RESEARCH

4(15), July - September, 2018

ISSN 2394–8558
EISSN 2394–8566

Climate Change

Spatio-temporal variations of wetlands in Masvingo district of Zimbabwe and influences of climate change and variability

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Article History
Received: 02 February 2018
Accepted: 05 March 2018
Published: July-September 2018

Citation
David Chikodzi, Linda Yeukai Mapfaka. Spatio-temporal variations of wetlands in Masvingo district of Zimbabwe and influences of climate change and variability. *Climate Change*, 2018, 4(15), 235-247

ABSTRACT

Wetlands are among the most important and productive ecosystems in the world. In addition to being rich in biodiversity, they are known to play a vital role in food production, water quality treatment and sustaining rural livelihoods. However, over the years, changes have been observed in wetland surface area. The absence of an effective monitoring system/ tool in Zimbabwe means that these changes have neither been quantified nor analysed. In addition, there is no comprehensive inventory on wetlands. Thus the study makes use of geographic information systems and remote sensing tools to establish and quantify the spatio-temporal changes in wetland area that have occurred over the period from 1984 to 2014 in the Masvingo district of Zimbabwe. Landsat satellite images for the years 1984, 1986, 1995, 2006 and 2014 together with climatic data for Masvingo district were used in the study. Multispectral index, modified normalized difference water index was used to separate wetlands from other features and area that they occupy was then dternined using the histogram function in ILWIS GIS. Furthermore, the spearman's rank-order correlation analysis was used to test for the nature of relationship between wetland areas with mean annual rainfall and mean maximum temperatures of the years understudy. The results show variability in wetland size over time but generally they show a declining trend. Mean maximum temperatures were also determined to have significantly changed, but the relationships between wetlands and climatic parameters were determined to be statistically not significant. Hence the research concludes that remote sensing can be used to accurately map and monitor wetlands and also that within the time scale under study climate change and variability alone cannot explain the changes in wetland area in Masvingo district.

Key words: Wetlands, Modified Normalized Difference Water Index, Masvingo, climate change.

1. BACKGROUND

Wetlands, as defined by the Ramsar Convention of 1971, cover a wide variety of habitat types, including rivers and lakes, coastal lagoons, mangroves, peat lands, and even coral reefs (Zhai et al. 2015). A number of different sub-classes of wetlands exist, but each can be defined as an area saturated with water for a duration that is sufficient to sustain various types of hydrologic and biological activities (Lee, 2011). Wetlands are among the world's most productive and valuable ecosystems. They provide a wide range of economic, social, environmental and cultural benefits also known as ecosystem services (Clarkson et al. 2013; Zinhiva et al. 2014). These services include maintaining water quality and supply, regulating atmospheric gases, sequestering carbon, protecting shorelines, sustaining unique indigenous biota, and providing cultural, recreational and educational resources (Manyari & Carvalho 2014). As noted by Du et al. (2017), despite covering only 1.5% of the Earth's surface, wetlands provide a disproportionately high percentage (40%) of global ecosystem services. They play a fundamental part in local and global water cycles and are at the heart of the connection between water, food, and energy which are all challenges for our society in the context of sustainable management. In Zimbabwe, wetlands popularly known as "matoro" or "dambos", cover over 1.28 million hectares (Whitlow, 1990). Over one million hectares of these wetlands occur in the former commercial farming areas (now resettlement areas) while about 260, 000 hectares occur in the communal areas where they are used as grazing and cultivation areas usually all year round (Frenken & Mharapara, 2002). The status of these wetlands and how they have changed over time is not known but are being encroached by development and agriculture.

Wetlands and climate change are closely inter-linked, and each impacting upon the other, with wetlands being threatened by human-induced climate change, but at the same time wetland resources can reduce the impacts of climate change on population and ecosystems (Slingenberg et al. 2009). The reality of climate change is now a well-accepted reality and there is emerging evidence that climate change and climate variability poses impacts on wetlands (Watts et al. 2004). Wetlands are susceptible to changes in quantity and quality of their water supply and research indicates that climate change and climate variability have distinct impact on wetlands through alterations in hydrological regimes with great global variability (Kitula et al. 2015; Jiping et al. 2011). An understanding of the emerging trends of climate change and its impacts on water resources in a starting point in addressing the impacts of climate change and climate variability on wetlands.

As the impacts of climate change and land use practices on the environment have become more abundantly clear, remote sensing becomes more of a vital tool for the assessment of the well-being of wetlands (Lee, 2011). Maintaining accurate records of the state of wetlands is crucial in their preservation, and remote sensing technology has proven to be effective in doing so since systematically conducting field studies can be an arduous task (Funkenberg et al. 2014). One of the important aspects that can be closely monitored remotely is the overall behaviour of wetlands over time. Geographic Information System (GIS) tools are commonly implemented to measure the certain hydrologic parameters, such as water level, through comparison of remotely sensed data from different dates (Hu et al. 2013). The flexibility of GIS allows the analyst to control the scale of their research, depending on the data available. Remote sensing is complemented by ground analyses in wetland mapping from local to global scales, allowing for wetland inventories to be compiled (Funkenberg et al. 2014). Due to a limited database mapping wetlands in Zimbabwe including a lack of detailed provincial or national wetland inventories, remotely sensed images become a valuable source for monitoring wetlands, and image classification and analysis allows the quantification of any changes (Chagumaira, 2015).

The problem

Traditionally, wetland mapping and monitoring requires intensive field work, including taxonomical information, collateral and ancillary data analysis, and the visual estimation of wetland area, this is labour intensive, costly and time-consuming and sometimes inapplicable due to the poor accessibility, and is thus, only practical on relatively small areas (Roger et al. 2011). A natural resources inventory of Zimbabwe's' Masvingo district done by Environmental Management Agency (EMA) indicates the presence of only 5 wetlands in the district which do not even appear on the conventional 1:50 000 maps of the district for the country (Mutisi, 2014). The other sources of the baseline data for wetlands are other government departments, private corporate and individual researchers but are not always readily available to both the users of wetlands and regulating authorities who should be monitoring and managing the wetlands (Chikosha & Kadziya, 2013). The wetland inventory for Masvingo district available based on direct field observations, does not show all the wetlands that exist in the district. This absence and sometimes limited availability of baseline data on the location, size, extent and condition of the wetlands creates a gap in the information available for the support of wetland monitoring and management. As such the utilization of wetlands by communities in many parts of Masvingo district has gone on unchecked to the extent that most of the wetlands are now degraded. In addition, very few studies in Zimbabwe have focused on determining the relationships between climate change and variability and wetland characteristics hence the need for such impact studies. Research efforts on wetlands in Zimbabwe have mainly been directed towards the bigger ones, ignoring the small and conspicuous hence any management and conservation plans for wetlands in Zimbabwe aimed at improving their services from this inadequate knowledge and understanding is likely to yield limited results (Musiyiwa et al. 2014). There is therefore a need to come up with rapid and more cost effective methods of wetland inventorying and monitoring. Remote sensing for example, offers a practical and economical means to map and monitor wetlands and it can make field sampling more focused and efficient. Its repeated coverage offers archive data for detection of change over time, and its digital data can be easily integrated into Geographic Information System (GIS) for further analysis. Despite its advantages, remote sensing has not been widely used in mapping the smaller wetlands. Hence, there is a need for systematic research which unpacks the spatial and temporal variations of wetlands using advanced technologies like GIS and remote sensing in Zimbabwe.

