Examining the Geographical Coverage of Floods Using Satellite Images and Discharge In LNRB

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Abstract- Flooding continues to be a common environmental hazard in both developed and developing countries. Crops, settlement and infrastructure are usually impaired wherever flooding occur. The severity of damage as a result of floods has been documented to have a relationship with the flood magnitude, flood frequency and settlement of population on flood prone areas. Whereas various intervention measures have been implemented, the problem still persists. This is partly due to lack of adequate information on the extent of Lower Nzoia River Basin Flood Flows. This has affected efforts to design and plan for proper intervention measures in the affected areas. This research focused on examining the geographical coverage of floods in Lower Nzoia River Basin for a period of 42 years from the year 1975 to the year 2017.). The research design employed in the study is time series design and the analysis of Satellite imagery data was performed using ArcGIS 10.3, to detect, delineate and map flood extent in the LNRB; Discharge data analyzed using excel. Flood trending results show that bare land increased with 42.20%.' while vegetation reduced by 51.96% and water mass increased with 22.38% between the year 1975 and the year 2017. The continued reduction in vegetation and increase in bare land loosens the soils exposing them to erosion and incase of floods the outcome is more hazardous. The study recommends that when erecting the dykes the flood mapped area of 112km^2 (22.38%) Water mass be considered in developing interventions, planning and preparedness for future management of the basin. Policy makers should ensure that the riverine areas are free from human activities which are attributed to land and vegetation destruction in the lower basin

