increased to 225.734 hectares in 2012 with total changes of 102.87 hectares in the overall area during the study period. The land use change in residential areas in Duthuni wetland was due to increase in population leading some members of the community to settle in wetland area without permission from the authority. This study agrees with the findings of Butt et al. 2015 who indicated that human settlements increased from 1038 ha in 1992 to 1870 ha in 2012 in Simly.

The increase of population within the area led to a detrimental impact on wetland ecosystem and during field observation, it was discovered that human settlement is expanding towards the wetland area causing a major threat to the wetland ecosystem such as water pollution, soil erosion, and unsustainable extraction of wetland resources, excessive water abstractions and overexploitation of wetland resources. Turpie, 2010 indicated that the population of Mfuleni informal human settlement within Kluis river flood plain of greater Cape Town increased causing dwellers to be the main users of wetland areas.

5.1.1.4 Change of dry and healthy vegetation

Healthy vegetation was 181.50 hectares in 1999, 116.002 hectares in 2005 and surprisingly was increased in 2012 to 161.28 hectares whereas in 1999 dry vegetation was 149.184 hectares, 212.129 hectares in 2005 and also found to decrease in 2012 to 150.106 hectares with total changes of 92.125 hectares. These losses are due to more hectares being converted to agricultural land, residential land and during utilization of wetland resources. This finding is consistent with the analysis of Mulatu *et a*l., 2015) who indicated that unsustainable use of wetland for cultivation and other anthropogenic activities create degradation or loss of wetlands system and other precious resources.

Significant changes were observed in some parts of the wetland and these were areas which were heavily drained and permanently converted into croplands or other land uses like grazing land. Duthuni wetland had parts, which were completely drained for field crops like maize. Those areas were year continuously cultivated reducing the chances for wetland vegetation re-growth or flooding possibilities in the wet season. This finding is consistent with the analysis of Madebwe *et al*., 2005) who concluded that vegetation loss was caused by an increase in cultivated area and livestock. This finding concurs with (Schuyt, 2005) findings who indicated that the suitability for farming and easy availability of water for cultivation and livelihood has caused population migration to the wetlands ecosystem leading to loss of biodiversity. The vegetation that occurs in wetlands is an important component of the ecosystem because vegetation provides soil stability, provides habitat and food for animals and also helps maintain a healthy wetland.

5.1.2 Examination of the present and past land use change dynamics using social survey

The respondents who reside along the wetland indicated that the reason for settling in the area is because of lack of space for human settlement, agricultural purposes while others are preserving their ancestral land. This was emphasized by the chief of the village during an interview session that previously the population of Duthuni village was low but due to the increase in population over the years, lack of space for human settlement and area for subsistence farming has led people to reside closer to the wetland area. This study concurs with that of Wsandi *et al*. (2006) who indicated that development and expansion of human settlement in Bali were the main cause that led to increased human settlement by 62.6 hectares because of land use changes over 22 years of observation. This finding is consistent with the analysis of Akhtar *et al.* (2011) who indicated that Hokar Sar wetland in the Doodhganga watershed of the western Himalayas in India increased cropland area because of the conversion and encroachment of wetland area into agricultural land by the local farmers. Furthermore, this was also emphasized during a focus group with local farmers who were found practicing subsistence farming in the wetland area that agricultural yield has been decreased due to the increase of the population in the area.

The Government Department indicated that they do not have any system of keeping records on the wetland statuses. The farmers were also concerned about not getting enough water from wetland for irrigation purpose as they used to receive it due to poor agricultural activities and drought. This proves that there was land use change dynamics over the years. Furthermore, 78.7% percent of the respondents indicated that overgrazing was not a problem compared to 21.3% of the respondents who indicated that overgrazing was a concern. Cattle and goats have been observed during field survey as the main grazers in the wetland area and overgrazing does not have huge impacts in the wetland area. This result differs from other study conducted by Musamba *et al*. (2011) indicated that the marginal increase in livestock size has caused an impact on Lake Victoria wetland by 2.8%.