Objective

The research aims at examining the spatio-temporal variability of wetlands in Masvingo district of Zimbabwe and to assess the extent to which climatic change and variability impacts on these changes.

Justification

Wetlands in Zimbabwe have not been mapped comprehensively with most existing wetlands not appearing on the conventional 1:50 000 maps from the Surveyor Generals Office. While efforts have been made by some institutions and individuals at mapping and inventorying wetlands, the data is often highly fragmented and random and therefore unusable for effective monitoring purposes (Chikosha & Kadziya, 2013). There is therefore a need to revisit the mapping of wetlands in order to inform an effective monitoring and management system. A mapping and monitoring system is critical to environmental managers who need to know the location and conditions (past and present) of the wetland resources they are protecting. The need for an effective monitoring system that reflects the past and current conditions of the wetlands is essential for ascertaining levels and trends in the degradation of these wetlands. Once the levels of degradation have been ascertained, appropriate conservation and protection strategies can be developed.

In Zimbabwe, the inventorying and monitoring of wetlands has been achieved in the short term, through direct physical observations of wetland parameters of vegetation and water saturation levels (Mawere et al. 2013). Community consultations to a large extent have also contributed to this cause through Participatory Rural Appraisals (Simba et al. 2012). While these in situ observations provide information on the current conditions of wetlands, so limited is information on past trends and obtaining measurements is often rigorous and time consuming, requiring personnel, equipment and transport logistics which are usually difficult to obtain. Some places in the study area are also difficult to access due rugged and difficult terrain. The proposed project therefore uses historical satellite imagery for the study area to analyse past wetland trends which are both cheaper in terms of time and resources and also achieve wider coverage of the area. In Zimbabwe very limited studies have focused on the impacts of climate change and variability of wetland resources which are important factors to consider when managing wetlands hence this study will provide information on this important relationship.

In this project a wetland is defined as a land area that is seasonally waterlogged and dominantly grass covered occurring at the headwaters of river systems. It has highly organic soils forming a thick, black, nutrient-rich environment for the growth of water-tolerant trees and bushes such as *syzygium guiness* (known as "*Mukute*" in Shona). These are popularly known as "bani" in Shona. In

Southern Africa, they are commonly referred to as Dambos which is a Chichewa word used to describe grasslands in Zambia and Malawi.

2. MATERIALS AND METHODS

Study area

Figure 1 shows the study area of the research. The research was carried out in the Masvingo district of Zimbabwe. The district is situated in the south eastern parts of Zimbabwe with an area of 6, 920.91 km² and a population of 299,101 people (Central Statistics Office, 2012). The district is predominantly semi-arid, rainfall is minimal, highly variable/erratic and uncertain making the province prone to droughts with the annual average rainfall of about 600 millimeters and daily average temperatures of 27.8ºC (Chikodzi et al. 2014). The district falls under the Runde catchment and within the Tokwe and Mtirikwi sub catchments and located in regions4 and 5 of Zimbabwe's natural agro-ecological regions. Though most of the district is generally dry, it does possess some of the most agriculturally fertile soils, inland water bodies and river systems (Shagashe, Tokwe and Mutirikwi river systems dominate the drainage system in the district). Drought tolerant and sturdy vegetation like Mopani, acacia trees, and very rich natural pastures also dominate the area. The dominant agricultural activities include subsistence cultivation of drought resistant cereal crops (sorghum, rapoko, millet, and some varieties of maize) and cattle rearing (and commercial cattle ranching).