Index Terms- Geographical extent; Satellite imagery; flood magnitude and dyke

I. INTRODUCTION

Flooding is considered as the world's most costly type of natural disaster in terms of both human causalities and property damage (Campillo *et al*., 2017; Aslam *et al*., 2017); (Singh and Sharma, 2009). The extreme flood events could cause severe damage to property, agricultural productivity, industrial facilities/installations, communication networks and infrastructure, especially in the downstream parts of catchments. The increasing frequency and intensity of disasters over the past three decade poses greater risk. According to projections, such disasters will continue to increase, making the need for more and better disaster risk reduction strategies ever more urgent.The Asia-Pacific region is particularly vulnerable to disasters. According to the International Strategy for Disaster Reduction's (ISDR) *2006 Global Assessment Report*, 75 percent of the global flood mortality risk is concentrated in only three countries: Bangladesh, China and India. Bangladesh and India account for 85 percent of cyclone deaths. The Asia-Pacific region has over 50 percent of the total world disasters, representing the widest and most disaster-prone area in the world, with a regular frequency of geological hazards such as earthquakes and tsunamis and increased frequency of weather-related hazards such as typhoons, floods, droughts and wildfires. More than 70 percent of lives lost to disasters occur in this region.Germany have also concluded that mitigation measures substantially reduce flood damage (Kreibich *et al.*, 2005, 2011, 2012; Olfert and Schanze, 2008; Kreibich and Thieken, 2009). Kreibich *et al.* (2005) and Kreibich and Thieken (2009) estimated that the use of flood adaption for buildings and furnishing reduced the flood damage to buildings by between 46 and 53 percent, and the flood damage to home contents by between 48 and 53 percent. Installing heating and electrical utilities on higher floors, adapting the structure of the home to floods, and water barriers, respectively reduced the damage to buildings by 36, 24, and 29 percent (Kreibich *et al.*, 2005; Kreibich and Thieken, 2009). Although the aforementioned studies provide useful insights into the potential damage savings from flood damage mitigation measures, it is evident that this empirical literature is scarce and focused on a few river basins, which are located in a few countries (mainly Germany). Moreover, few studies examined the effectiveness of these measures by putting in consideration the water mass extent of flooding; Kreibich *et al.* (2011, 2012). The determination of flood mapping to identify areas that is floodedor not flooded and water versus non-water areas before and during the flood event, respectively; have little been applied in the Lower (Wang*etal.*2002). Disasters also disproportionately affect the most vulnerable, eroding hard-won development gains and setting back progress toward the Millennium Development Goals. High-income countries are exposed to 39 percent of tropical cyclones while bearing only 1 percent of the mortality risk. (Yengoh *et al.*, 2017)The majority of disasters in Africa are hydro-meteorological in nature, with droughts still affecting the largest number of people on the continent and floods occurring frequently along the major river systems and in many urban areas (Yengoh *et al.*, 2017). Cyclones mainly affect Madagascar, Mozambique, and some of the Indian Ocean islands Intergovernmental Panel on Climate Change (IPCC, 2007c. Most African countries have limited resources to invest in disaster risk reduction and minimal fiscal space to fund relief and recovery efforts after a major disaster (Noy and Edmonds, 2016). Disasters can be a tremendous setback for economic growth and performance. Poor, small island states and land-locked countries are particularly vulnerable to the economic impact of disasters. The capacities of many national and local DRM authorities remain limited. In many areas, the economy is based on rain-fed agriculture, which is highly susceptible to climate variability, (Venäläinen *etal*., 2016). Critical infrastructure such as roads, telecommunication, and dams often lag behind rapidly growing needs or are not constructed according to risk prone standards. In Kenya floods occur due to natural factors like flash floods, river floods and coastal floods. They may also occur due to human manipulation of watersheds, drainage Basins and flood plains (Cutter, 2017). For example, in some cases floods have occurred in the river Basins even with normal rains because of excess surface water runoff occasioned by deforestation, land degradation upstream. Kenya is affected by floods following torrential rainfall (Karanja and Saito, 2017). These force thousands of people living in the lowlands to move to higher grounds. Further empirical research is needed on the effectiveness of individual flood damage mitigation measures. Such information is imperative for policy-makers who are involved in the design of flood risk management policies, insurance companies who are interested in reducing flood vulnerability of their policyholders, and households and businesses who want to reduce the flood risk to their property (Kull *et al.*, 2013). This study, therefore, aims at examining the geographical coverage of floods using satellite images and discharge to provide data on land cover and its trending. Flood extent is estimated by satellite images using Arc Hydro tools under Arc- GIS 10.3 for the stipulated period of 42 years from the year 1975 to the year 2017. Discharge data was estimated using excels to provide trending for stream flows obtained from Webuye (RGS-IDA02) and Rwamba (RGS-IEFE01)

II. RESEARCH MATERIALS AND METHODS

2.1 Study site

The study was conducted in Lower Nzoia River Basin which lies between Latitude 00 04’ North and 00 11’ North and Longitude 33^0 57’ East and 34^0 14’ East with area of 8500KM2 flat and swampy; elevation range from 1130m to 1225m, with annual rainfall variations. The study site for this research is indicated in Figure 1

Figure 1: Lower Nzoia River Basin showing administrative areas, lakes and elevation derived from Digital Elevation Model (30m DEM) using ArcGIS 10.3

2.2 Digital Elevation Model (DEM)

In this study the Advanced Space borne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model (GDEM) a 30m by 30m launched by US and Japan mid-2009, downloaded from https://wist.echo.nasa.gov was used to provide the physical characteristics of the study area that are required for Flood Mapping. The interface allows DEM to use real numbers for elevation values to generate basin topographic characteristic. DEM was used to delineate the basin and analyze drainage patterns using discharges

2.3 Satellite imagery data

Satellite imagery data obtained from (RCMRD) within 42 years period (the year 1975, 1985,1986,2010 were compared with, 2014, 2015 and the year 2017, were extracted ,composed and developed into maximum likelihoods for determination of LNRB Flood extent. The years had good data. The LANDSAT images of TIFF Format were sourced courtesy of U.S Geological Survey http://eros.usgs.gov/products/satellite) with a resolution of 30m x 30m.