5.2 Trends and spatial extent of land use cover change

This section discussed the findings of both GIS and Remote sensing techniques and social survey as it complements each other respectively:

5.2.1 GIS and Remote sensing techniques

From the remote sensing/GIS technique analyses of the results to determine the trends and spatial extent of land use change has detected and revealed that Duthuni wetland ecosystem had undergone some form of land use/cover changes between periods of 1999 to 2012. Overall accuracy assessment of the land use/cover classification results obtained showed an overall accuracy of 94% for 1999, 88% for 2005 and 90% for 2012 which is satisfactory level. This is the most dynamic land cover type which is extending itself every year posing a major problem in the area. In general, the trend and spatial extent of land use/ cover change in Duthuni wetland has been examined and the study establishes that the residential land use cover was the major land use type by (39.6%) in the study area due to increase in population followed by health vegetation (28.3%) and dry vegetation (26.3%). This drastic change in a residential human settlement over the years is likely to treat negative environmental effects such as drought, soil erosion, the intensity of floods and biodiversity loss due to habitat conversion. This study concurs with the analysis by Murungweni (2015) who indicated that wetland has been lost either to cultivation, human settlement, recreational activities or construction leading to detrimental effects on the wetland biodiversity.

5.2.2 Social survey

The study revealed that the least changes occurred in more than 20 years back and the land cover was predominantly a natural vegetation and this is because of the human population density was relatively low with minimal pressure on resources compared to the present situation. It is therefore logical to argue that as a result of an increase in human population and agricultural yield within the wetland area, a number of areas were cleared of vegetation in order to give room for agriculture activities and space for human settlement.

A field visit by the author revealed that indeed most of the area is currently dominated by agricultural activities and human settlement. The farmers also testified that there is competition between agriculture and human settlement especially on the eastern part of the Duthuni wetland ecosystem. Similar studies conducted by Musamba *et al*. (2011) indicated that land use changes around Lake Victoria wetland at Musona Municipality might be due to rapid population growths which increase pressure and demands for natural resources so that people can meet their basic needs.

5.3 Major drivers of land use change in the study area

The major driver identified in this study is population, agricultural expansion, and utilization of wetland resources by local people. This study concurs with the analysis by Zorrilla-Miras *et al*. (2013) who indicated that in Spain, land use change for intensive agriculture is the main driver behind biodiversity loss led to the conversion of 60% of the original wetland area. It is therefore logically to argue that population increase and agricultural expansion are the major driving force of wetland use and consequent degradation. As other economic options disappear, increasing numbers of rural residents engage in wetland resource utilization to support their livelihood. Currently, many people in the study area engage in field crops for food security. However, in the study area, wetlands utilisation is undertaken without control and proper management and the consequence of uncontrolled utilization is wetland degradation and loss of wetland resources.

This study concurs with the analysis in the study conducted by Musamba *et al*. (2011) at Victoria wetlands at Musona Municipality and the study revealed that the wetland was converted to other land uses such as crop production which is more dominant for local people to meet their basic needs. This finding also agrees with the analysis conducted by Begg, 1987) who concluded that the United States of America shows that more than 54% of the wetland has been degraded and 87 million hectares of wetland has been converted to development such as human settlement and agricultural purposes and similar trends in wetland losses have occurred in South Africa.

5.4 Socio-economic impacts and environmental impacts of land use change in wetland

5.4.1 Socio-economic impacts

Duthuni wetland provides socio-economic benefits. The low income, lack of knowledge and high rate of unemployment has contributed to the dramatic increase in anthropogenic activities in wetland ecosystem such as harvesting; washing cloth and vehicles; harvesting of natural resources; cropping and livestock grazing all contributed to the cash income by the households. In Duthuni wetland, natural resources are often harvested and are sold locally or are used to produce mats, baskets, and brooms. Water, medicines, foods and raw materials are collected by households from wetland for their own use. This study aligned to the analysis in the study conducted by Mulatu *et al*. (2015) who indicated that wetland is the most important resource for the livelihoods of the community on the wetland resources.