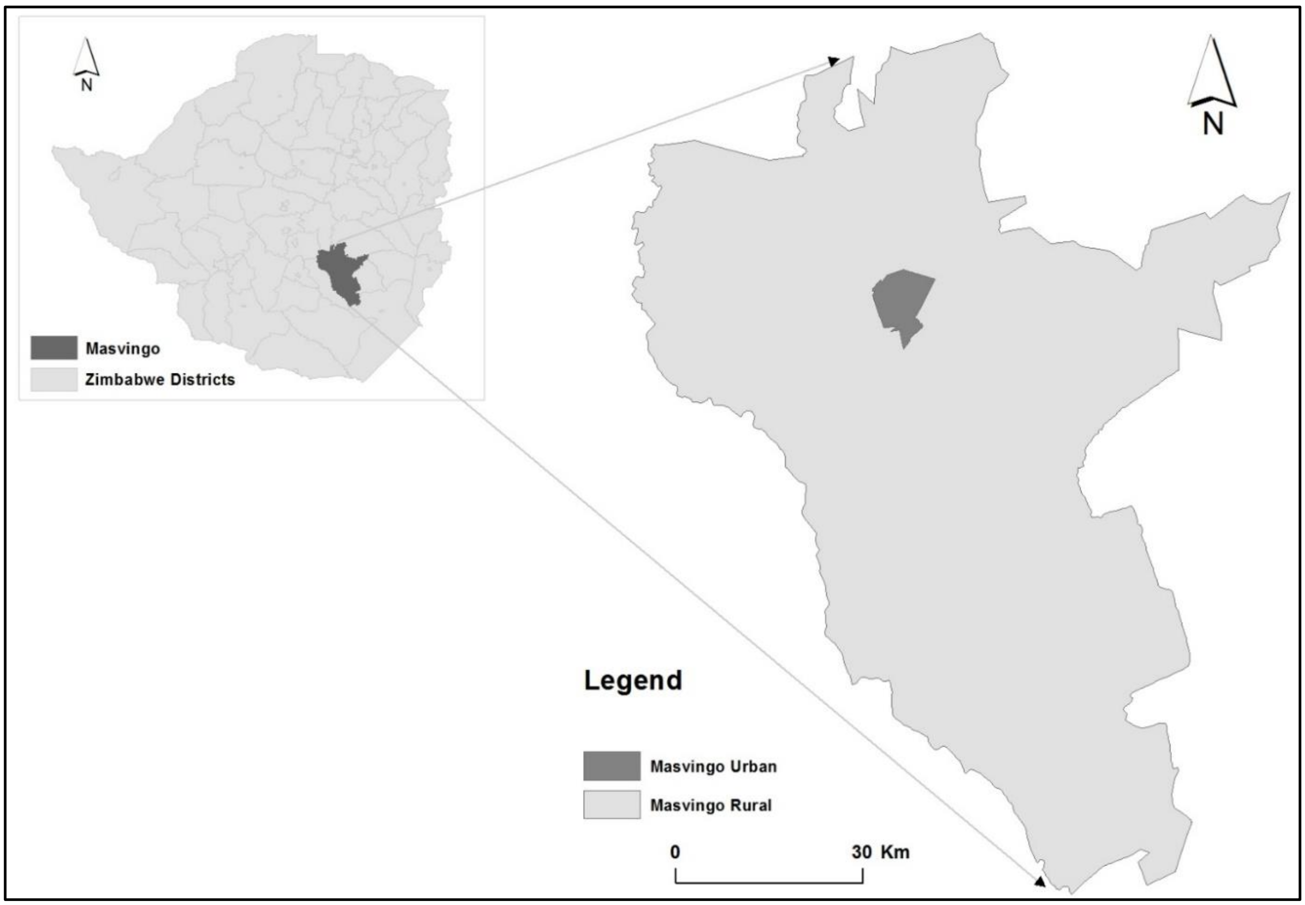

Figure 1 Study area map

Sampling

The research used GIS and remote sensing in the collection and analysis of data. Temporal systematic sampling was used to select years for satellite image analysis. A 10 year interval was used for the satellite image selection and analysis.

Remotely sensed data

In this study, Landsat satellite images (path 169 row 074) were used in calculating the Modified Normalised Difference Water Index (MNDWI). Table 1 shows the sensor and day of acquisition of the satellite images used in the study.

Table 1 Images and dates of acquisition

Year	Landsat sensor	Day
1984	TM5	25 June
1986	TM5	16 July
1995	TM5	09 July
2006	TM5	08 June
2014	LC8	29 May

Climatic data

Rainfall and temperature data for the study are were downloaded from the National Centres for Environmental Information (NOAA) website, www.ncdc.noaa.gov.The Climate Data Online (CDO) provides free access to NCDC's archive of global historical weather and climate data in addition to station history information. These data sets include quality controlled daily, monthly, seasonal, and yearly measurements of temperature, precipitation and wind speed. The downloaded data covered four weather stations namely Makoholi, Masvingo Airport, Zaka and Buffalo Range. The available data sets covered the period from 1980 to 2016, and coincided with the time periods of the satellite images selected for the study (1984 to 2014).

Data analysis

Modified Normalised Difference Water Index (MNDWI) was used in this study because it can be utilised to identify the spatial features of open water bodies based on the green and near-infrared bands of Landsat Thematic mapper images (Zhai et al. 2015). MNDWI can reveal subtle features of water bodies more efficiently than NDWI or the use of other visible spectral bands. The major advantage of MNDWI is that it can remove shadow effects on water which is difficult to remove (Du et al. 2017). The MNDWI was calculated as follows:

$$MNDWI = \frac{Green - SWIR}{Green + SWIR}$$

Where for Landsat 5, green is band 2 with the wavelength of (0.52-0.60) micrometers and shortwave infrared (SWIR) is band 5 with the wavelength of (1.55-1.75) micrometers. For Landsat 8, green is band 3 with the wavelength of (0.53-0.59) micrometers and shortwave infrared (SWIR) is band 6 with the wavelength of (1.57-1.65) micrometers. After calculation of MNDWI, the map was sliced into wetland and non-wetland areas. A MNDWI value of between 0 and 0.3 was taken to be a wetland, while values less than 0 where non-wetland areas. The histogram function in ILWIS GIS was then used to determine the area under wetlands for each of the years 1984, 1986, 1995, 2006 and 2014.

The Mann-Kendall test method was used to determine significance of trends in the analysis of long-term time series data from climatic parameters. Mann Kendall test is a statistical test widely used for the analysis of trend in climatologic and in hydrologic time series (Mcfeeters, 2013). Variation in quantities such as precipitation and temperature is often assessed by detecting and characterizing trends in available meteorological data (Melton et al. 2013). In the study trends in mean maximum temperatures and mean annual rainfall were tested for trends. There are two main advantages of using this test are first, it is a non-parametric test and does not require the data to be normally distributed. Secondly, the test has low sensitivity to abrupt breaks due to inhomogeneous time series (Du et al. 2017).

Correlation analysis specifically the spearman's rank-order correlation coefficient was used to test for the relationship between wetlands and (a) total annual rainfall and (b) the mean maximum temperatures for years under study. Correlation analysis is the process of studying the strength of that relationship with available statistical data.

3. RESULTS AND DISCUSSIONS

Figure 2 (a-e) shows the spatial and temporal distribution of wetlands within Masvingo district from 1984-2014.

