NAME OF STUDENT **:** KUDENGA NYASHA

DISSERTATION TITLE **:** Effects of urbanisation in Upper Manyame on the flow of Manyame River at Gauging Station C21

DEGREE TITLE **:** Bachelor of Science Degree (Honours) in Land and Water Resources Management

YEAR : 2016

APPROVAL FORM

The undersigned certify that they have read the thesis and have approved its submission for marking after confirming that it conforms to the departmental requirements of Midlands State University, The project is entitled “Effects of urbanisation in Upper Manyame catchment on the flow of Manyame River at Gauging Station C21”.Submitted by Kudenga Nyasha in partial fulfilment of the requirements of Bachelor of Science Degree (Honours) in Land and Water Resources Management offered by Midlands State University.

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EXTERNAL EXAMINER	DATE

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PERMANENT ADDRESS : 6698 Domboshava Road Zimre Park Harare

DATE : June 2015

DEDICATIONS

To my parents Mr and Mrs Kudenga, my brother Farai and my sisters Fadzai and Omega you are ones who give me the support to keep on going. May the Lord our God keep on blessing you.

ABSTRACT

Regression analysis was used to establish the relationship between urbanisation in Harare and river yield of Manyame River at gauging station C21. To detect the effects of urbanisation, Landsat images were downloaded from USGS website *(http://landsatlook.usgs.gov/viewer)* and they were processed in Quantum GIS and System for Automated Geoscientific Analysis. Image classification was carried out in SAGA were the images were classified into five main classes which were Forest, Scrub, Ground, Water and Built up. Change detection was then carried out in SAGA and also the changes that occurred were calculated as a percentage in SAGA. The results showed that in Upper Manyame, forests were totally deforested by 18.04 percent. The area that was covered by scrub was reduced by 10.2 percent. Built up area increased sharply by 11.2 percent and the area that was covered by bare ground drastically expanded by 17.8 percent. The average NDVI for C21which showed the reduction in vegetation was calculated in Arc GIS. The median NDVI values were then calculated in Excel and it showed that there was a general decrease in the NDVI values in C21 catchment with the highest 0.47 in 1998 showing a healthier forest and lowest was 0.36 in 2011 showing a degraded forest. The river yield for Manyame river at gauging station C21 was calculated in excel and showed that there was a general increase in the river yield as a percentage from 104 percent to 129 percentage although there was a sharp decrease in 2008 to 109 percent where there was a draught in Zimbabwe. Linear least square regression analysis was run to establish the relationship between river yield and NDVI and the relationship was statistically significant with $p<0.05$ tested by Gen stat 2014 edition . The NDVI and river yield had a strong inverse relationship of -0.72. The r^2 value for NDVI and river yield was 0.5199.

ACKNOWLEDGEMENTS

First and foremost , I would like to thank the Almighty who is the Author and Finisher of my life for sustaining me throughout the tremendous work during the writing of this thesis, glory is to Him.

Secondly I would like thank my supervisor Mr Mupfiga for his guidance and support, without him truly this project would have not been completed. Deepest gratitude is also due to all the members and staff of the Department of Land and Water Resources Management at Midlands State University, without whose much appreciated knowledge and skills in equipping me with the knowledge at this college. Special gratitude is extended to the author's matesRuth Bandawe, Tinashe Muringani, Innocent Sande and Wellington Mandizvidza.

I would also want to pass my sincere gratitude to my mum and dad Mr and MrsKudenga and my siblings Fadzai, Shamiso and Farai Kudenga for being supportive and encouraging,

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List of Acronyms

DBF	Data Base File
DEM	Digital Elevation Model
EMR	Electromagnetic Radiation
GIS	Geographic Information Systems
NDVI	Normalised Difference Vegetation Index
NIR	Near Infra-Red
RS	Remote Sensing
SAGA	System for Automated Geoscientific Analysis
USGS	United States Geological Survey
LUCC	Land Use and land Cover Change
QGIS	Quantum Geographic Information System
ZINWA	Zimbabwe National Water Authority

Chapter 1

1.0Introduction

Urbanization in Africa is common due to urban migration resulting in an increase in paved and built-up areas in the urban settings. Africa is one of the hotspots of serious urban growth and will continue to be so for the next four decades (UNDES, 2013). In Zimbabwe, the population of Harare has grown from 1.8 million in 2002 to 2.1 million in 2012 (ZIMSTATS, 2012). As a consequence, the demand for land for housing increased and peri-urban and rural areas have been converted to urban areas.Increases in impervious areas through urbanization may result in the following hydrological impacts (i) reduced interception by tree canopies; (ii) reduced infiltration; (iii) increased surface runoff; (iv) increased flow velocities in urban areas due to decreased surface roughness and (v) increased peak flow discharges.

Due to increased urbanisation, rural to urban migration and the land reform programme, there has been increased land use and land cover changes in the Upper Manyame sub catchment (Chenje et al., 1998). All these programmes have got the effects of increased discharge on the hydrological cycle of the Upper Manyame sub catchment. These land cover changes have got negative impacts on the water quality and quantity of both Manyame River and Lake Chivero.

Lake Chiverois the main source of the water supply of Harare therefore the quality and quantity of the water in the Manyame River and Chivero Dam should be constantly monitored so that the water supply of the city of Harare will not be affected. There has been much study of the effects of land use and land cover changes on the hydrology of many rivers across the world but here in Zimbabwe little has been done in terms of the quantification of the effects.

The increase in urbanisation in cities affects many components of the ecosystem which includes the soil structure, diversion of the natural flow of water and the infiltration rate. Increase in the area that is covered by impermeable surfaces due to urbanisation leads increased river discharge due to the impediment of infiltration.

The cutting down of trees by people to clear land for agriculture, urbanisation and other land uses has got many impacts on the water cycle .The research of the impact of land-use changes on surface hydrology has therefore received considerable attention from both field observations and model simulations

Land use is characterised by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change or maintain it (FAO/UNEP, 1999).Land use and land cover change has got a lot of negative effects on the runoff and evapotranspiration. The effects includes increased flooding, poor water quality,increased runoff, sedimentation and the eutrophication of rivers(Yuan et al. 2016).All these negative externalities must be minimised in Zimbabwe given its situation that it is in a semi-arid region and the greater part of the country receives little rainfall. Zimbabwe was classified as a water stressed country for the period of 2008 up to 2012 (Nhedzi, 2008). So there is need to have stringent water management practices for the country to have sustainable economic growth.

According to Fry et al. (2015), the current and future development in water resources is very sensitive to land use and the intensification of human activities. The main objective of this research project is to investigate and to determine to which extend has the effects of urbanisation affected runoff in Manyame River the subsequent water body which is Lake Manyame.

Particularly in semi-arid areas, the impact of land use changes on basin runoff is of interest to water resource planners,managers and local authorities(Futter et al. 2016). This is mainly due to the unpredictability of rainfall in terms of both time and amount and this a reality here in Zimbabwe due climate change and economic hardships which are leading to poor meteorological services. This has caused devastating effects on the standards of living of the Zimbabwean people.

Due to the continual scarcity of water, damming has been considered as an alternative. In the 1990s Government of Zimbabwe noted that, due to population growth, industrial activities, mining activities, urban development and the increasing need for irrigation there has been competition for water across sectors. Dams are built as reservoirs to contain the much precipitation received in the rainy season so as to make use of the water in the dry season. In Zimbabwe damming started in the early 1990's, and more dams were constructed due to the widespread of commercial farming. However if the land use practises in the catchments of Zimbabwe are not closely monitored , the gains and the fruits of many damming projects will not be realised due to sedimentation, eutrophication and other negatives externalities of poor land use practices.

The different types of land use like an increase in the land for agriculture in the Manyame catchment has led to the cutting down of trees in the process of clearing agricultural land.

These areas which are cleared used to be forests which have got new properties in terms of binding the soil, release of water vapour into the atmosphere, soil moisture content, surface roughness and runoff. This will affect river discharge in Manyame River as well as the amount of water in the subsequent dam which is Lake Manyame.

1.2Problem Statement

There has been an increase in the demand of land for urbanisation in Harare, there has been rapid destruction of forest in the Upper Manyame catchment. This increase in the demand for land is causing the degradation of the Upper Manyame catchment due to the land which is being left bare due to cleared lands for residential stands, but the quantification of the effects of these changes onManyame River is not known. There is urgent need to establish the relationship between changes in land uses in this catchment and the effects on Manyame River. The establishment of this relationship will be a major step towards sustainable watershed management by relevant authorities. There is also need for this in-depth scientific research on the relationship of land cover changes in Upper Manyame on Manyame River so that the current position is known in terms of effects and proper solutions to these effects are proposed.

1.3Justification

Zimbabwe is a semi-arid region with little rainfall and Manyame catchment is within region two,three and five of which the greater part of the catchment is in region five which receives little rainfall. Due to this situation that this catchment is arid plus the devastating effects of climate change, there is need for an in-depth scientific research on the effects of land use of Upper Manyame catchment on Manyame River.

