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Research Paper

Landsat Data for Quantifying Impacts of Land and Land Cover Changes on Water resources of Rufiji Delta

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ABSTRACT; *Decline of water resources following the impacts of LULC change is vivid in Tanzania. However inadequate information is available to facilitate informed decision making on sustainable monitoring and management the impacts of LULC changes in water resources of Tanzania. The overall objective of this research study was to quantify the impacts of LULC dynamics in water resources of Rufiji Delta using Landsat data and LCM. The Landsat data were downloaded from the USGS website and classified using ERDAS Imagine software while adopting Maximum Likelihood Classification (MLC) algorithm. Post classification and accuracy assessment was carried out using ArcGIS 10.3 and ERDAS Imagine 2014 software, respectively. LULC change detections were carried out using LCM through pair wise comparison of classified image of year 1998-2008; 2008-2018 and 1998-2018. In year 1998 the impervious land cover was the largest class with 53413.40 ha (35.74% composition), followed by water bodies with 42506.10 ha (28.44% composition) while mangrove forest and non-mangrove vegetation consisted of 38060.40 ha (25.47 % composition) and 15468.50 ha (10.35% composition), correspondingly. In year 2018 the impervious land cover increased to 60759.70 ha (40.66% composition) while mangrove forest and non-mangrove vegetation consisted of 35062.2 ha (23.46% composition) and 23019.2 ha (15.40% composition), correspondingly. Water bodies declined to 30607.10 ha (20.48% composition) following the consumption of water in hydro-electrical and agricultural expansion proximal to the Rufiji Delta. In year 1998 to 2018, a net gain in area covered by mangrove forest by 7541 ha was recorded following the loss and gain of about and 11246 and 18817 ha, respectively as per Figure (8 & 9). A net gain of 13227 ha of non-mangrove forest were recored following a gain of about 13227 ha and loss of about 0 ha from year 1998 to 2018. A net loss of 17529 ha of impervious class following a loss of about 27108 ha and gain of about 9579 ha. A net loss of 3239 ha of water bodies was recorded following a loss of about 5080 ha and gain of about 1842 ha from year 1998 to 2018. Hence water resources of Rufiji district have substentailly declined from 1998 to 2018 and proper monitoring and management of water resources in Rufiji Delta is required in Rufiji Delta in Tanzania.*

Key words*: LULC impcats,Water resources; Rufiji Delta*

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I. INTRODUCTION

1.1 Background information

Understanding the Land Use Land Cover (LULC) change and its implication to water resources is vital future decision making and planning for water resources in the country. According to (Li et al., 2007) the LULC change is expected to alter regional hydrologic conditions which will continue resulting in varieties of impacts on ecosystem functioning (Rufiji Basin Water Board, 2013). While Sophia & Emmanuel, (2017) and (Balama et al., 2013) reported the increasing competition for water resources coupled with LULC changes in the upstream of many rivers to have contributed to change in hydrological regimes of many rivers and wetlands. The ever increasing population and economic growth also have are increased water demands and consumption (Nindi et al., 2014 & Connors, 2015) in many parts of the world with expectation of inducing stress which will constrain human development and economic growth. On the other hand, the implication of LULC changes in water resources when combined with the ongoing impacts of climate change has both have negatively impact water supplies, ecosystems, biodiversity, food security, rural economies, human health and economic development (Shaghude, 2005 & Pitman et al., 2012).