2.4 Stream flow data

Stream flow datasets were obtained from Water Resource and Management Authority. These were collected from three river gauging stations (IDA02, IEG02 and IEF01), Webuye, Wuoroya and Rwambwa), Stream flow data for the period from the year 1974 to the year 2017 were used in this study. The method used to compute the discharge for the station was use of excel that determined the trend in the flow.

2.5 Flood Extent determination

Mult-temporal LANDSAT Thematic Mapper satellite imagery was used to detect, delineate and map out land cover change on LNRB. The data were extracted and developed into maximum likelihood for determination of LNRB geographical flood extent. Emphasis was extent of water mass on the land surface with time and changes in land area with time. The LANDSAT obtained were clipped using LNRB Shape file in ArcGIS10.3 Methodology for flood extent is indicated in Figure 2 see (Appendix I) steps

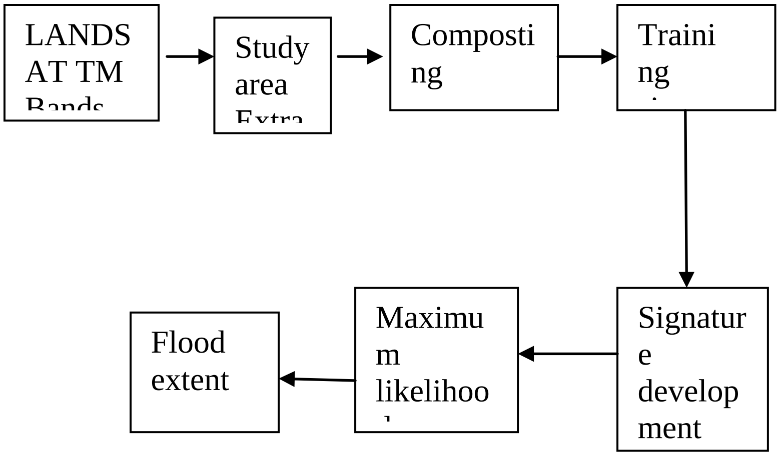

Figure 2 Methodology for flood extent determination adopted for research study in LNRB in Western Kenya
Source: Adopted from (Gadain, 2006)

III. RESULTS AND DISCUSSION

3.1 Trend analysis of LandSat data

The results from this images (Appendix II&III) shows how the flooding trends were increasing at the LNRB between the year 1975 and the year 2017 by estimating the vegetation cover, bare land and water in terms of square Kilometers. The results indicated that vegetation has reduced since the year 1975 where it was highest occupying 988 km2 to the year 2017 where it was lowest occupying 393 km2 representing 51.96%. Reduction of vegetation is due to clearance of land for settlement, farming, building material and fuel. The trend in Figure 4.8 shows that the land will be bare in the near future a factor which increase flood occurrence. Bare land is increasing due to clearance of vegetation, the trend shows that bare land has increased from the year 1975, (58km2) to (541km2) in the year 2017 representing 42.20%. Water areas have also increased with a margin of 112km2, representing 22.38% of the total area of the study. This scenario is likely to continue based on climate change projections in Western parts of Kenya (USGS, 2010) and human activities being carried out in the basin. This means that the flood extent when extrapolated the LNRB is still at risk experiencing floods despite the existence of dykes.

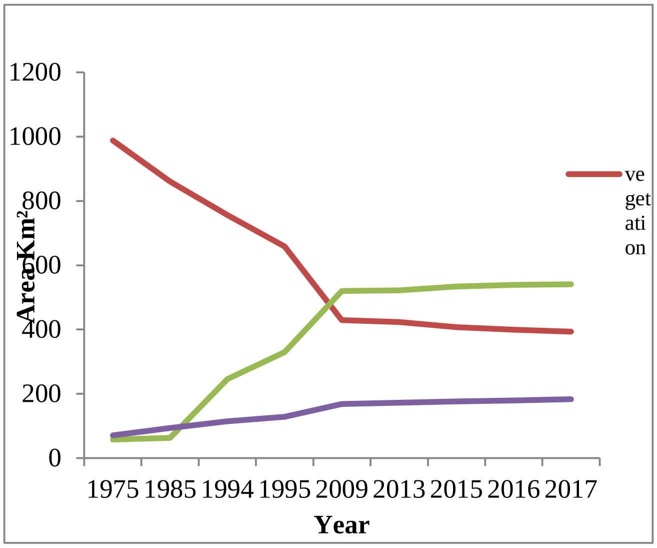

Figure 3 LANDSAT image analysis from the year 1975 to the year 2017 for LNRB
Source: Author, 2016