The other main reason for this research is that of an increased population in Zimbabwe, this is putting pressure on the already strained water resources of the Manyame catchment. The main reason why this research is looking on the effects of land use and land cover change in the Manyame catchment is that of the increased uncontrolled urbanisation in Harare .The increase is mainly being caused by rural to urban migration and poor polices and planning by the city of Harare .This has resulted in uncontrolled issuing of residential stands in Harare. There is need to develop policies which will result in the best use and sustainable management of land, this is one of the specific needs of Agenda 21, (FAO, UNEP, 1999)

The rest of the Manyame catchment is filled with newly resettled farmers, both A1 and A2 famers,so it is one of the aim of this research to examine and see how these newly settled farmers are affecting the water resources in the Manyame catchment. This is mainly because the farmers maybe cutting down trees in preparation of their new fields and as a source of fuel, they may be practising poor farming methods like stream bank cultivation ,overstocking or even cutting down firewood for sale.

Regression analyses was used to establish the relationship between NDVI and river yields because this method needs a few input data requirements compared to other models like the ACRU model, PITMAN model and HEC-HMS model which needs a lot of data. However the main inputs for these models are the ones that were used in this research. This other reason for the use of this model was that of the availability of input data. This input data for this model was locally available in the suitable resolutions both temporal and spatial.

There has been a notable progress in terms of damming of water in Zimbabwe in the past ,however if there is no protection of this development by controlling land use and land cover change within Manyame catchment, the benefits of thesewater supply development projects which leads to water sufficiency will not be attained. This is mainly because different human activitieslike urbanisation, poor farming methods and alluvial mining,leads to increased river discharge, siltation of rivers and dams, eutrophication of rivers poor water quality.

Worldwide, the study of the effects of land use and land cover changes has been high compared to rate at which they are being done here in Zimbabwe. Yes the general effects of land use and land cover changes on hydrology is known but the extent is not known in Zimbabwe. This research tries to quantify the effects and provides the bases over which the solutions can be drawn from.

The other reason why this research is done is that forests have got very paramount use in reducing the amount of carbon dioxide in the air .Forests acts as carbon tanks that is they are able to absorb the carbon dioxide in the atmosphere and they are able to store it. Natural forests are also able to absorb more carbon dioxide compared to grasslands and exotic trees. Due to this reason, there is need for close monitoring of forests in Zimbabwe so as to reduce the effects of greenhouse gases on earth.

1.4Research Questions

What land cover and land use changes have occurred in the Upper Manyame Catchment?

What impact has urbanisation had on the flow of Manyame River?

By how much has the area of forests been reduced due to urbanisation?

By how much has urbanisation in Upper Manyame catchment affected the flow of Manyame River?

1.5Main Objective

To assess the effects of urbanisation in Upper Manyame catchment on the flow of Manyame River at Gauging Station C21.

1.5.1Specific Objectives

To determine the extent of urbanisation and deforestation from 1980 to 2014 using GIS and RS

To determine the effects urbanisation and deforestation on the flow of Manyame River

Hypothesis for the second objective

H_o: There is no effect on the flow of Manyame River as a result of urbanisation.

H1: There is effect on the flow of Manyame River as a result of urbanisation.

Chapter 2 : Literature Review

2.0Land use and land cover changes

land use is defined as arrangements, activities and inputs people do undertake in a certain land cover to produce change and maintain it (FAO/UNEP, 1999). There are many land uses in Upper Manyame catchment, but some of the main land uses includes agriculture, urbanisation, mining and logging. Land cover is the observed bio-physical cover on the earth’s surface (Di Gregorio and Jansen, 1998).

Land cover changes due to increase in the rate of urbanisation causes deforestation which leads to the reduction of tree density .This reduces the leaf area index of an area, the reduction in the leaf area leads to reduced interception leading to increased runoff. This will leads to an increased runoff again due to reduced surface roughness and an increase in impervious area(Fry et al. 2015).

Changes in land use and corresponding changes in land cover can alter the basic functioning and resilience of ecological systems(Thom and Borde, 1998). Watersheds, for instance, experience numerous effects among the critical ones are physical, chemical, and biological processes when land cover changes. For example, removal of vegetation can increase erosion, leading to impacts on soil and water quality, and increases in developed land typically result in a corresponding increase in impervious surfaces with consequences for runoff, among other issues. While individual impacts to a landscape may appear as small changes, the combined impacts of particular land uses or land management practices on watersheds can have notable effects on water quality and quantity, species composition, and flooding patterns(Huang and Klemas, 2012).

Agriculture is currently accountable for about one third of the World’s Green House Gas emissions and this share is projected to increase, particularly in developing countries. At the same time, the sector also can reduce these emissions especially through improvements in land-use management. 89% of IPCC identified technical potential lies in enhancing soil carbon sinks which higher in more organic matter provided by vegetation. There are, however, significant costs and barriers to overcome in the short run to realize the level of change required to achieve significant mitigation benefits .Jensen,(2009) stated that human activities were proven to make land-use/cover patterns change more rapidly, and thus brought different impacts on bio-physical processes while (Syvitski, 2003*)* also suggested that rapid land-use/cover changes may affect both water and sediment discharges and (Futter et al. 2016) pointed out that after human settlement effects, and climate shifts are often the major driving factor on sediment discharges.

In the African context, the assessment and the measurement of the impacts of urbanization on streamflow is important for water development and management (Gumindoga et al., 2014). This is mainly because Zimbabwe for example has got high cases of water shortages. Water is scarce in Zimbabwe.

2.1Hydrology and land cover changes

Hydrological ecosystem services (base flow conservation, storm flow regulation and erosion control) are of greatest significance for buffering the impacts of climate change on water users.According to (Guo et al, 2010), human induced land-cover changes lead to undesirable impacts to watershed ecosystems. It has been widely acknowledged that changes such as forest cover reduction through deforestation and conversion for agricultural purposes can alter the response of a watershed to rainfall events, that often leads to increased volumes of surface runoff and greatly increase the occurrence of flooding (Cebecauer and Hofierka, 2008). The detection of these changes is crucial to provide information as to what and where the changes have occurred and to analyse these changes in order to formulate proper mitigation measures and rehabilitation strategies.

Zhou, (2001) alluded that urbanisation can alter the velocity of water, whether in the form of streams or runoff, by changing slope or gradient and the roughness encountered by the flow, which affect sediment loads, and consequently impact the downstream ecosystem.

2.2Effects of urbanisation on Hydrology

The construction or increase in urbanisation leads to the increase in the area covered by impermeable surfaces and this has got an effect on the functions of the water or hydrological cycle (Jensen, 2009). The effects of the conversion of the soils covered with vegetation to impervious surfaces has got the effects on the flow which includes reduction in the amount of water that is stored both on the surface and in soil and also increases runoff as shown on figure 1 below. The speed of overland flow also increases, the amount of evapotranspiration reduces due to reduction in forest cover and the amount of water that percolates is reduced due to impermeable surfaces (Hollis, 2015).

The other augmentation is on channel networks of storm drains and side road drains which increase the density of drainage in the watershed shown on figure 1 below. This leads to reduction in the distance that runoff has to travel before it reaches the river. Also this increases the speed of runoff as these manmade drains are smother compared with natural waterways. These manmade storm drains also reduces the amount of water that is stored in them because they do not have pools and ponds, they are designed in such a that all the water that they contain will be drained of completely(Hollis, 2015).

The construction activity which includes the building of houses, bridges, pavements and roads also affects the hydrological processes of the catchment. This leads to the clearing of vegetation which leads to the exposure of the soil and encourages overland flow. The soil is also disturbed and its erodibility is increased. The natural slope of the watershed is replaced by the urban landscape with the soil profile being disturbed space vegetation cover (Hollis, 2015).

The other point is on the creation of urban heat islands in urban areas that. In urban areas there is greater aerodynamic roughness of tall buildings compared to a natural watershed. There is also the issue of fossil fuels in thermal electricity generation, vehicles and industries, this process leads to the profusion of condensation nuclei which leads to high amounts of rainfall being received in summer compared to rural areas. It also leads to high frequency of convective thunderstorms and rainstorms (Hollis, 2015).