In Tanzania, water scarcity is experienced in many places and sectors (Chilagane, 2017& (Mahoo & Simukanga, 2015) following the changes in LULC and climate. In particularly, higher average rainfall coupled with increases in intense rainfall events has posed greater risks of flooding in area with factors that exacerbate flooding. Among of factors which exacerbate flooding risks include growth in population (Nindi, 2009) and poor management of infrastructure and land use change; clearing of vegetation (Ottema, 2009); filling of wetlands; and ineffective disaster prevention, preparedness, warning and response systems. While low rainfall, coupled with decrease in intense rainfall events has posed greater risks of droughts in area with factors that exacerbate drought (Haroun et al., 2013). Rufiji delta is not exempted from the implication of LULC and climate change though there is inadequate information on LULC and climate change which is crucial for routine monitoring and management of the delta. Long history of Landsat data in capturing Earth information is offering viable opportunity for generating updated information on the Rufiji delta. Rufiji Delta is one of the important biodiversity hot spots in the Indian Ocean and is part of the Rufiji-Mafia-Kilwa Marine Ramsar Site where three important WWF-Tanzania Conservation thematic areas meet (marine, terrestrial & freshwater) (REMP, 2001). It has been considered as, a home of extraordinary ecosystem services and biodiversity hot spots in the Indian Ocean (FAO, 1960). However, the multiple-use and extractable nature of mangroves in Rufiji Delta have exacerbated the resources degradation, though comprehensively information on the impacts of these multiple-use is still understood.

There are several methodological approaches for understanding the impacts of Land and Land Cover and Climate Changes to water resources including the field survey and use of satellite data. Field data collection is cumbersome, tiresome and don’t cover entire study area. Alternatively**,** launch of the Earth Resource Technology Satellite (ERTS) 1, latterly called Landsat 1 in July 1972, has contributed significantly to the development of remote sensing applications such as land cover classification (Phiri & Morgenroth, 2017). The main aim of the Landsat satellite program was to provide a tool for continuous monitoring of Earth’s resources. Landsat is a multispectral sensor with moderate resolution acquiring images in several spectral bands at spatial resolution of 30 meters and temporal resolution of 16 days (Bruce & Hilbert, 2004). Landsat data have long history and reliability hence regarded as the popular source for documenting changes in land cover and use over time (Reis et al., 2003). For the purpose of this research study, Landsat 5 Thematic Mapper (TM) and Landsat 8 were considered useful. The technical description of Landsat 5 Thematic Mapper (TM) and Landsat 8 are presented in Table 1 and

Table 1: The bands of Landsat 5 TM

Bands	Region in EMS	Temporal resolution	Spatial Resolution
Band 1	Visible (0.45 - 0.52 μm)	16 days	30 m
Band 2	Visible (0.52 - 0.60 μm)	16 days	30 m
Band 3	Visible (0.63 - 0.69 μm)	16 days	30 m
Band 4	Near-Infrared (0.76 - 0.90 μm)	16 days	30 m
Band 5	Near-Infrared (1.55 - 1.75 μm)	16 days	30 m
Band 6	Thermal (10.40 - 12.50 μm)	16 days	120 m
Band 7	Mid-Infrared (2.08 - 2.35 μm)	16 days	30 m

Source: Global Land Cover Facility (2004)

Table 2: The bands of Landsat 8 Bands

Bands	Region in EMS	Temporal resolution	Spatial Resolution
Band 1	Coastal (0.433 - 0.453μm)	16 days	30 m
Band 2	Blue (0.450 – 0.515 μm)	16 days	30 m
Band 3	Green (0.525 - 0.600 μm)	16 days	30 m
Band 4	Red (0.630 - 0.68 μm)	16 days	30 m
Band 5	NIR (0.845 – 0.885 μm)	16 days	30 m
Band 6	SWIR(1.560-1.660 μm)	16 days	60 m
Band 7	SWIR (2.100- 2.300 μm)	16 days	30 m
Band 8	PAN (0.5 – 0.680 μm)	16 days	30 m
Band 9	Cirrus (1.360- 1.390 μm)	16 days	30 m
Band 10	Thermal (10.6-11.2 μm)	16 days	100 m
Band 11	Thermal (11.5-12.5 μm)	16 days	100 m

Source: Global Land Cover Facility (2004)

On the other hand GIS, the capability of GIS in storing, processing, analyzing and disseminating vast categories of information also dole out as substitute to conventional approaches for data storage, processing and dissemination. Thus, this research study used Landsat and Geographical Information Systems (GIS) for determination of the impacts of LULC and climate change to water resources of Rufiji Delta in Tanzania.

