THE EFFECT OF RESETTLEMENT INDUCED LAND USE CHANGES ON MAVAIRE RIVER DISCHARGE IN SHASHE SUBCATCHMENT.

By

Blessing Ndau

A research project submitted in partial fulfillment of the requirements for the Master of Science in Land Resources Assessment for Development Planning in Semi-arid Areas.

Faculty of Natural Resources Management and Agriculture

Midlands State University

June 2015

ABSTRACT

Land use changes have been occurring as a result of human uses for developmental purposes. These changes will certainly have a negative influence on the hydrological characteristics of catchments, thereby inducing an increase in surface runoff, soil erosion and sediment inputs. In the year 2000, Rio Tinto discovered kimberlite diamonds in Murowa, Zvishavane. This discovery led to the relocation of 142 families to Shashe resettlement block in Masvingo Province near Mashava. The area which was once rangeland area was then converted to settlement and cultivation in 2004. The land conversion has had significant effects on runoff which results in sedimentation of the Mavaire river. To determine the effect of the resettlement induced land use changes on Mavaire river discharge firstly, the spatial and temporal land use changes that took place in Shashe were determined using landsat images with ArcGIS 10.1 and the results showed that a significant change in the spatial and temporal land uses existed. The major land use changes which took place for the 3 years of 1998, 2006 and 2014 were as follows; Water percent area was decreasing for this time period and it was 1%, 3% and 2% respectively. Mining percent area was also decreasing and was 18%, 12% and 4% respectively. A decrease in forest area was also noted. It was 29%, 22% and 3% respectively. Grassland percent area was 34%, 16% and 12%. Cultivation percent area was 13%, 17% and 32%. Rangeland was 29%, 30% and 47%. Secondly the relationship between the selected land uses and runoff was then tested using linear regression. Further statistical analysis was done with R^2 value and standard error. A strong relationship between selected land uses and runoff of Mavaire river was found. A strong positive relationship was $y = -0.146x+66713$ for mining, the R^2 value 0.970 and it had a standard error of 18% .A decrease in forest area resulted in an increase in runoff and a strong positive relationship existed between the two at a slope of $y = 0.077x+66669$. The R^2 value was 52% and its standard error was 0.930. Cultivation area was increasing, this resulted in an increase in runoff at a slope of $y = 0.125x+65790$. The standard error was 32% and the R^2 value of 0.930. Rangeland area was also increasing but it resulted in a decrease in runoff at a slope of $y = 0.119x+65433$. The R^2 value was 0.786 and its standard error was 54%. The results from this research are particularly relevant for Shashe resettlement block in formulating, implementing and monitoring strategies for sustainable development such as farmer training programmes on conservation agriculture, promoting the use of biofuels to reduce deforestration, also monitoring of the cutting down of trees with the help of the Environmental Management Agency and chiefs as well as headmen with the help of the Ministry of Agriculture should designate properly managed paddocks to control overgrazing. The government and eminent domains should also ensure that negative effects of resettlements are given due consideration in the planning procedure to avoid environmental consequences. Also there is need to conduct research on future land use change effects on dam sedimentation of Mavaire river.

ACKNOWLEDGEMENT

My deep gratitude goes to my supervisors, Prof J.Masaka, Mr S. Zirebwa and Mr E. Mupfiga for the great work and unwavering support. Without them this work would not have been a success. I would also to extent my gratitude to my family and friends for bearing with me and encouraging me, especially when the going got tough. Glory be to God who gave me the strength to soldier on.

DEDICATION

This thesis is dedicated to my loving husband, my adorable son, my caring mother, my sister and friends.

Declaration

I hereby declare that this thesis has been a result of my original efforts and investigations and such work has not been presented elsewhere for any degree. All additional sources of information have been acknowledged by means of references.

Blessing Ndau…………………………

Date

Certification of Thesis

I the undersigned certify that Blessing Ndau, a candidate for the Masters in Land Resources Assesment for Development Planning for Semi Arid Areas has presented this thesis with tittle:

The Effect of Resettlement Induced Land Uses Changes on Mavaire River Discharge in Shashe Subcatchment.

That this thesis is accepted in form and content in that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate through an oral examination on the 27th of May 2015.

Academic supervisors

Prof Masaka ……………………………...

Mr Zirebwa ……………………………..

Mr Mupfiga ……………………………..

Table of Contents

LIST OF FIGURES

List of figures

CHAPTER 1: INTRODUCTION

1.1 Background

The terms land use and land cover are often used interchangeably and inappropriately and in the end they are confused. Land use is a term that refers to a series of activities that are undertaken to produce goods and services. It is described on the basis of the functions of land and can also be described as the range of direct human induced uses such as agriculture, forestry recreation among many other uses (IPCC, 2001). Land use is thus described as the manner in which land is utilised and exploited for its resources by humans and this is usually at the expense of the environment (Bhatta, 2010). Land cover on the other hand is the observed physical cover that can be visualized on the ground such as water, ice and sand. These covers can also be seen through remote sensing techniques such as geographical information systems for example Landsat images can be acquired and processed through ArcGIS software (FAO, 1997).

Human's activities have led to the transformation of a large proportion of the planet's land surface as a result of population increases. For example humans destroy the environment when they clear up forests and converse it to urban area and also through practices such as subsistence agriculture. Intensification of farmland production and the conversion of rangeland to settlement is also conducted by human beings hence the results of their actions have changed the world's landscapes in pervasive ways by leading to air, water and soil pollution (De Fries et al., 2004). These activities also certainly have a negative influence on the hydrological characteristics of catchments, as they lead to an increase in surface runoff, soil erosion and sediment inputs (Calder, 2007).

The mining industry is one of the major causes of development induced resettlement along with dam construction. This has seen most land being converted from rangeland to settlement or cultivation causing negative impacts on the environment. Development induced resettlement involves the involuntary resettlements of populations without the informed consent of the displaced persons or, if they give their consent, without having the power to refuse resettlement (IFC, 2011). A typical example of such displacement is a government agency's expropriation of land for a capital development project by eminent domain. People occupying or otherwise dependent on that land for their livelihoods may be offered fair compensation for their losses. However, they have little recourse to oppose the government's expropriation, regardless of their desire to continue occupying or using the affected land

(IFC, 2002). Of the top ten exports in Zimbabwe in 2008 diamonds were ranked 9th. Globally the country is among top ten diamond producers with estimated revenue of US$334 million (Partnership Africa Canada, 2009). According to a 2001 Oxford Refugee Centre report, the mining industry is the fourth greatest reason of development induced displacement resettlement (Rew et al., 2000). In Zimbabwe mining it is the fastest growing economic sector and a major stimulus for economic recovery (African Development Bank, 2011). In 2010 the mining sector contributed 65% of total exports (Ministry of Finance, 2011; Mtisi et al., 2011). It is a recurring land use function in Zimbabwe hence a major contributory factor to most land use-cover changes.

Rio Tinto discovered kimberlite diamonds in Murowa, Zvishavane in December 1997. During the discovery phase it was decided that the operation of the mine would require the the relocation of about 142 families to Shashe in Masvingo province. In 2002 resettlement agreements were signed between the company, the government of Zimbabwe and the communities affected. In 2004 preparations for the mining operations were completed and 926 people of 142 families were relocated to Shashe resettlement area (Rio Tinto, 2010). Rio Tinto had built new homes, roads, clinics, and a shopping centre for these affected communities (Bogumil, 2012). According to Nish and Blice (2012), Rio Tinto’s resettlement programme was socially acceptable as the company signed a public agreement with the affected families. This agreement led to the relocation of 265 graves from Murowa to Shashe.

The conversion from rangeland to settlement and cultivation are typical land use-cover changes that have potentially large impacts on the hydrological cycle and water resources (Stonestrom et al., 2009), particularly now with the climate change phenomena and increasing water demand in regions where water availability is limited such as semi arid areas (Mugabe, 2005). Research on the effect of changes in land use- cover have been found to have significant changes in leaf area index(Mao and Cherkauer, 2009), soil moisture content, infiltration capacity (Fue et al., 2009) runoff as well as surface roughness (Feddema et al., 2005) together with soil erosion. These effects are caused as a result of the complex interactions among vegetation, soils, geology, terrain and climate processes. Land use modifications also affect flood frequencies and magnitudes (Ward et al., 2008; Remo et al., 2010) and changes in water supply and quality (DeFries and Eshleman, 2004).

The increase in water demand and the potential for land use-cover change to compromise the hydrological cycle and reduce water availability calls for a better understanding of water budget and movement to enable a sustainable management of water catchments, one way to achieve this is by exploring effective methods and mechanisms of water resource management with geographical information systems (Surur, 2010).

Effects of land use changes on hydrological effects can be done through time series analysis of historical data. This method is however not conclusive in nature. Catchment experiments can also be conducted (Hibbert, 1967; Hewlett et al., 1969; Bosch and Hewlett, 1982; Andréassian, 2004) as well as the establishment of empirical relationships that exist between hydrological variables with land uses (Turner, 1991; Zhang et al., 2001; Lu et al., 2003; Oudin et al., 2008). Hydrological models can also be used to determine these effects (Onstad and Jamieson, 1970; Jain et al., 1992; Hundecha and Bárdossy, 2004) as well as geographic information system (Jasrotia and Singh, 2006; Calder, 2007).

This study will explore the relationship between runoff and major land uses as well as ascertain the strengths of these relationships and the major causal factors for Shashe resettlement block with the use of field observed data and remotely sensed data. This will enhance the sustainable management of Shashe catchment.

1.2 JUSTIFICATION

The Shashe block is a semi-arid area in natural region IV of Zimbabwe (Vincent and Thomas, 1960). It was previously white minority owned and was specifically used by six large scale commercial agricultural farm owners as rangeland before a major conversion was done to settlement and cultivation in 2001(Rio Tinto, 2001). Natural Regions IV and V lie in the semi-arid areas of Zimbabwe. They receive rainfall that is less than 600 mm per annum and frequent droughts are experienced in this region (Vincent and Thomas, 1960). The little rainfall the area experiences is however ineffective as it is not uniformly distributed.(Gowing, 2003). Effective yields are received in three out of five years (Nyamudeza, 1998), this forces the affected communities to rely mainly on subsurface underground (Mbetu, 1993; Lovell, 2000) or water stored in dams during the dry years.

The major challenge in Shashe is of the severe drying up of Mavaire reservoir, borehole water as well as the siltation of that small catchment. This causes for concern as small surface reservoirs play an important role of providing ready and useful source of water for various uses to rural communities (Andrein et al., 2009) such as small scale community gardens, livestock watering, brick making, building, dip-tank watering thus are a buffer during dry seasons and drought years (Senzanje et al., 2008).

A substantial amount of research work has been carried out on catchment hydrology and how it affects water resources (Bosch and Hewlett, 1982; Smith, 1987; Burch et al., 1987; Butterworth, 1997; Green and Marsh, 1997; McCartney et al., 1998; Schulze, 2000) .Most of that work was mainly focusing on wet areas. The few studies in the semi-arid areas are by (Butterworth, 1997, Lorup et al., 1998 and McCartney et al., 1998). Characterising the response of a catchment to rainfall, in terms of the production of runoff versus the interception, transpiration and evaporation of water, is the first important step in understanding water resource availability in a catchment. This is particularly important in small semi-arid catchments, where a few intense rainfall events may generate much of the season's runoff and where there is a spatial and temporal variability of rainfall can be high (Butterworth, 1997)

There exists a gap in semi-arid areas in terms of land use changes on catchment hydrology as fewer studies have been conducted in these catchments as compared to other areas. Most work has considered extreme hypothetical situations whereby change is implemented on the whole catchment (Bosch and Hewlett, 1982), yet such changes are often in different sections of the catchment. The impact of land use changes on surface water resources thus needs to be established, as a lot of households in the semi-arid areas depend on surface water resources (Lovell, 2000).

The effect of land use changes on the hydrology is not clear in catchment where studies have not yet been conducted. This study in Shashe will establish the relationship that exists so as to effectively manage this subcatchment. In Shashe resettlement block, there are no variation in the physical characteristics of the catchment, the major conversion of land use led to a massive decrease in forested areas and an increase in cultivated area thereby influencing the discharge for this site. Given that there are about 600 small to medium dams in Masvingo Province, most of which were built in the1970s, with some dating back to the 1940s (Zirebwa and Twomlow, 1999). No records of whether these small dams fill up every year or the quantity of water still retained at the beginning of the wet season is available. Lack of such information complicates water management decisions for the communities as they do not know how much water can be used in a given season and how much should be left before the onset of the wet season, in which there is a risk that the dam may not refill, because of the typical pattern of rainfall in semi-arid areas. This study will help in the sustainable management of small catchment dams which are experiencing severe land use changes through identification and establishment of crucial relationships of land uses that have a strong influence on runoff. This will be aided with the use of geographical information systems and remotely sensed data.

1.3 Objectives

Main Objective

To establish the response of Mavaire river discharge to resettlement induced land use change.

Specific Objectives

a. To determine the spatial and temporal land use changes of Shashe resettlement area from 1998 to 2014.
b. To establish the relationship of selected land use changes on Mavaire river discharge in Shashe resettlement area from 1998 to 2014.

1.4 Hypotheses

a. Ho: There is a significant change in land uses of Shashe resettlement block from 1998 to 2014.

   H_1: There is no significant change in land uses of Shashe resettlement block from 1998 to 2014
b. Ho: There is a strong relationship between selected land use changes and Mavaire river discharge in Shashe resettlement area from 1998 to 2014.

   H_1: There is no strong relationship between selected land use changes and Mavaire river discharge in Shashe resettlement area from 1998 to 2014.

Chapter 2: LITERATURE REVIEW

2.1 Global land use functions

The modification of the earth's surface by human actions have led to deforestation, an increase in natural disasters, biodiversity loss and global warming (Ruelland et al., 2011, Beuchille et al., 2011, Potakov et al., 2012) due to mismanagement of agricultural lands, forest lands and urban as well as rangeland. These land use negative effects are being caused by the increase in the human populations as well as the growing socio- economic necessities. This scenario has built a need to have information on the available land uses so as input data that can be used to enhance proper environmental management and planning in a sustainable manner (Skole et al., 1993; Brink et al., 2009).

One of the main uses of land is cultivation. This use has been on the increase as from the 1980's (Xiomei and Ronqing, 1999), particularly in semi arid areas such as Zimbabwe (Lumbing et al., 2001). Croplands and pastures have developed so much and are now occupy the largest area in the planet and they have rivaled the extent of forest area. Their area extent is approximately 40% (Rumankutty and Foley 1999; Asner et al., 2004). This type of changing land use has enabled the growth of world grain harvests to increase such that they exceed two billion tons per year (Mann, 1999). This increase can be attributed to a 12% increase in earth cropland area (Matson et al, 1997).

Land use change, however, does not come without costs . Conversion of farmland and forests to urban development reduces the amount of lands available for food and timber production. Soil erosion, salinization, desertification, and other soil degradations associated with intensive agriculture and deforestation reduce the quality of land resources and future agricultural productivity (Lubowski et al. 2006).

Land uses disrupt the surface water balance, partitioning of precipitation into evapotranspiration and runoff as well as groundwater flow. Surface runoff and river discharge generally increase as forest area decreases (Shiklomanov, 1998). Tocantins River basin which is located in Brazil showed a 25% increase in river discharge between 1960 and 1995, this increase was as a result of the expanding agriculture as there was no major change in precipitation (Costa et al., 2003). Overall water withdrawals in the world are now 10% of the entire global renewable resource (Shiklomanov, 1998). Agriculture alone accounts for 85% of global consumptive use (Annu et al., 2003).A lot of large rivers in semiarid regions are experiencing reduced flows. Some of them are drying up. In addition, the extraction of groundwater reserves is almost generally unsustainable thus has resulted in declining water tables in many regions (Rosengrant et al., 2002; Postell, 1999. Intensive agriculture also results in an increase in erosion hence sediment load also increases. Intensive agriculture leaches nutrients and agricultural chemicals to both surface and subsurface water resources thus it has In fact become the largest cause of excess nitrogen and phosphorus to water bodies (Benett et al., 2001; Carpenter et al., 1998).

.