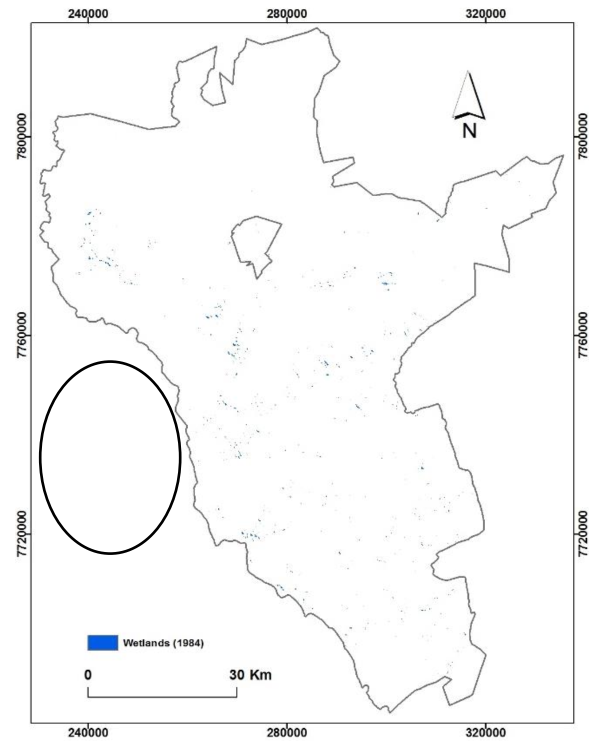

Figure 2 (a): 1984 wetland areas

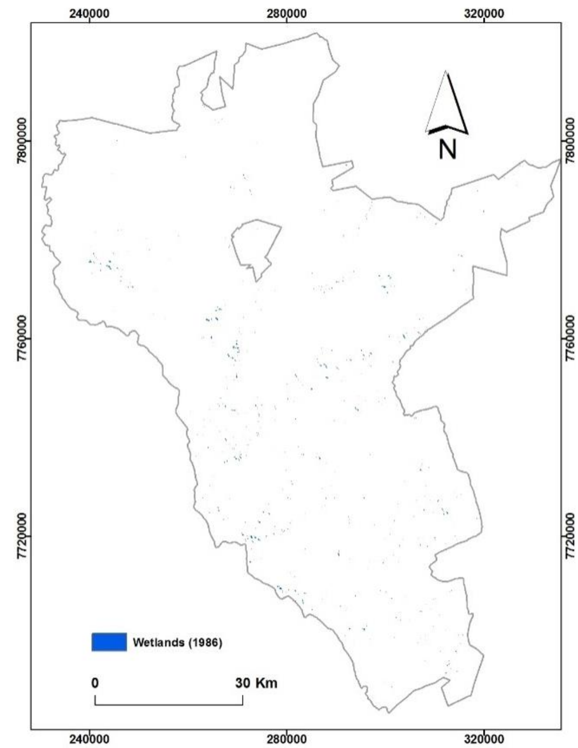

Figure 2 (b): 1986 wetland areas

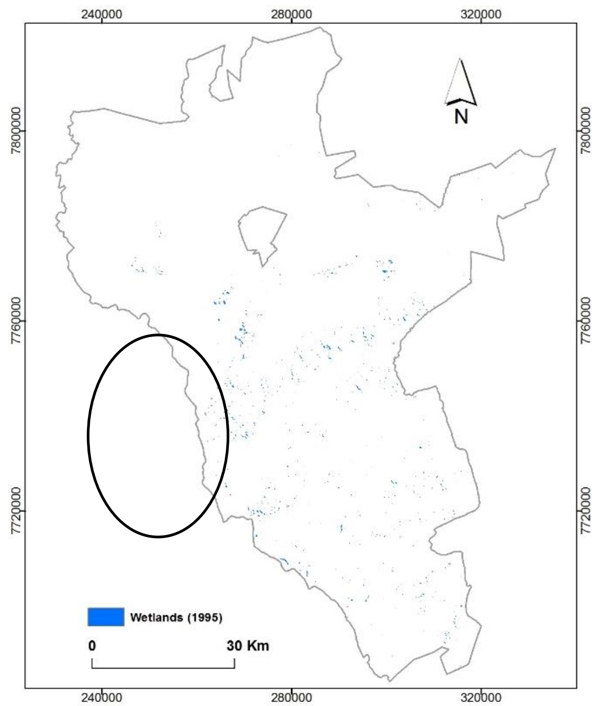

Figure 2 (c): 1995 wetland areas

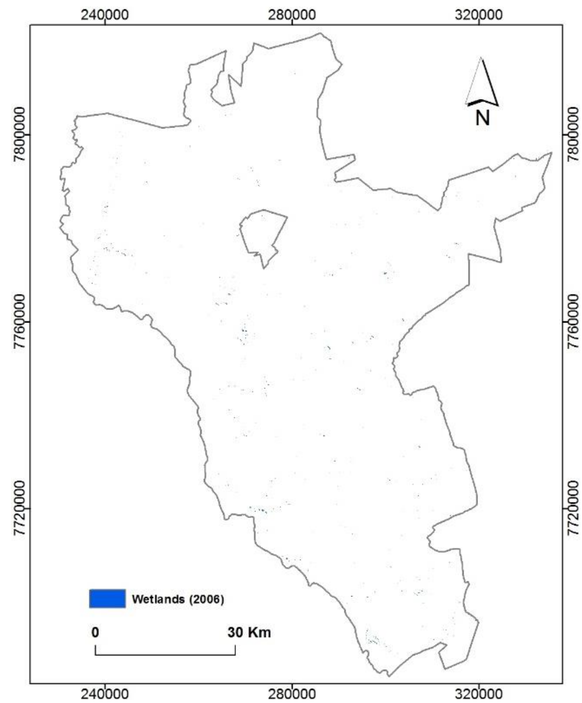

Figure 2 (d): 2006 wetland areas

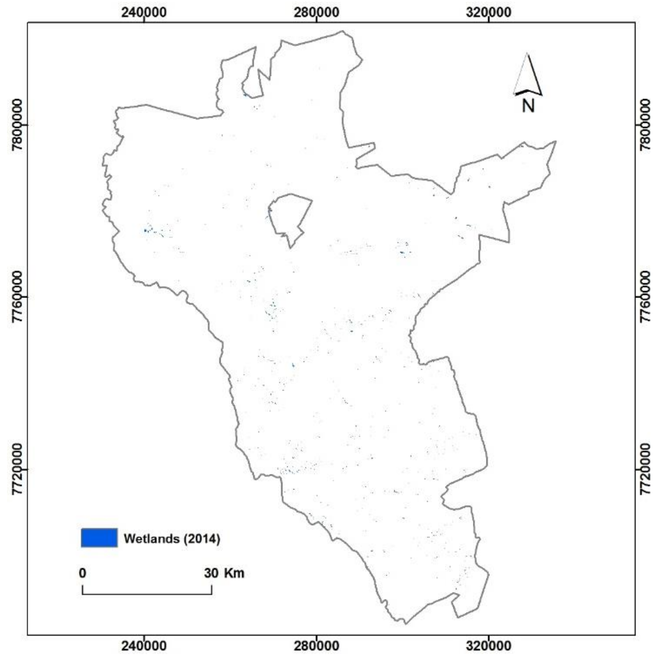

Figure 2 (e): 2014 wetland areas

Figure 2 (a-e) show wetland areas in Masvingo district for a period of thirty years at five year intervals. The figure shows a total reduction in wetland occurrence over the years from 1986-2006 with some areas in the district seeing a complete disappearance of the wetlands. The wetlands sizes and location vary from season to season but major changes are observable in the North West section of the district especially in the 2006 season where the changes are most visible. The ellipse in figure 2 (a) and (c) shows the area of greatest contrast in spatial variations of wetland area over the years. The overall picture on Figure 2 (a-e) indicates fluctuation in wetland surface area over the past 30 years as well as shifts on their spatial locations. In 1984 the Figure 2 (a-e) shows that there were relatively large areas of occupied by wetlands, however in 1986 there was a decrease from the previous years and in 1995 there was an increase in wetland surface area. Nevertheless some wetlands failed to recover as they were not discernible in proceeding years on the maps. A drastic change occurred in 2006 were a major decrease in wetlands surface area was observed but also followed by an increase in in 2014 as shown in Figure 2 (e) and (d).

Wetland systems have been also been noted by Ji et al. (2011) to decline due to their sensitivity to especially to human activity which has been observed to be one of the major threats to their integrity. Agriculture, industrial development, and urban and suburban sprawl have caused the greatest losses of freshwater wetlands (Poulin 2012). Increasing human population, coupled with the growing need for increased food production to meet the high demand, have also put tremendous pressure on wetlands around the world (Funkenberg et al. 2014).

Table 2 shows wetland surface area in square kilometers for the years under study. The table shows that wetlands within Masvingo district to be spatially changing from year to year. There is a slight difference in total surface area between 1984 the base year and 2014 the final year of observation (1.27km^2). This however this does not necessarily mean that wetlands have not changed 30 year period. Inter annual variations are noted with 2006 having the least wetland (7.76km^2) and 1995 having maximum wetland surface area (20.68km^2).

