International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Assessing Changes on the Floodplain of Sandy Rivers Using Geospatial Techniques; Case of Athi Sub-Catchment in Makueni

Koskei Kipkirui Michael[1], Ngigi Thomas[2]

[1, 2]Department of Geomatic Engineering and Geospatial Information Systems,
Jomo Kenyatta University of Agriculture and Technology, Kenya.

Abstract: ***Degradation of floodplains by land-use pressures requires sustainable management and conservation measures to protect them. Delineating and mapping changes which have occurred in such ecologic valuable areas is important in planning those measures. GIS and remote sensing techniques have been utilized in this study to delineate and assess the changes which have occurred on the floodplain of sandy rivers in Athi sub-catchments. The study is concerned within three sub-catchments found in Makueni County. This area is semi-arid and experience water resources challenges. The use of sand dams on the seasonal rivers is common in the area. A geomorphological approach which uses DEM, slope and stream network has been used to delineate the floodplain. Landsat TM and ETM+ images of 1986, 1995, 2002 and 2011 has been used to do land cover classification of the floodplain. Four land cover classes: dense vegetation, sparse vegetation, wetland and sand were identified. In this study, change detection shows that dense vegetation on the floodplain has decreased over the years; mostly to sparse vegetation. There is also an increasing trend of sandy land and notably most of the wetland has changed to sand over the years.***

Keywords: Riparian, Floodplain, GIS, Land cover, Change detection

1. Introduction

Riparian zones, river-marginal wetland environments and flood plains are key landscape elements with a high diversity of natural functions and services [1]. Floodplains are the flat land adjacent to rivers created by the deposition of sediment as the channel migrates laterally [2] and are inundated during floods [3]. Floodplains serve many important functions. They offer rich soils that support the diverse plant life of riparian areas. Riparian areas are found adjacent to streams and rivers where terrestrial and aquatic ecosystems overlap to provide homes for a tremendous diversity of plants and animals [4].

Whatever the size of the stream, riparian areas are critical for maintaining the ecological health of the stream. Streams and adjacent riparian areas are subject to frequent disturbances. Human activities, such as mining, grazing, farming, damming, channelization, logging, urbanization and recreation disturb riparian areas. It is important to understand the historical rate of disturbances for any given riparian system and not to exceed that frequency, size or duration of disturbance [5].

Flood plains are among the most altered landscapes worldwide and they continue to disappear at an alarming rate, since the „reclamation" rate is much higher than for most other landscape types [6]. Flood plains have been highly degraded throughout the world by river and flow management and by land-use pressures. Therefore, flood plains deserve increased attention for their inherent biodiversity, for the goods and services provided to human societies and for their aesthetic and cultural appeal [1]. Flood plains need to be inventoried in a way that identifies the level of anthropogenic impact [1].

The Athi River Catchment is one of the water catchment areas in Kenya that have experienced rapid land cover changes due to changes in land uses and population pressure [7]. According to Water Resources Management Authority (WARMA) Strategic Plan of 2012- 2017[8], Athi catchment area has water resources issues which are quite challenging to address. This is due to vulnerability of the region especially in the middle and lower reaches which are mainly semi-arid. The area is quite heterogeneous and therefore experiences variable runoff response especially in the Thwake and Tsavo management units. Other issues which aggravate the problem are catchment degradation due to deforestation. WARMA has also identified encroachment and cultivation of wetlands as a factor which worsens the situation. Furthermore, sand harvesting has been a major economic activity in the area which has negatively affected river banks and destroyed riparian zones of many rivers making them become unstable. These activities destroy surface cover resulting in increased surface run-off and soil erosion. Eroded soils are carried by the surface run-off and deposited in rivers, lakes and dams, resulting in reduced storage capacity.

Attempts to come up with intervention measures to these challenges have been hampered by lack of information on the past rates, location and the likely future land cover changes. In addition, recent development strategies such as Kenya Vision 2030 which emphasizes on agricultural expansion and rapid urbanization are likely to cause major land cover and environmental changes [7].