Looking at the trend analysis interception curve in Figure 3.1 clearly indicates that the water level was actually increasing with dynamics in the years. The gradient factor is positive; the land also indicates an increase with the years. The vegetation however shows a decrease with dynamic in the years. The gradient from the graph indicates a negative meaning there is continuous destruction of the riverine areas

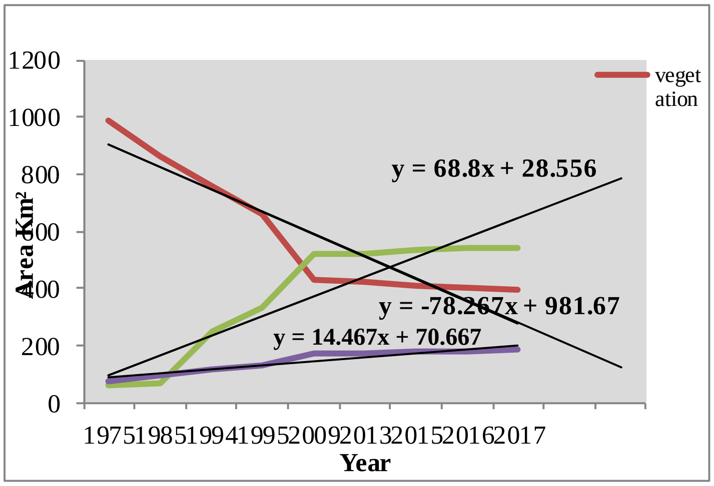

Figure 3.1 LANDSAT image trend analysis between the year 1975 and the year2017

Source: Author, 2016

3.2 Discharge and rainfall data Results to map out flood area extent

The discharge data from the selected area were used to compliment the Landsat images and obtained a trend to see if the flooding effects were likely to continue being experienced at the LNRB. Figure 3.2 indicates the comparison between the upper stream and downstream discharge flow results shows the stream flow in cubic meter per second indicates that at the Upstream in Webuye the flow was increasing as per the trend line from the year 1974 to the year 2017. This means that the increase in upstream leads to increase of water capacity at the downstream this therefore has implication in the amount the basin can accommodate. The carrying capacity of the river is compromised meaning water will find its way out leading to flooding of the areas and land within the reach, this is in line with Akali, (2015) in his study on GIS-Based modeling of land use Dynamic in River Nzoia Basin Kenya where he indicated that the Upstream has effect on the Lower stream of the basin hence the problems of land-use dynamics must be emanating from the upper down to the lower basin. The stream flow in cubic meter per second indicates that at the Downstream in Rwambwa the flow was increasing as per the trend line from the year 1974 to the year 2017. The gradient in the trend line in the Downstream clearly indicates a high value of 0.743x compared to the upstream that has 0.685x creating a margin of 0.038. This therefore means the carrying capacity of the lower basin is compromised. Once the capacity is beyond; this is a factor that contributes to flooding. The extent of how far the water will spread should assessed and be used in the enactment of the dykes which will contribute to its role in flood mitigation at the basin.