II. METHODOLOGY

2.1 Description and geographical locations and of study area

The Rufiji delta is located on the Rufiji basin situated between Longitudes 33^{o}55’E and 39^{o}25’E and between Latitudes 5^{o}35’S and 10^{o}45’S. The Rufuji delta is formed by the confluence of the Kilombero and the Luwegu rivers; it flows for about 175 mi northeast and east to enter the Indian Ocean, opposite Mafia Island. The river has major potential for irrigation and hydroelectric power development. Its principal tributary is the Great Ruaha. From its start at the confluence of the Kilombero and Luwegu rivers, the Rufiji flows for about 100 km to the Pangani Rapids at the entrance of the Stiegler’s Gorge, where the river cut through a low ridge, forming a steep-sided narrow gorge, about 8 km long. The general flow direction of the river is from west towards east. Furthermore, the Rufiji delta is characterised as mangrove wetlands.

The Rufiji Delta covers 53,255 ha and forms part of the Rufiji River basin which extends for some 177,000 km2 (RUB ADA, 1981a) (Figure 1). As a result of deposition of sediment carried by the Rufiji River towards the coast, the shoreline has shifted seaward and presently protrudes some 15 km into the Mafia Channel. During floods, silt laden Rufiji waters penetrate far into the delta and deposit river sediments, especially along the most active deltaic branches. The estuary and delta of the Rufiji River seem to be in a state of dynamic equilibrium. The geometry and the course of the several tidal branches changes continuously by sediment deposition and erosion. The morphological conditions are disturbed by changing hydraulic features, such as fluctuating discharges, varying intrusion of salinity, and changes in sediment transport.