There has also been a concerted effort by the Government of Kenya (GOK) to improve food security in ASAL areas by increasing water harvesting and establishing irrigation projects. Water harvesting is very common in Makueni County due to its water scarcity challenges. The most popular water harvesting technique which has been adopted in Makueni is sand storage dams. Sand dams are established along ephemeral rivers where water will be scooped in the sand during the dry season. This technique has encouraged vegetable growing along the riverbanks. The residents will also scoop sand and sell to be used for construction, therefore earning them income.

These human activities, together with natural effects such as severe droughts caused by climate change leads to overexploitation and degradation of floodplains which are moist for most part of the year. They adversely affect river banks and destroy riparian zones of many rivers making them become unstable.

This study, therefore, endeavors to provide essential information on the changes which have occurred over the years on the floodplains of the Athi sub-catchments. Before assessing the changes which have occurred on the floodplains, an effort has been made in this study to delineate using a functional approach. This information is useful in planning for sustainable management and conservation of floodplains and riparian areas which have high ecological value.

2. Study Area

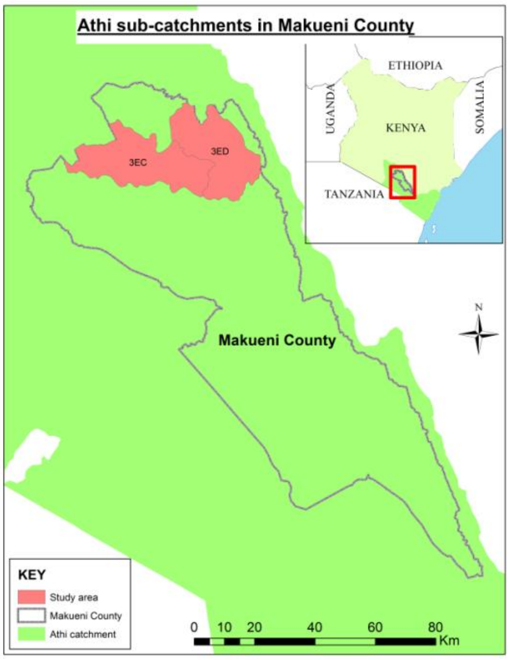

Figure 1: Location of study area

The study area is two Athi river sub-catchments identified as 3EC and 3ED; which are drained mainly by river Thwake and Kaiti , all traversing Makueni County from west to east , draining into the Athi river which is the main permanent river. The sub-catchments are generally found in the northern and central part of Makueni, which is hilly with agricultural potential.

The area is located on relatively undulating terrain with a general slope running in a north-easterly direction.

The study area falls within the greater Tana and Athi drainage basin which includes mostly the central and eastern parts of the country. The drainage pattern of the greater Makueni County is highly influenced by the Athi River and its tributaries (Kambu, Kaiti, Kiboko, MtitoAndei, Thwake, Thange, Uani, Muoni, Tawa and Kiangini among others) rising from the central highlands running eastwards toward the Indian Ocean as the Galana/Sabaki River.

Most areas around Makueni are generally covered by deep sandy alluvium and red sandy soils in addition to patches of black cotton soils and murram. Typical soils are sandy (eroded from the base sedimentary rock) and contain little organic matter and hence have low fertility. Valleys and river flood plains, however, have notable productive soils due to accumulation of silt and minerals though they are limited by lack of adequate rainfall.

The hills to the north and central parts of the County highly influence the climate in Makueni. The study area receive scarce rainfall throughout the year with an average of 500mm per annum spread over two seasons [9], a situation that contributes to a serious scarcity of surface water sources in the area. Rainfall is also unevenly distributed over time and space with long periods of dry weather. The long rains occur in March/April while the short rains occur in November/December. Low rainfall is attributed to the trends in winds from the ocean towards the central highlands and high temperatures [9]. Due to the rainfall fluctuations and long dry spells, the generation of silt from the catchments is relatively high.