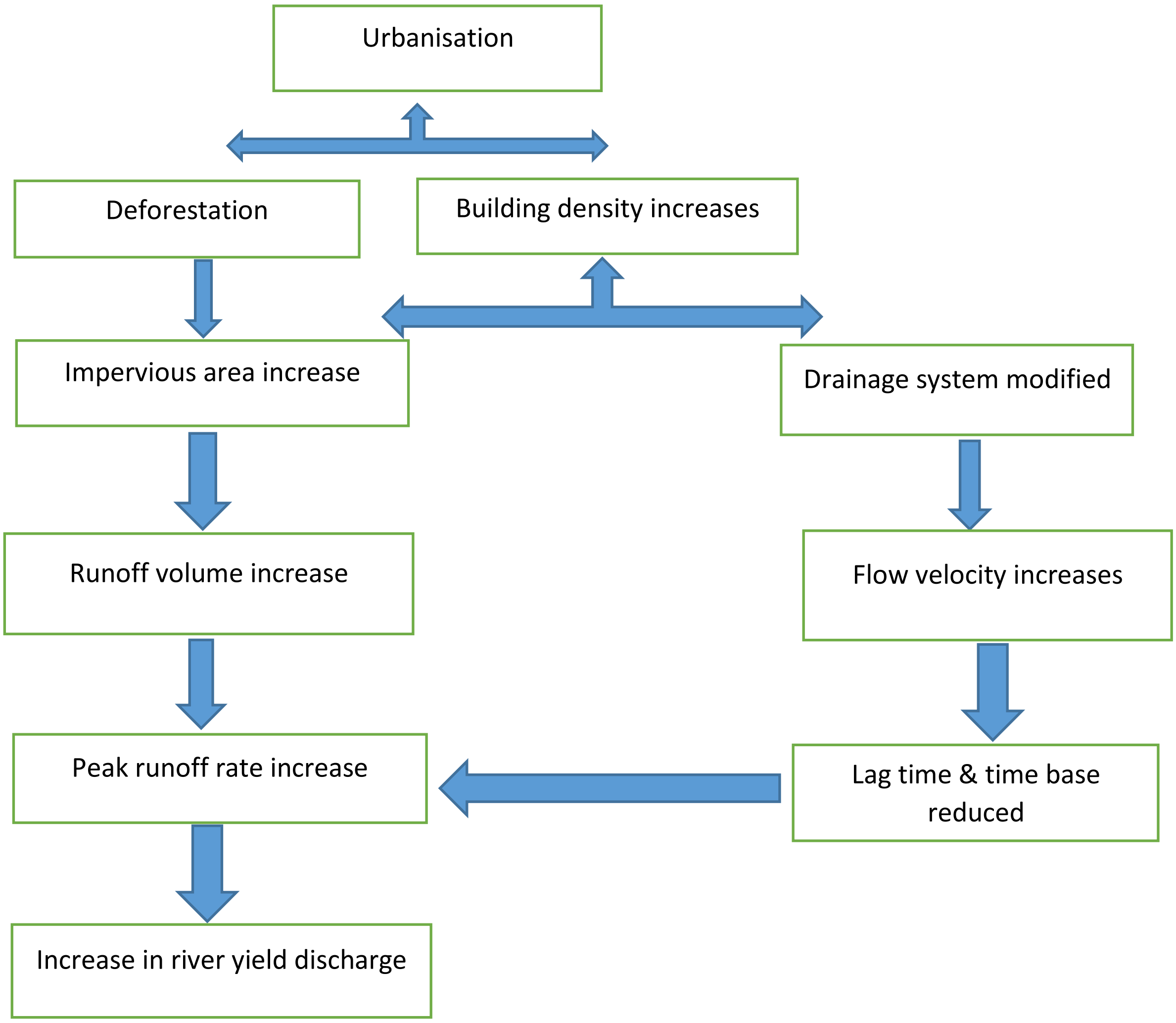


Figure 1:Effects of urbanisation on hydrological processes (After Hall 1984)

2.3Effects of deforestation on Hydrology

Many studies on the effects of deforestation on river discharge were mainly done by researchers who were studying the effects of deforestation on the river discharge that was used for hydro-electric power generation.When deforestation occurs and the forests are replaced by bare grounds or crops, this situation leads to an increase in the river discharge (Allen, J and Barnes 1985). This is mainly because trees which reduces runoff velocity will be removed, leading to high runoff velocity. Also trees increases the rates of infiltration, so if trees are removed the rate of infiltration is reduced leading to increased runoff which will eventually leads to high river discharge. Also deforestation reduces interception, this means that all water that was supposed to be intercepted will now flow as runoff leading to an increase in the river yields.

2.4Use of GIS in hydrology

GIS and remote sensing are some of the tools which can be used in natural resources management in this century. GIS allows advanced analysis and modelling and remote sensing provides efficient and reliable tools to measure, monitor, forecast and model spatial and temporal variations of water in the environment in near-real-time (Nhedzi, 2008).

2.5Applications of RS in mapping LULCC

Remote sensing is a technique to observe the earth surface or the atmosphere from out of space using satellites (space borne) or from the air using aircrafts (airborne) ,(Sharma and Sakar 1985).It involves the use of certain electromagnetic spectrum in measuring the amount of electromagnetic energy reflected by the earth's surface. Remote sensing imagery has many applications in mapping land-use and cover ,agriculture, soils mapping, forestry, city planning, archaeological investigations ,military observation, and geomorphological surveying, land cover changes, deforestation, vegetation dynamics, water quality dynamics, urban growth, etc. ,(Sharma and Sakar 1985).

Researchers have used satellite the trend of changes in satellite images to detect land cover changes (Huang and Klemas2012). For accurate results to be found the images that are downloaded from the satellite must be of the same periods and they also be of the same spectral bands. This means that the environmental conditions under which the images that will be used for comparison and change detection must be the same (Huang and Klemas 2012)

2.6Use of DEM in watershed delineation

According to the USGS, the Digital elevation model (DEM) is a model which represents terrain elevations for ground positions at regularly spaced horizontal intervals. The DEM is used to produce three dimensional graphics displaying terrain slope, aspect (direction of slope), and terrain profiles between selected points. The understanding and study of elevation and topography in general over the past 30 years has been enhanced by the use of the DEM(Lambinet at., 2001). The Advanced Space borne Thermal Emission and Reflection Radiometer Global Digital Elevation Model Version 2 (ASTER GDEMv2) has been used to delineate watersheds and stream networks (Saadat et al., 2008; Khan et al., 2014) and to investigate geomorphic and hydrologic processes at landscape to regional scales (de Vente et al., 2009; Santini et al., 2009).

2.7Relationship of NDVI and urbanisation

The Normalised Difference Vegetation Index is the common vegetation index which is used to detect changes vegetation cover. A decrease in NDVI values will be representing an increase in urbanisation. This is mainly because vegetation will be depleted or reduced due to urbanisation. The NDVI is found by the difference of the NIR and red reflectance's divided by their summation. Green plants characteristics are mainly represented by these two spectral bands. The red band spectral band radiation is absorbed by chlorophyll in the surface layers of the plants (Palisade parenchyma) and the NIR is reflected from the inner leaf cell structure (Spongy mesophyll) as it penetrates several leaf layers in a canopy. The NDVI can also be used to show the health status of a forest because the values of the NDVI can represents the plant biomass and the NIR reflects the quantity of plant tissue whilst the red spectral band reflects the surface condition of plant tissues (Jinliang Huang1 and Victor Klemas 2012)

Vegetation index is a number that is generated when certain bands of the images has a relationship on the amount of vegetation (Sharma and Sarhart, 1998). After the images have been processed, difference methods like the Normalised Difference Vegetation Index can be used to assess and detect the vegetation differences. Below is the equation used for finding the NDVI.

$NDVI = (NIR + R) / (NIR - R)$

Your lit review must show a flow of ideas from one paragraph to the next. It is not a collection of standalone paragraphs.

Your lit review, while it carries some of the important aspects, it is not well coordinated

CHAPTER 3
3.0STUDY AREA

Geographically, the Upper Manyame catchment lies between the 18.320S (latitude) and the 18.330S (latitude) and between the 30.50E longitude and the 31.50E longitude .Upper Manyame catchment covers mainly Harare , so most of the vegetation is being removed by human activities like the development of housing schemes, urban agriculture and urbanisation. Below is the map of Manyame catchment showing the runoff gauging stations location within the catchment. The catchment receives all most all its rainfall in summer and it is in rainfall regions two which receives about 800mm. The soils which are dominant in this catchment are called Paraferrallitic (6G) soils. The catchment has got a Savannah climate which is characterised by seasonal rainfall in which rainfall falls in summer and the winters are cool with no rainfall. The size of the catchment is about 1510 square kilometres.