5.4.2 Environmental impacts of land use change in Duthuni wetland

Even though wetland in the study area is the sources for various ecological resources that are directly or indirectly used for different socio-economic purposes, the survey results indicated that such resources are degraded due to unsustainable utilisation of wetland ecosystem. Furthermore, the finding indicated that conversion of the wetland to residential land use has impacted negatively on the natural functioning of the wetland. It was observed during field observation that community is clearing the land for the establishment of human settlement and agricultural area (Plates 4.3 and 4.4 refer). It is therefore, logical to argue that the expansion of human settlement and lack of space for agriculture has impacted the wetland ecosystem.

As was highlighted earlier on, the practices of agriculture and human settlement expansions that are taking place in Duthuni wetland, fragmented the wetland habitat because most of the cultivated land is in permanently waterlogged parts of the wetland and is dominantly occupied by maize. The clearing of land in preparation for agricultural activities and building of human settlement has also impacted heavily on the natural scenic view of the wetland. The reeds and grasses are cut, thus disturbing the wetland ecosystem. This was also found by Liu *et al*. (2004) who indicated that the loss and fragmentation of wetlands because of agricultural development over 50 years has impacted wetland communities and its biodiversity. During the focus group discussion, it was found that fertilizers are used by farmers and their greatest concern was that they are receiving polluted water from upstream.

In the study area, most cultivators use hoes and only a few people used the tractor to prepare the crop field. 80% of the farmers used ammonium nitrate fertilizers and chemicals in their field leading to the threat of infiltrating into Duthuni wetland causes eutrophication of the aquatic life as the fields are near to the wetland. Several toilets have been built on the wetland which is a major threat to wetland. This finding concurs with the finding conducted by

(Kotze, 2009) who indicated that urbanization, industrialization and population growth have aggravated the significance of water pollution as a threat to the persistence of South Africa's wetland resources. This finding is also consistency with Malatu *et al*. (2015) research which indicated that the main source of pollution on wetland area was agricultural run-off and organic waste.

It was also found that majority of population lack knowledge of wetland management. This finding is consistency with the analysis conducted by Adaya *et al*. (1997) who indicated that lack of information can result in unclear decision making leading to land use change and lack of knowledge leads to unsustainable development taking place. It is therefore logical to argue that lack of knowledge has contributed to wetland deterioration. The loss of vegetation in Duthuni wetland may have serious effects on ecosystem such as the introduction of the foreign plant which can compete with native plant species for resources and can disrupt the intricate food chains that exist within the ecosystem. A loss of native plant species generally reduces the resource base for medicine, thatching, crafts and livestock grazing.

5.5 Current utilization of wetland resources by the local people

One of the major findings in this study is that wetland is utilised for various purposes such as washing clothes, grazing land, handcraft production, construction material, extracting medicines, water for drinking and irrigation. All these activities have led to wetland deterioration. Food is the most common resource derived from wetland by the community followed by handcraft production and construction material. This is similar to the findings from (Turpie *et al*., 2010) where he found that most of the rural community in South Africa source medicines and wild food from the wetlands ecosystem. This finding also agrees with the finding by (Musamba *et al*., 2011) who revealed that 84% of household around Lake Victoria wetlands at Musona Municipality needs more land to produce food for their family leading to the conversion of wetland to other land uses such as crop production which is more dominant for local people to meet their basic needs. This agrees with Kotze *et al*. ((2002) who indicated that the community wetland management in Mbongolwane wetland reveals that wise use of wetland helped communities to alleviate poverty by generating income by growing wetland and weaving craft from wetland plants.

5.6 Chapter summary

Based on the results of remote sensing/GIS and social survey, it can be deduced that land use/cover changes have transformed Duthuni wetland ecosystem. Land use/cover changes occurred in all land use/cover classes between the study periods (1999 to 2012) has impacted Duthuni wetland ecosystems. The study shows a negative change in land use/cover change in a wetland ecosystem. This is because of the human population (increase), expansion of agricultural area, grazing land, high consumption of wetland resources and other anthropogenic activities. All land use/cover change in Duthuni wetland has resulted in soil erosion, loss of biodiversity, over-grazing and water pollution. Food is the most common resource derived by the community from wetland followed by handcraft production and construction material. The next chapter will present the conclusions of the research results and recommendation in detail.