Table 2 Wetland surface area in Masvingo District from 1984-2014

Year	Area (km^2)
1984	13.6296
1986	11.5272
1995	20.6757

2006	7.7625
2014	14.8878

Figure 3 shows the time-series of wetland surface area for Masvingo District. It shows that the wetland surface area is overall on the decline as evidenced by the negative trend line equation (y= -0.1248x+14.071) on the figure.

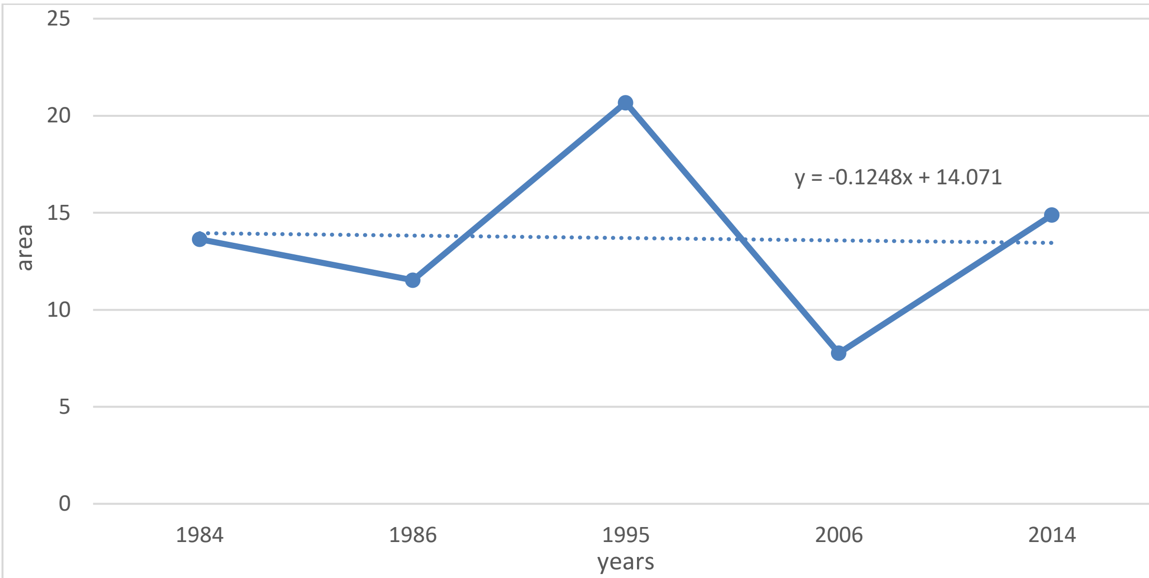

Figure 3 Wetland area

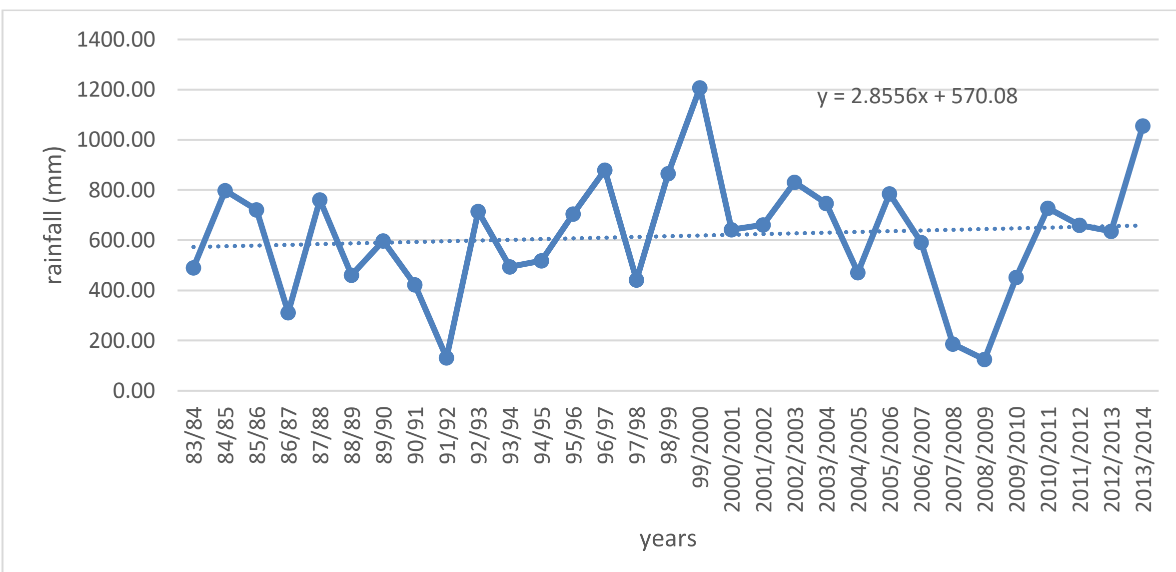

Figure 4 Compound rainfall time series for Masvingo District

Figure 4 shows the composite rainfall time series for the Masvingo district derived from the four rainfall stations used in the study. Figure 4 shows a slight increase in total rainfall activity in Masvingo district since 1984 as shown by the positive trend line equation (y = 2.8556x + 570.08) of the time-series. The pattern of rainfall in the district also shows extreme variance from season to season with no two consecutive seasons receiving the same amounts of rainfall. The first 15 years of the time-series (1984-1999) had fluctuations biased more towards below average rainfall while the last 15years (2000-2014) fluctuations were biased towards above average rainfall. The peak seasons of rainfall and the dips were noted to be increasing in intensity over the years with notable peaks in the 1999/2000 and 2013/14 seasons. Notable dips in rainfall activity were noted in the 1991/92 and 2009/10 seasons.

The Mann-Kendall test was then run on the rainfall time-series to determine if the observed trends were significant. The Mann-Kendall test results showed that the observed positive trend in rainfall activity was not statistically significant (p= 0.686and α=0.05). This means that the observed fluctuations are still within the normal circle of events in the district. The results is also similar to a study conducted by Chikodzi et al. (2014) in the south-eastern parts of Zimbabwe who observed that, despite, the seasonal variability in rainfall in south-eastern Zimbabwe, the average rainfall amounts for the area had not changed significantly.

Figure 5 shows the composite daily maximum temperatures for Masvingo district from the four weather stations used in the study. It shows an observed increase in the maximum temperatures from 1984-2014 as evidenced by the positive trend line equation (y = 1E-04x + 27.609) of the time series. The mean maximum temperatures have increased from an average of 27.3^{0}C during the 80s to an average of 28.2^{0} C by 2014, an increase of almost 0.90 C.