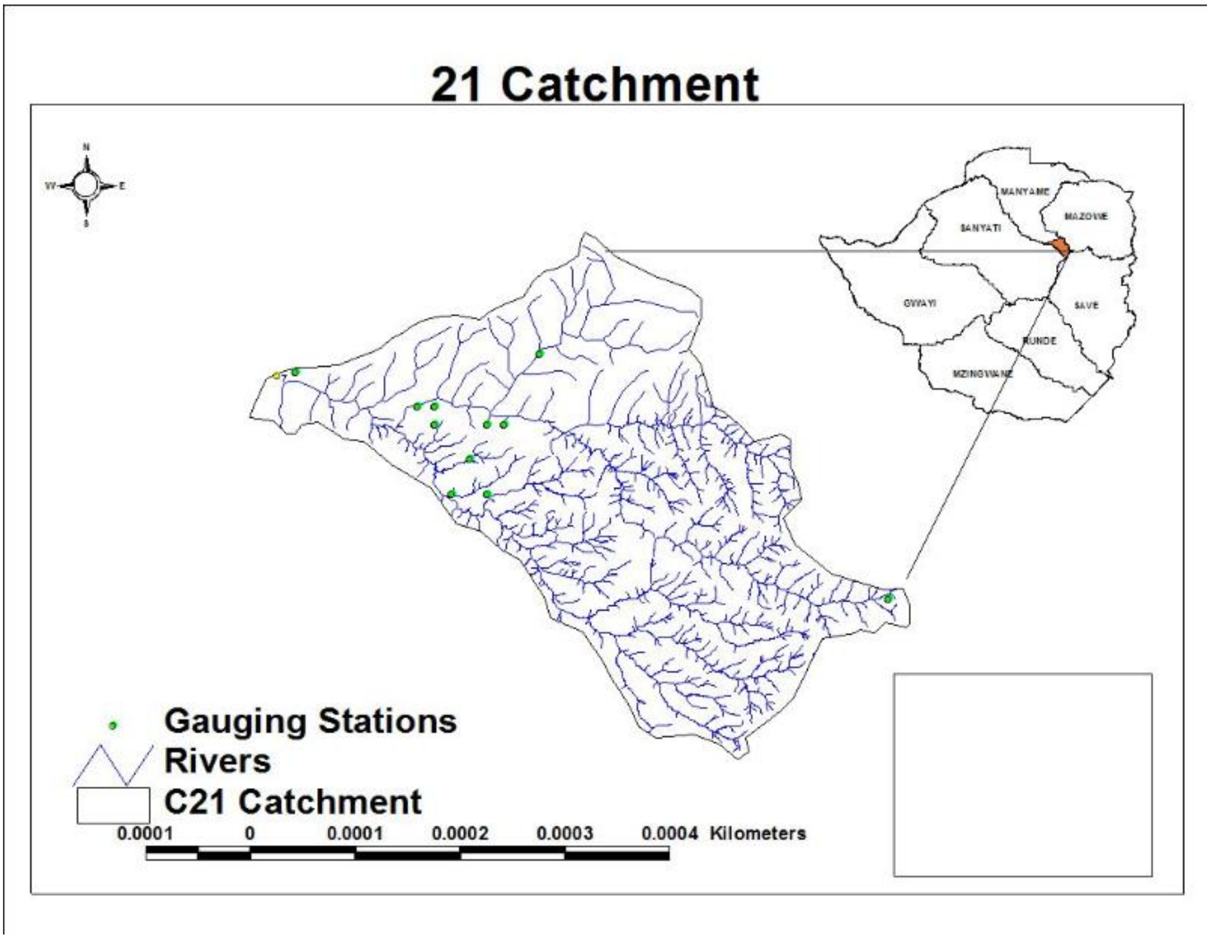
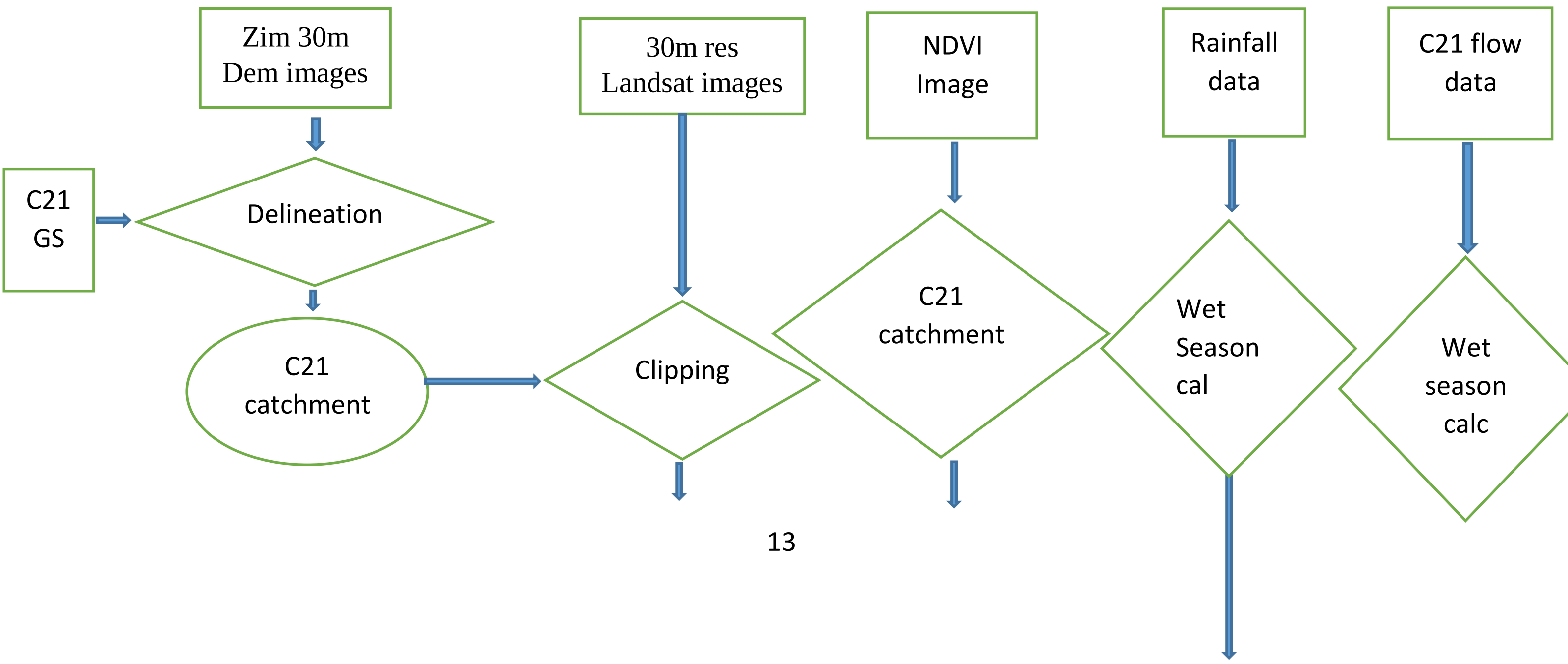