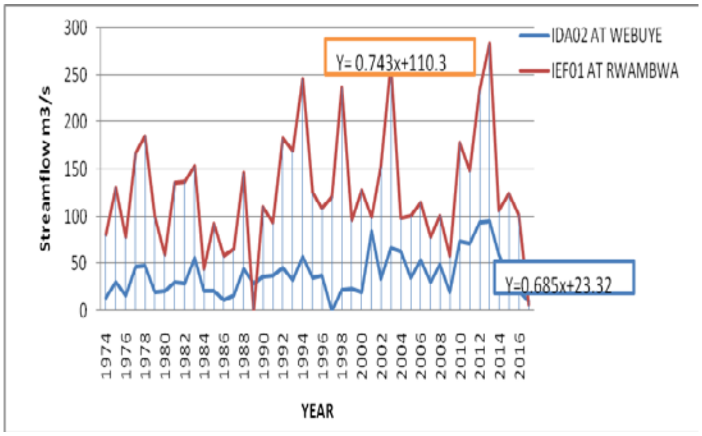

Figure3.3Annual Average stream flow trend for downstream River Nzoia at Rwambwa (RGS-IEFE01) and Webuye (RGS-IDA02), 1974-2*017*

Source: Author, 2016

IV. CONCLUSIONS AND RECOMMENDATIONS

Conclusion

The mapped out flood area extent change in water mass of 112km^2 should be considered when planning especially by Busia County Government when enacting the dykes to streamline its role in flood mitigation since the findings indicates that the area lacks a permanent solution in control of floods

Recommendations

The developed flood extent maps should be intensified by the real time data to beef up or complement satellite Imagery data to obtain actual output and that the gauging stations be guarded well to obtain actual data and avoid missing gap in the data due to destruction of gauging stations

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REFERENCES

[1] Akali,N.M., (2015) GIS-Based modeling of land use Dynamic in River Nzoia Basin Kenya

[2] Aslam, A.Q., Ahmad, S.R., Ahmad, I., Hussain, Y., Hussain, M.S., 2017. Vulnerability and impact assessment of extreme climatic event: a case study of southern Punjab, Pakistan. Sci. Total Environ. 580, 468–481.

[3] Campillo, G., Mullan, M., Vallejo, L., 2017. Climate Change Adaptation and Financial Protection.

[4] Cutter, S.L., 2017. The Changing Context of Hazard Extremes: Events, Impacts, and Consequences. J. Extreme Events 1671005.

[5] IPCC, (2007b). Fourth Assesment Report. Intergovernmental Panel on Climate Change, Geneva.www.ipcc.ch.Date Accessed 20th April, 2009

[6] ISDR, (2006). Third International Conference on Early Warning (EWCIII). Developing Early Warning System: A checklist, Bonn, Germany.

[7] Kramer, R.J., Soden, B.J., 2016. The sensitivity of the hydrological cycle to internal climate variability versus anthropogenic climate change. J. Clim. 29, 3661–3673.

[8] Kreibich, H., Christenberger, S., Schwarze, R., 2011. Economic motivation of households to undertake private precautionary measures against floods.Nat Hazards Earth Syst. Sci. 11, 309–321.

[9] Kreibich, H., Christenberger, S., Schwarze, R., 2012. Corrigendum to ''Economic motivation of households to undertake private precautionary measures against floods'' published in Natural Hazards and Earth System Sciences, 11: 309–321 2011. Nat. Hazards Earth Syst. Sci. 12, 391–3

[10] Kreibich, H., Thieken, A.H., 2009. Coping with floods in the city of Dresden,Germany. Nat. Hazards 51, 423–436.

[11] Kreibich, H., Thieken, A.H., Petrow, T., Mu¨ ller, M., Merz, B., 2005. Flood loss reduction of private households due to building precautionary measures: lessons learned from the Elbe flood in August 2002. Nat. Hazards Earth Ecosyst.5, 117–126.

[12] Kull, D., Mechler, R., Hochrainer-Stigler, S., 2013. Probabilistic cost–benefit analysis of disaster risk management in a development context Disasters 37 (3), 374–400

[13] Noy, I., Edmonds, C., 2016. The economic and fiscal burdens of disasters in the Pacific.