Land use activitie caused by agriculture have resulted in a net loss , have resulted in 7 to 11million km² of forest being lost in the past 300 years (Ramankutty and Foley, 1999; Gibbs, 2001; FAO, 2004). Many land use practices such as wood collection for fuel, forest grazing and encroachment of cultivation land in forest and settlement expansion can degrade forest ecosystem conditions in terms of productivity, biomass, stand structure, and species composition even without changing forest area. Land use can also degrade forest conditions indirectly by introducing pests and pathogens, changing wood for fuel fuel loads, altering patterns and frequency of ignition sources as well as altering local meteorological conditions (Nepstad, 1999). However in East Asian countries, reforestation and afforestation measures that are undertaken have resulted in an increase in the area of forested lands (Fung et al., 2001). Also forest management in many regions is acting to improve forest conditions such as inadvertent nitrogen fertilization, peatland drainage. Direct management efforts increased the standing biomass of European forests by 40% between 1950 and 1990 (Kauppi et al., 1992; Nabuurs et al., 2003).

Land is one of three major factors of production in classical economics (along with labor and capital) and an essential input for housing and food production. Thus, land use is the backbone of agricultural economies and it provides substantial economic and social benefits. Land use change is necessary and essential for economic development and social progress. Land–use change is arguably the most pervasive socioeconomic force driving changes and degradation of ecosystems. Deforestation, urban development, agriculture, and other human activities have substantially altered the Earth's landscape. Such disturbance of the land affects important ecosystem processes and services, which can have wide–ranging and long–term consequences (Table 2) Farmland provides open space and valuable habitat for many wildlife species. However, intensive agriculture has potentially severe ecosystem consequences. For example, it has long been recognized that agricultural land use and practices can cause water pollution and the effect is influenced by government policies. Runoff from agricultural lands is a leading source of water pollution both in inland and coastal waters. Conversions of wetlands to crop production and irriga tion water diversions have brought many wildlife species to the verge of extinction. Forests provide many ecosystem services. They support biodiversity, providing critical habitat for wildlife, remove carbon dioxide from the atmosphere, intercept precipitation, slow down surface runoff, and reduce soil erosion and flooding. These important ecosystem services will be reduced or destroyed when forests are converted to agriculture or urban development. For example, deforestation, along with urban sprawl, agriculture, and other human activities, has substantially altered and fragmented the Earth's vegetative cover. Such disturbance can change the global atmospheric concentration of carbon dioxide, the principal heat–trapping gas, as well as affect local, regional, and global climate by changing the energy balance on Earth's surface (Marland et al. 2003). Urban development has been linked to many environmental problems, including air pollution, water pollution, and loss of wildlife habitat. Urban runoff often contains nutrients, sediment and toxic contaminants, and can cause not only water pollution but also large variation in stream flow and temperatures Habitat destruction, fragmentation, and alteration associated with urban development have been identified as the leading causes of biodiversity decline and species extinctions (Czech, Krausman and Devers 2000; Soulé 1991). Urban development and intensive agriculture in coastal areas and further inland are a major threat to the health, productivity, and biodiversity of the marine environment throughout the world.

2.2 Resettlement induced land use changes

Mining is the one of the main causes of development induced displacement is probably the second largest category of resettlement (IDMC, 2010). Mining Induced Resettlement (MIDR) has not been researched fully thus lack of data on its severerity exists. Each year, about fifteen million people are displaced as a consequence of large investments. The problem was exposed in the mid-fifties during the construction of large dams in Africa such as the Kariba dam in Zimbabwe (Cernea, 1998). Scientific understanding of development-induced displacement and resettlement was formed by the effects of building large dams. Development induced displacement is caused by the the construction of dams, hydroplants, and large irrigation projects, building of roads, urbanization, development of agriculture (IDMC, 2010).

The first cases of MIDR was in the 19th-century in India. It was caused by the actions of the Britain and the United States of America. In Africa, which was divided at that time among the colonial empires as well as against Indians broken out in America. In the majority of cases, the natives became the victims, a situation which has not changed to the present day. The rapid development of technology in the 20th century has transformed mines into large industrial facilities. Big companies exploiting open-pit mines rarely pay attention to the situation of local communities (Oxford Refugee Centre Report, 2001).

MIDR exists in many countries and constitutes a visible and burning social issue that poses a threat to human rights as well as the environment. It is present in countries such as India (Fernandes and Walter, 2006), Ghana, China (Dewtt, 2006), Philippines, South Africa, Tanzania, Democratic republic of Congo, New Guinea, Mali and Zimbabwe.

In China there is not much literature on mining-induced displacement. Available publications, however, draw attention to the dangers of resettlement associated with the exploration of new coal rich areas in China, such as Xinjiang province. Various Uighur communities living in this area are particularly vulnerable to this problem (Dewet, 2006).

Mining in the Philippines has caused massive displacement of indigenous peoples from their ancestral lands. The expansion of mining has led to many negative consequences for indigenous populations such as loss of ownership, management, and control of land and resources which are the material base of the peoples' identity, culture, and survival, and denial of the peoples' resource-management systems. It has also caused massive loss of livelihood and destruction of local economies and has resulted in numerous threats to food, health and water security. The dislocation of settlements and villages and weakening of socio-cultural systems is another effect of mining in the Phillipines destruction of bio-diversity, pollution and degradation of the environment. Mining –induced displacement also resulted in the loss of traditional knowledge and systems of resource management (Bhengera, 1996). Among the communities most threatened by forced displacement are B'laan, Kasibu, Nueva, Vizcaya, and Igorot.

The problem in Papua New Guinea is the expansion of the two largest open-pit mines in the country: OK Tedi mine and Porgera mine. Particular attention was paid to human rights violations in the first project for Tedi mine, more than 30,000 people have been displaced by pollution associated with the development of OK, Tedi gold mine. According to some sources (Hillson, 2006) environmental damages have displaced 4,000 people. As for Porgera mine, during its development of gold and silver mining operation, many people were relocated. Resettlement principles were identified in the Porgera Relocation Agreement in September, 1988, the Tolukuma Compensation Agreement in November, 1993, and the Lihir Integrated Benefits Package in April, 1995 (Dewett, 2006).

More than 30,000 people were displaced between 1990 and 1998 in the Tarkwa district of Ghana by gold mining operations. At least several hundred people each year are resettled in the region as a result of mining development. Mining in this area has destroyed 14 communities between 1990 and 1998, mass displacement has led to the large-scale migration of young people to urban centres mostly in Tarkwa. The second planned mining project in Ghana called the Akyem project is likely to destroy surrounding habitat and move hundreds of people from their initial places of residence. One of the most controversial projects in Ghana is also the Ahafo gold mine. Since its commencement in 2006, the mine has been faced with allegations of human rights abuses committed by the security forces protecting the mine, along with the displacement of 10,000 people, inadequate compensation, and environmental disruption such as cyanide spill in October 2009 (Cernea, 1991).

Displacement in Mali is the consequence of gold-mining development in three areas which are Sadiola, Syama, and Morila. In the Sadiola region, 46 villages lost their space due to MIDR. Sadiola mine, which will operate until approximately 2011, is the largest gold extraction investment in Mali. Experts state that only in the area of three villages that are Sadiola, Farabakouta, and Niamboulama has the development of mining led to the displacement of more than 1,000 people. In the Forou region near the Syama gold mines, 121 communities have lost their land because of mining (Mali foreign government, 2011). According to Eyolf Jul-Larsen (et al., 2011), the major social consequences of industrial gold mining in Ghana are the expropriation of land and displacement of villages; a reduction in agricultural and pastoral activities; environmental hazards; housing bottlenecks; social changes, unemployment, and inflation(Larsen, 2012). Lack of comprehensive statistical data makes it impossible to determine the scale of MIDR in Mali. According to Sonnenberg and Munster (2001), 2135 people from 85 households were resettled in Sadiola Hill where an open-pit gold mine was opened in 1996 in Kayes Region of Mali and 165 people from 8 households were resettled in Yatela where the expansion of the Yatela open-pit gold mine, opened in 2001 and was situated 25 km north of Sadiola. In mid 1996, Anglo Gold Ashanti worked to resettle the villages near the Sadiola mining area, Sadiola, Farabakouta, and the Niamboulama and between April 1999 and October 2000, 1200 inhabitants of these villages were then resettled.

Resettlement issues in Botswana are particularly connected with the rights of aboriginal people, cultural heritage, and the conservation of nature. The most well known example of displacement is the forced relocation of two aboriginal San communities of the Gana and Gwi tribes from the Central Kalahari Game Reserve. This action led to the violation of several human rights: indigenous people rights, water rights, and the right to land. The San people’s case, among others, was undertaken by the Human Rights Commission of the United Nations in Geneva. Since the mid-nineties, there is also the subject of court battles in Botswana. The reasons for the relocation of aboriginal peoples are for the conservation of nature and for mining. According to Survival International, in three big clearances, in 1997, 2002 and 2005, virtually all the Bushmen were forced out. Their homes were dismantled, their school and health posts were closed, their water supply was destroyed and the people were threatened and trucked away (Nish, 2012) .In 1997 the government of Botswana decided to resettle hundreds of San people living in the Central Kalahari Game Reserve (CKGR). According to official statements, the aim of the operation was “proposed conservation and development" and to raise the functioning standards of the rest of the San living in the reserve. In July 2004, the authorities decided to resettle the next several hundred residents of the reserve because deposits of diamonds were discovered. This decision led to protests by 250 San people residing there. The world-renowned corporation De Beers expressed interest in the exploitation of diamond deposits in the reserve (Nish, 2012).

Another attempt to remove San people from the Central Kalahari Game Reserve was in 2008. In 2009, a Botswana government official has admitted that the Kalahari Bushmen were evicted from their land to make way for diamond mining, and that authorities cut off the water supply to force Bushmen out of the Central Kalahari Game Reserve (Colchester,2002). In 2009, about 1,000 San people were seeking to return to the Kalahari Reserve. The Central Kalahari Game Reserve is a disgraceful example of a place where mining and tourism development were more important than the rights of indigenous peoples.

The Democratic Republic of Congo has Africa’s largest mineral resources, but the vast majority of its people live in poverty. The fight to control mining has been a major factor in the violent conflict which has raged in eastern Democratic Republic of Congo for at least 16 years. The problem of so-called blood diamonds exists where the profits from the diamond trade are used to fund conflicts. Rebel forces control some of the diamond fields, extracting diamonds, then selling them and spending the earned money to continue the conflict. In 2011, Randgold Resources announced plans to start mining Africa’s biggest undeveloped gold deposit in eastern DR Congo. The beginning of gold mining in Kibali will require the re-location of 15,000 people. The new Kibali gold project is located close to the Ugandan border in a corner of DR Congo. According to Randgold representatives, all people will be moved to a new village constructed by the company. In June 2011 the first of 14 affected villages started moving to the Kokiza resettlement village, which will include approximately 3700 newly built homes. Only two of 12 villages have already been resettled to date (Randgold, 2012).

The development of titanium mining in Kenya's Kwale region led to the displacement of at least several thousand people. In 2001, 3300 to10000 people (450 households) were resettled as a consequence of mining conducted by Tiomin Resources (Sonnenburg and Munster, 2001). In July 2004, the Kenyan government and Toronto-based Tiomin Resources signed a deal for a 21-year mine for titanium in Kwale. It was estimated that, by 2007, the mining project would displace 5,000-10,000 in the Kwale district. Many of them are indigenous people.

Konkola Copper Mines is the biggest copper produced in Zambia. According to Sonnenberg and Munster (2001), 750 people from 143 households had been resettled at that time by mining operations. The affected people (67 households) were moved to Ming'omba village on 14 January, 2002. In February 2002, 74 households from Kawama were resettled. The resettlement plans were implemented in accordance with IFC Guidelines. Residents were given access to social services: schools, a health centre, water supply, sanitation (Curtious, 2008).

The Bulyanhulu Gold Mine, opened in 2001, forced the resettlement of 511 people from 56 households (Sonnenberg and Munster, 2001). In 1996, the mine was the scene of one the most infamous cases of mine-related violence. Over 50 artisanal miners were buried alive by bulldozers used to construct new mine. About a thousand people were displaced due to development of the Buzwagi Gold Mine in the Kahama District. More than 30,000 artisan miners were resettled as a consequence of the construction of Geita and Nzega, two large-scale gold in Tanzania (Curtious, 2008).

Resettlements in Mozambique are associated with the mining of titanium in its Chibuto District (Corridor Sands Titanium) and Moma District (Moma Sands Titanium). According to Sonnenberg and Munster (2001), 4200 people in 840 households were resettled in connection with the Corridor Sand Heavy Mineral Sand Project. Resettlement implemented by the Brazilian mining company Vale in the Moatize district, in the western province of Tete aroused the protests of affected people. Between November 2009 and April 2010, Vale resettled hundreds of people from the area of mining concession in Chipanga. About 717 households regarded as 'rural' were resettled in the locality of Cateme, about 35 kilometres from Moatize town and 288 households, regarded by mining company as 'semi-urban', were resettled in the neighbourhood within the town. About 308 households refused to change their place of residence, and demanded monetary compensation instead. In Cateme 750 new houses were built and people have access to social services, an elementary school, a police station, a health center, and water and electrical infrastructures. Despite this fact, displaced people protested against a number of problems encountered. According to some sources, 400 of the 750 houses had been poorly built and access to electricity, water, and agricultural land. On January 10, 2012, more than 400 families blocked the road and railway line in Tete to protest against poor living conditions and the failure of the resettlement programme. Vale has now promised to resolve all the problems at the Cateme resettlement area within half a year.

A particularly infamous example of MIDR in Zimbabwe is connected with the recent development of the Marange Diamond Fields. The Chiadzwa area, located in the eastern part of the country is considered the world's biggest diamond find in more than a century. In January 2009, the government announced its plans to resettle 4,700 Chiadzwa villagers to the 12,000 ha Arda Transau Farm, on the Odzi River. Resettlement plans provoked protests amongst Chiadzwa villagers (Madehwe et al., 2011). Over 500 Manicaland families from Chiadzwa to date have been relocated to Arda Transau Relocation Village, 24 km from Mutare. The villagers moved into three-bedroom houses, built by a private contractor, which cost $55,000 per unit (Katsaura, 2010). Mbaba Diamonds, the company responsible for the exploration, promised to build schools and clinics and to provide residents with basic social services. This might be just the beginning of resettlement issues in Zimbabwe, as more and more diamond deposits are discovered in this country. The development of mining can bring about a host of negative consequences for the rural population of Zimbabwe.

Rio Tinto, a mining company operating in many countries, is a good example of a corporation applying the principles of sustainable development and ethical responsibility. Rio Tinto's Murowa diamond mine in Zimbabwe is an example of ethical and appropriate resettlement. The Murowa is a diamond mine opened in 2004, located in southern central Zimbabwe, 350 km south-west of Harare. During the discovery phase, it was ascertained that the development of the project would require the relocation of 100 families. In June 2001, the initial resettlement mapping plan was completed, according to which 926 people from 142 families were resettled. In May 2002, resettlement agreements were signed among the company, local authorities, and the resettled community. The preparation of mine facilities was completed in late 2004. These activities included the relocation of 926 people living in the immediate vicinity of the mine to 6 farms purchased by the government resettlement program. In 2005, the company relocated 142 families to Shahse, about 150 kilometres east of Murowa (Rio Tinto, 2001). A public infrastructure agreement was signed between the company and local authorities on access to social services and the construction of school and health facilities. A separate public agreement was associated with the relocation of 265 graves from the old settlement to the specially prepared new area. Additionally, after the initial resettlement plan, 224 families were relocated to Shashe resettlement area in Mashava, Masvingo Province.

According to Rio Tinto, the company then built new roads, a health centre and a primary school. They also implemented community development projects including micro-irrigation and agricultural and business training programmes, allowing the people to adapt to their new situation and the development of a local economy (Nish, 2012). As Simon Nish and Sara Bice pointed out, each family received access to approximately 8 ha of arable land for their own purposes and access to 32 ha of common arable land (Bogmuli, 2010). The case of the Murowa diamond mines is a good example of broad public participation in resettlement schemes, negotiations significantly in advance of resettlement, and detailed public infrastructure agreements but the environmental consequences are not fully catered for. This study was thus carried out to establish the relationship between resettlement induced land use changes on selected hydrological characteristics on this site.