Figure 2: Location of C21 catchment in Zimbabwe

FLOW CHART OF THE METHODOLOGY



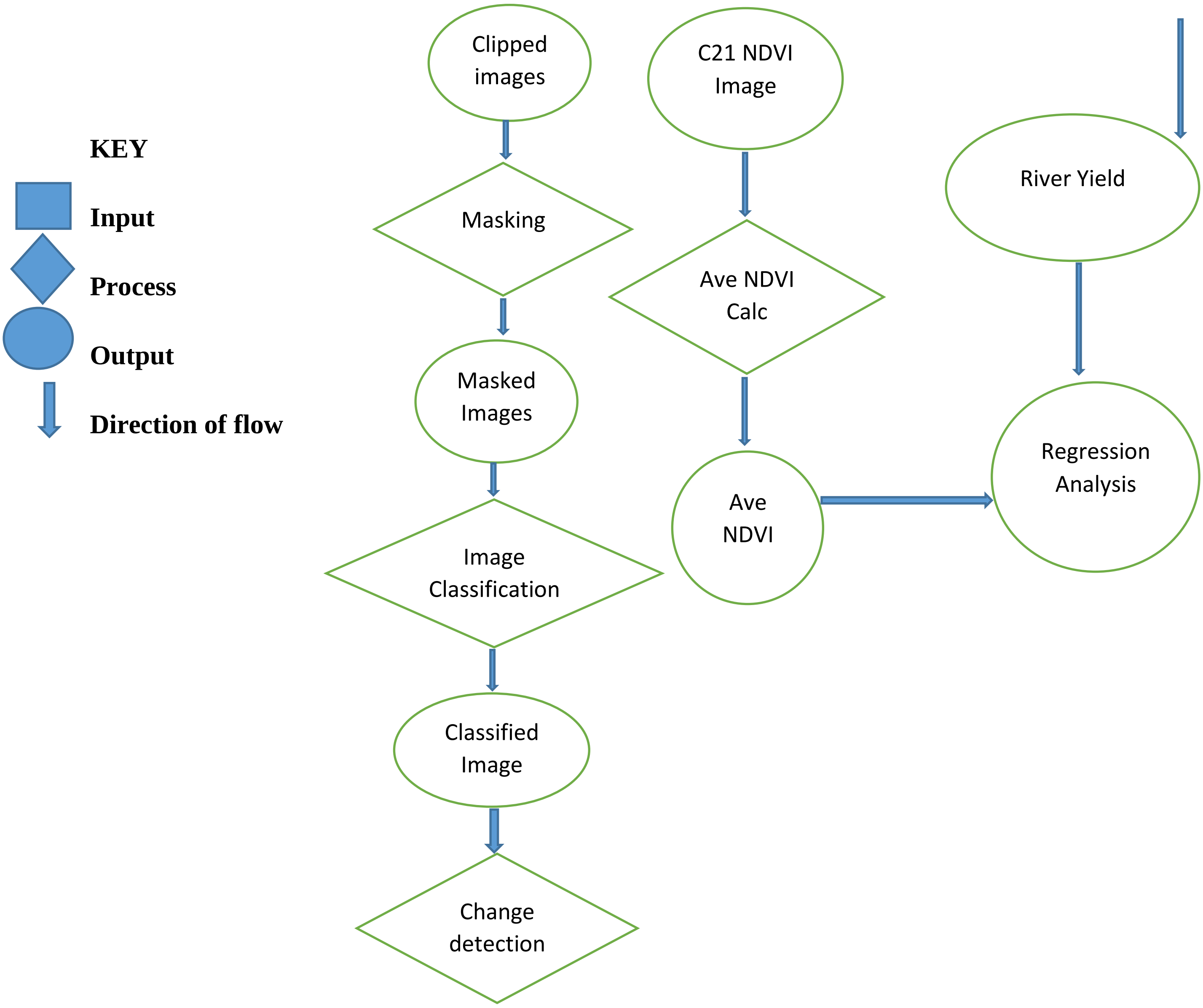


Figure 3:Flow chart of the methodology

3.2C21 Catchment Delineation / Watershed Delineation

The specific catchment area under study or the watershed of C21 which is the study area was delineated in Arc GIS using the Digital elevation model. Watershed delineation is a process of drawing the boundaries of a watershed. The watershed represents the contributing area of water drawn to certain point which will be the outlet in the case gauging station C21. The importance of watershed delineation is that it gives attention to the specific area which is under study.

A Digital Elevation Model (DEM) is a gridded array of elevations(Gumindoga et al. 2014). Digital Elevation Model shows the altitude of the different areas within a catchment. The Digital Elevation Model was used to demarcate the contributing area in terms of flow for the gauging station C21. Below is the contribution area of C21 that was demarcated by the digital elevation model.

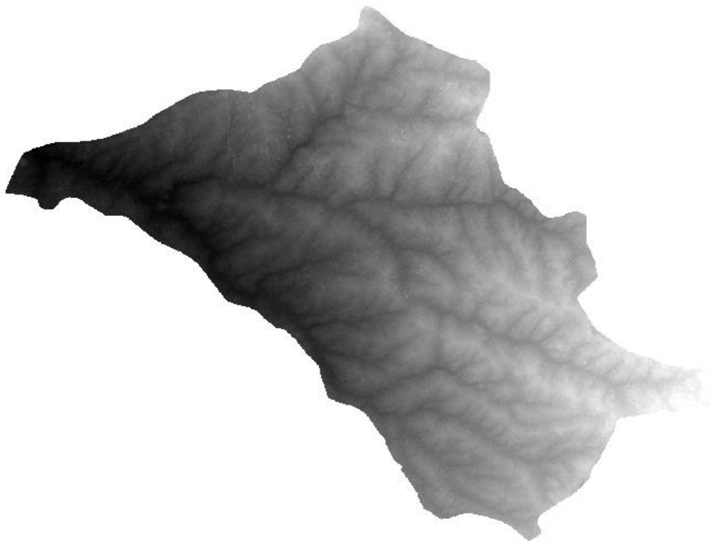


Figure 4:Drainage area generated by DEM for C21 catchment

Figure 4 of the drainage area of c21 was developed by the Digital Elevation Model. Italso shows the elevations of all areas in the C21 catchment. Elevation of an area is the height of an area above sea level. The areas that are light or greyish in colour are the areas with high elevations like crest of mountains and generally high lands. The areas that are dark in colour shows low laying areas, these are valleys and the rivers in this catchment are flowing through these areas, this was shown when an over lay of a shape file of rivers was placed on this image, rivers were following this low laying areas because water always flows from high places to low places.

After the determination of the actual catchment area of C21 gauging station, land sat images covering C21 gauging station were downloaded and processed through the following stages **Acquisition, Image processing, Change detection, Supervised classification, Taking ground control points, Training or site selection, Image processing, NDVI calculation**

Figure 3 shows flow chart that describes the stages in which the research was conducted that is the acquisition of images, corrections, processing, assessment and classification of land use and land cover changes.

3.5Acquisition

The images were downloaded from the website *(http://landsatlook.usgs.gov/viewer)*. The images used were of the same period or season of the year so that there won't be any distortion or difference due to different periods being used. This is mainly because if rain season images are taken, crops will be cause confusion with other vegetation like shrubs. The period under which the images were downloaded was during September to October season which is dry season here in Zimbabwe and forests and shrubs were easy to identify. This period was chosen so that vegetation will not be confused with crops which will be grown during the rain period. The images taken were for three different years which were 1986, 2000 and 2014. The images downloaded had zero percent cloud cover. This was done to prevent unnecessary process of removing the cloud cover The C21 study area covered two satellite images so two sets of images were downloaded from the satellite and they were processed to become one complete image through the processes of mosaicking.

Table 1:Images downloaded and their specifications

Satellite	**Path & Raw**	**Year**	**Source**
Landsat Thematic Mapper	170/72 & 169/73	31/10/1986 & 18/09/1986	United States Geological Survey Website
Landsat Thematic Mapper	170/72 & 169/73	17/10/2000 &10/09/2000	United States Geological Survey Website

Landsat 8 Operational land Imager	170/72 & 169/73	17/10/2014 & 20/09/2014	United States Geological Survey Website

3.6Image pre-processing or image correction

The image corrections included the geometric corrections, radiometric corrections and atmospheric corrections. Geometric correction was the correction of the errors that are caused by the satellite or air craft not staying on the same or constant altitude.*Radiometric* correction was when the amount of light that is EMR recorded by a sensor was calibrated for the images (Yuan et al., 2005). *Atmospheric* correction this is when the images were corrected for atmospheric interaction or processes like scattering the *radiographic* correction includes the earth to sun distance and the viewing resolution (Zhou and Robson 2001). The most crucial steps in the pre-processing of images were the registration of the multi date images and their radiometric rectification (Jin Liang Huang and Victor Klemas ,2012). Also another critical requirement for change detection was attaining a common radiometric response for the quantitative analysis for one or more of the image pairs acquired on different dates (Jin Liang Haung and Victor Klemas, 2012). This process was the normalisation of variations of absorption, solar illumination and atmospheric scattering. They were processed using Quantum GIS and in this research Quantum GIS was be used.

A process of removing the black part of the images was also done in Quantum GIS. The black was removed by assigning zero values to all the pixels of the images that had a black part. This will leads to the parts being removed and our images were now easy to mosaic because these parts were removed

3.7Mosaicking

The mosaicking of the two images that covered my study area which is the catchment of gauging station C21 was done with Quantum GIS. Mosaicking is a process whereby two images covering the area of interest are attached together to form one. The images mosaicked were there one with path 170 and raw 72 and the one with path 169 and raw.

3.8Layer stacking

When land sat images are being downloaded from the satellite, they will be in form of different bands and the number of bands depends on the type of the used. As the satellite will be taking images on the earth, deferent bands will be recording different properties of the earth, so these different bands were staked together to form one image through the process of layer stacking. For example the for land sat 5 the first band is blue and has a wave length of 0.45 to 0.52 and its useful for bathymetric mapping and distinguishing vegetation from deciduous forest, band 2 is green and is used for identifying peak vegetation and the health of vegetation. The bands are many up to band seven for land sat 5 so bands with different properties were staked together to form a single images which contained the useful information which was under study.

3.9Supervised classification

Supervised classification was done when the researcher has got the knowledge of how the area under study looks like. The information about the area was found on google earth. On supervised classification the researcher choose the number of classes he wanted and assigned them the actual pixels, this process is called the training phase. The number of classes was five and the classes included forest, built up, scrub, ground and water. The number of sites that were used on the training phase was representative enough for the whole image .After the training phase, the researcher then choose the algorithm to use on the classification. The algorithm used on this research was maximum likelihood classifier. This algorithm is the one that was used to classify pixels of images into the above five classes.

The five classes that the images were classified into were built up which was class 1, ground which was class 2, scrub which was class 3, water was class 4 and lastly forest was class 5. The built up area composed of areas that were covered with buildings, houses, roads and pavements. The second class was ground and this class composed all the areas that was bare the bareness was caused by land development activities and fields that were not planted crops by this period of the year. The third class was scrub and this class composed of a mixture of grasslands and bushes, it also composed of a massively deforest rated area. The fourth class composed of water and this class composed mainly of the water in Manyame River and also water in water harvesting structures like the reservoirs and small dams. The last class was class five and it composed of forest, the forested area was an area with a well-developed forest with a high tree density. Table 2 shows the description of the land cover classes used in image classification.