CHAPTER SIX: CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

The primary focus of this chapter is to relate the findings to the objectives of the study. The conclusions and recommendations are made based on the results. The first section presents the conclusions of the research results whereas the second presents the recommendations for future work. The main reason for this section is to draw a conclusion on the research findings. The conclusions are drawn based on the main findings per specific theme. The study set out to assess the impacts of land use changes on the Duthuni wetlands ecosystem using remote sensing/GIS and social survey. Within this broad aim, the specific objectives were to:

- Examine the impact of the present and past land use change dynamics in the study area;
- Determine the trends and spatial extent of land use change;
- Determine the major drivers of land use changes;
- Assess the socio-economic and environmental impacts of land use change in the study area; and;
- Assess the current utilization of wetland resources by the local people.

6.1 Conclusions

The results and key findings of the study are summarized according to the specific objectives set out in the study in an effort to address the issues raised by the research questions. The conclusions are based on the key findings of the study and are presented as follows:

6.1.1 Utilization of wetland resources by local people

Wetland ecosystem played a major role in terms of providing resources that can be utilized by local people. The current utilization of wetland resources in the study area has been examined and the most resources the community gets from the wetland is food, handcraft production, construction material, medicines and water for human consumption. Seasonal crops such as maize and vegetables are being harvested yearly from wetland area.

6.1.2 Major drivers of land use change in the study area

The empirical data indicated that the major drivers identified in this study are population increase, agricultural expansion, and high utilization of wetland resources by local people. Currently, many people in the study area engage in field crops for food security. However, in the study area, wetlands utilization is undertaken without control and proper management and the consequence of uncontrolled utilization is wetland degradation and loss of wetland resources. The clearing of land in preparation for agricultural activities and building of human settlement has also impacted heavily on the natural scenic view of the wetland and the natural functioning of the wetland. The change detection method in remote sensing /ArcGIS and social survey do complement each other in terms of analyzing drivers of land use change.

6.1.3 Socio-economic and environmental impacts of land use change in the study area

It was important to use social survey method of analyses so that researcher gets some information that cannot be easily obtained when using remote sensing/ArcGIS such as socio-economic status of the participants. The research finds that majority of the respondents in the study area earned low income and unemployment were found to be one of the contributing factors affecting the ecosystem of the wetland. Empirical evidence also show that lack of knowledge is one of the contributing factors in land use change and the majority of the respondents in Duthuni wetland depend directly and indirectly on wetland resources. The empirical data indicated that there is unsustainable use of wetland which is causing degradation or loss of wetland.

The natural resources and agricultural products generated from the wetland ecosystem by residents and local farmers mostly are utilized in order to sustain their livelihood. Other major findings are that overgrazing was not a major threat to Duthuni wetland. This is because the majority of the people in the area don't have livestock. Water pollution and soil erosion were found to be the major concern by wetland users such as farmers and residents who reside along wetland area, and as a result causing negative impacts on the wetland ecosystem. The other major finding is that there are no management strategies being currently implemented to utilised wetland in a sustainable manner by wetland users.

The expansion of human settlement, water pollution and soil erosion in the area is causing detrimental impacts for agricultural productivity as the farmers complained about low agricultural yield and reduction of water amount. The increase of population in the area was found to be the major driver to socio-economic challenges forcing community to over-exploit wetland resources in the study area. The most observed reason behind the rapid increase in the human settlement is due to the lack of space to settle as the population is rapidly increasing. This resulted in the extensive clearance of natural vegetation along the wetland area. The clearing of vegetation along the wetland ecosystem has impacted largely on the wetland due to the establishment of human settlement area and agricultural for both human settlement and agricultural activities. During the field survey, it was observed that some part of wetland ecosystem has been drained due to crop production, vegetation clearance, and water diversion by farmers for the purpose of irrigating the plants.