[14] Olfert, A., Schanze, J., 2008. New approaches to ex-post evaluation of risk reduction measures: the example of flood proofing in Dresden, Germany. In: Samuels, P.,Huntington, S., Allsop, W., Harrop, J. (Eds.), Flood Risk Management: Research and Practice. Taylor & Francis Group, London

[15] Sabuni , E.W. (2016).Hydrologic Modelling for Management of Yala River Flood Flows ,Western Kenya.

[16] Singh, A. K and Sharma A. K., (2009). GIS and a remote sensing based approach for urban floodplain mapping for the Tapi catchment, India,.Hydroinformatics in Hydrology, Hydrogeology and Water Resources at the Joint IAHS and IAH Convention, Hyderabad, India, 389-394

[17] USGS, 2010, USGS U.S. United states for Geographical Surveys

[18] Venäläinen, A., Pilli-Sihvola, K., Tuomenvirta, H., Ruuhela, R., Kululanga, E., Mtilatila, L., Kanyanga, J., Nkomoki, J., 2016. Analysis of the meteorological capacity for early warnings in Malawi and Zambia. Clim. Dev. 8, 190–196.

[19] Wang, M., Zhang, L., Baddoo, T.D., 2016. Hydrological Modeling in A Semi-Arid Region Using HEC-HMS. J. Water Resour. Hydraul. Eng. Sept 5, 105–115.

[20] Yengoh, G.T., Fogwe, Z.N., Armah, F.A., 2017. Floods in the Douala metropolis, Cameroon: attribution to changes in rainfall characteristics or planning failures? J. Environ. Plan. Manag. 60, 204–230.

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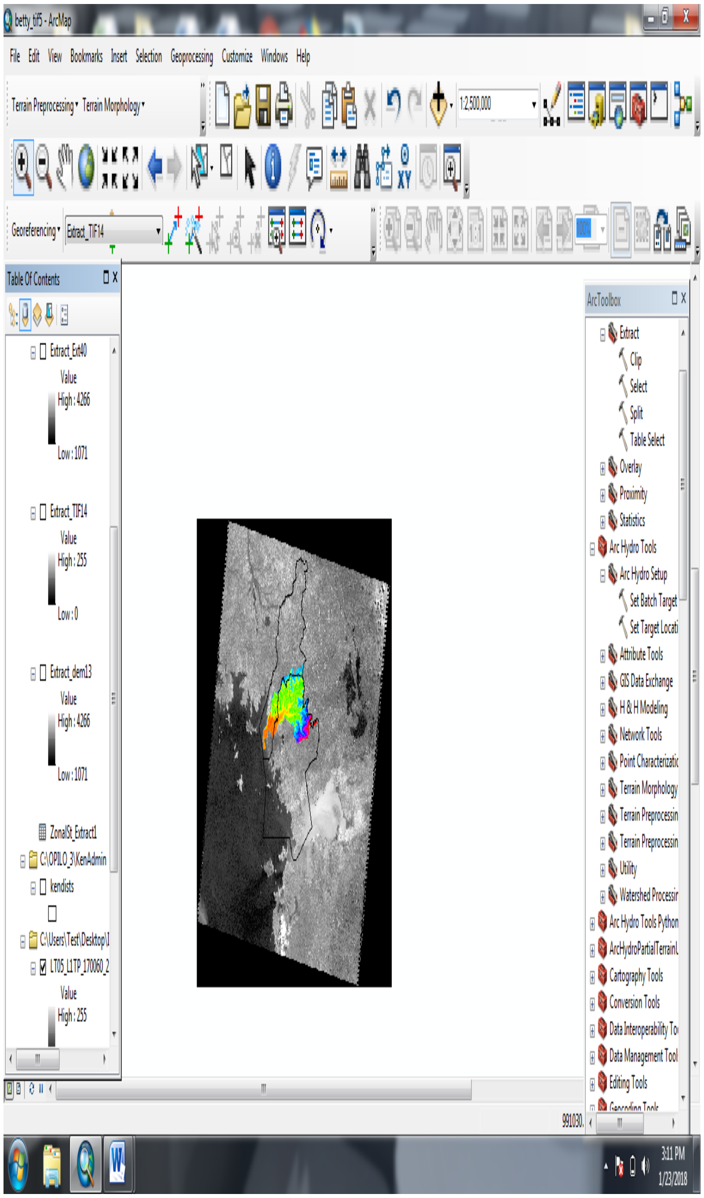
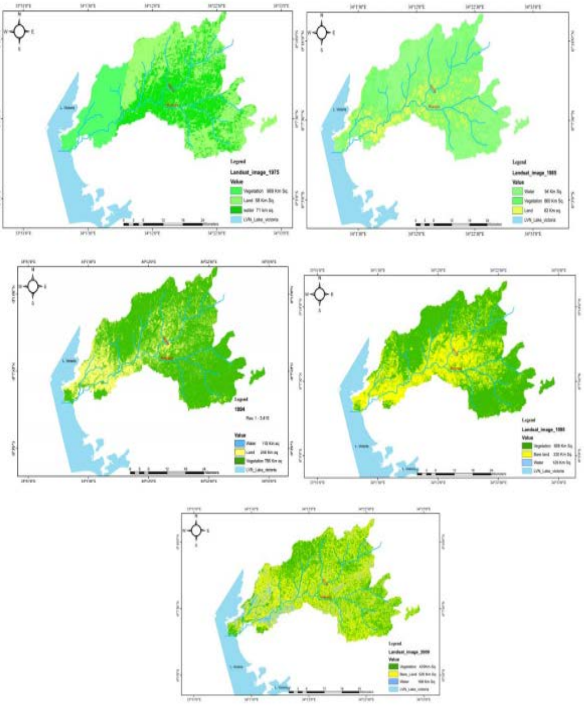
APPENDICES