Mining Induced Displacement is a problem that has been duly and thoroughly penetrated in the last 40 years. Yet this theme still remains marginal from the perspective of environmental consequences especially hydrological characteristics aspect (Downing, 2002). Mining-induced displacement exists in several dozen countries around the world and mostly in developing countries it leads to numerous negative consequences. Thus, the effects of displacements should be given due consideration in order to avoid such environmental consequences.

2.3 Land use changes and remote sensing

In order to assess past land use changes, satellite images provide valuable spatially distributed information. Historic multispectral satellite images can be used to produce past land use classifications. In the absence of historic ground truth data, different methods and data such as historic topographic or land use maps are employed to derive accurate past classifications (Miller et al., 2002; Seeber et al., 2010). These classifications are superior to commonly used freely available, global data sets (Hansen et al., 1998), as they provide a higher spatial resolution (30 m) and often have a higher level of detail with regard to the number of distinguished classes. Each land use classification is representative of the date of the satellite image and the phenology of the plants at this time in the year (Jensen, 2007), particularly in regions with a high temporal variability in temperature such as temperate and continental climates or precipitation such as tropical wet and dry climates, the date of the satellite imagery has a pronounced impact on the identifiable and distinguishable land use classes. In order to derive a classification which is representative of the whole year, several land use classifications from different times in the year can be combined to produce one multitemporal land use classification (Villarreal et al., 2011; Yuan et al., 2005). By this means, the intra-annual differences are minimized. Thus, a series of such multitemporal land use classifications can be analyzed to identify the inter-annual or, in the present case, inter-decadal changes over a past period of time.

2.3 Remote sensing and Geographical Information Systems.

Remote sensing and Geographical Information Systems (GIS) are powerful tools that are used to derive correct and appropriate information on the spatial allocation of land use and land cover changes .They execute so particularly on large areas and as well remote areas frequently for a period of more than 40 years (Persson, 1977; Tappan et al., 2004; Archard et al., 2002; Bodart et al., 2011). Remote sensing imagery is thus the most important data resources of GIS because it provides satellite imagery which that is used for the recognition of synoptic data on the earth's surface (White, 1983). It also provides a rich archive and spectral resolution satellite images. Remote sensing sensors such as the Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data have been broadly employed in studies towards the determination of land use and cover since 1972.This was also the starting year of Landsat program. These images have been used mainly in forest and agricultural areas management (FAO,1993).

Landsat images are processed with GIS to provide land use and land cover changes. One of the processes that they go through is called change detection.The aim of change detection process is to recognize LULC on digital images that change features of interest between two or more dates (Wittig et al., 2007). There are many techniques that have ben developed in literature that uses post classification comparison, conventional image differentiation, using image ratio, image regression, and manual on-screen digitization of change principal components analysis and multi date image classification (Esteve et al., 1998). A variety of studies have addressed that post-classification comparison was found to be the most accurate procedure and presented the advantage of indicating the nature of the changes (Larsson, 2002). GIS provides a flexible environment for collecting, storing, displaying and analyzing digital data necessary for change detection (Chandle et al., 2009; Pekkarinen et al., 2000; Tucker et al., 2014).

GIS is can also be described as an integrated system of computer hardware and software that is capable of capturing, storing, retrieving, manipulating, analyzing and displaying geographically referenced information for the purpose of aiding development-oriented management and decision-making processes (Aboyade, 2001). Remote sensing and GIS have covered wide range of applications in the fields of agriculture (Yeh and Li, 1998), environments (Fung and Ledrew, 1987), and integrated eco-environment assessment (Long et al., 2008). Current remote sensing technology offers collection and analysis of data from ground-based, atmospheric, and Earth-orbiting platforms, with linkages to GPS data, GIS data layers and functions, and emerging modeling capabilities (Franklin, 2001). For applications at the global or continental levels, coarse spatial resolution images with pixel size from 250 m to 1 km and more, large swath width and high revisiting period, such as Advanced Very High Resolution Radiometer (AVHHR), Satellite Pour l'Observation de la Terre (SPOT), Medium Resolution Image Spectrometer (MERIS), and Moderate Imaging Spectrometer (MODIS) have been considered as the only sources of image data which regularly deliver information about large areas. However their coarse resolutions is mainly focused on the detection of broad scale land cover change patterns, hence they fail to monitor changes like deforestation and land degradation which usually occurs on a smaller scale (Tziztiki et al., 2012).

To overcome these limitations and acquire more detailed information of the Earth's land surface, medium resolution satellite images with pixel sizes of 30–80 m pixel such as Landsat TM and Landsat MSS are used as they have got greater spatial accuracy although they have lower revisit cycle. These sensors have been used for mapping and monitoring land cover and its changes (Tziztiki et al., 2012, Fung and Ledrew, 1987).

Coarse-spatial resolution meteorological satellite data have been available since the 1960s and civilian remote sensing of the Earth's surface from space at medium spatial resolutions (250 m) only began in 1972 with the launch of the first of a series of Earth Resource Satellites (Landsat). This was the initiation of significant research activity in remote sensing technology, data analysis and applications, which continue to present day. From 2000 there has been a proliferation of satellite platforms with a large number of sensors such as Terra and ENVISAT and increasing spatial resolutions such as IKONOS and Quickbird.Also in these years there has been an ever-expanding constellation of satellite platforms which have acquired thousands of trillions of bytes of data invaluable for planning and land management applications (Jensen, 2000). It has been estimated that approximately 100 new satellites will be launched during the 10-year period between 1996 and 2006 (Fritz, 1996). Furthermore, high-resolution airborne data acquisition technology has developed rapidly in recent years. As a result, there is a large selection of remote sensing data of the Earth's surface with respect to spatial, spectral and temporal sampling.

Remote sensing technology has been driven by three interrelated factors which are the advancements in sensor technology and data quality, improved and standardized remote sensing methods, and research applications (the least developed of the three(Franklin, 2001).

2.4 Types of Remote sensors

2.4.1 Coarse-spatial resolution sensors

Coarse-resolution image data (spatial resolution .250 m) fall outside of the minimum spatial resolution requirements outlined. Coarse-resolution data have been used for many years to acquire basic land-cover and land-use information over large areas. Spatial resolution is the obvious limiting factor in these studies, especially when urban and suburban land-cover and land-use change is considered. For example (Stow and Chen , 2002) examined the sensitivity of anniversary-date multitemporal AVHRR1 data to map land-cover and land use change and found significant confusion between changed and unchanged areas, even with the application of a geometric mis-registration model. Recently (Zhan et al. 2002) described the monthly 250 m resolution Vegetative Cover Conversion (VCC) product generated from Moderate Resolution Imaging Spectroradiometer (MODIS) data.

2.4.2 Medium resolution sensors

This type of sensor was created to offer proper scales of data for the different earth observation and applications. One such type of sensor is Landsat. Landsat was developed in 1972(Franklin, 2001) with the launch of the Landst Multi Spectral Scanner. This sensor provides data that has got a spartial resolution of about 80m.This data is acquired at four spectral bands.However its limiting factor is that it provides data that has got noise (Schowengerdt, 1997).This type of data regardless of this disadvage offers rearchers data that has been used at regional scales to come up with conclusive natural resources management options.

The second launch of landsat occurred in 1984 with the launch of the Landsat Thematic Mapper. This sensor had a higher spectral resolution as well as the spartial and radiometric resolution. The spectral channels of this sensor were chosen to map vegetation as well as geologic features (Jensen, 2000). The Indian Space Research Organization (ISRO) has also added to the suite of medium resolution sensors. ISRO has launched four linear array sensors to date (IRS-1A, 1B, 1C and 1D). In general, the IRS sensors offer a combination of TM/ETMþ spectral resolution, with SPOT sensor spatial resolution. The IRS-1C and 1D (launched in 1995 and 1997, respectively) offer visible and near-infrared bands at 23 m spatial resolution and a midinfrared band at 70 m spatial resolution. Moreover, these IRS sensors acquire panchromatic information at 5.8 m spatial resolution, which has significant implications for higher-order mapping capabilities. The contribution of medium-resolution sensors is expected to continue long into the future (Franklin, 2001). Indeed, follow-on sensors have already been put in place. The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), an instrument on the Terra platform, acquires visible and near-infrared information at 15m spatial resolution and mid-infrared information at 30 m spatial resolution. Further, the Earth Observer (EO-1) platform includes the linear array Advanced Land Imager (ALI) with 10 bands, ranging from the visible to mid-infrared regions of the electromagnetic spectrum at 30 m spatial resolution and a panchromatic band acquired at 10 m spatial resolution (Jensen, 2000).

2.4.3 High-spatial resolution sensors

These type of sensors have got a great characteristic of offering information on a visible and also a near infrared spartial resolution of 4m at 11 bit. They also show panchromatic information at 1metre spartial resolution (Jensen, 2001). The flexibility of this sensor implies that people do not have to rely on scheduled data but can acquire it data at specific times. Such is the valuability of this onboard sensor. The famous type of high resolution sensors are IKONOS-2 and Quickbird-2.IKONOS was launched in in 1999 and Quickbird in 2001.

2.4.4 Hyperspectral sensor.

Imaging spectrometry for land use and land cover analysis has been the centre work of current research work (Treitz and Howarth, 1999). This type of data has shown a possibility for future use in terms of identifying phenomenas that cannot be currently detected with broadband systems (Herold et al., 2002).Two types of hyperspectral sensors are available at the moment are Moderate Resolution Imaging Spectrometer known as MODIS .The other type of hyperspectral sensor is the Earth Observer Hyperion instrunment. Research work on this type of sensor is being undertaken to gain knowledge of this sensor in the natural environment (Rashed et al., 2001)

2.4.5 Microwave sensors

Radar technology has been on the market for 50 years. It is a type of an active microwave sensor. This type of technology has however not been extensively used in land cover and land use monitoring (Kasischke et al., 1997).This is so because there is lack of basic understanding of it use combined with the inadequate analysis method that are applicable to it. Despite this drawback a number of synthetic radar systems have been developed together with the deployment of spaceborne systems like SIR-C/X-SAR, ERS-1, ERS-2, JERS-1 and RADARSAT-1 (Jensen, 2000)

2.4.6 APPLICATIONS AND PROCESSES OF REMOTE SENSING

Applications of remote sensing were aided by the hierarchical land cove classification that was developed by Anderson and his colleagues in 1976. This classification is now being used globally to describe the various land uses and land cover in remote sensing classification (Franklin et al., 2003). This has facilitated research to be carried out in determining changes in vegetation cover, wetland monitoring and making future predictions in various land use-change cover (Jensen, 2000).

Accurate per-pixel registration of multi-temporal remote sensing data is essential for change detection since the potential exists for registration errors to be interpreted as land-cover and land-use change, leading to an overestimation of actual change (Stow, 1999). It can also ensure the user that the change that is identified is accurate and not an artefact of an image processing procedure. Geometric registration is required to remove or reduce the effects of non-systematic or random distortions present in remote sensing data namely, variations in sensor system attitude and altitude, and these can only be accurately corrected by developing a model to tie per-pixel image features to specific per-pixel ground features such as ground control points (GCPs) where geographic coordinates are known (i.e. from an accurate reference map/image or GPS data, (Kardoulas et al., 1996).

Geometric registration error among two images can be articulated in terms of angood enough total root mean square error (RMSE), which represents a measure of deviation of corrected GCP coordinate values from the original reference GCPs used to develop the correction model. Robust and unbiased estimates of RMSE should be calculated using independent GCPs not used in model formation (Kardoulas et al., 1996). Tolerable RMSE value of ,0.5 pixels (Jensen, 2000) is recommended by quite a number of authors, however others have recommended acceptable RMSE values ranging from .0.2 pixels to ,0.1 pixels, depending on the type of change being investigated (Townshend et al., 1992).

Several methods have been developed to compensate for the effects of misregistration on image change detection. Justice et al. (1989) suggested pixel aggregation to a larger spatial resolution to assess change, thus changing the analysis to a larger minimum mapping unit (MMU), and reducing mis-registration effects. Gong et al. (1992) used two image-filtering algorithms with some success in reducing mis-registration effects. Finally, Stow (1999) and Stow and Chen (2002) presented and tested a new model on TM and AVHRR data that used estimates of misregistration across a scene (known as misregistration fields) combined with calculation of spatial brightness gradients to adjust the magnitude of multitemporal image differences. Their study demonstrated the effects of image resolution on the potential to compensate for misregistration error, as this error may be more significant in coarse resolution data. Improvements are needed in reporting the characteristics of geometric registration, including improved error analysis in both geometric accuracy and geometric uncertainty (Franklin, 2001).

Variations in solar illumination conditions, atmospheric scattering, atmospheric absorption and detector performance result in differences in radiance values unrelated to the reflectance of land cover. Absolute radiometric quantification is an expensive, time consuming and likely untenable goal for land-cover and land-use monitoring (Song et al., 2001). Therefore, the primary goal of most change detection studies is to achieve imageto- image normalization, so that spatial–temporal differences in image brightness or derivative values primarily convey information about changes in land cover and land use (Roberts et al., 1998). The two most commonly used radiometric normalization techniques are Dark object subtraction (DOS) (Chavez, 1996) and relative radiometric normalization using pseudo-invariant features (PIFs) (Schott et al., 1988). Both approaches are based on the assumption that the atmospheric scattering component is consistent throughout the imagery (Carlotto, 1999).

Song et al. (2001) compared seven DOS algorithms and one PIF method with uncorrected ‘raw’ multitemporal Landsat TM data and found that all corrections provided an improvement over the raw data. However, these atmospheric normalization algorithms are often unsuitable for removing spatially varying haze resulting from smoke plumes or smog in remote sensing data acquired over both natural and urban areas (Rogan et al., 2001). Carlotto (1999) presented a new method for reducing the effects of wavelength-dependent scattering in multispectral imagery, which is intended for use in situations, where atmospheric scattering affects visible wavelengths and varies across space. This method results in an image in which space-varying scattering has been equalized over the entire image so that previously developed techniques such as DOS for removing constant scattering effects can be used. Even when great care is taken to normalize satellite data for exogenous effects to allow image analysts to focus on change-related events revealed in the remote sensing data, intra-annual differences in climate, particularly precipitation, can cause significant differences in pixel brightness (Rogan et al., 2002). These seasonal effects often lead to errors in change detection products where estimates of land-cover abundance, composition and condition are required (Cihlar, 2000). Recently, Jakubauskas et al. (2002)

found Fourier harmonic analysis of a NOAA AVHRR NDVI biweekly composite time series data, useful for examining the interactions between landscape environmental factors and inter-annual variability of land-cover types in the southern Great Plains region of the United States.

Change enhancement applies to pre-classification enhancement only, as it is not required in post-classification approaches. One of the most commonly applied change enhancements is 'image subtraction'. This involves calculating a change image based on the difference between corresponding image-channels from two dates. Change images are easily interpreted because their histograms are normally distributed (i.e. unchanged pixels fall along the center of the histogram, with change pixels falling to the left and right of the histogram, depending on the darkness and brightness of these areas, Jensen, 2000). The same procedure is often performed on enhanced imagery, such as vegetation indices (Singh, 1989). This approach can also be performed on a ratio-based or perpendicular index.

Principal components analysis (PCA) involves the orthogonalization of a multispectral and multi-date dataset based on components generated from an eigenvector-derived factor-loading matrix (Schowengerdt, 1997). The factor-loading matrix is based on a correlation matrix approach (standardized), or based on the variance-covariance matrix (non-standardized). Studies have shown that the choice of matrix can affect the statistical nature of the final components (Patterson and Yool, 1998). In general, when PCA is performed on a multi-date layer stack, the first component will be representative of the overall multi-date image variance (similar to an albedo image, Rogan and Yool, 2001). Higher components such as PC2, PC3 will be representative of changes in image variance between the dates. These high-order components, therefore, are responsive to inter-date change and can be used to classify changes in a study area. PCA works well, and is widely used for this purpose (Lunetta and Elvidge, 1998). In addition, the process results in data reduction (i.e. a large data set is compressed into a limited number of components). A drawback of PCA, however, is that the technique is based only on the statistical properties of the data, and is therefore limited in its application to different times and different areas. In addition, the statistical nature of PCA determines that areas of high inter-date variance in the imagery tend to 'drive' the eigenvector process, which can prove frustrating if those areas are not the change features of interest to the interpreter. Some of the drawbacks associated with PCA are easily overcome using the Multitemporal Kauth Thomas transformation (MKT). This index is based on the orthogonalization of a multiband, and multi-date dataset (Collins and Woodcock, 1996).