6.1.4 Trends and spatial extent of land use change

Understanding the changes in the use of land resources is critically important for the wetland management and planning for the future. Remote sensing/ ArcGIS and social survey are effective tools that have made it possible to source information with regard to trend and spatial extent of land use change in Duthuni wetland. The overall accuracy assessment of the land use/cover classification results obtained showed an overall accuracy of 90% which is satisfactory level. The empirical data indicated that the period between the year 1999 to 2012, the land use/cover of the entire study has changed significantly and water bodies, bare soil, and vegetation decreased drastically due to vegetation clearing whilst there was a significant increase in residential area due to increase in human population.

The decline of wetland water quantity/quality, bare soil and vegetation in the wetland area within 1999 to 2012 would, therefore, suggest that there may have been an increase in the human population and agricultural expansion in the study area. However, over the past 8 years 2005 to 2012, the survey results showed a massive increase in a residential area within the study area. This research finds that the use of change detection method in remote sensing/ArcGIS and social survey do complement each other in terms of analyzing the trends and spatial extent of land use change.

6.1.5 Examination of the impacts of present and past land use change dynamics in the study area

The main aim of the study was to examine the impacts of land use changes on the Duthuni wetlands ecosystem. The empirical evidence shows that the land use/cover changes have occurred at an unprecedented rate over the years due to various land use activities taking place in the study area such as extracting food from the wetland, washing cars and clothes, handcraft production, construction material, extracting medicines, water for drinking and irrigation. The research indicated that for the past 20 years, the population of Duthuni village was low but due to the increase in population over the years, lack of space for human settlement and area for subsistence farming has led people to reside closer to the wetland area. The socio-economic factors such as low income and high rate of unemployment in the area have contributed to the huge impact on wetland ecosystems. The farmers were also concerned about not getting enough water from wetland for irrigation purpose as they previously used to receive more. This proves that wetland has been impacted by various factors such as climate change, drought and anthropogenic activities. The results of this research indicated that the impact of the present land use/ cover changes due to increase in human population growth in the study area, improper use of land and other socio-economic activities which are major driving forces for the observed changes. This research finds that the use of change detection method in remote sensing/ArcGIS and social survey do complement each other in terms of analyzing the impact of present and past land use change dynamics.

6.2 Recommendations

The study only provided preliminary insight into the problem of wetland change assessment using remote sensing/GIS and social survey at Duthuni wetland ecosystem. The specific suggestions for future work are as follows:

1. In order to judiciously manage wetland resources, there is a need for awareness programs directed to the local community, where community leaders and the members of wetland management committees must recognize the full range of stakeholders who use these areas and involve them in all wetland decision making processes. This will ensure that wetland use is not only ecologically sustainable but also socially responsive to the needs of the community.
2. Improved wetland management in Duthuni must acquire different types of knowledge from a variety of sources, through a range of different channels, both indigenous and external in origin. The transfer of ancestral knowledge should play a vital role in providing farmers with basic information on wetland management.
3. The tribal authority must develop policies and strategies and make sure that it is implemented by the community in order to protect the wetland ecosystem from being destructed in the name of landless and subsistence farming. There must be a good relationship between tribal authority and farmers.
4. There is a need for government to develop reliable updated database on wetland statuses at the district level as there is no system of keeping records on the wetland statuses.
5. There is a need for the government through working for wetland program to map the wetland ecosystem from further degradation through population increase and cultivation. This would help to restore degraded wetland and allow natural condition for animals and plants to grow.
6. Further research on different cause/ drivers both anthropogenic and natural on wetland ecosystem land cover change must be assessed regularly.

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APPENDIX A: SURVEY QUESTIONNAIRE

Questionnaires directed to the heads of households at Duthuni village.

Survey aims at assessing the impacts of land use changes on the Duthuni wetland stream.

Consent: The information collected will be used for academic purposes. Profile of the respondent will be kept private and participation is voluntary.

Use a cross (**X**) to mark your answers where appropriate.

Section A: The socio-economic profile of respondents.