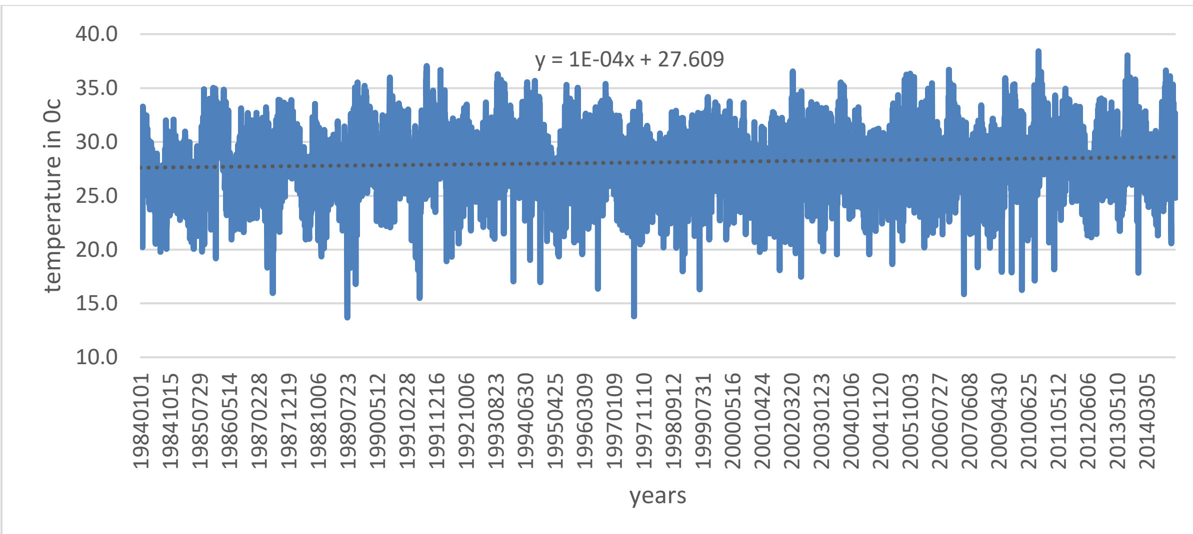

Figure 5 Daily maximum temperatures for Masvingo district

The Mann-Kendall test was also run to determine if the observed trends in maximum temperatures were statistically significant. The test showed that the observed positive rise from in temperatures were statistically significant (p=0.0001 and α=0.05). This observed increase in temperatures have a potential to change wetland ecosystems and services that they provide. As noted by the IPCC (2007), any increase in global average temperature above the range of 0.5-1.5°C is likely to result in significant alterations in the structure, function and geographical ranges of ecosystems.

To determine the impacts of climate change and variability on wetlands correlations were determined using the Spearman's rank-order correlation. Table 3 shows a summary of the correlations between temperature, rainfall, wetland area and their interpretations.

Table 3 Correlations between temperature, rainfall and wetland area

Relationship	Correlation Coefficient	P-values	Alpha	R^2	Interpretation
wetlands & temp	0.1	0.95	0.5	0.01	Very weak positive correlation which is not statistically significant
wetlands & rainfall	-0.7	0.233	0.5	0.49	Negative correlation which is not significant

Table 3 shows a weak positive correlation which is not significant between temperature and wetlands with a correlation coefficient of 0.1 and the p-value of 0.95, R-squared is 0.0.095 all showing that there is very little causality between wetlands surface area and temperatures in Masvingo district. This therefore implies that although temperatures have significantly increased in the district, they alone are not a major contributing factor to wetland surface area hence other possible contributing factors related to the spatio-temporal variations of wetlands surface area could be at play. The correlation between wetland area and rainfall were determined to negative with a correlation coefficient of -0.7 which is strong but not statistically significant with a p-value of 0.233 as well as an R-squared value of 0.49. The results show that rainfall alone cannot explain the observed changes in wetlands in the Masvingo district. However, other studies have noted wetlands, climate change and variability to be closely inter-linked, and each impacts upon the other for example Slingenberg et al. (2009), observed climatic variability and change to have strong impacts on wetland area.

In Masvingo district, other factors not explored in the study could be responsible for the observed spatio-temporal variations in wetland size. Since physical factors have failed to adequately explain changes in wetland area, anthropogenic influences have been noted in some areas to explain presence of wetlands. Chihombori et al. (2013) observe weak enforcement of management systems and lack of clear policy framework to guide sustainable wetland management has resulted in wetland loss and degradation. Moreover, these negative influences are expected to increase as human populations grow, unless deliberate steps are taken to halt encroachment and conserve and restore degraded areas. For wetlands to thrive, a reliable source of good quality water is a prerequisite, even if seasonally, to support aquatic-dependent animal and plant species (Chapungu & Hove 2013). Encroachment of forests that are the major sources of streams and rivers that feed major wetlands is a major threat to the existence of freshwater wetlands. According to Daryadel & Talaei, (2014), a research carried out in Kenya found out that, degradation of the Mau Forest Complex, Mount Kenya, Cherengani Hills, Aberdares and Mount Elgon where many streams and rivers in Kenya originate from has caused siltation and reduced water levels in downstream wetlands.

Wetlands have historically been thought of as "unexploited wastelands". Although there are many ecosystem services provided by wetlands, society does not always affix a value on those functions (Chihombori et al. 2013). The value of a wetland will often depend on the dynamic economic circumstances at the time, its location and what the wetland is perceived to be providing. In spite of increase in public knowledge toward importance of natural environments particularly wetlands, there is no real understanding of sensitivity and fragility of these vital ecosystems (Melton et al. 2013) hence they continue to be degraded or wiped out regardless of a stable climatic regime.

Overgrazing also potentially can harm wetlands through soil compaction, removal of vegetation, and stream bank destabilization. A study was also conducted by Chapungu & Hove (2013) in Zimbabwe's Chivi district for the Magwenzi wetland found excessive grazing to be dominant and has reportedly resulted in the depletion of specific graminae species in the wetland and has degraded wetlands that are used as a food and water sources by the rural communities. Zinhiva et al. (2014) in their study of the Chingombe community in the Gutu district of Zimbabwe noted overgrazing of riparian areas by livestock to reduce streamside vegetation, preventing runoff infiltration, increasing stream temperatures, and eliminating food and cover for fish and wildlife. Moreover Chikodzi et al. (2014) highlighted that, as vegetation is reduced, wetlands can be destroyed by sloughing and erosion leading to downstream sedimentation.

As observed by Sithole & Goredema (2013) in Africa including Zimbabwe, roads and bridges are frequently constructed across wetlands since wetlands have low land value. It is often considered to be more cost effective to build roads or bridges across wetlands than around them. Roads can impound a wetland, even if culverts are used (Frederick, 2017). Such inadvertent impoundment and hydrologic alteration can change the functions of the wetland. Road and bridge construction activities can increase sediment loading to wetlands. According to (Gray & Bay 2016), roads can also disrupt habitat continuity, driving out more sensitive, interior species, and providing habitat for hardier opportunistic edge and non-native species. Hence, roads can impede movement of certain species or result in increased mortality for animals crossing them. Borrow pits (used to provide fill for road construction) that are adjacent to wetlands can degrade water quality through sedimentation and increase turbidity in the wetland (Brown et al. 2012). Thus, the construction of roads and bridges across wetlands as resulted in their degradation and reduction.