For example, the MKT can produce six output features based on the transformation of a 12-band multi-temporal Landsat TM dataset. These output features represent, stable brightness, stable greenness, stable wetness, change in brightness, change in greenness and change in wetness. The MKT has been used in several studies to date (Levien et al., 1999; Rogan et al., 2002), and appears to be a robust indicator of land-cover change. Unlike the PCA, MKT is not scene-dependent, and its use of stable and calibrated transformation coefficients ensures that its application is suitable between regions and across time. The fact that the MKT produces several sets of change features, rather than a single feature (Normalized Difference Vegetation Index (NDVI) is another attractive quality. Further, the MKT produces stable spectral components, which could be used in developing baseline spectral information for long-term studies (Rogan et al., 2003).

Change vector analysis (Malila, 1980) involves the calculation of two change features magnitude of change, and direction of change based on a multitemporal dataset. Magnitude (quantity of inter-date change) is calculated based on the Euclidean distance of a bi-temporal (or multi-temporal) spectral vector. The direction image is calculated based on the angularity of the vector (Cohen and Fiorella, 1998). Several methods exist for calculating the vector angle. Lambin and Strahler (1994) used PCA of a 12-date AVHRR dataset to calculate the angular distance of the multispectral vectors. Further, Cohen and Fiorella (1998) based their calculation on the Gramm-Schmidt orthogonal distance from a baseline. Both approaches produced physically meaningful magnitude and Composite analysis (CA) has been used often in change detection applications (Yuan and Elvidge, 1998). This approach involves compositing all desired bands into a multi-date layer stack (the layer stack may contain raw or enhanced image data).Supervised classification with the use of calibration data or unsupervised classification is selected and performed to get the preferred number of output classes. The basis of CA is that ‘change’ classes are located in the whole set of existing classes (Cohen and Fiorella, 1998). However the disadvantage of this approach is that non-change classes can mask statistical variance of the change classes. It is highly recommended that a thresholding method be performed on the data, so that change and no-change pixels are located in the change imagery. Thresholds are regularly based on the number of standard deviations and the mean of the change image (Lunetta et al., 2002). Recent research has examined the selection of thresholds based on a sound statistical basis (Rogerson, 2002).

Image classification is done to both post-classification and pre-classification change detection approaches. It can be performed with either supervised or unsupervised approaches. Prior to supervised classification, calibration data must be sufficiently sampled from appropriate areas to account for the spectral variability of each class in question. In unsupervised classification, an algorithm is chosen that will take a remotely sensed image data set and find a pre-specified number of statistical clusters in measurement space (Schowengerdt, 1997). Although these clusters must then be assigned to classes of land cover and land use, this method can be used without having prior knowledge of the ground cover in the study site. Supervised classification, however, does require prior knowledge of the ground cover in the study area and is, therefore, a more intuitive method for land-cover change mapping. With the supervised approach, calibration pixels are selected and associated statistics are generated for the classes of interest. Recent work by Chen and Stow (2002) compared the performance of three different calibration strategies for supervised classification (single pixel, seed, and polygon). The calibration set size, the image resolution, and the degree of autocorrelation inherent within each class influenced the performance of these strategies, and polygon-based calibration performed best in areas of heterogeneous land-cover type. The vast majority of land-cover and land-use monitoring approaches have used traditional image classification algorithms for example maximum likelihood, which assume that image data are normally distributed, the images are H-resolution2 and pixels are composed entirely of a single land-cover or land-use type (Franklin et al., 2003).

Conversely, L-resolution3 approaches have employed empirical models to estimate biophysical, demographic and socio-economic information (Rashed et al., 2001). Recently, researchers have investigated scenes using a combination of L- and Hresolution approaches (Roberts et al., 1998; Rogan et al., 2002). For example, spectral mixture analysis (SMA) can be used to estimate sub-pixel information about both natural and urban/suburban scenes (Phinn et al., 2002). Fuzzy sets approaches, where an observation can have degrees of membership in more than one class, have also shown promise (Foody, 1999). Machine learning classifiers such as decision trees and artificial neural networks have been used effectively in a variety of single-date land-cover mapping studies (Huang and Jensen, 1997; DeFries and Chan, 2000). In almost all cases, these classifiers have proven superior to conventional classifiers such as maximum likelihood, often recording overall accuracy 'improvements of 10–20%. The success of machine learning classifiers in resolving land cover and changes in land cover and land use for complex measurement spaces can be attributed to several factors. Machine learning is a combination of the objects within the classifiers is not constrained by parametric statistical assumptions. Hence, they are better suited for analyzing multi-modal, noisy, and/or missing data; and a combination of categorical and continuous ancillary data. However, few studies, to date, have examined the potential of this approach in a change detection context (Gopal and Woodcock, 1996; Abuelgasim et al., 1999; Rogan et al., 2002).

2.5 Land use change and water resources management

Rapid socio-economic development drives land use changes, which include changes of land use classes for example the conversion of cropland to urban area due to urbanization or the conversion of forest to settlement and cultivation due to resettlement, as well as changes within classes such as a change of crops or crop rotations. In regions where water availability is limited, land use changes could result in an increase of water scarcity which will contribute to a deterioration of the living conditions of the general population (Stonestrom et al., 2009). DeFries and Eshleman(2004) underline the importance of understanding the impact of land use change on water resources, which they identify as a key research topic for the decades ahead as these changes have potentially large impacts on water resources.

The effect of land use changes especially on water availability have been studied in many regions of the world (Miller et al., 2002; Im et al., 2009; Li et al., 2009; Ghaffari et al., 2010). These effects have been studied in some of the following, Germany (Kl¨ocking and Haberlandt, 2002; Barthel et al., 2012), Canada (Wijesekara et al., 2012), Ethiopia (Legesse et al., 2003), and Kenya (Mango et al., 2011).

Chauhan and Nayak (20050 reported that industrial development and population pressure in Hazira, Gujarat, India led to an increase of built up area and a decrease in forest and agricultural areas between 1970 and 2002. An increase of cropland and a decrease of grassland and shrubland in a study on a part of the Eastern Ghats in South India were also found (Jayakumar and Arockiasamy, 2003). Deforestation between 1973 and 1995 was reported in a study on the southern part of theWestern Ghats (Jha et al. 2000). Similarly, a study about Indian Himalayan catchments found a decrease of natural forest and an increase of agricultural land (Sharma et al., 2007).

Impacts of land use change on the water resources in India were mainly assessed by using scenario analysis and it was found out that agricultural water interventions had a pronounced impact on water resources (Gharg et al., 2012). Mishra et al. (2007) analyzed the effects of land use on runoff and sediment yield to prioritize the construction of structural water management measures. Wilk and Hughes (2002) conducted a study in South India employing several land use scenarios, and found that only the extreme and very unlikely scenarios had a pronounced impact on runoff. The largest increases of runoff were found when converting forest and savanna to agriculture, whereas the largest decrease of runoff resulted from a conversion to forest in this study (Khan et al., 2011; Ramesh, 2001).

A number of studies that have been conducted have found that land use activities significantly alter the hydrological response of a catchment especially deforestation and urbanization (Karvonen et al., 1999).This results were mostly conducted at experimental studies of catchments (Jackson et al., 2008). Runoff generation has become one of the hydrological consequences that has been studied on.It has been found to increase as economical development improves. The control of land use on rainstorm runoff production has been found to be complicated. Land use and soil cover up include an effect on interception, surface retention, evapotranspiration as well as resistance toward overland flow (Olivera and Maidment, 1999). Forests removal reduces infiltration, it also improves the condition of overland flow (Kuchment, 2008). Increase in runoff is thus due to land use change, particularly land clearing (Leblanc et al., 2008) thus unoff becomes mostly of the “hortonian” type which is produced when rainfall intensity exceeds the soil infiltration capacity (Horton, 1933).Surface runoff thus occurs when the soil is unable to absorb rainwater and removes it through the processes of transpiration, infiltration, and sub-surface runoff. It thus depends on the synchronized action of factors classified as abiotic factors for example relief and geomorphological characteristics, parent rock and soil composition, and climate. The other factors are biotic factors for example vegetative cover of the slope, land use, anthropogenic factors. Vegetation cover represent one of the most dominant factors which influence runoff regime as since it modify and moderate numerous other factors.

CHAPTER 3 METHODOLOGY

3.0 Site description

3.1.1 LOCATION.

Shashe resettlement scheme(30º29´E, 20º10´S) is situated in ward 6 of Masvingo Rural District Council (MRDC) in Masvingo Province, close to Mashava business center in Masvingo.

3.1 Climate.

It is in Agro-ecological Region IV with an annual rainfall total ranging from 450 to 500 mm and an annual rainfall coefficient of variation of 19% (Vincent and Thomas, 1961). The distribution of effective rains in the summer season extending from November to March is poor and mid-season droughts are common. The region experiences high average monthly temperature of 38°C, high potential evapotranspiration rates of up to 1800mm per year (Mupangwa et al., 2006) The few heavy showers received during summer are often followed by high air and ground temperatures coupled with hot and desiccating south-easterly winds that sweep away the surface moisture.

3.1.2 Vegetation and Land Use

The block is an area of 15 020ha, resettled +/- 500 small holder farming families hence it is used for settlement. It is occupied by asbestos and gold mining activities and is also used for agriculture.

3.1.2 Soils

Most of the soils are from granitic rocks which give rise to Fersiallitic soils that are light to medium textured soils with high amounts of coarse sand (Nyampfene, 1991). They have low inherent fertility and low water holding capacities .They have a low cation exchange capacity and water retention due to low soil organic matter and clay contents (Chua et al., 1997; Nzuma and Murwira, 2000).

3.2 Determining the spatial and temporal land use changes of Shashe resettlement area from 1998 to 2014.

3.2.1 Image acquisition

Image selection was done in which Landsat images were downloaded at the following website www.landsatlook.usgs.gov. Landsat remote sensing data was used as the primary data source for derivation of generalized land cover information. Landsat satellites provide multispectral data from the early 1970s to the present. Given that the purpose of this project was to provide a general landscape characterization and change analysis instead of detailed vegetation and resource mapping, the spatial resolution of Landsat data was appropriate. Data availability and cost were also a consideration in the selection of this source of data (Ju and Roy, 2008). Images for the years 1998, 2006 and 2014 were collected for analysis.

Table 3.2.1: Landsat Image data sources.

Type of sensor	Path	Row	Date of acquisition	Cloud cover
Landsat 8 OLI(2013-present)	174	60	14/10/2014	0%
Landsat 7 ETM +SLC off	174	60	12/09/2006	0%
Landsat 4-5 TM(1982-2011)	174	60	30/10/ 2014	0%

3.2.2 Image Classification

ArcGIS 10.1, was used for the classification and change detection of the landsat data for the 1998, 2006 and 2014 images. The derived landsat images were converted into composite bands 3, 4, 5. The Zimbabwe ward shapefile for Masvingo area was used to clip, rectangularily the ward 4 Shashe image which was found in ward 803 with the aid of geospartial coordinates.

Training sites of the chosen classes were selected using prior knowledge of the area and Google Earth. The training sites were distributed throughout the study area taking sub-classes of the main categories. The sub-classes include: dense, moderate and sparse forest, open and closed grassland, open and closed rangeland, open and closed mines, annual and perennial cropland and water body. Spectral signatures of individual land use/land cover classes were developed based on selected training sites that were merged.

To conduct image classification and accuracy Rogan and Chen (2004) suggested that supervised classification methods are be intuitive for land cover change detection if the required prior information about the landscape is gained through personal knowledge of the study area, in addition to a combination of ground visits and aerial photography interpretation. The maximum likelihood classification is based on the probability density function that is associated with a particular training site signature. All pixels are assigned the label of the most likely category based on an evaluation of the subsequent probability that the pixel belongs to the class with the highest probability of membership (Atkinson and Lewis, 2000; Jensen, 2004). Although the maximum likelihood method assumes a normal distribution of the data, it is still considered as one of the most useful classifiers, as it does not always require large training data sets and its performance is comparable to other algorithms if the training sites are of good quality or limited size (Wu and Shao, 2002). It is a statistical table that uses Bayesian formula to allocate a pixel to classes with the highest probability(Tso and Mather,2009)From this classification six classes were generated for the three images, 1998; 2006 and 2014 which according to Anderson(1976), are as follows,

Table 3.1.2 Shashe Land use classes description.

Land use	**Description**
Water	Water bodies
Mining	Active mining and mine dumps
Forest	Decidious forest land
Cultivation	Cropland
Grassland	Pasture
Rangeland	Shrub and brush rangeland

3.2.3 Post Classification

The overall classification accuracy for the three1998, 2006, 2014 maps were computed (Silva, 2006). In order to quantify the area extent (in hectares) of the resulting land use / land cover type for each study year and for subsequent comparison, calculation of the percentage and area coverage by each class was done by adding 2 fields in the ArcGIS attribute table of the classified images, that is the percentage covered by each land cover and its area. The two equations which were used were defined as follows, ([COUNT]/Sum of pixels)*100 and ([COUNT]/Sum of pixels)*(sum of pixels *900m2) for calculating percent cover and area respectively.

3.3 Establishing the relationship between selected land use changes on Mavaire river discharge in Shashe resettlement area from 1998 to 2014.

The Mavaire river in Shashe's streamflow data for the period 1998 to 2015 was collected from ZINWA, Masvingo. The climate data for Shashe area for the period 1998 to 2015 was collected from the Masvingo Meteorological station number 679750. Land use changes were determined by the researcher using a spartial analyst called ArcGIS 10.1. A linear relationship between the relative change in land uses and the corresponding relative change in runoff was tested using linear regression. The strength of the prediction accuracy was then tested using the coefficient of determination $(R^{2)}$ and the standard error.