Table 2: Classes and their definition

Land cover Category	Definition
Built-up	Areas with high building densities, most of the area will be covered by structures
Scrub	Tree height 1-5m, canopy cover 20-80%
Ground	Large areas of bare surface with little or no plant cover.
Forest	Tree height >15m, canopy cover 80 %
Water	Areas covered by rivers and large dams

3.1.0Change detection

The process of change detection was done using System for Automated Geoscientific Analysis (SAGA). Change detection between registered and radio metrically corrected images was done using post classification comparison. In this process two images for the same area for different dates before and after change were independently classified. The pixels between these two images were compared. The change between two images was found when a pixel of a certain area changed in its value. The classes of the images that were compared were the 1986 image and the 2000 images and the overall change for the period was seen when the 1986 image was compared with the 2014 image.

3.1.1Normalised Difference Vegetation Index (NDVI)

The calculation of the NDVI values for the C21 catchment was done using Arc GIS from images obtained from the USGS website. The NDVI images were decadal so this means that 36 images were taken per year, but for this analysis only 21 images for the rain season that started in October ending April was used. These 21 images for each rain season, an average NDVI for them was calculated. The equation below was used to convert the image values of the image to actual NDVI values.

NDVI = (0.004*DN) – 0.1

Where DN are the values for the average image of the season

When the actual NDVI values were found the median value was then calculated in Microsoft Excel. Before the median value was calculated, there was a process of extracting the value. This process included the creation of a Data Base File (DBF). This was a file which contains all the information of each and every pixel of the image. The information included the NDVI values and x and y coordinates for each and every pixel of the image. This DBF was saved and opened in excel for the calculation of the median NDVI value.

3.12River Yield

Rainfall plays a crucial role in the occurrence of the variations of the river flow. The river depth was normalised by dividing the annual river flow depth the annual rainfall totals. Annual river flow divided by annual rainfall totals gives us the river yield (Q/P), where Q and P are annual river flow and annual river total respectively (Hope et al. 2009).

3.13 Linear Least square Regression model

Linear least square regression analysis is used to establish the empirical relationship between the annual river yield and the average NDVI (Hope et al. 2009). Also the linear least square regression model was used to regress the annual river yield on the NDVI. The regression equation was also tested for statistical significance. For a linear relationship, r value of above 0.8 will show a strong direct relationship between land use and land cover changes on the flow of Manyame River. Linear regression model is used to estimate the relationship between two variables and in this case the variables were an increase in urbanisation or land use and land cover changes as the independent variable and increase in the flow of Manyame River as the dependent variable.

3.14River Flow Data

The river flow data for this part ofManyame River was measured at C21. This position of the gauging station within this small catchment is shown by a yellow dot in the map on figure 2. It is located up stream at the mouth of Chivero Dam. It is located at latitude 1788 S and longitude 3054 E. The catchment area of gauging station C21 is 1510 square kilometres. The gauging station was opened on 15 December 1952. The daily river flow data was obtained at Zimbabwe National Water Authority under the department Data and Research. The data was daily mean discharges measured in cubic metres per second.

The daily river flow data at C21 GS was summed up for the period starting from October to April that is a period of seven months. This period was chosen because it is the period when rainfall will be flowing. The river flow data was divided by the rainfall data to get the river yield.

3.15Rainfall Data

The average daily rainfall data for C21 catchment was found at Kutsaga Station. This station is within the catchment of the gauging station C21. The data with a daily temporal resolution was downloaded from the National data centre at the following websitehttp://www1.ncdc.noaa.gov.pub/oders. The data was summed up for seven months which were for the rain season and the total rainfall which was received during the rainy season was calculated. The total amount which was received during the rainy season is the one that was used to normalise the river flows, because rainfall is the main determinant of the amount of water that flows in rivers. This rainfall data is the one that was divided into the flow data to get the river yield.

Chapter 4

4.0Results and Discussion

4.1Landsat images

Landsat images for three different periods that is 1986, 2000 and 2014 showed changes in different land uses and land covers. The 1986 image was used as a base map for comparison between the 2000 and the 2014 land classes because that’s when my research starts. The images had 5 main classes which were forest, ground, water, scrub and built-up.

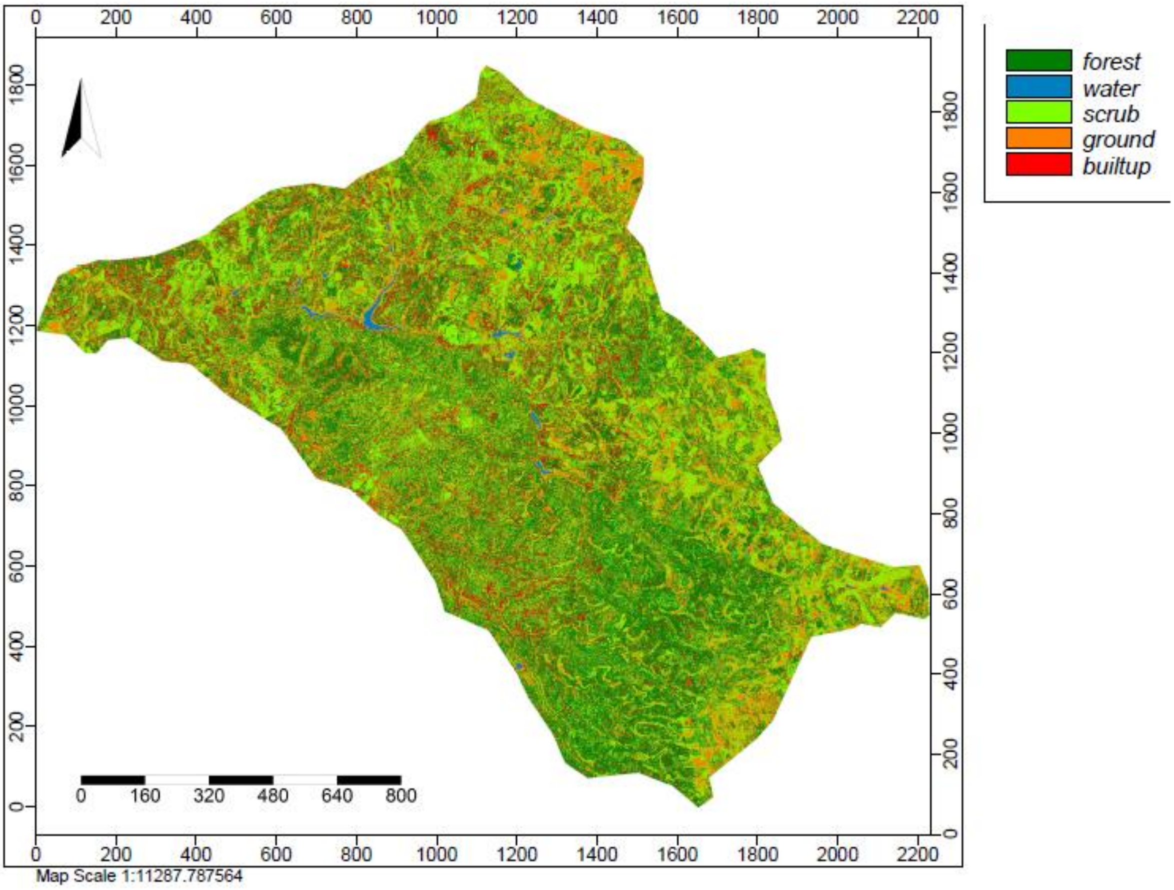


Figure 5:C21 1986 image

Figure 5 shows the 1986 satellite image of the catchment of C21. The image shows that the catchment was still covered by forest on the South Eastern side of the catchment and other doted areas within the catchment. This was still when the rate of urbanisation in Harare was still low. Here housing schemes in Harare were still very few. The number of people that migrated to Harare was still small due to fact that the economy was still functional and people could get jobs in farms, mines and small cities (Gumindoga. et al 2014). The area that was covered by built up was still very insignificant by this time although the signs of increase in urbanisation was being noticed. The area that was covered by bare ground was still low in the whole catchment. The area that was covered by scrub was still very small.