3. Data and Methodology

3.1 Data

Four satellite images were acquired from the Landsat TM and EMT+ sensor (TM Jan 1986, TM Jan 1995, TM Feb 2002 and ETM+ Feb 2011). The effects of acquiring all images during the dry season are that phenological differences are minimized, and the riparian area stands out because it has dense green vegetation at the time compared to other areas.

The Landsat images have also been preferred for this study because of its free availability. The ASTER GDEM is also easily available Digital Elevation Model(DEM) data having moderate spatial resolution.

Table 1: Data used

Data	*Format*	*Spatial resolution*	*Source*
ASTER GDEM	Raster	30m	https://reverb.echo.nasa.gov
Landsat TM and ETM+	Raster	30m	USGS(http://earthexplorer.usgs.gov/)

3.2 Image pre-processing

The Landsat imagery of 2011 was geo-rectified and the other images were co-registered to 2011 image using Universal Transverse Mercator (UTM) coordinate systems.

3.3 Floodplain delineation using GIS

In this work floodplain surface by means of GIS-based geomorphological approach using DEM has been created, in an attempt to find hydrologically meaningful potential riparian zones for river networks.

The method used to define the floodplain, and therefore riparian zone, in this study is referred to as the path distance (PD) approach [10]. PD is the least accumulative cost distance to the river channel when accounting for slope and elevation change, indicating the relative costs of moving from the stream cells up into the stream valley.

The PD approach uses a raster showing the PD value for each cell to generate a surface covering all the locations along a river network which are encompassed by a certain path distance to the river channel. The approach requires a DEM and a stream line as inputs to generate the floodplain surfaces.

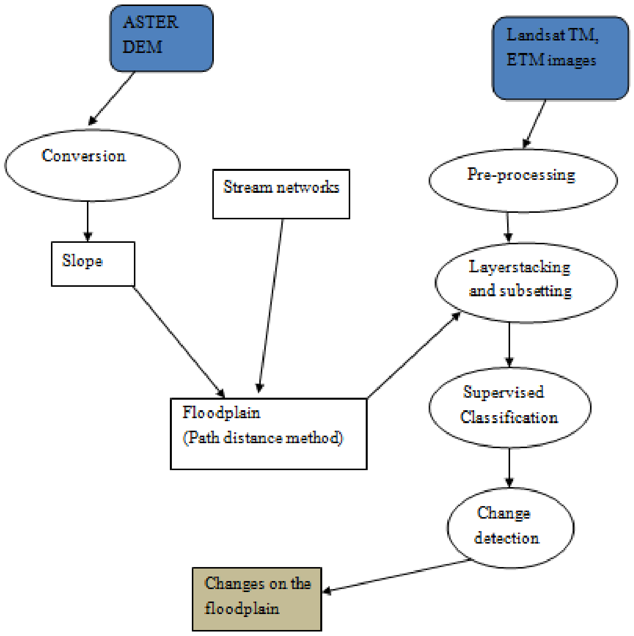

Figure 2: General methodology procedure

3.4 Change Detection

The 1986, 1995, 2002 and 2011 images were classified by adopting a post-classification change detection method, which used supervised classification technique (utilizing a maximum likelihood classifier). In reality, the only way to determine the best change detection method to use depends totally on the application or problem to be solved [11]. 5 bands: band 1,2,3,4 and 7 have been used to obtain land cover classes. The final classification yielded four classes for each image: dense vegetation, sparse vegetation, wetland/water and sand. Classification accuracy assessment was done using random samples generated in ArcMap, picked on Google Earth and used for cross validation matrix.

4. Results

The floodplain was delineated using Path Distance method, which requires DEM (elevation values), slope and stream network as the inputs. The PD result was reclassified and the lowest inner cells extracted as the floodplain.