CHAPTER FOUR RESULTS

4.1 The spartial and temporal land use changes of Shashe resettlement area from 1998 to 2014

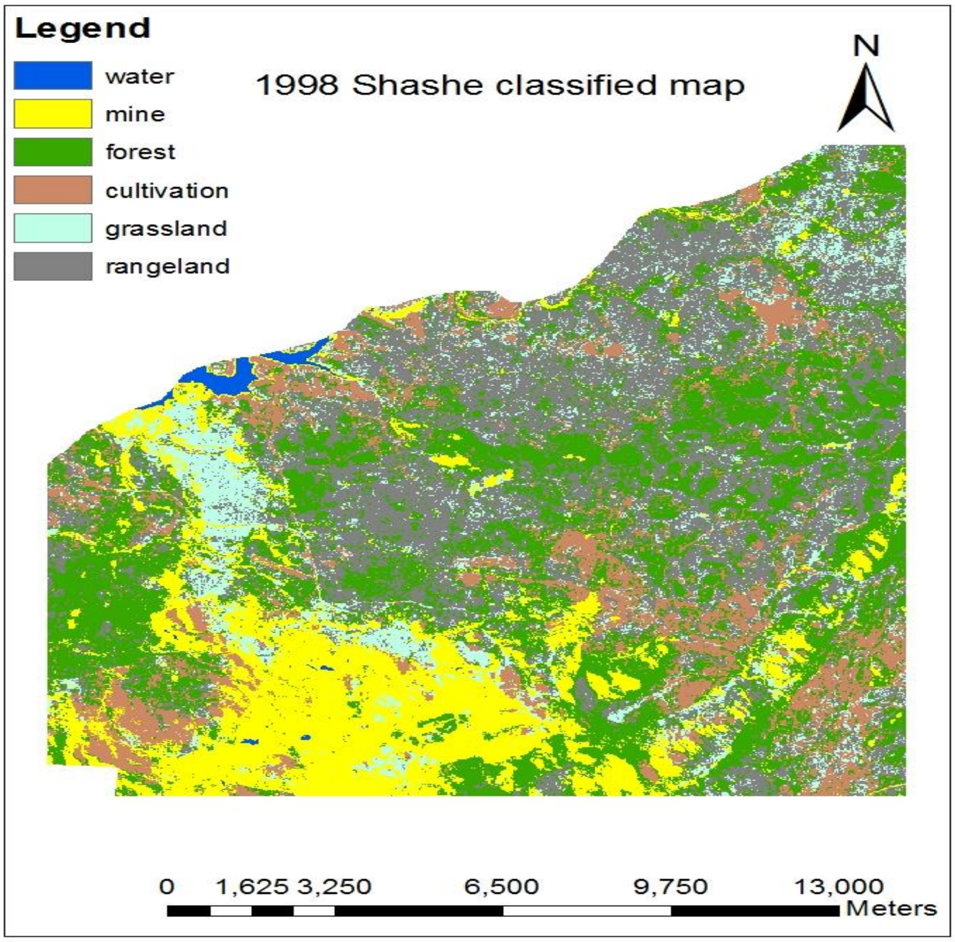


Figure 4.1.1: 1998 Shashe classified map

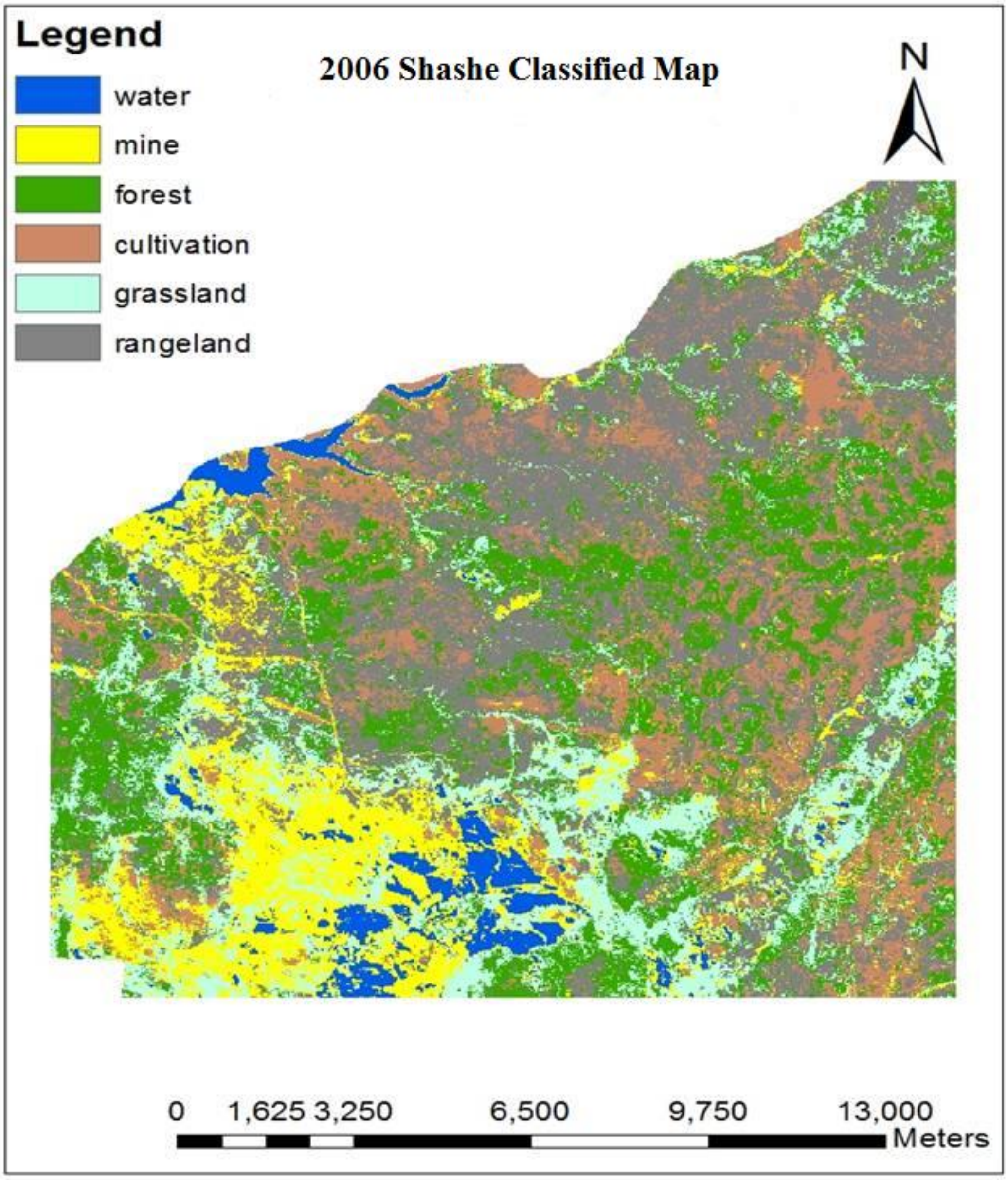


Figure 4.1.2: 2006 Shashe classified map

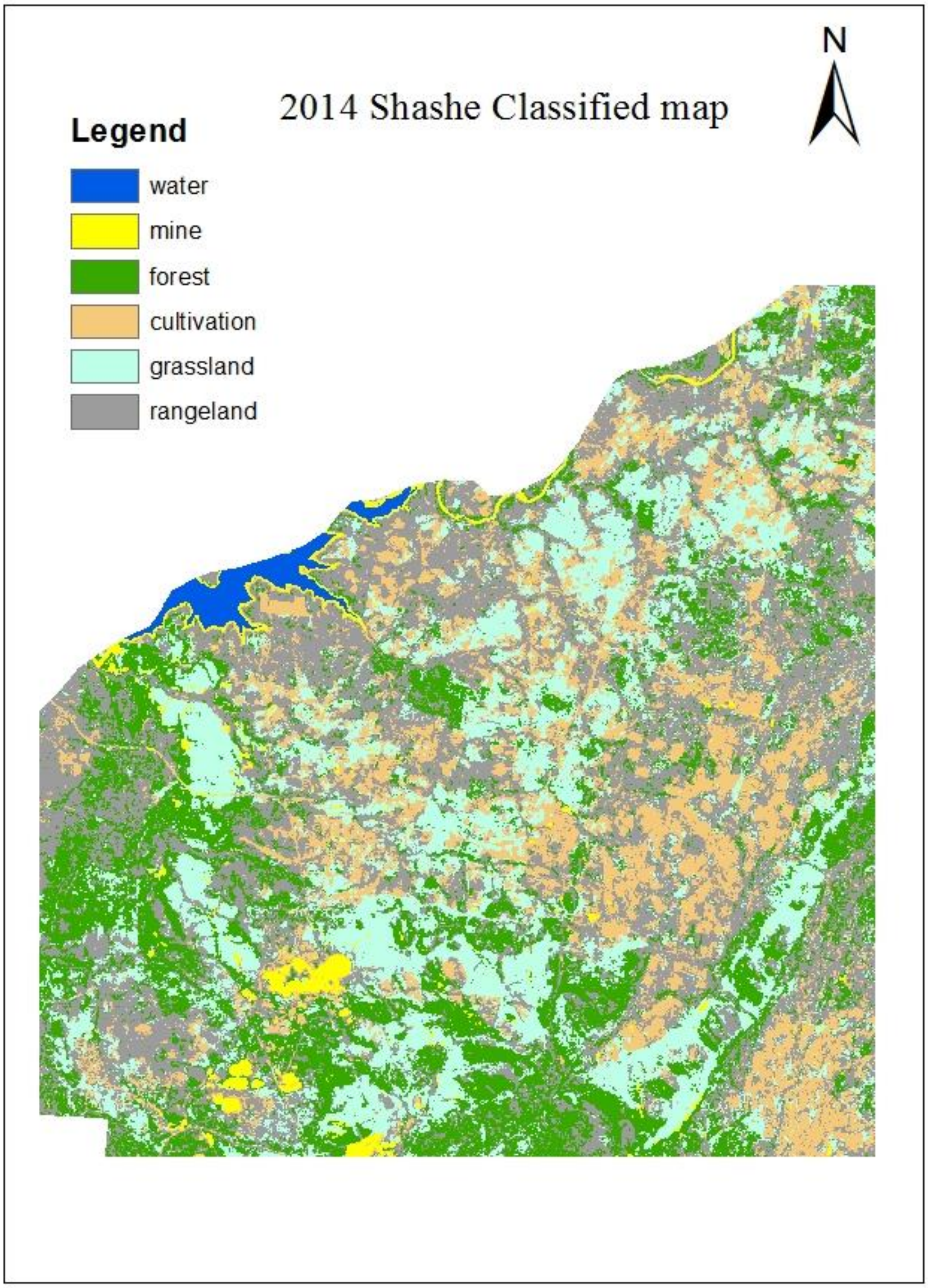
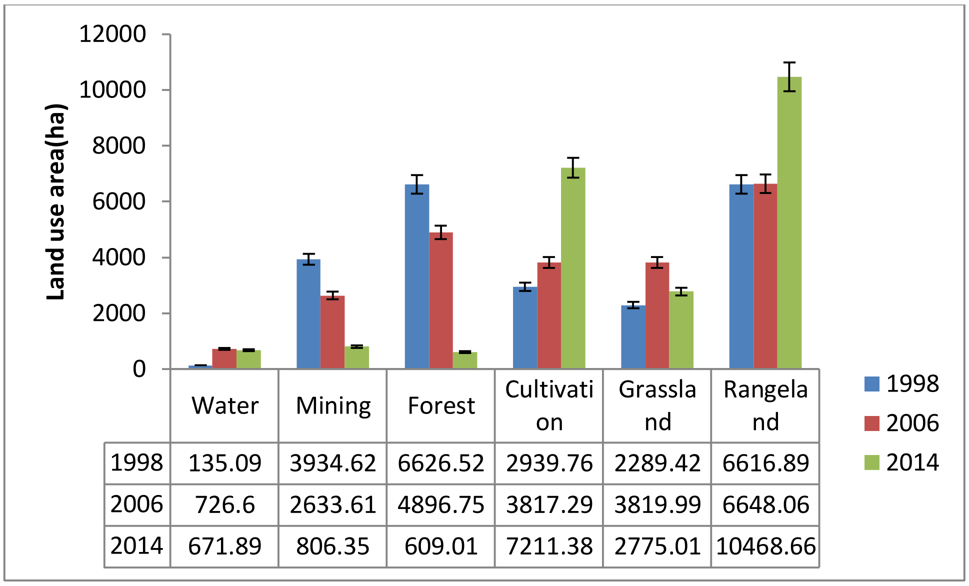


Figure 4.1.3: 2014 Shashe classified map



	Water	Mining	Forest	Cultivation	Grassland	Rangeland
1998	135.09	3934.62	6626.52	2939.76	2289.42	6616.89
2006	726.6	2633.61	4896.75	3817.29	3819.99	6648.06
2014	671.89	806.35	609.01	7211.38	2775.01	10468.66

Figure 4.1.4: A graphical presentation for the land uses for Shashe area in hectares from 1998 to 2014

From figure 4.1.4, it can be seen that the area extent of Shashe was 22542.3 hectares. Water for the period of 1998 had an area of 135.09 hectares, which increased to 726.6 hectares in the year 2006 and later decreased to 671.89 hectares in 2014 time period. Mining area in 1998 covered 3934.6 hectares and decreased to 2633.6 in the year 2006. It also decreased in the 2014 time period to 806.35 hectares.

Forest area in the year of 1998 was 6626.5.This area extent decreased in 2006 to 4896.7 and also decreased in the year 2014 to 609.01 hectares. In the year 1998 forest area was 6626.5 hectares and in 2006, that area decreased to 4896.7 hectares. For the year 2014 the area extent of forest further declined to 609.01 hectares.

Cultivation area in the year 1998 was 2939.7 hectares, in 2006 it increased to 3817.2 and in the year 2014 it increased also to 7211.3 hectares. Grassland area was 2289.4 in the year of 1998.This area increased to 3819.9 in 2006 and it decreased in the 2014 year to 2775.0 hectares. Rangeland area for the 1998 period was 6616.8 hectares. This area increased in 2006 to 6648 and in the year 2014, it increased as well to 10468 hectares.

Table 4.1: Total percent area of land uses in Shashe resettlement area from 1998 to 2014.

Land Use	1998 Area (ha)	1998 Area (%)	2006 Area (ha)	2006 Area (%)	2014 Area(ha)	2014 Area (%)
Water	135.09	1	726.6	3	671.89	2
Mining	3934.62	18	2633.61	12	806.35	4
Forest	6626.52	29	4896.75	22	609.01	3
Cultivation	2939.76	13	3817.29	17	7211.38	32
Grassland	2289.42	34	3819.99	16	2775.01	12
Rangeland	6616.89	29	6648.06	30	10468.66	47
Total	**22542.3**	**100**	**22542.3**	**100**	**22542.3**	**100**

Table 4.2: Percent area change of land uses in Shashe resettlement area from 1998 to 2015.

Land Use	1998-2006 % area change	2006-2014 % area change
Water	-2	1
Mining	6	8
Forest	7	19
Cultivation	-4	-15
Grassland	18	4
Rangeland	-1	-17

From table 4.1 and 4.2 it can be seen that water constituted 1 % area of Shashe resettlement area in 1998 and in 2006 it increased to 3% hence it had a change 0f -2% from 1998 to 2006. In 2014 it decreased by 2% and the percent change from 2006 to 2014 was 1. Mining area in 1998 constituted 18% of the total area in Shashe resettlement area. In 2006 it decreased to 12 % hence it had a % area change of 6 between 1998 and 2006. In the year 2014 it further declined to 45 and had a % area change of 8%.

Forest area constituted 29% of the total area for Shashe resettlement area in 1998, this area reduced in 2006 to 22%.Its % area change was 7% from 1998 t0 2006. In 20014, forest area decreased to 3% and the percent area change from 2006 to 2014 showed a decline of 19%. Cultivation area was 13% of the total Shashe resettlement area in 1998. It showed an increasing trend from 2006 and 2014 where in

2006 its area was 17% and 325 respectively. From 1998 to 2006 its percent area changewas-4 and from 2006 to 2014 it was -5%.

Grassland area in 1998 was 34% and in 2006 it decreased to 16%. Its percent area change from 1998 to 2006 was 18% and in 2014 it also decreased to 12% and the percent area change from 2006 to 2014 was 4%. Rangeland area constituted 295 of the Shashe total area in 1998. This area increased to 30% for the year 2006 and the percent area change from 1998 to 2006 was -1%. In 2014, rangeland area increased to 47% in Shashe resettlement area. The percent area change from 2006 to 2014 was -17%.

4.2 Establishing the relationship between selected land use changes on Mavaire river discharge in Shashe resettlement area from 1998 to 2014.