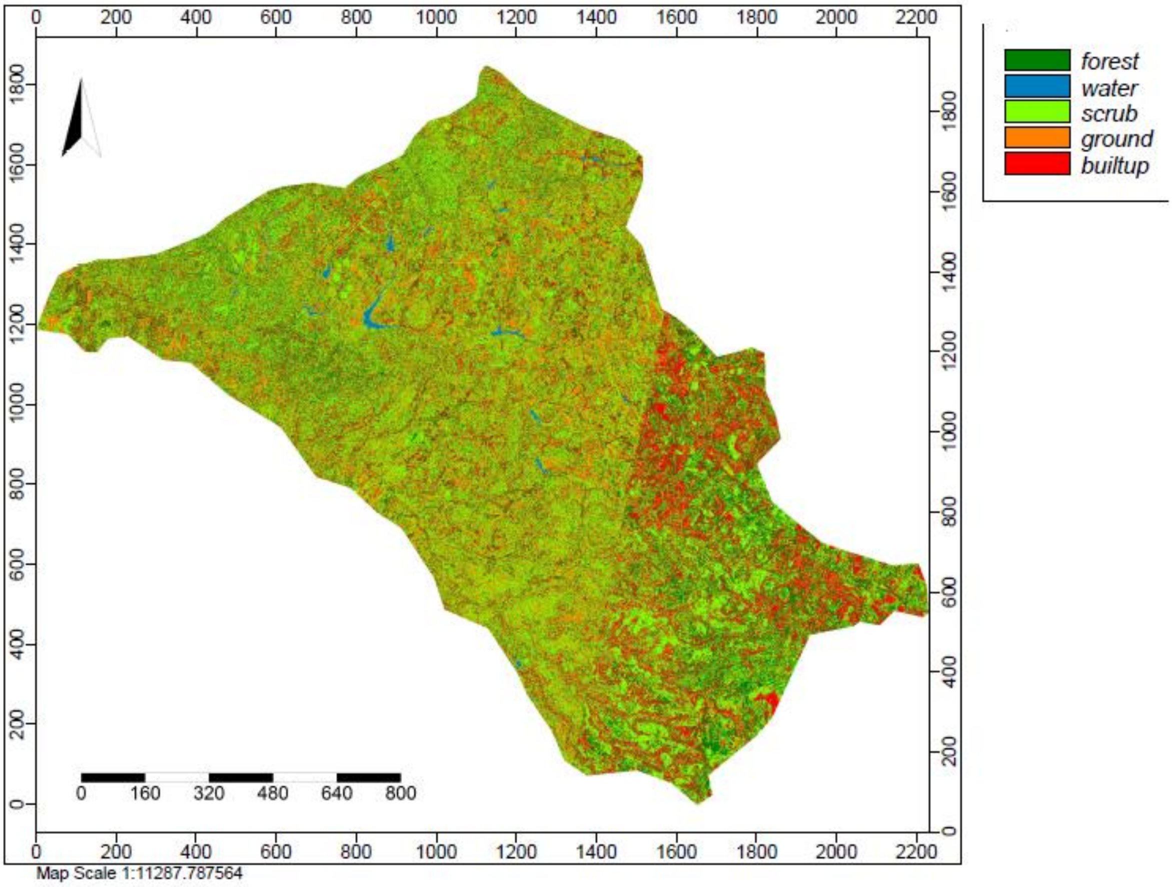


Figure 6:C21 2000 image

In the year 2000, there was great increase in the area that was covered by buildings due to urbanisation,This is the time when the land reform programme was introduced, and there was rampant increase in the illegal housing schemes in Harare, the built up area increased by 5.3 %. Also the area that was covered by ground increased by 13.7% . However the area that was covered by forests reduced by 11.2 %, This was mainly due to the fact that people were now using firewood as a source of fuel in Harare and also newly settled farmers at the periphery of Harare were now clearing their lands to make new fields. Also the area that was covered by shrubs was reduced by 6%. Similar results were found by Gumindoga W, et al (2014) when he was looking at the effects of urbanisation in Marimba and Mukuvisi catchment

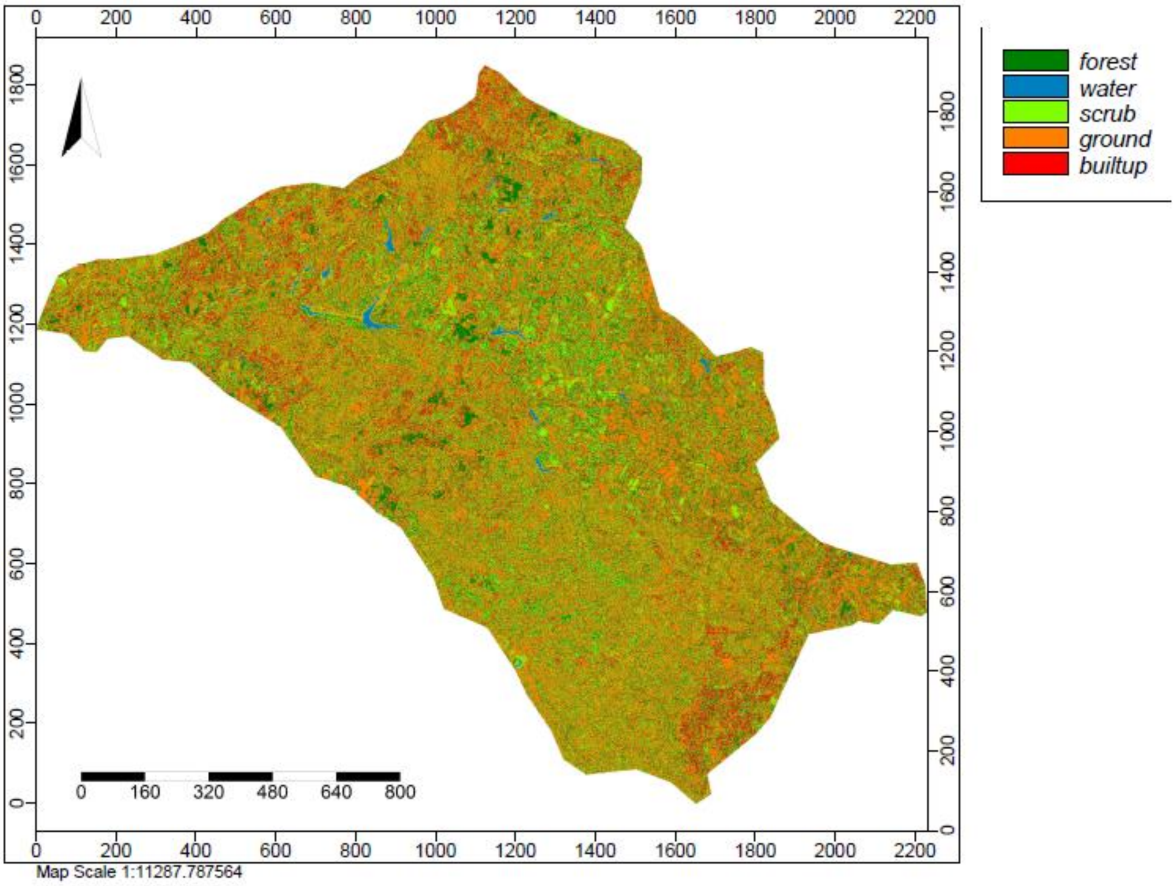


Figure 7:C21 2014 image

In 2014 the overall increase in the area that was covered by buildings increased by 11.2 %. There has been an increase in the number of illegal housing schemes in Harare some of which are built due to corrupt practices. The area that was covered by ground increased drastically by 17.8%. This was mainly due to urbanites who are now farming everywhere in Harare due to economic challenges, so by the time these images were taken around October, these areas will be bare because they practice rain fed agriculture. These bare grounds are also cleared areas where newly housing schemes are starting to be built. However during the 1986 to 2014 period, forests were slashed by 18.04 % in C21 catchment.Similar results were found by Gumindoga W, et al (2014) when he was looking at the effects of urbanisation in Marimba and Mukuvisi catchment. Then the area that was covered by scrubs during this period was reduced by 10.2%. These areas were converted into fields to assist for income generation as the residents of Harare were unemployed and they are also facing economic challenges. Also scholars like (Hitler et al 2009, Huang et al.,2011) also discovered the same changes in land cover. The table shows the overall changes that occurred in C21 catchment that affected river discharge and the graph shows only changes for urbanisation and deforestation because they are the main land covers that affect river discharge. The table below shows a summary of the overall changes that happened in C21 catchment.

Table 3:Overall land use changes between 1986 and 2014

LAND CLASS	ORIGINAL AREA AS A PERCENTAGE	PERCENTAGE INCREASE / DECREASE
Forest	29.4	-18.4
Built up	24.5	+11.2
Scrub	26.3	-10.2
Ground	17.7	+17.2
Water	2.1	+0.2

4.2NDVI results

NDVI values shows the health status of a forest, the quality and the phonological stage of vegetation. This values can be used to show the effects of land uses on vegetation. NDVI values of 0.6 to 0.8 shows a very health vegetation, NDVI values of -1 shows water and NDVI values of 0 shows bare ground, values of 0.3 shows space vegetation and values of around 0.8 shows a dense vegetation.Figure 8 shows the NDVI or C21 catchment in Harare.