1. What is your age group?

Age		No.
Under 18 years		1
19-25 years		2
26-35 years		3
36-45 years		4
46 and above years		5

2. Sex

category		No.
Male		1
Female		2

3. Marital status

Status		No.
Never married		1
Married		2
Divorced		3
Widowed		4

4. Occupation

Status		No.
Employed		1
Unemployed		2
Self-employed		3

5. Income ranges

Category		No.
0>1000		1
1000>3000		2
3000>5000		3
5000 and more		4

6. What is your education level?

Category		No.
Non-formal education		1
Primary		2
Secondary		3
Tertiary		4

7. (A) What kind of toilet does the household use?

Type		No.
Pit toilet		1
Flush		2
Other specify…		3

B) How did you set up your toilets?

Toilet set up		No.
Household sewage system to nearby septic tank		1
Household Sewage system to nearby, using bricks to build septic tank		2
Sewer pipe connected to a sewage pipe system		3
Pit toilet using concrete slab and bricks from foundation		4
Pit toilet without using concrete slab and bricks from foundation		5
Other specify…		6

7(C) How do you manage your toilet

Toilet Management		No.
Applying chemicals for decomposition		1
Cover the hole with dirt and digging another hole		2
No management		3
Other specify…		4

Section B: Land use change

8. How long have you lived in this village?

Period		No.
Less than 5 years		1
5-10 years		2
11-20 years		3
more than 20 years		4

9. What was on the land cover before you settle here?

Type		No.
Grave		1
Cultivated land		2
Natural Forest		3
Wetland		4
Settlement		5
Grass		6
Other specify…		7

10. Why did you come to settle here?

Reasons		No.
Agricultural purpose		1
Preserve ancestral land		2
Relocation		3
Lack of space to settle		4
Other specify…		5

11. (A). How was the population density in this area before you settle here?

Conditions		No.
Low		1
moderate		2
High		3

11. (B). Specify which year? …………………..

12. From your perspective, is the any competition in land use in terms of spatial development/trends, extent/size and patterns?

Opinions		No.
Yes		1
No		2

13. (A). Since you're living here, have you noticed any land use/cover changes in the area?

Opinions		No.
Yes		1
No		2

13. (B). If yes what are those land use/ cover changes that was dominated in the area?

Type		No.
Grave		1
Cultivated land		2
Natural Forest		3
wetland		4
Settlement		5
Grass		6
Other specify....		7

13. (C). Which years land cover was dominated?

Period		No.
Less than 5 years		1
5-10 years		2
11-20 years		3
more than 20 years		4

14. (A). What are the most primary major drivers of land use change?

Causes		No.
Agriculture		1
Institutional factors		2
Population density		3
Cultural factors		4
Natural variability		5
Mining activities		6
Land for grazing		7
Other specify…		8

14. (B). Specify why is the major driver?

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15. Do you experience problem of overgrazing in the wetland and adjacent areas?

Opinions		No.
Yes		1
No		2

Section C: Land use change impacts on wetland

16. Do you know that the wetland around you play significant role in the ecosystem of this area?

Opinions		No.
Yes		1
No		2

17. What ecosystem service do you think are most provided by the wetland?

Type		No.
Drinking water		1
Education and research		2
Harvestable resources		3
Cultivated food		4
Erosion control		5
Other specify…		6
I don't know		7

18. (A). Do you have anything you practice along the wetland? (E.g. Agriculture)

Opinions		No.
Yes		1
No		2

18. (B). If yes specify (what activity and how far in terms of distance, your practicing such activity from wetland ecosystem?

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19. Which equipment do you use for tilling within the wetland stream?

Type		No.
Tractors		1
Hand hoe		2
Animal driven hoe		3
Other specify………		5

20. What type of animals mostly grazes in this area?

Type		No.
cow		1
goat		2
pigs		3
Other specify…		4

21. Which resource do you get most from wetland?

Type		No.
Construction material		1
Food		2
Building sand		3
Water for drinking		4
Medicines		5
handcraft production		6
None		7
Other specify…		8

22. (A). From your perspective what are most major impact of land use change on the wetland ecosystem?

Issue		No.
Deforestation along buffer zone of wetland		1
Soil erosion		2
Loss of biodiversity		3
Water pollution		4
Over-grazing		5
Loss of habitat of endemic species		6
Other specify…		7

22. (B). Specify why?