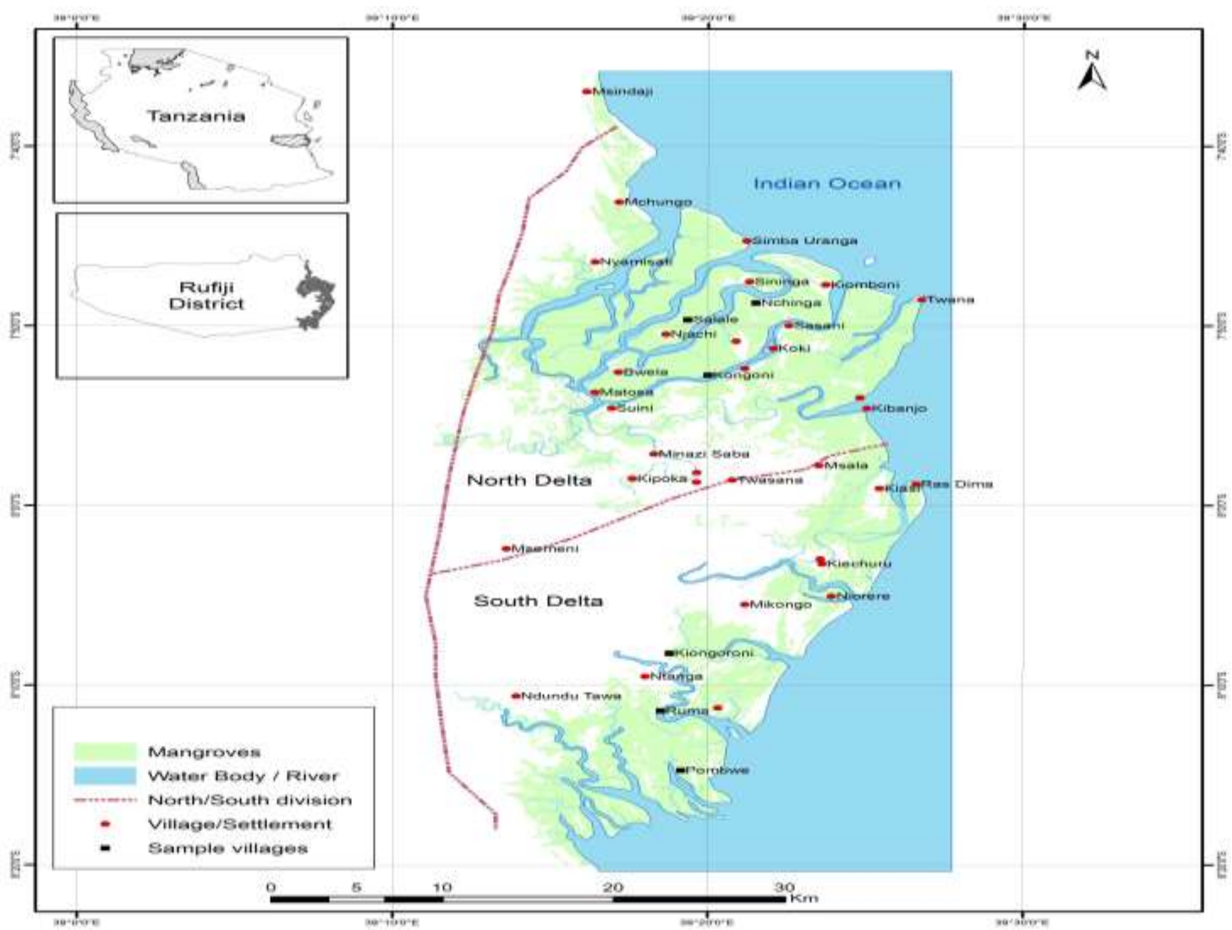

Figure 1: Geographical location of Rufiji Delta (Source: Mwansasu, 2016)

2.2 Data collection and analysis

To gain better understanding on the previous and current impacts LULC and climate changes in water resources of Rufiji delta, the Landsat data captured by multispectral sensor with moderate spatial resolution of 30 meters and temporal resolution of 16 days (Bruce & Hilbert, 2004) were used in this research study. Landsat 5 TM data and Landsat 8 data with history and reliability in capturing Earth information and documenting changes Earth ecosystems (Reis, 2008) were used in this research study.

Landsat data collection: The Level 1 Terrain (Corrected) Product (L1TP) of Landsat 5 TM of year 1998, 2008 and 2018 was downloaded from United State Geological Survey (USGS) official web site (http://www.earthexplore.usgs.gov.com). The Landsat data were subjected to visual assessment of the percentage cloud cover d and images of cloud cover of less or equal to 20% were found appropriate and were downloaded for the purpose of this research study. **Error! Reference source not found.** presents the Landsat dataset collected for this study.

Table 1: Landsat dataset collected for this study

Dataset	Path and row	Date acquired
Landsat 5 TM	P166r65	1998-06-17
Landsat 5 TM	P166r65	2008-06-20
Landsat 8	P167r65	2018-05-3

Source : (United State Geological Survey Website)

Image processing

Conversion of digital numbers (DN) into reflectance: The conversion of digital numbers (DN) into reflectance was carried to normalize the Landsat datasets for better comparisons between images of different years of research study. The conversion involved two different steps that were carried out using ArcGIS 10.3 software. In the first step the digital number (DN) values of each pixel was converted into the radiance while the second step involved conversion of radiance into reflectance.

Layer stacking and image Mosaicking: Band 2, 3 and 4 of Landsat 5 TM images of year 1998, 2008 and 2018 from path and row of 166065 were layer stacked using ERDAS Imagine software. While the band 3, 4 and 5 of Landsat 8 of year 2018 from path and row of 166065 were layer stacked using ERDAS Imagine software. In Landsat 5 TM data, the band 6 were excluded due to its spatial resolution of 120 M while in Landsat 8 the band 6,8,10 and 11 were excluded as it possess the spatial resolution of 60, 15 and 100 M , respectively.

Image sub-setting: This was done to extract the Area of Interest (AOI) using ERDAS Imagine software. The shape file of Rufiji delata was created and used to extract the Rufiji Delta from Landsat 5 TM of year 1998, 2008 and Landsat 8 of year 2018.