Furthermore, urbanization and construction are a major cause of impairment of wetlands. They result in direct loss of wetland acreage as well as degradation of wetlands. Degradation is due to changes in water quality, quantity, and flow rates, increases in pollutant inputs and changes in species composition as a result of introduction of non-native species and disturbance (Musiyiwa et al. 2014). The major pollutants associated with urbanization and construction are sediment, nutrients, oxygen-demanding substances, heavy metals, hydrocarbons, bacteria, and viruses (Li & Chen 2017). These pollutants may enter wetlands from point sources or from nonpoint sources. A study conducted by Hiyama et al. (2014) in Namibia supports the above discussion by postulating that, construction activities are a major source of suspended sediments that enter wetlands through urban runoff.

Moreover, invasive alien species have had severe impacts on wetlands and can upset the natural balance of an ecosystem. Moser et al. (2014) notes that without the usual biological controls on their populations, alien species may become invasive and endanger or wipe out indigenous species through predation, competition for the same resource, the spread of disease and even draining of wetlands. Gray &Bay (2016)notes that as a result of disturbance and habitat degradation, wetlands can be invaded by aggressive, highly-tolerant, non-native vegetation, such as purple loosestrife (Lythrum salicaria), water hyacinth (Eichornia crassipes), and salvinia (Salvinia molesta), or can be dominated by a monoculture of cattails (Typha spp.) or common reed (Phragmites spp.) as noticed in South America. Alien species can also cause problems for wetland habitats and for genetic diversity. Invasive plants have also threatened native wetland vegetation and plant diversity (Panigrahy et al. 2012). Particularly in constructed wetlands, including restored wetlands, non-native and tolerant native species may outcompete other species leading to a reduction in species diversity within a wetland (Mwingira et al. 2011). Another study by Bernhard et al. (2010) at Driefontein grasslands wetland in Zimbabwe (a Ramsar site) in partnership with Mukuvisi Woodland Wildlife and Environment centre noted that water hyacinth and similar species can rapidly fill a wetland and are a threat to water quality and quantity in some areas.

Wetlands often have fairly flat areas of rich organic soil that is highly productive agricultural land if drained. For this reason many wetlands have been drained and converted to agricultural lands. A study was conducted by Musiyiwa et al. (2014) noted that in Zimbabwe, both the extensive use of water for irrigation and excessive nutrient loading associated with the use of nitrogen and phosphorus in fertilizers have resulted in a decline in the delivery of services such as fresh water and some fish species. Irrigation ditching can increase contamination of wetlands receiving irrigation drainage water, particularly where soil is alkaline or contains selenium or other heavy metals. Erle & Pontius (2007) observe that although humans have been modifying land to obtain food and other essentials for thousands of years, currents rates, extents and intensities of land use changes are far greater than ever in history, deriving unprecedented changes in ecosystems and environmental processes at local global and regional scales.

4. CONCLUSIONS

The research concludes that the spatio-temporal variation of wetlands in Masvingo district of Zimbabwe can be successfully mapped using remote sensing and specifically using the modified normalised difference water index (MNDWI) derived from Landsat imagery. Results also show that wetlands in Masvingo district declined in terms of size from 1984-2014. The variations in wetlands were noted in the spatial and temporal domains with some wetlands shrinking, others expanding and others disappearing all together, hence wetlands in Masvingo district are in a constant state of change. The climatic scenarios of Masvingo district showed that in the 30 years under study, there is evidence of climatic variations with rainfall patterns showing extreme variations in terms of inter-seasonal totals with trends determined to be positive although not statistically significant. Daily maximum temperature variations within the district also showed variability from season to season and showed positive trends that were statistically significant. The results also showed links between climatic variables and wetland to be not statistically significant implying that these variables alone cannot explain changes in the spatio-temporal variations of wetlands of Masvingo district. Hence, other factors including anthropogenic could be contributing changes in the spatio-temporal variations of wetlands hence the need for further studies.

REFERENCE

1. Bernhard, P., For, F. & Foundation, D.F., 2010. for Wattled & Grey Crowned Cranes in Zimbabwe with a particular focus on the Driefontein Grasslands Conservation action plan for wattled and grey crowned cranes. *Biogeosciences*, 8, pp.44–67.
2. Brown, D. Chanakira, R., Chatiza, R., Dhliwayo, K., Mutuso,D., &Masiiwa, M., 2012. *Climate change impacts , vulnerability and adaptation in Zimbabwe*, IIED Climate Change Working Paper No. 3, London.
3. Central Statistics Office, 2012. *Census 2012: Preliminary Report*, Harare.
4. Chagumaira, C., 2015. *Perceivedlocal evidence of climate change and variability impacts on natural resources in smallholder communities of eastern zimbabwe by a thesis submitted in partial fulfilment of the requirements for the degree of master of philosophy department of soil science*. University of Zimbabwe.
5. Chapungu, L. & Hove, C., 2013. Human Perceptions on Degradation of Wetland Ecosystems : The Case of Magwenzi Wetland in Chivi District ; Zimbabwe. *greener jpurnal of geology and earth sciences*, 1, pp.013–022.
6. Chihombori, J. Gamira, D. & Nyoni, K., 2013. Causes and Rate of Reservoir Sedimentation Due to Changes in Catchment Management . A Case of Marah Dam in Masvingo Province of Zimbabwe By Marah Dam in Masvingo Province of Zimbabwe. *Greener Journal of Geology and Earth Sciences*, 1 (2354–2268), pp.007–012.
7. Chikodzi, D., Murwendo, T. & Simba F.M., 2014. Climate