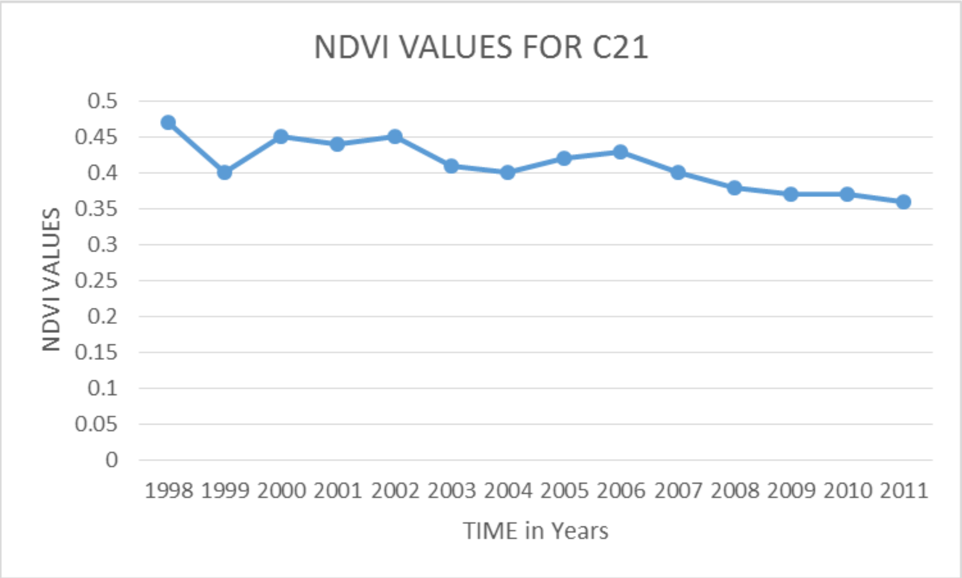


Figure 8: NDVI values for C21

Figure 8 shows the trend from shows that there was general decrease in the NDVI values for C21 catchment. This was caused by the land use practices that were taking place in the catchment for gauging station C21. There were high deforestation rates in the catchment of C21, this was also complementary with the results from satellite images where the overall deforestation rate was 18. 04 %. The reduction in the NDVI values was also caused by high rate of urbanisation that was taking place in the catchment of C21 which covers the other part of Harare.

Figure 9 shows river yield for Manyame River at gauging station C21 calculated in percentage. The general trend on the graph shows that there was general increase in the river yield for Manyame River at gauging station C21 although there was drop in 2008 which was caused by drought. The general increase in the river yield of Manyame River at gauging station C21 maybe was mainly caused by deforestation and urbanisation that was happening in the catchment of C21 which is mainly covered by Harare. Deforestation and urbanisation leads to reduction in the amount of water that infiltrates into the soil, this leads to high runoff which leads to an increase in stream discharge. The increase in the river yield was also due to impervious surfaces like roads,compaction of the soil, pavements, armoured drains and buildings which impedes infiltration and promotes runoff leading to high discharge at C21. Also the cutting down of trees reduces interception and increases runoff leading to a general increase in the river yields at gauging station C21.

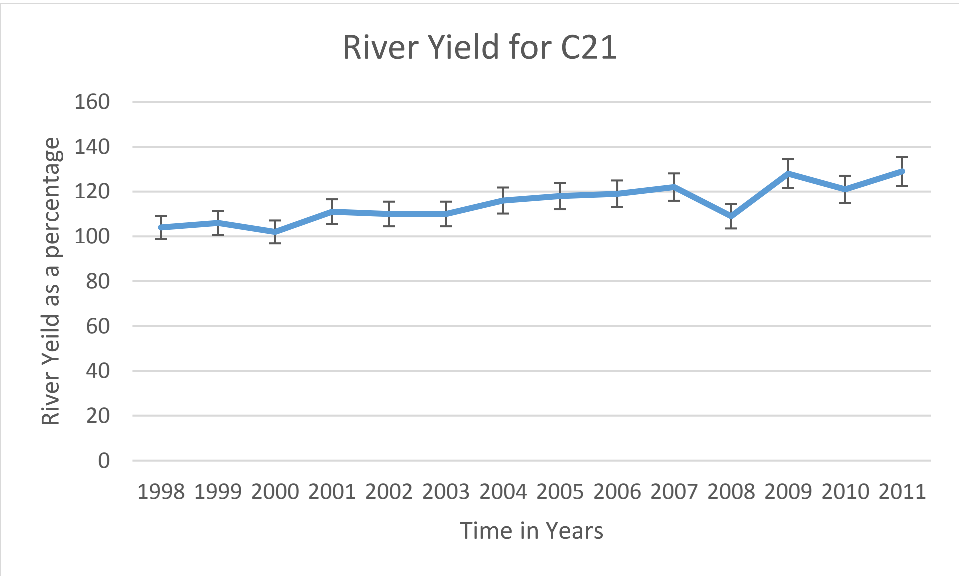


Figure 9:River Yield for C21

Regression analysis was used to establish the relationship between the NDVI and the river yield. Figure 10 below shows the results of the regression analysis. The NDVI was the dependent variable and the river yield was the dependent variable. The sample size was 13. There was a partially strong negative relationship between NDVI and the river yield in C21 catchment. There was negative or inverse relationship of -0.72 between NDVI and river yield as a percentage, this was supported by the coefficient of determination. The relationship was significant($p<0.05$) this was tested by Gen stat 2014 edition. It established that there was a partially strong or significant relationship R^2 value of 0.5199 between NDVI and river yield. The results of this research were also the similar to the results that were found by (Allen Hope et al 2009) when he was studying the effects of invasive species on river yields.

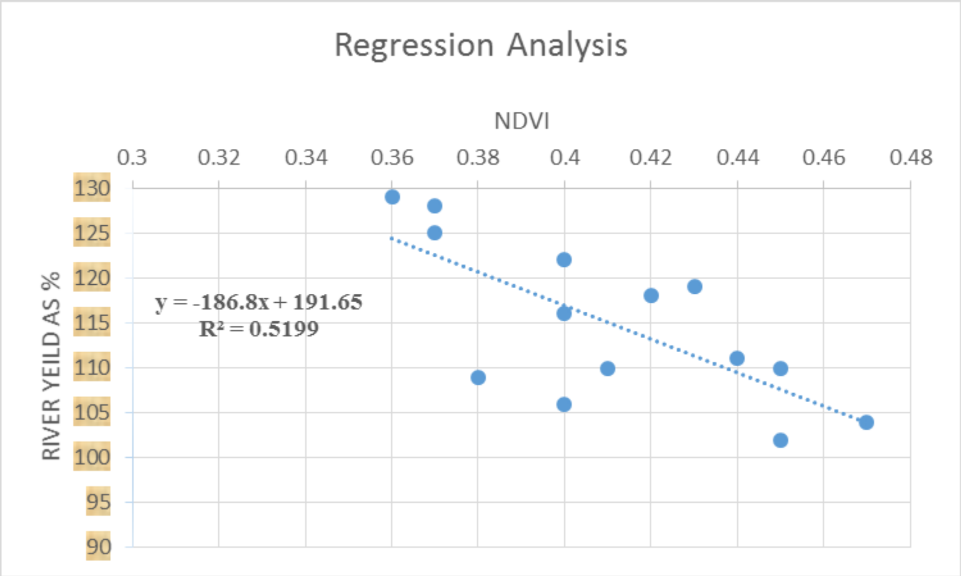


Figure 10:Regression analysis graph

CHAPTER 5

5.1Conclusions

This research was carried out to see the changes in land use and land cover in the catchment area of Manyame River at C21 gauging station and it showed that urbanisation has been increasing at a high rate. Area covered by bare ground was increasing and also forest were decreasing at a high rate. Similar results were found by (Kang et al 2010 and Lee et al 2009) when they carried out a research on the effects of urbanisation on water quality in and These results were also complementary or supported by the results from the NDVI values which also showed that there was decrease in the values for NDVI which shows the quantity and quality of vegetation in C21 catchment, showing that the vegetation quantity in C21 catchment was decreasing due to urbanisation and deforestation in this catchment that was promoting the destruction of forests.

Also this research also showed that the river discharge was sensitive to urbanisation and deforestation. The second goal of this research was to establish the relationship between the NDVI values of C21 catchment with the river yield as a percentage and it showed that there was a strong inverse relationship between the NDVI values and river yield in this catchment. This was also similar to the findings by (Hope et al 2009). These results showed that an increase in urbanisation and a reduction on the forest cover has got an effect on the discharge of Manyame River. The research showed that an increase river yield was caused reduction in forest cover due urbanisation.

5.2Recommendations

However there is need to increase the study area and have a study area which includes the whole of Harare. This will give a greater and clearer picture of the effects of urbanisation on the river yields of Manyame River. Also the inclusion of the whole of Harare will produce a stronger correlation because urbanisation will be occurring in the whole catchment.

There is also the need to use newly developed indices like the Normalised Difference Built up Index (NDBI) and the Enhanced Built up and Bares Index (EBBI) to study the effects of Urbanisation and deforestation on the river yield. The indices are very efficient, they gives a clearer picture the relationship between the two variables will be direct.

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APENDIX

Regression analysis

Response variate: C5

Fitted terms: Constant, C4

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	1	526.6	526.63	13.00	0.004
Residual	12	486.3	40.52		
Total	13	1012.9	77.92		

Percentage variance accounted for 48.0

Standard error of observations is estimated to be 6.37.

Message: the following units have high leverage.

Unit	Response	Leverage
1	104.00	0.30

Estimates of parameters

Parameter	estimate	s.e.	t(12)	t pr.
Constant	191.6	21.3	8.98	<.001
C4	-186.8	51.8	-3.60	0.004

Correlations between parameter estimates

Parameter	ref	correlations	
Constant	1	1.000	
C4	2	-0.997	1.000
		1	2