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23. What do you think will happen in the future of Duthuni wetland stream as results of land use change?

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Section D: Rate of land use change

24.(A) Thinking about the areas close to where you live, over the past years do you think the area of land being used for Agriculture has increased, decreased or remained unchanged?

Conditions		No.
Increased		1
Decrease		2
Remain unchanged		3
Don't know		4

24. (B). Which years did you noticed that?

Period		No.
Less than 5 years		1
5-10 years		2
11-20 years		3
more than 20 years		4

25.(A) Thinking about the areas close to where you live, over the past years do you think the area of land being used for grazing has increased, decreased or remained unchanged?

Conditions		No.
Increased		1
Decrease		2
Remain unchanged		3
Don't know		4

25. (B). Which years did you noticed that?

Period		No.
Less than 5 years		1
5-10 years		2
11-20 years		3
more than 20 years		4

26. (A). Thinking about the areas close to where you live, over the years do you think the area of land being used for residential has increased, decreased or remained unchanged?

Conditions		No.
Increased		1
Decrease		2
Remain unchanged		3
Don't know		4

26. (B). Which years did you noticed that?

Period		No.
Less than 5 years		1
5-10 years		2
11-20 years		3
more than 20 years		4

Section E: Wetland Management

27. (A). Do you know any laws which regulate the use of wetlands ecosystem?

Opinions		No.
Yes		1
No		2

27. (B). If yes specify any laws that you know...
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28. How often have you discussed your views on the issue of wetland degradation with friends and family members?

Conditions		No.
Never discussed		1
Not often		2
Quite often		3
Extremely often		4

29. Who else is involved in environmental management in this area?

Participants		No.
Community		1
Government officials/Extension Officers		2
Non-Governmental Organization		3
No one		4
Don't know		5
Other specify…		6

30. (A). Do you have any knowledge on the environmental impacts of practicing different land uses on the wetland ecosystem?

Opinions		No.
Yes		1
No		2

30. (B). If yes, what is your main reason of doing so?

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31. Which management strategy do you use usually to sustain wetland ecosystem?

Management strategies		No.
Sustainable burning		1
Sustainable grazing		2
Minimal tillage		3
Controlling alien plants		4
Minimal road access to the wetland		5
Sustainable plants harvest		6
Prohibited the use of fertilizers, herbicides and pesticides		7
No management strategies		8
Other specify…		9

THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

Questionnaires directed to the Farmers at Duthuni village.

Survey aims at assessing the impacts of land use changes on the Duthuni wetland stream.

Consent: The information collected will be used for academic purposes. Profile of the respondent will be kept private and participation is voluntary.

Use a cross (**X**) to mark your answers where appropriate.

32. When did you start practicing subsistence farming in this wetland?

Period		**No**
Less than 5 years		1
5-10 years		2
11-20 years		3
more than 20 years		4

33. What was on the land cover before you started to practice here?

Type		**No.**
Grave		1
Cultivated land		2
Natural Forest		3
Wetland		4
Settlement		5
Grass		6
Other specify…		5

34. How do you access water from the main wetland stream?

Type		**No.**
Furrows		1
Pumping		2
Fetching		3
Other specify…		4

35. (A). Are you still getting enough water from wetland for irrigation purpose as you used to get it before?

Opinions		**No.**
Yes		1
No		2

35. (B). If no, what will be the course?

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36. Why did you come to cultivate here?

Reasons		**No.**
Shortage of food		1
Preserve ancestral land		2
Relocation		3
Lack of space to cultivate		4
Other specify…		5

37. How did you get the land you cultivate?

Reasons		No.
Bought		1
Inherited		2
Borrowed		3
Given by the Government		4
Other specify…		5

38. Which equipment do you use for tilling within the wetland stream?

Type		No.
Tractors		1
Hand hoe		2
Animal driven hoe		3
Other specify………		4

39. What kind of farming are you practicing?

…………………………………………………………

40. (A). Do you use herbicides,/pesticides or artificial fertilizer?

Opinions		No.
Yes		1
No		2

40. (B). If yes specify which fertilizer do you use?