APPENDIX I: Steps involved in Delineating the Landsat Images for LNRB



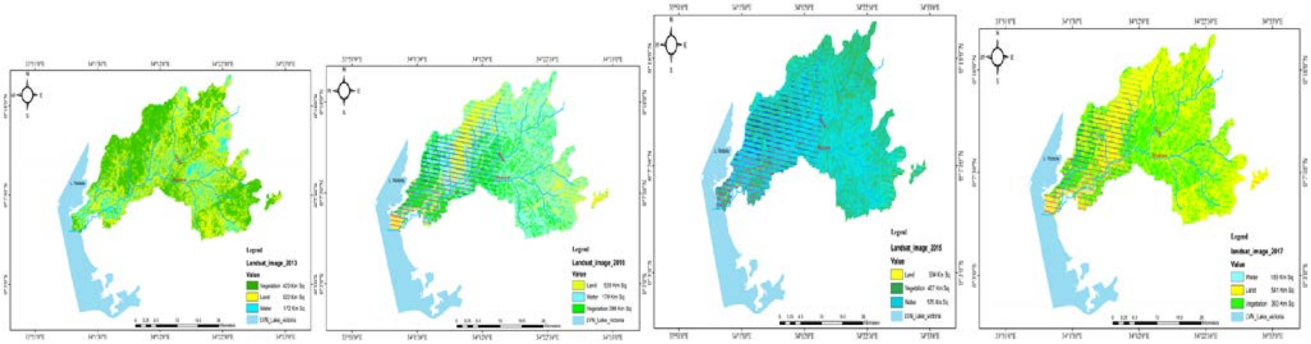
Source: Author, 2016

APPENDIX II: Raw Clipped Landsat Image for Flood Area Extent mapping for the Year 1975 to the year 2009



Source: Author, 2016

APPENDIX III: Raw Clipped Landsat Image for Flood Area Extent mapping for the Year 2013 to the year 2017



Source: Author, 2016