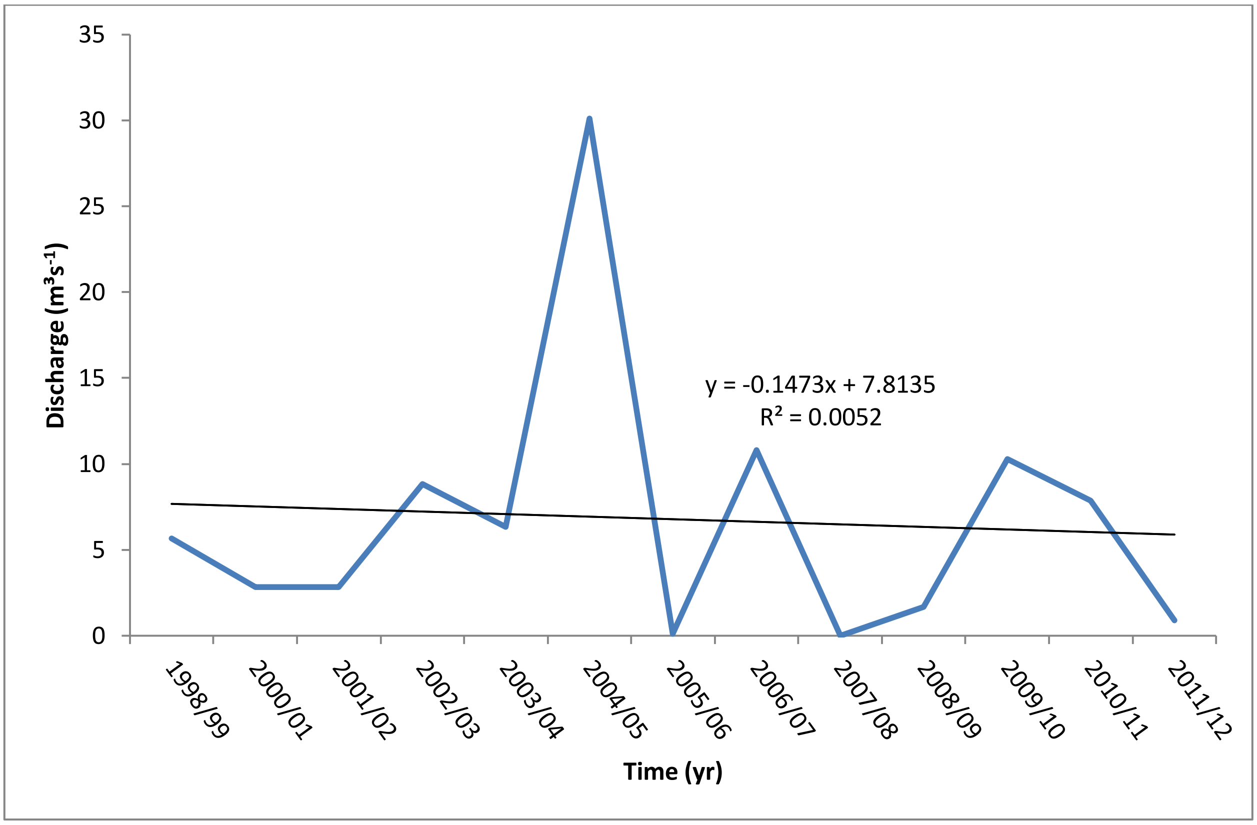


Figure 4. 2.1: Mavaire river streamflow (1998/99-2011/2012)

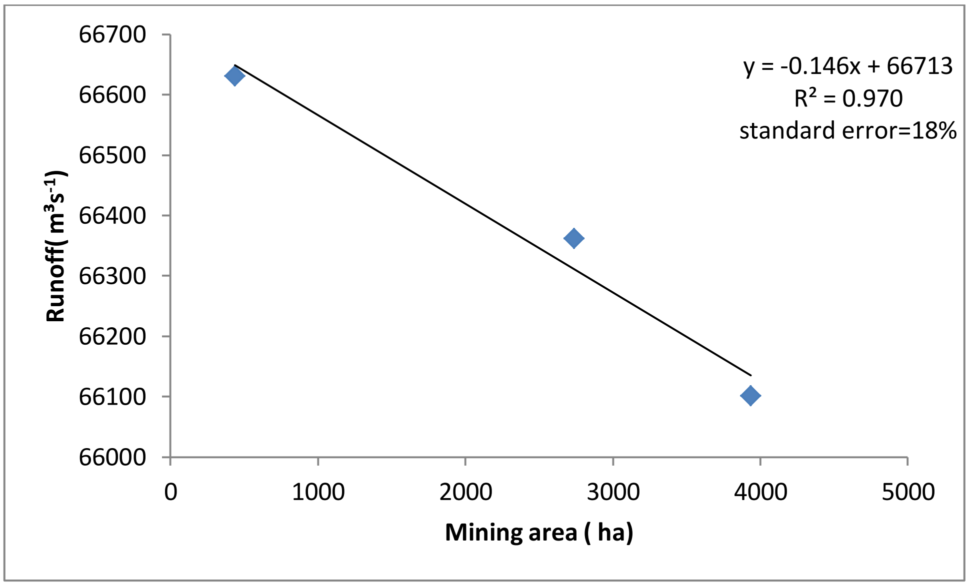


Figure 4.2.2: A detailed description of the relationship between runoff and mining.

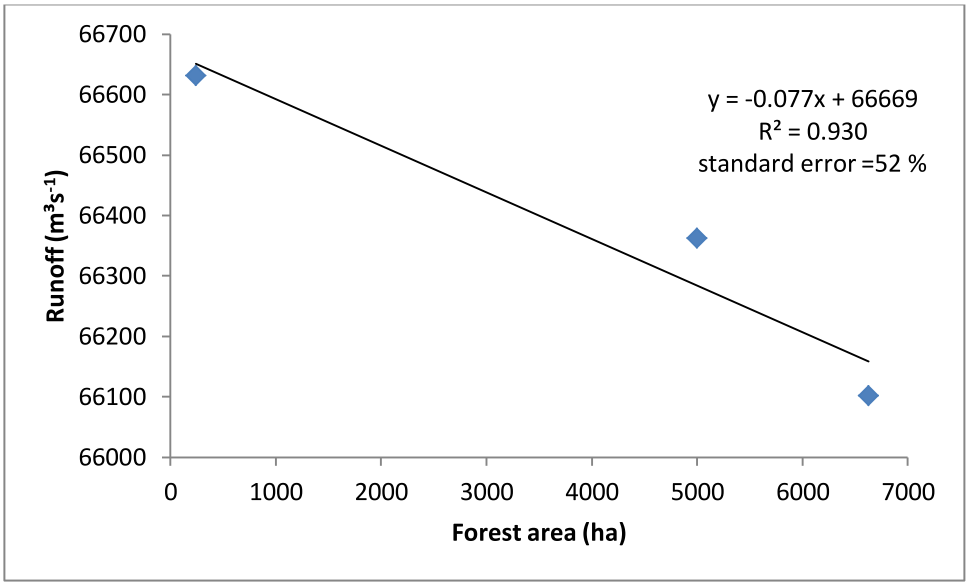


Figure 4.2.3: A detailed description of the relationship between runoff and forest

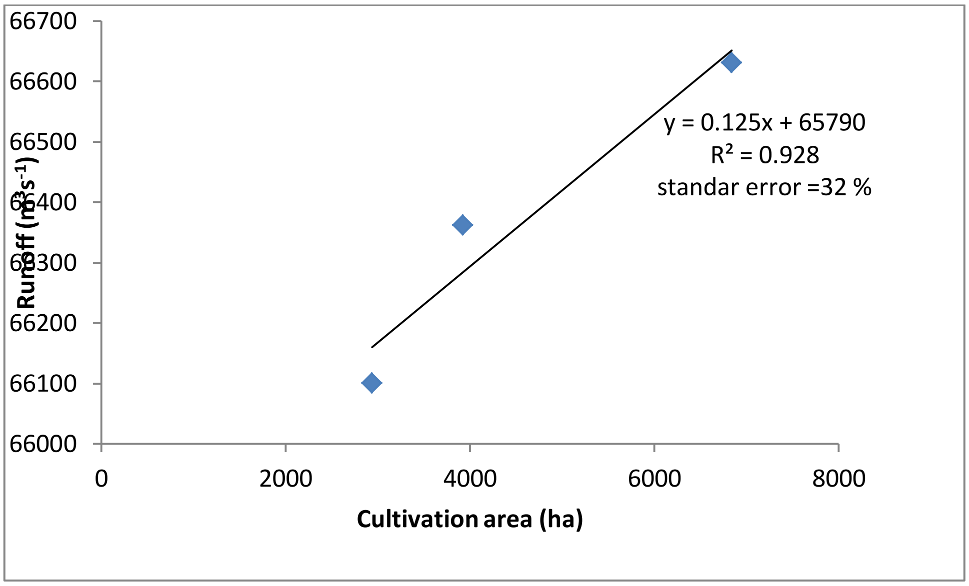


Figure 4.2.4: A detailed description of the relationship between runoff and cultivation

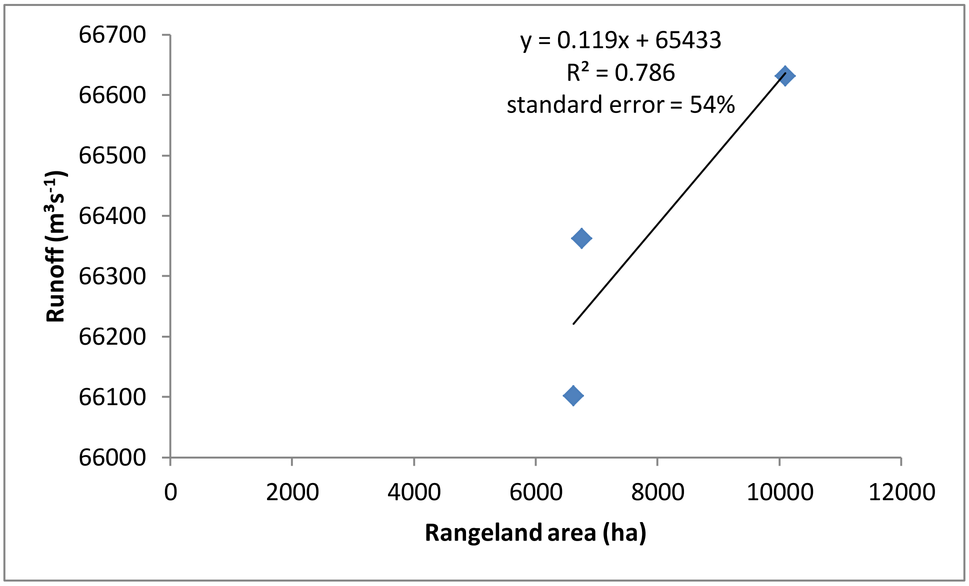


Figure 4.2.5: A detailed description of the relationship between runoff and rangeland

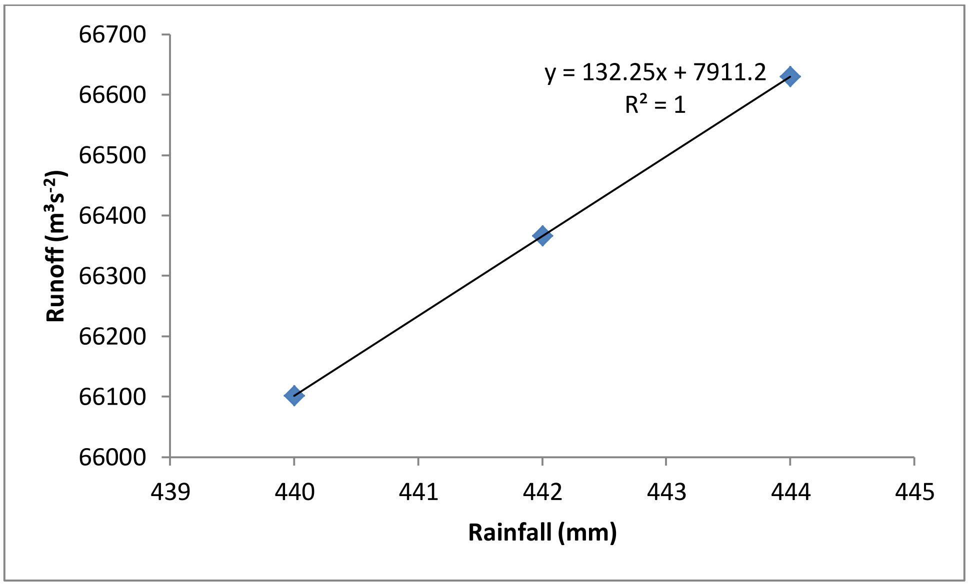


Figure 4.2.6: A detailed description of the relationship between runoff and rainfall.

From the regression analysis that was done, there was a significant difference between the selected land uses and runoff characteristic of Mavaire stream. There was a strong negative correlatioship between mining and runoff from 1998 to 2015 which was at a slope of y = -0.146x+66713, as mining area was increasing runoff in Shashe was decreasing. Mining had a standard error of 18%, a coefficient of determination of 0.970 (figure4.2.2).

As forest area was decreasing, runoff of Mavaire was increasing (figure 4.2.3) at a slope of y = 0.077x+66669. Forest had a standard error of 52%, a coefficient of determination value of 0.930. There was also a strong negative correlationship between runoff and forest from this study between 1998 and 2015. As cultivated area for Shashe was increasing an increase in runoff was also taking place (figure 4.2.4) at a slope of y = 0.125x+65790. Cultivation had a standard error of 32%,a coefficient of determination value of 0.930.There also was a strong positive relationship between runoff and cultivation for Shashe resettlement area. For rangeland area as illustrated in figure 4.2.5, there was an increase in runoff at a slope of y = 0.119x+65433.Rangeland had a standard error of 54%, a coefficient of determination value of 0.786 thus there existed a strong positive relationship between runoff and rangeland for Shashe resettlement area.

CHAPTER FIVE DISCUSSION

5.1 Spatial and temporal land use changes

Water had a lower area of 1% in 1998 as compared to 2006 .This was as a result of an increase in water content after the year 2006 from the slime dams in Shashe . Water area decreased in 2006 (table 4.1) as a result of an increase in water content in from3% in 2006 to 2% in 2015 as a result of land degradation that has been taking place in Shashe caused by cultivation without mechanical works .The high increase in population in the communal area sector has resulted in land degradation hence dam siltation (Magadza, 1992). In Shashe population increase was as a result of resettlement that took place in 2004. Unfortunately, this increase in runoff does not mean an increase in surface water resources since the dams lose their storage capacity due to siltation (Elwell, 1983).

Mining decreased in 1998 (table 4.1) as a result of the slime dams in the area. It further decreased to 4% in 2014 also as a result of the closure of Gathsmine which took place in 2011. In 1998 grassland had a lower area in hectares as compared to the 2006 area of 16% because it was mainly used for grazing land which was the main land use for that period.

The grazing land area improved in 2006 by to 16% as a result of a decrease in the livestock units which was caused by resettlement in 2001. The newly resettled communities used the land mainly for cultivation purposes as compared to the previous 6 commercial farmers whose main use was for rangeland. In 2007 the Shashe community got donations of livestock units which were beyond the carrying capacity for Shashe area, this resulted in overgrazing hence there was a further 12% decrease in grassland area in 2006 as shown in table 4.1.

Forest area percentage for Shashe area decreased by from 1998 to 2006 by 7% and also by 19% between 2006 and 2014. The decrease in 2006 was as a result of resettlement that took place in 2004 which resulted in the conversion of forest land to settlement and cultivation. Cultivation area hence encroached on forest. Shashe community’s households depend on natural wood for heating and cooking this further reduced the forest area (FAO, 2003; Cottler, 2014). Between 2006 and 2014 the decrease in forest area was as a result of the cutting down of trees which led to bare ground that was exacerbated by overgrazing and a need to cut poles for cattle pens as more livestock units were introduced in 2007 in this area. In 2011 Gathsmine which was one of the sources of the communitie’s livelihood was closed, this resulted in people looking for alternative means of survival such as cultivation .This also reduced the forest area of Shashe between 2006 and 2014 as shown in table 4.1 and 4.2.

Cultivated land has been on the increased from 1998 to 2014 as shown in figure 4.1.3.In 2004 a relocation exercise was conducted in Shashe area, this resulted in 142 families being resettled in the area (Rio Tinto, 2001).Their main use of land was for cultivation purposes. This relocation exercise was the major cause of increase in cultivation area by 4%. Between 1998 and 2006 cultivation area increased by 16% as a result of

Rangeland area increased between 1998 and 2006 2014 by Rangeland are areas in which indigenous vegetation is predominantly grasses, it consists of grass like plants, forbs or shrubs. This type of land use increased between 1998, 2006 and 2014 as a result of deforestation which occurred in 2001 caused by cultivation and settlement encroachment in forest land. The other causal factor was the increase in livestock unit for Shashe area in 2007; this also led to an increase in rangeland as forests were continually being degraded by this effect. Rangeland area also increasing between 1998 to 2014 as a result of a decrease in mining areas which are not compatible for cultivation hence there was an improvement in the vegetation cover although it was sparsely populated.