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41. (A) Do you know that different land uses that are practiced in the wetland ecosystem have detrimental impact in the wetland ecosystem?

Opinions		No.
Yes		1
No		2

41. (B) If yes what are those impacts?

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42. (A) Do you know any laws which regulate the use of wetlands ecosystem?

Opinions		No.
Yes		1
No		2

42. (B) If yes what are those laws?

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43. What benefits are you getting from this wetland?

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44. Who else is involved in the management of farming activities in this area?

Participants		No.
Head man		1
Officials from government		2
Extension officers		3
Non-Governmental Organization		4
No one		5
Don't know		6

45. (A). Do you have appropriate mitigation strategies that you are using to minimize the impacts on wetland ecosystem?

Opinions		No.
Yes		1
No		2

45. (B). If yes what are those mitigation that you use often?

Management strategies		No.
Sustainable burning		1
Sustainable grazing		2
Minimal tillage		3
Controlling alien plants		4
Minimal road access to the wetland		5
Sustainable plants harvest		6
Prohibited the use of fertilizers, herbicides and pesticides		7
No management strategies		8
Other specify…		9

46. What are the challenges as farmers do you come across within this wetland ecosystem?

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THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

Questionnaires directed to Chief of the village.

Survey aims at assessing the impacts of land use changes on the Duthuni wetland stream.

Consent: The information collected will be used for academic purposes. Profile of the respondent will be kept private and participation is voluntary.

Use a cross (**X**) to mark your answers where appropriate.

47. Do you know that there is a problem of land cover change in your area?

Opinions		**No.**
Yes		1
No		2

48. (A). Do you know that the wetland around you play significant role in the ecosystem of this area?

Opinions		**No.**
Yes		1
No		2

48. (B). If yes, what are those roles?

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49. (A). Do you know that different land uses that are practiced in the wetland ecosystem have detrimental impact in the wetland ecosystem?

Opinions		**No.**
Yes		1
No		2

49. (B). What are those impacts?

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50. Why do you allow people to cultivate, washing car, mining and settle within the wetland ecosystem?

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51. (A) Do you know any laws which regulate the use of wetlands ecosystem?

Opinions		No.
Yes		1
No		2

51. (B) If yes what are those laws?

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52. How often have you discussed your views on the issue of wetland degradation with community, Farmers, Government and non-Governmental Organization?

Conditions		No.
Never discussed		1
Not often		2
Quite often		3
Extremely often		4

53. (A). Do you have appropriate mitigation strategies that you are using to minimize the impacts on wetland ecosystem?

Opinions		No.
Yes		1
No		2

53. (B). If yes what are those mitigation that you use often?

Management strategies		No.
Sustainable burning		1
Sustainable grazing		2
Minimal tillage		3
Controlling alien plants		4
Minimal road access to the wetland		5
Sustainable plants harvest		6
Prohibited the use of fertilizers, herbicides and pesticides		7
No management strategies		8
Other specify…		9

54. What are the challenges that you encounter in to make our wetland to be sustainable without degradation?

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THANK YOU FOR COMPLETING THIS QUESTIONNAIRE

Questionnaires directed to Government Officials

Survey aims at assessing the impacts of land use changes on the Duthuni wetland stream.

Consent: The information collected will be used for academic purposes. Profile of the respondent will be kept private and participation is voluntary.

Use a cross (**X**) to mark your answers where appropriate.

55. Do you know that there is a problem of land cover change in the Duthuni area?

Opinions		**No.**
Yes		1
No		2

56. Do you have a wetlands inventory of this area?

Opinions		**No.**
Yes		1
No		2

57. How often do you monitor all the wetlands that you have including Duthuni wetland stream?

Conditions		**No.**
Never monitor		1
Not often		2
Quite often		3
Extremely often		4

58. Do you have wetland management plan within this area?

Opinions		**No.**
Yes		1
No		2

59. (A). Are wetland management policies are being implemented?

Opinions		**No.**
Yes		1
No		2

59. (B). If yes what are the challenges during implementation?

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APPENDIX B: ETHICAL CLEARANCE