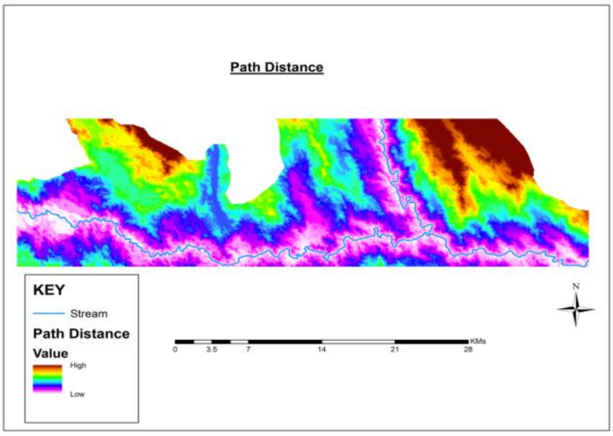

Figure 3: Path distance for floodplain delineation

The Landsat image scenes, three, were mosaicked band by band to cover the study area and then layerstacked to get composite images. Subsetting was also performed on the Landsat composite images, using the floodplain boundary, to produce composite images covering the floodplain for 1986, 1995, 2002 and 2011.

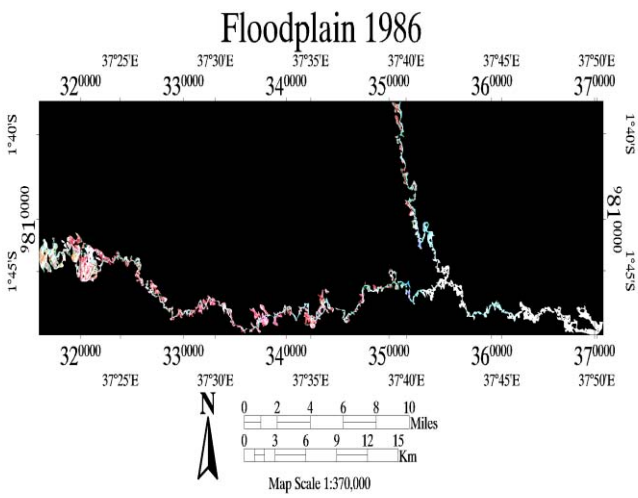

Figure 4: False colour imagery of floodplain 1986

Supervised classification was done using Maximum Likelihood approach on the four year imagery. Supervised classification requires previous knowledge of land cover classes in the area under study [12]. The training sites were distributed evenly in the floodplain. 5 bands: band 1,2,3,4 and 7 were utilized to get the land cover classes. Four main classes were achieved: dense vegetation, sparse vegetation, wetland/water and sand. In this study, dense vegetation represents the lush vegetation along the rivers which is majorly riparian vegetation. The sparse vegetation, in this case includes other vegetation and crops while sand represents those on the dry river beds and any others on the floodplain areas. Sand can be easily distinguished from other soil because it reflects a lot of light.

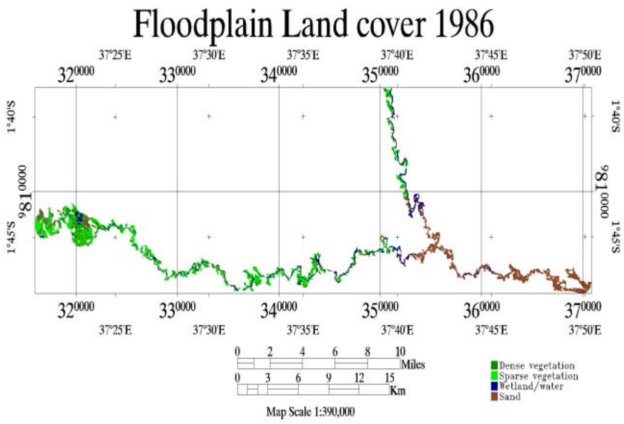

Figure 5: Floodplain cover of 1986

Table 2: Land cover area 1986 - 2011

	Land cover area(Km²)			
Class	**1986**	**1995**	**2002**	**2011**
Dense vegetation	4.48	5.35	2.08	1.03
Sparse vegetation	13.15	11.11	15.03	12.77
Wetland/water	5.15	5.93	3.02	8.82
Sand	13.02	13.43	15.69	13.18

An overall accuracy of 68% and kappa coefficient of 0.62 was achieved using the reference image of 2011.