5.2. Relationship between selected land uses and river discharge

Studies that have been done in Tocantins River basin which is located in Brazil showed a 25% increase in river discharge between 1960 and 1995. This was coincident with expanding agriculture without any major change in precipitation (Costa et al., 2003). In Shashe no major change in precipipitation was experienced (figure 4.2.6). There was a strong relationship between the selected land uses and Mavaire river discharge

It is known that as mining area increases it reduces water availability (Polard et al., 2001), this is because during mining, water will be pumped away from the shaft thereby reducing groundwater thus increasing infiltration for groundwater recharge. However for Shashe mining area decreased as a result of the closure of Gathsmine. This may have resulted in high runoff as ground water will have increased and the antecedent moisture reduced thus lower infiltration and high runoff. Gathsmine was used for asbestos mining. This cemented the soil surface hence may have resulted in low infiltration and high runoff.

Cultivated area increased to cater for 142 families that were relocated in Shashe in 2004 (Rio Tinto, 2001). This caused a reduction in forest land and cultivation practices that were now the major land uses in the area encroached in forest areas. The removal of forests reduces infiltration and increases overland flow (Kuchment, 2008) hence a positive increase in runoff was noted (figure 4). This was linked to the partial removal of vegetation cover which decreased the interception potential of forests hence an increase in soil crusting as a result of a lower interception due to increased kinetic energy of raindrops, causing a reduction in soil water holding capacity thus runoff was produced when rainfall intensity exceeds the soil infiltration capacity (Horton, 1933). Also forests generally have lower surface albedo, higher surface aerodynamic roughness, higher leaf surface area and deeper roots than other types of vegetation, with each characteristic tending to contribute towards an increase in runoff, as the reduction of forest cover can increase runoff (Calder, 2007).

An increase in cultivation land as an alternative livelihood source was noted between 2006 and 2014 prior to 2006. The main livelihood was mining and after the closure of Gathsmine in 2011 employees were forced into subsistence farming to compensate for the lost income. This increase in cultivation land is also characterized by an increase in runoff for Shashe of (figure 4.3). The other reason for increased runoff was lack of mechanic conservation practices in the lands converted for cultivation. And the use of conventional tillage which is animal drawn with a tendency to form a subsurface crust at plough depth as a result of cultivation at same depth over a long time. This impedes infiltration and increase runoff by altering soil hydraulic properties and soil surface roughness (Larson, 1964). Infiltration is increased due to increased soil porosity and breaking up of surface crusts. Tillage operations have been reported to increase the infiltration capacity by 1 to 50 mm h-1 on crusted soils (Larson, 1964).

Despite an increase in rangeland, runoff in Shashe was also increasing. This was because the rangeland in Shashe resettlement area was composed of mainly poor quality plant cover with low plant height and less leaf area and also sparsely populated vegetation cover. These characteristics contributed to the lower interception potential of this land use, which resulted in an increase in the kinetic energy of raindrops. Also given the climatic characteristics of the semi arid regions, plant cover, especially the crops grown are of poor stamina, hence there is less potential interception in these areas resulting in increased raindrop impact on ground surface, compacting it and reducing the infiltration rates for the area. This causes an increase in compaction and a decrease in infiltration rates hence hortonian overlandflow was enhanced. Livestock units for Shashe area also increased in 2007, this led to a degradation of forest areas and increased the rangeland area. The trampling activity by animals in these rangelands reduces infiltration as they alter the bulk density by reducing aggregation thereby reducing porosity of soils, water will not be evenly distributed hence a decrease in infiltration but will be channelized causing an increase in runoff .These factors may have contributed to an increase in runoff .

CHAPTER SIX CONCLUSION AND RECOMMENDATION

6.1 Conclusion

There was a significant change in the spatial and temporal distribution of the different land uses for Shashe resettlement area from 1998 to 2015. The percent area for water was 1%, 3% and 2% for 1998, 2006 and 2014 respectively. Mining percent area was decreasing and was 18%, 12% and 4% respectively. A decrease in forest area was also noted. It was 29%, 22% and 3% for 1998, 2006 and 2014 respectively. Grassland percent area was 34%, 16% and 12%. Cultivation percent area was 13%, 17% and 32%. Rangeland was 29%, 30% and 47%.

A strong relationship between the selected land uses on Mavaire river discharge existed. The standard errors for the selected land uses were (mining 18%; forest 52%; cultivation 32% and rangeland 54%).

6.2 Recommendation

The results from this research are particularly relevant for Shashe resettlement block in formulating, implementing and monitoring strategies for sustainable development such as

- Farmer training programmes on conservation agriculture.
- Promoting the use of biofuels to reduce deforestration
- The monitoring of the cutting down of trees with the help of the Environmental Management Agency.
- Chiefs, headmen with the help of the Ministry of Agriculture should designate properly managed paddocks to control overgrazing.
- The government and eminent domains should ensure that negative effects of resettlements are given due consideration in the planning procedure to avoid environmental consequences.
- Conducting research on future land use change effects on dam sedimentation of Mavaire river

REFERENCES

Aboyade, O. (2001). Geographic information systems: application in planning and decision making process in Nigeria. Unpublished paper presented at the Environmental and Technological unit in the Development Policy. Ibadan.

Abuelgasim, A. A., Ross, W., Gopal, S., Woodcocock, C. E. (1999). Change detection using adaptive fuzzy neutral networks: environmental damage assessment after the Gulf War. Remote Sensing of Environment 70, 208-223.

Achard, F., Eva, H. D., Stibig, H. J., Mayaux, P., Gallego, J., Richards, T., Malingreau, J. P (2002). Determination of deforestation rates of the world's humid tropical forests. Science. 297, 999–1002.

Aina, P. O., Lal, R., Roose, E. J. (1991). Tillage methods and soil and water conservation in West Africa. Soil Tillage Res. 20:165-186.

America, Oxfam America. (2004)

Amogu O., Descroix L., Yéro K. S., Le Breton E., Mamadou I., Ali A., Vischel T., Bader J.-C., Moussa I. B., Gautier E., Boubkraoui S., Belleudy P. (2010). Increasing River Flows in the Sahel Water. 2(2):170-199.

Amogu, O. (2009). The land degradation in the sahel and its consequences on the sediment balance of the Mid Niger River PhD thesis, university Grenoble 1, 420 p and Land Use. Wiley, Chichester. pp. 163–188.

Andrews, A. J., Bullock, A., 1994. Hydrological Impacts of Afforestation in Eastern Zimbabwe. Institute of Hydrology Overseas Development Report No. 94/5. Wallingford. UK.

Anderson, J. R., Hardy, E. E., Roach, J. T., Witmer, R. E. (1976). A land-use and land-cover classification system for use with remote sensor data. US geological Survey Professional Paper 964, Washington, DC.

Barthel, R., Reichenau, T. G., Krimly, T., Dabbert, S., Schneider, K., Hennicker, R., Mauser, W. (2012). Integrated modeling of global change impacts on agriculture and groundwater resources,Water Resources Managagement., 26, 1929–1951, 2012.

Bernier, P. Y., Woodard, P. D. (1987). Forest Hydrology and Watershed Management, Proceedings of the Vancouver Symposium, IAHS Publication no. 167 pp.

Bhatta, B. (2010). Analysis of urban growth and sprawl from remote sensing data: Springer

Bodart, C., Eva, H., Beuchle, R., Rasi, R., Simonetti, D., Stibig, H. J., Brink, A., Lindquist, E., Achard, F. (2011). Pre-processing of a sample of multi-scene and multi-date Landsat imagery used to monitor forest cover changes over the tropics.ISPRS J. Photogramm. Remote Sens., 66, 555–563.

Bogumil, T. (2012). Przesiedlenia inwestycyjne: Nowa kategoria przymusowychmigracji, Wydawnictwo Akademickie Łośgraf, Warszawa.

Bonell, M., Balek, J., (1993). Recent and scientific developments and research needs in hydrological processes of the humid tropics, In: Bonell, M., Hufschmidt, M.M., Gladwell, J.S,. (1982), Hydrology and Water Management in the Humid Tropics. UNESCO, Paris, pp. 167–260.

Bosch J. M, Hewlett J. D. (1982). A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration. Journal of Hydrology 55: 3–23

Boutayeb, N., Gustard, A., Kundzewicz, Z. W., Rasmussen, P. F. (1997). Sustainability of Water Resources under Increasing Uncertainty (Proceedings of the Rabat Symposium.

Bruijnzeel, L. A. (1989). Deforestation and dry season flow in the tropics. A closer look. J. Trop. For. Sci., 1 (3), 229–243. J.K. Lørup et al./Journal of Hydrology 205 (1998) 147–163 161

Bultot, F., Dupriez, G. L., Gellens, G. (1990). Simulation of land use changes and impacts on the water balance a case study for Belgium. J. Hydrol. 114, 327–348.

Campbell, B. M. (1994). The environmental status of the Save Catchment. In: Matiza, T.,Crafter, S.A. (Eds.), Proceedings of the Wetland Ecology and Priorities for Conservation in Zimbabwe Seminar, 21–33. Kentucky Hotel, Harare, Zimbabwe. IUCN, Switzerland.

Calder, I.R**.** 2007. Forests and water – ensuring forest benefits outweigh water costs. Forest Ecology and Management, 251: 110–120.

Cernea. M. (1988). Involuntary resettlement in development projects: policy guidelines in World Bank-financed projects. World Bank Publications.Washington.

Cernea, M. (1991). Putting people first: Sociological variables in rural development, World Bank and Oxford University Press, Oxford-Washington.

Chander, G., Markham, B. L., Helder, D.L. (2009). Summary of current radiometric calibration coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI sensors. Remote Sens. Environ., 113, 893–903.

Chauhan, H. B. and Nayak, S. (2005). Land use/land cover changes near Hazira Region, Gujarat using remote sensing satellite data, J. Indian Soc. Remote Sens., 33, 413–420.

Chen, D., Stow, D. (2002). The effect of training strategies on supervised classification at different spatial resolutions. Photogrammetric Engineering and Remote Sensing 68, 1155–1161.

Cihlar, J. (2000). Land-cover mapping of large areas from satellites: status and research priorities. International Journal of Remote Sensing 21, 1093–1114.

Clarke, K. C., Gaydos, L. (1998). Loose coupling a cellular automaton model and GIS. Long-term growth prediction for San Francisco and Washington/Baltimore. International Journal of Geographical Information Science 12,699–714.

Coulter, L., Stow, D. A., O'Leary, J., Hope, A., Longmire, P., Peterson, S. (2000). Comparison of high-spatial resolution imagery for efficient generation of GIS vegetation layers. Photogrammetric Engineering and Remote Sensing 66, 1329–1335.

Czech, B., Krausman, P.R., and Devers, P.K. (2000). Economic associations among causes of species endangerment in the United States, BioScience 50, 593–601.

Danida, 1 (988). Plan of Action for Integration of Environmental Considerations into Danish Development Assistance. A Strategy for Water Resources Management.

DeFries, R. S., Chan, J. (2000). Multiple criteria for evaluating machine learning algorithms for land-cover classification from satellite data. Remote Sensing of Environment 74, 503–515.

DeFries,R.S, Foley, A.J and Asner, G.(2004). Land Use choices-Balancing human needs and ecosystem function.The Ecological Society of America 249-257.

Downing, T. E. (2002). Avoiding New Poverty: Mining-Induced Displacement and Resettlement, IIED and WBCSD, London, Research Paper No. 58.

Du Toit, R. F., 1985. Soil loss hydrological changes and conservation attitudes in the Sabi catchment of Zimbabwe. Environ. Conserv.12, 157–166.

Edwards, K. A. (1979). The water balance of the Mbeya experimental catchments. In: Blackie, J. R., Edwards, K. A., Clarke, R. T. (Eds.), Hydrological Research in East Africa. East Afr. Agric. For. J. Special Issue 43, 231–247.

Edwards, K. A., Blackie, J. R .(1981). Results of the East African Catchment Experiments 1958–74. In: Lal, R., Russell, E.W. (Eds.), Tropical Agricultural Hydrology—Watershed Management.

Elwell, H. A. (1994). Conservation Tillage for Sustainable Crop Production Systems, Consultancy Report. Institute of Agricultural Engineering, Harare, Zimbabwe.

Ewen, J., Parkin, G. (1996). Validation of catchment models for predicting land-use and climate change impacts. 1. Method, J. Hydrol., 175, 583–594.

Fang, H. (1998). Rice crop area estimation of an administrative division in China using remote sensing data. International Journal of Remote Sensing 19, 3411–3419.

Food and Agriculture Organization of the United Nations, (1993). Forest Resources Assessment 1990—Tropical Countries Rome; FAO Forestry Paper No. 112. FAO: Rome. Italy.

FAO. 1997. Africover Land Cover Classification. Rome

Fernandes. W (2006). "Mines. Mining and Displacement in India". In Singh, Gurdeep,

Ferry. L., Mietton, M. (2011). L'équilibre du fleuve Niger perturbé. Sciences au Sud, 60, 3

Foreign Affairs, Copenhagen. DHI. (1994). MIKE11 Short Description. Danish Hydraulic Institute, Hørsholm.

Franklin, J., Phinn, S. R., Woodcock, C. E., Rogan, J. (2003). Rationale and conceptual framework for classification approaches to assess forest resources and properties. In: Wulder, M., Franklin, S.E. (Eds.), Methods and Applications for Remote Sensing of Forests: Concepts and Case Studies, Kluwer Academic Publishers,Dordrecht, pp. 279–300.

Franklin, J., Woodcock, C.E., Warbington, R. (2000). Digital vegetation maps of forest lands in California: integrating satellite imagery, GIS modeling, and field data in support of resource management. Photogrammetric Engineering and Remote Sensing 66, 1209–1217.

Franklin, S.E., (2001). Remote Sensing for Sustainable Forest Management, Lewis Publishers, Boca Raton, FL .407 pp.

Fritz, L.W. (1996). The era of commercial earth observation satellites. Photogrammetric Engineering and Remote Sensing 62, 39–45.

Fu, G. B., Charles. S. P., Yu J. J., Liu. CM.(2009). Decadal climatic variability, trends and future scenarios for the North China Plain. Journal of Climate 22: 2111–2123.

Fung, T., Ledrew, E. (1987). Application of principal components analysis to change detection, Photogrammetric Engineering & Remote Sensing, vol. 53, no. 12, pp. 1649–1658, 1987.

Gowing, G. (2003).Food security for sub-Saharan Africa: does water scarcity limit the operations?. Land Use and Water Resources Research, 2: 1-7

Hamilton, L. S., King, P. N. (1983). Tropical Forested Watersheds— Hydrologic and Soils Response to Major Uses or Conversions. Westview Press, Bolder, Colorado.

Herold, M., Gardner, M., Hadley, B., Roberts, D.(20020. The Spectral Dimension in Urban Land Cover Mapping from High-Resolution Optical Remote Sensing Data, Proceedings of the 3rd Symposium on Remote Sensing of Urban Areas, Istanbul, Turkey, 11–13 June,.

Hewlett, J. D., Lull H. W., Reinhart, K. G. (1969). In defence of experimental watersheds. Water Resources Research 5: 306–316.

Hilson, G., Nyame, F. (2006). “Gold mining in Ghana's forest reserves: a report on the current debate”, *Area*, vol. 38, no. 2, pp. 175-185.

Hirsch, R. M., Helsel, D. R., Cohn, T. A., Gilroy, E .J. (1993). Statistical analysis of hydrologic data. In: Maidment, D.R. (Ed.), Handbook of Hydrology. McGraw-Hill, New York, pp. 17.1–

Hookey, G. R. (1987). Prediction of delays in groundwater response to catchment clearing, J. Hydrol., 94, 181–198. ICWE, 1992. Dublin statement and report. International Conference

Horton, R.E. (1933). The role of infiltration in the hydrologic cycle. EOS. American Geophysical Union Transactions 14, 44–460.

Hundecha Y., Bárdossy A. (2004). Modeling of the effect of land use changes on the runoff generation of a river basin through parameter regionalization of a watershed model. Journal of Hydrology 292: 281–295. DOI:10.1016/j.jhydrol.2004.01.002

IDMC2010:http://www.internaldisplacement.org/8025708F004BE3B1/(httpInfoFiles)/8980F134C9CF4373C1257725006167DA/$file/Global_Overview_2009.pdf

IFC. (2002). Handbook for Preparing a Resettlement Action Plan, 2002.