Change and Variability in Southeast Zimbabwe: Scenarios and Societal Opportunities Climate Change and Variability in Southeast Zimbabwe: Scenarios and Societal Opportunities. *American Journal of Climate Change*, 2, pp.36–46.
8. Chikosha, F. & Kadziya, L., 2013. Wetlands and Urban Growth in Bindura ,. *Greener Journal of Environment Management and Public Safety*, 2(6)(2354–2276), pp.195–199.
9. Clarkson, B.R., Ausseil, A.E. & Gerbeaux, P., 2013. Wetland ecosystem services. *Wetland ecosystem services*, 3, pp.192–202.
10. Daryadel, E. & Talaei, F., 2014. Analytical Study on Threats to Wetland Ecosystems and their Solutions in the Framework of the Ramsar Convention. *International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, 8, pp.2100–2110.
11. Du, Z.,Li, W.; Zhou, D.; Tian, L.; Ling, F.; Wang, H.; Gui, Y.; Sun, B., 2017. Analysis of Landsat-8 OLI imagery for land surface water mapping. *Remote Sensing Letters*, 5, pp.672–681.
12. Erle, E., &Pontius, R., 2007 (eds). Encyclopaedia of the Earth. Washington D.C.
13. Frederick, P., 2017. Freshwater Wetlands , Rainfall , and the Breeding Ecology of White Ibises in Coastal South Carolina Author (s): Keith L . Bildstein , William Post , James Johnston and Peter Frederick Published by: Wilson Ornithological Society Stable URL: http://www. *Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 102, pp.84–98.
14. Frenken K & Mharapara I, 2002. *Wetland Development and Management in SADC Countries: Proceedings of a Sub-regional Workshop.*, Harare.
15. Funkenberg, T. Thai, T., Moder, F & Dech, S., 2014. The Ha Tien Plain – wetland monitoring using remote-sensing techniques. *International Journal of Remote Sensing*, 35, pp.2893–2909.
16. Gray, M.J. & Bay, J., 2016. Wetland Losses and Human Impacts Distribution of North American Wetlands Current North American Wetland Estimates Current Acreage of Wetland Types in the United States Wetlands: A Barrier to American Progress! *Journal of Environmental Management*, 9, pp.1–6.
17. Hiyama, T. Suzuki, T., Hanamura, M., Mizuochi, H.,Kambatuku, Jack R., Niipele, J.N., Fujioka, Y, Ohta, T & Iijima, M, 2014. Evaluation of surface water dynamics for water-food security in seasonal wetlands , north-central Namibia. *Hydrospheric Atmospheric Journal*, 10, pp.380–385.
18. Hu, Q.,Wu, W., Xia T., Yu, Q.,Yang, P, Li, Z &Song, Q., 2013. Exploring the Use of Google Earth Imagery and Object-Based Methods in Land Use/Cover Mapping. *Remote Sensing*, 5, pp.6026–6042.
19. Ji, L., Jiang, K., Geng, X., Tang, H., Yu, K.&Zhao, Y., 2011. Improving Wetland Mapping by Using Multi- Source Data Sets. *Remote Sensing Letters*, 9(12), pp.24–43.
20. Jiping, Z. Yili, Z., Linshan, L., Mingjun, D., Zhang l., 2011. Identifying Alpine Wetlands in the Damqu River Basin in the Source Area of the Yangtze River Using Object-based Classification Method. *Journal of Resources and Ecology*, 2, pp.186–192.
21. Kitula, R.A. Larwanou, M., Muoghalu, J.I., Popoola, L., 2015. Climate vulnerability ofsocio-economic systems in different forest types and coastal wetlands in Africa: a synthesis. *International Forest Review*, 17(3), pp.78–91.
22. Lee, S., 2011. *Detecting Wetland Change through Supervised Classification of Landsat Satellite Imagery within the Tunkwa Watershed of British Columbia, Canada Steven Lee*. Hogskolan.
23. Li, J. & Chen, W., 2017. A rule-based method for mapping Canada â€™ s wetlands using optical , radar and DEM data. *International Journal of Remote Sensing*, 26, pp.5051–5069.
24. Manyari, W. V & Carvalho, O.A., 2014. Wetlands conservation: an integrative approch. *European Scientific Journal*, 2, pp.308–322.
25. Mawere, M., Madziwa, B.F. & Mabeza, C.M., 2013. The international journal of humanities & social studies Climate Change And Adaptation In Third World Africa: A Quest For Increased Food Security In Semi-Arid Zimbabwe. *The International Journal of Humanities and Social Studies*, 1, pp.14–22.
26. Mcfeeters, S.K., 2013. Using the Normalized Difference Water Index (NDWI) within a Geographic Information System to Detect Swimming Pools for Mosquito Abatement: A Practical Approach. *Remote Sensing*, 5, pp.3544–3561.
27. Melton, J.R. Wania, R, Hodson, E L, Poulter, B, Ringeval, B, Spahni, R, Bohn, T & Avis, C A., 2013. Present state of global wetland extent and wetland methane modelling: conclusions from a model inter-comparison project. *Biogeosciences*, 1, pp.753–788.
28. Moser, L., Voigt, S., Schoepfer, E., & Palmer, S, 2014. Multitemporal Wetland Monitoring in Sub-Saharan West-Africa Using Medium Resolution Optical Satellite Data. *Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 7, pp.3402–3415.
29. Musiyiwa, K., Filho, W., Leal, H.D & Nyamangara, J., 2014. Implications of Climate Variability and Change for Smallholder Crop Production in Different Areas of Zimbabwe. *Research Journal of Environmental and Earth Sciences*, 6, pp.394–401.
30. Mutisi, L., 2014. *An investigation into the contribution of housing developments*. University of South Africa.
31. Mwingira, C.E., Elias, G. & Meing, O., 2011. *Impacts of Climate Change on Biodiversity and Community Livelihoods in the Katavi Ecosystem Submitted by:*, Washington DC.
32. Panigrahy, S., Sushma M, Patel, T.V. R, Singh J G., 2012.

Wetlands of India: inventory and assessment at 1: 50 , 000 scale using geospatial techniques. *Current Science*, 102, pp.852–856.

33. Poulin, B., 2012. Wetland monitoring using classification trees and SPOT-5 seasonal time series. *Remote Sensing of Environment*, 3, pp.552–562.
34. Roger, F. Feumba B., Ngounou N.,Youmbi, T., Ghislain, J.,Emmanuel & Ekodeck G., 2011. Relationship between Climate and Groundwater Recharge in the Besseke Watershed (Douala-Cameroon). *Journal of Spatial Hydrology*, 2011, pp.607–619.
35. Simba, F.M., Chikodzi, D. & Murwendo, T., 2012. Earth Science & Climatic Change Climate Change Scenarios , Perceptions and Crop Production: A Case Study of Semi-Arid Masvingo Province in Zimbabwe. *Earth science and Climate Change*, 3(3), pp.100–124.
36. Sithole, A. & Goredema, B., 2013. Building in Wetlands to Meet the Housing Demand and Urban Growth in Harare Midlands State University Midlands State University. *International Journal of Humanities and Social Science*, 3, pp.193–201.
37. Slingenberg, A. Braat, L., Windt, H., Van DerRademaekers, K, Eichler, L &Turner, K., 2009. Study on understanding the causes of biodiversity loss and the policy assessment framework. *ECORYS*, 1(October), pp.192–206.
38. Watts, J.D., Kimball, J.S. & Bartsch, A., 2004. Focus on the impact of climate change on wetland ecosystems and carbon dynamics. *Environmental Research Letters*, 11, pp.1–4.
39. Whitlow, R., 1990. Conservation status of wetlands in Zimbabwe: past and present. *GeoJournal*, 20, pp.191–202.
40. Zhai, K. Xiaoqing W, Yuanwei, Q & Peipei, D, 2015. Geo-spatial Information Science Comparison of surface water extraction performances of different classic water indices using OLI and TM imageries in different situations. *Geo-spatial Information Science*, 18, pp.32–42.
41. Zinhiva, H.Chikodzi D, Mutowo G, Ndlovu S, Mazambara P., 2014. The Implications for Loss and Degradation of Wetland Ecosystems on Sustainable Rural Livelihoods: Case of Chingombe Community , Zimbabwe. *Greener Journal of Environmental Management and Public Safety*, 3, pp.043–052.