Table 3: Land cover changes

Class	Changes (percent)			
	1986 - 1995	1995 - 2002	2002 - 2011	1986 - 2011
Dense vegetation	48.252	77.192	73.677	88.208
Sparse vegetation	40.615	41.312	42.227	44.994
Wetland/water	57.407	77.862	46.113	61.95
Sand	34.351	40.704	37.502	43.338

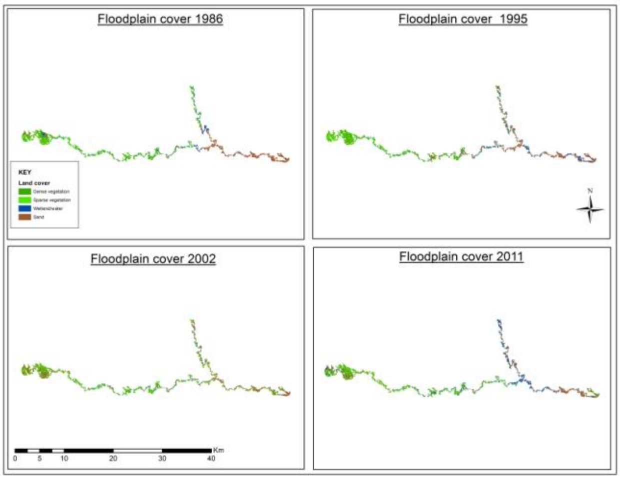

Figure 6: Floodplain cover changes

5. Discussion and conclusion

There was a significant change in dense vegetation throughout the years, but significantly a negative change of 77.19% between 1995 and 2002. The major change during this period resulted to sparse vegetation by 64.08%. This can be attributed to clearing vegetation for farming. Generally, dense vegetation negatively changed by 88.20% between 1986 and 2011.

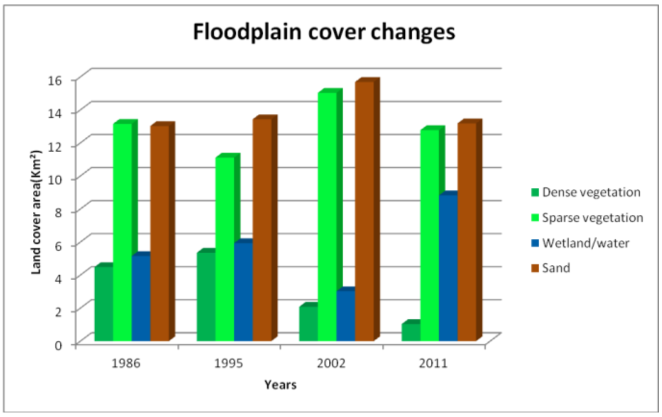

Figure 7: Floodplain cover changes

Also, most of the dense vegetation, in this case riparian vegetation, was converted to sparse vegetation by 58.94% between the study periods. Population pressure on the available land for farming has pushed people into the floodplain and riparian areas for more space. Food insecurity due to perennial droughts has also aggravated the issue, encouraging people to clear riparian areas and grow crops i.e. vegetables because of nearness to water and availability of soil moisture.

The wetland also experienced a high negative change between 1995 and 2002, of 77.86% and the notable change of 56.30% occurred to sand. During this period, the wetland was overexploited mainly due to sand harvesting. People have been trying to diversify their sources of income due to unreliability of agriculture. There is also demand for sand due to the growing construction sector in the capital city of Nairobi and neighbouring metropolitan areas of Machakos and Kajiado. There was a general change of 61.95% in wetland within the study period and much of the change, 42.49% of this is towards sand.

An interesting scenario is also noted in this study whereby during the study period, there is a significant change of 23.53%, 42.49% in sparse vegetation and wetland respectively to sand. Much of the floodplain area, over the years, is covered by sand: 13.02Km², 13.43Km², 15.69Km² and 13.18Km² in 1986, 1995, 2002 and 2011 respectively.