IFC. (2011) . Guidance Note 5 – V2 Land Acquisition and Involuntary Resettlement

Im, S., Kim, H., Kim, C., Jang, C. (2009) Assessing the impacts of land use changes on watershed hydrology using MIKE SHE, Environ. Geol., 57, 231–239.

Jain, S. K., Storm, B., Bathurst J.C., Refsgaard J. C., Singh, R.D. (1992). Application of the SHE to catchments in India-- Part 2: Field experiments and simulation studies with the SHE on the Kolar subbasin to the Narmada River. Journal of Hydrology 140: 25–47.

Jasrotia, A.S., Singh R. (2006). Modeling runoff and soil erosion in a catchment area, using the GIS. in the Himalayan region. India. Environmental Geology 51: 29–37. DOI 10.1007/s00254-006-0301-6

Jensen, J .R. (2000). Remote Sensing of the Environment: an Earth Resource Perspective, Prentice Hall, Saddle River, NJ, 544 pp.

Jensen, J. R., Cowen, D .J. (1999). Remote sensing of urban/suburban infrastructure and socio-economic attributes.Photogrammetric Engineering and Remote Sensing 65, 611–622.

Justice, C. O., Markham, B. L., Townshend, J. R. G., Kennard, R. L.(1989). Spatial degradation of satellite data. International Journal of Remote Sensing 10, 1539–1561.

Kardoulas, N.G., Bird, A.C., Lawan, A.I., 1996. Geometric correction of SPOT and Landsat imagery a comparison of map- and GPS-derived control points. Photogrammetric Engineering and Remote Sensing 62, 1173–1177.

Katsaura, O. (2010). "Violence and the political economy of informal diamond mining in Chiadzwa, Zimbabwe", *Journal of Sustainable Development in Africa*, vol. 12, no. 6, pp. 340-353.

Kendall, M. G., Stuart, A. (1979). The Advanced Theory of Statistics. Wiley, New York.

Khan, H. H., Khan, A., Ahmed, S., Perrin, J. (2011). GIS-based impact assessment of land-use changes on groundwater quality: Study from a rapidly urbanizing region of South India, Environ. Earth Sci., 63, 1289–1302.

Klemes, V. (1986). Operational testing of hydrological simulation models, Hydrol. Sci. J., 31 (1), 13–24.

Knudsen, J., Thomsen, A., Refsgaard, J. C. (1986). WATBAL, a semi-distributed, physically-based hydrological modelling system, Nordic Hydrol., 17, 347–362.

Kuchment, L. S. (2008). Runoff generation (genesis, models, prediction), Water problems institute of RAN, 394p. (in Russian).

Kuczera, G., Raper, G .P., Brah, N. S., Jayasuriya, M. D.(1993). Modelling of yield changes after strip thinning in a mountain catchment: an exercise in catchment model validation, J. Hydrol., 150, 433–457.

Legesse, D., Vallet-Coulomb, C., Gasse, F. (2003). Hydrological response of a catchment to climate and land use changes in Tropical Africa: case study South Central Ethiopia, J. Hydrol., 275, 67–85.

Levien, L. M., Fischer, C. S., Roffers, P. D., Maurizi, B. A., Suero, J., Fischer, C., Huang, X., (1999). A Machine- Learning Approach to Change Detection Using Multi-Scale Imagery, Proceedings of ASPRS Annual Conference 1:22, Portland, Oregon.

Li, Z., Liu, W., Zhang, X., Zheng, F. (2009). Impacts of land use change and climate variability on hydrology in an agricultural catchment on the Loess Plateau of China, J. Hydrol., 377, 35–42.

Liu, Y., De Smedt, F. (2005). Assessing Land Use Impacts on Flood Processes in Complex Terrain by Using GIS and Modeling Approach. Journal of Environmental Modeling and Assessment 9(4):227-235.

Long, H. Wu, X., Wang, W., Dong, G. (2008). Analysis of urban rural land-use change during 1995-2006 and its policy dimensional driving forces in Chongqing, China. Sensors, vol. 8, no. 2, pp. 681–699, Lorup J.K., Refsgaard J.C. and Mazvimavi D., (1998), Assessing the effect of land use change on catchment runoff by combined use of statistical tests and hydrological modelling: case studies from Zimbabwe, Journal of Hydrology, **205**, 147-163.

Madehwe, C., Madebwe V.,Mavusa, S. (2011), "Involuntary displacement and resettlement to make way for diamond mining: the case of Chiadzwa villagers in Marange, Zimbabwe", Journal of Research in Peace, Gender and Development, Vol. 1(10), pp. 292-301.

Mango, L. M., Melesse, A. M., McClain, M. E. Gann, D., Setegn, S. G. (2011). Land use and climate change impacts on the hydrology of the upper Mara River Basin, Kenya: results of a modeling study to support better resource management, Hydrol. Earth Syst. Sci., 15, 2245–2258, doi:10.5194/hess-15-224.

Marland G., R.A. Pielke Sr., M. Apps, R. Avissar, R.A. Betts, K.J. Davis, P.C. Frumhoff, S.T. Jackson, L. Joyce, P. Kauppi, J. Katzenberger, K.G. MacDicken, R. Neilson, J.O. Niles, D.D.S. Niyogi, R.J. Norby, N. Pena, N. Sampson and Y. Xue. (2003). The climatic impacts of land surface change and carbon management, and the implications for climate-change mitigation policy. Climate Policy 3:149-15

Mbetu, R. M. 1993. The impact of the drought on primary water supplies in Zimbabwe and remedial measures taken. Zimbabwe Science News, 27(4-6): 27-31.

McNairn, H., Ellis, J., Van Der Sanden, J.J., Hirose, T., Brown, R.J., 2002. Providing crop information using RADARSAT-1 and satellite optical imagery. International Journal of Remote Sensing 23, 851–870.

Miller, R. C., Goodrich, D. C., Devonald, K. K. Heggem., D. T., Miller, W. P. (2002). Integrating landscape assessment and hydrologic modeling for land cover change analysis, J. Am. Water Resour. As., 38, 915–929

Mishra, A., Kar, S., and Singh, V. P. (2007). Prioritizing structural management by quantifying the effect of land use and land cover on watershed runoff and sediment yield, Water Resour. Manag., 21, 1899–1913.

Mugabe, F. T. (2011). Physics and Chemistry of the Earth 36.1025–1032

Nash, I.E., Sutcliffe, I.V.(1970). River flow forecasting through conceptual models. Part I—A discussion of principles, J. Hydrol., 10, 282–290.

Nielsen, S. A., Hansen, E. (1973). Numerical simulation of the rainfall–runoff process on a daily basis, Nordic Hydrol., 4, 171–190.

Nish, S., Bice, S. (2012) .Community-based agreement making with land-connected peoples In Vanlay, Frank, Esteves Ana Maria. New Directions in Social Impact Assessment.Conceptual and Methodological Advances, Edward Elgar Publishing Limited.

Nyamudeza, P. 1993. The effects of growing sorghum (Sorhum bicolor) in furrows and on the flat at three populations and three row width in a semi-arid region of Zimbabwe. I. Grain yield and yield components. Zimbabwe Journal of Agricultural Research 31: 1-10.

Olivera, F., Maidment, D. (1999). Geographic Information Systems (GIS)-Based Spatially Distributed Model for Runoff Routing. *Water Resources Research* 35(4):1155-1164

Onstad C.A., Jamieson D G. (1970). Modelling the effects of land use modifications on runoff. Water Resources Research 6: 1287–1295.

Oudin, L., Andréassian,V., Lerat ,J., Michel C. (2008). Has land cover a significant impact on mean annual streamflow? An international assessment using 1508 catchments. Journal of Hydrology 357: 303–316.Patnershp Africa 2009,Zimbabwe Diamonds and the wrong side of history, Otawa,Canada.

Pekkarinen, A. Reithmaier, L., Strobl, P. (2009). Pan-European forest/non-forest mapping with Landsat ETM+ and CORINE land cover 2000 data. ISPRS J. Photogramm. Remote Sens. 64, 171–183.

Pereira, H.C., 1973. Land Use and Water Resources—In Temperate and Tropical Climates. Cambridge University Press, Cambridge.

Quegan, S., Le Toan, T., Yu, J.J. (2000). Multitemporal ERS SAR analysis applied to forest mapping. IEEE Transactions on Geosciences and Remote Sensing 38, 741–753.

Ramesh, R. (2001). Effects of land-use change on groundwater quality in a coastal habitat of South India, IAHS-AISH P., 269, 161–166, 2001.

Rashed, T., Weeks, J.R., Gadalla, M.S., Hill, A.G.(2001). Revealing the anatomy of cities through spectral mixture analysis of multispectral satellite imagery: a case study of the greater Cairo region, Egypt. Geocarto International 16, 5–15.

Refsgaard, J. C., Alley, W. M., Vuglinsky, V. S. (1989). Methods for Distinguishing between Man's Influence and Climatic Effects on the Hydrological Cycle. IHP-III Project 6.3. Unesco,

Refsgaard, J. C., Knudsen, J. (1996). Operational validation and intercomparison of different types of hydrological models, Water Resour. Res., 32 (7), 2189–2202.

Refsgaard, J.C., Storm, B .(1995). MIKE SHE. In: Singh, V.P. (Ed.), Computer Models of Watershed Hydrology. Water Resources Publications, pp. 809–846.

.

Rio Tinto. (2001). Murowa Project Newsletter, Harare, Zimbabwe.

Roberts, D.A., Batista, G.T., Pereira, J., Waller, E.K., Nelson, B.W., 1998. Change identification using multitemporal spectral mixture analysis: applications in Eastern Amazonia. In: Lunetta, R.S., Elvidge, C.D. (Eds.), Remote Sensing Change Detection: Environmental Monitoring Methods and Applications, Ann Arbor Press, Chelsea, MI, p. 318.

Rogan, J., Franklin, J., Roberts, D.A. (2001). A comparison of methods for monitoring multitemporal vegetation change using Thematic Mapper imagery. Remote Sensing of Environment 80, 143–156.

Sandstro¨m, K., 1995. Modelling the effects of rainfall variability on groundwater recharge in semi-arid Tanzania, Nordic Hydrol., 26, 313–330.

Schott, J., Salvaggio., C., Volchok, W. (1988). Radiometric scene normalization using pseudoinvariant features.Remote Sensing of Environment 26, 1–16.

Schowengerdt, R.A., 1997. Remote Sensing: Models and Methods for Image Processing, Second ed, AcademicPress, San Diego, 522 pp.

Schulze, R. E. 2000. Modelling hydrological responses to land use and climatic change: A Southern African Perspective. *Ambio,* 29(1): 12-22.

Sharma, E., Bhuchar, S., Xing, M., Kothyari, B. P. (2007). Land use change and its impact on hydro-ecological linkages in Himalayan watersheds, Trop. Ecol., 48, 151–161.

Shaw, E. M. (1983). Hydrology in Practice, 2nd edn. Van Nostrand Reinhold, UK.

Singh, A. (1989). Digital change detection techniques using remotely sensed data. International Journal of Remote Sensing 10, 989–1003.

Smith, R.E., Scott, D.F.(1992). The effects of afforestation on low flows in various regions of South Africa, Water SA, 18 (3), 185–194.

Song, C., Woodcock, C. E., Seto, K., Lenney, M. P., Macomber, S. (2001). Classification and change detection using Landsat TM data: when and how to correct atmospheric effects. Remote Sensing of Environment 75, 230–244.

Sonnenburg , D., Munster, F. (2001). Mining Minerals Sustainable Development Southern Africa. Research Topic 3: Mining and Society. Involuntary Resettlement, African Institute

Stonestrom, D. A., Scanlon, B. R. and Zhang, L. (2009). Introduction to special section on Impacts of Land Use Change on Water Resources, Water Resour. Res., 45, W00A00,doi:10.1029/2009WR007937.

Storm, B., Jørgensen, G. H., Styczen, M. (1987). Simulation of water flow and soil erosion processes with a distributed physically-based modelling system. In: Swanson, R.H.,

Stow, D. A. (1999). Reducing mis-registration effects for pixel-level analysis of land-cover change. International Journal of Remote Sensing 20, 2477–2483.

Stow, D. A., Chen, D. (2002). Sensitivity of multitemporal NOAA-AVHRR data for detecting land cover changes. Remote Sensing of Environment 80, 297–307. Survey. Salisbury: Government Printers.

Tappan, G. G., Sall, M., Wood, E. C., Cushing, M. (2004). Ecoregions and land cover trends in Senegal. J. Arid Environ. **2004**, 59, 427–462. Remote Sens. **2014**, *6* **675** over 50 years from aerial photographs and satellite images in a sahelian catchment..

Tiffen, M., Mortimore, M., Gichuki, F. (1994). More People, Less Erosion. Environmental Recovery in Kenya. Wiley, Chichester.

Timberlake, J., 1989. Brief description of the vegetation of 162 *J.K.* Lørup et al./Journal of Hydrology 205 (1998) *147–163* Mondoro and Ngezi communal lands, Mashonoland West. National Herbarium, Harare, Zimbabwe.

Townshend, J. R. G., Justice, C. O., Gurney, C., McManus, J.(1992). The effect of mis-registration on the detection of vegetation change. IEEE Transactions on Geosciences and Remote Sensing 30, 1054–1060.

Treitz, P. M., Howarth, P. J. (1999). Hyperspectral remote sensing for estimating biophysical parameters of forest ecosystems. Progress in Physical Geography 23, 359–390.

Tso, B., Mather, P. M. (2009). Classification methods for remotely sensed data (Second ed.). London: Taylor and Francis Group.

Tucker, C. J., Grant, D. M., Dykstra, J. D. (2014) Nasa's global orthorectified Landsat data set.Photogramm. Eng. Remote Sens. *70*, 313–322.

Turner, K. M. (1991). Annual evapotranspiration of native vegetation in a Mediterranean-type climate. Water Resources Bulletin 27: 1–6, 1991. Copyright © 2012 John Wiley & Sons, Ltd.

Tziztiki, J .G. M., Jean, M. F., Everett, A. H. (2012). Land cover mapping applications with MODIS: a literature review, International Journal of Digital Earth, vol. 5, no. 1, pp. 63–87. 6 The ScientificWorld Journal. Use and Water Resources Research, 2: 1-7

Ustin, S. L., Smith, M. O., Jacquemoud, S., Verstraete, M., Govaerts, Y. (1999). Geobotany: Vegetation Mapping for Earth Sciences. In: Renca, A.N., (Ed.), Remote Sensing for the Earth Sciences, Third Edition, Manual of Remote Sensing, vol. 3. Wiley, New York, pp. 707, Published in Cooperation with the American Society for Photogrammetry and Remote Sensing.vegetation changes on water yield and evapotranspiration. *Journal of Hydrology*, 55: 3-23.

Vanlay, Frank., Esteves Ana Maria. (2012). New Directions in Social Impact Assessment.

Vincent, V., Thomas, R. G. 1960. Agricultural survey of Southern Rhodesia. Part 1. Agro-Ecological Survey. Salisbury: Government Printers.

White, F. (1983). The Vegetation Map of Africa; UNESCO: Paris, France, 1983.

Whitlow, J. R.(1979). An assessment of cultivated lands in Zimbabwe Rhodesia, 1972 to 1977, Zimbabwe Rhodesia Sci. News, 13 (10), 233–238.

Wijesekara, G. N., Gupta, A. Valeo, C., Hasbani, J.-G., Qiao, Y., Delaney, P., Marceau, D. J. (2012). Assessing the impact of future land-use changes on hydrological processes in the Elbow River watershed in southern Alberta, Canada, J. Hydrol., 412– 413, 220–232.

Young, A. (1999). Is there really spare land? A critique of estimates of available cultivable land in developing countries. Environ. Dev. Sustainability 1:3-18

Zhang L., Dawes W. R., Walker G.R. (2001). Response of mean annual evapotranspiration to vegetation changes at catchment scale. Water Resources Research 37: 701–708. DOI: 10.1029/2000WR900325

Zirebwa, J., Twomlow, S. (1999). Historical profiles of selected small dams in communal areas of of Masvingo Province. Silsoe Research Institute, IDG/99/11.