Therefore , most changes which occurred in all the land cover classes is majorly to sand; except in dense vegetation where the big change is to sparse vegetation. Over the years, sand harvesting has immensely changed land cover. Deposited sand in the floodplain has increased over the years due to accelerated erosion caused by deforestation while looking for space to carry out agriculture and charcoal burning.

The following are the significant conclusions that have been drawn by way of having achieved the overall objectives of this research study.

1) A GIS-based geomorphological approach can be used to delineate the floodplain and represent riparian zones.
2) Dense vegetation along the floodplain has decreased over the years by 3.95 Km^2 and most of it has changed to sparse vegetation.
3) Most part of floodplain is covered by sand over the years and there has been an increasing trend of sandy land.
4) The wetland has undergone through rapid changes with the highest negative change experienced between 1995 and 2002, most of the conversion happened to sand.

References

[1] K. Tockner, S. Bunn, C. Gordon, R. Naiman, G. Quinn and J. Standford , " Flood plains: critically threatened ecosystems," In Aquatic Ecosystems, N. Polunin (ed) Foundation for Environmental Conservation, Cambridge University Press, 2008.
[2] B. Marriot, "Channel-floodplain interactions and sediment deposition on floodplains," In: United Kingdom floodplains. R.G. Bailey, P.V. José and B.R. Sherwood, (Eds.). Westbury Academic and Scientific Publishing, Otley, UK. 43–62.
[3] C.G. Nanson and C.J. Croke, "A generic classification of floodplains," Geomorphology, 4, pp. 459–486, 1992.
[4] Flathead Watershed Sourcebook: A Guide to an Extraordinary Place, "Floodplains and Riparian Zones," flatheadwatershed.org, para. 1, 2010. [Online]. Available: http://www.flatheadwatershed.org/watershed/floodplains.shtml. [Accessed Sept. 2, 2015]
[5] S. Bolton and J. Shellberg, "Ecological Issues in Floodplains and Riparian Corridors," Final White Paper. Washington State Transportation Center (TRAC), University of Washington, Seattle, Washington, 2001.
[6] M. D. Olson and E. Dinnerstein, "The global 200: a representation approach to conserving the earth‟s most biologically valuable ecosystems," Conservation Biology, 12, pp. 502-515, 1998.
[7] J.S. Katana, E.K. Ucakuwun, T.M. Munyao, " Detection and Prediction of Land Cover Changes in Upper Athi River Catchment, Kenya: A Strategy towards Monitoring Environmental Changes," Greener Journal of Environmental Management and Public Safety, Vol. 2 (4), pp. 146-157, 2013 .
[8] Water Resources Management Authority (WARMA), "Strategic Plan 2012-2017," Government of Kenya, Kenya, 2013.
[9] Environmental Social Impact Assessment (ESIA) summary: Thwake Multi-purpose Dam Project, Kenya, 2009.
[10] D. Fernandez, J. Barquin, M. Alvarez-Cabria, F.J. Penas, "Quantifying the performance of automated GIS-based geomorphological approaches for riparian zone delineation using digital elevation models," Hydrology and Earth System Sciences, 16, pp. 3851-3862, 2012.
[11] J. Jensen, 1996 , Introduction to Digital Image Processing: A remote sensing perspective, Piscataway, NJ: Prentice Hall
[12] I. Vorovencii, M.D. Muntean, "Evaluation of Supervised Classification Algorithms for Landsat 5 TM Images," RevCAD 14/2013, 1 Decembrie 1918 University of Alba Iulia, 2013.

Author Profile

Michael Koskei received the B.A. in Geography from Moi University in 2011 and currently pursuing Msc. in GIS and Remote Sensing from Jomo Kenyatta University of Agriculture and Technology, Kenya. He now has four years work experience in GIS and Remote sensing, after working with a number of organizations in Kenya.