Delineation of training sites in Landsat 5 TM and Landsat 8: The sub-set image of Landsat 5 TM of year 1998, 2008 and 2018 each were separately subjected to visual assessment using three bands that were displayed as Red, Blue and Green (RGB) color composite using ERDAS Imagine software. The RGB color composites images were developed to facilitate visualization, interpretation and delineation of training sites. Band 4, 3 and 2 were used in displaying in RGB color composites images for Landsat 5 TM of year 1998, 2008 and 2018. While the band 5, 4 and 3 were used in displaying in RGB color composites images for of Landsat 8 of year 2018. The training sites were delineated following the classification scheme level II by Anderson et al., (1976) with some modification. Thus in this research study only four classes which are mangrove forest, non-mangrove vegetation, water bodies and impervious LULC class were considered during image classification. Table (2) narrates the classification scheme for this research study. Delineation of training sites comprised of selecting the training sites based on visual interpretation on the image, knowledge of LULC types identified and information visualized in Google earth images. At least 20 samples of training site were developed for each identified LULC class based on the LULC type been numerous, representative, relatively homogeneous and as large as possible while maintaining homogeneity and avoiding mixed pixels at the edges of objects. Finally, the 20 samples selected for each LULC class were merged using signature editor of ERDAS Imagine to form one class.

Table 2: Classification scheme proposed for the research study.

S/N	LULC CLASS	DESCRIPTIONS
1	Mangrove forest	Forest class was formed by trees at least 5m high and canopy cover more than 50%, it comprise of deciduous, evergreen land and mixed forest.
2	Impervious	This comprised of residential places, commercial and services, industrial, transportation, communication and utilities, industrial and commercial complexes. Impervious land use also comprised of sandy areas, bare exposed rock, strip mines, quarries, and gravel pit, mixed barren land.
3	Water bodies	This comprised of water bodies comprised of rivers, streams, flooded lands and ponds
4	Non-mangrove vegetation	This comprised of vegetations other than mangrove forest

Source: (Modified from Anderson et al., 2001

Classification, post classification and accuracy assessment of Landsat dataset: The ERDAS Imagine software was used for classification of Landsat dataset for year 1998, 2008 and 2018 covering the Rufiji delta. Maximum Likelihood Classification (MLC) algorithm was used to develop classified images of year ear 1998, 2008 and 2018 using the signature files of Landsat image of year ear 1998, 2008 and 2018, respectively.

Quantification of the LULC changes for epoch of year 1998 to 2018: The LCM of Idris Selva software was used for change detection procedure and quantification of the LULC changes for epoch of year 1998 to 2018. A pair wise comparison of classified images of year 1998-2008; 2008-2018; 1998-2018 were used for developing graph of gains, loss and net change of LULC categories. The LCM of IDRISI Selva software generated the graph of gain and loss as well as the graph of net change of each LULC categories for period between years of 20 years in total. While the graph of net change by LULC was constructed by taking the earlier LULC areas, adding the gains and then subtracting the losses was also constructed using IDRISI Selva.

III. RESULTS AND DISCUSION

3.1 LULC classification results

The classification results of four different study periods have depicted the quantity land use land cover status in year 1998, 2008 and 2018. Four LULC classes classified were mangrove forest, non- mangrove forest, water bodies and impervious. Using **Error! Reference source not found.** in year 1998 the impervious land cover was the largest class with 53413.40 ha (35.74% composition), followed by water bodies with 42506.10 ha (28.44% composition) while mangrove forest and non-mangrove vegetation consisted of 38060.40 ha (25.47 % composition) and 15468.50 ha (10.35% composition), correspondingly. In year 2008, the impervious land cover was the largest class with 61977.00 ha (41.47 % composition), followed by Mangrove forest with 36646.20 ha (24.52% composition) while water bodies decline to 31519.40 ha (21.09% composition). Moreover, the non-mangrove vegetation and water bodies declined to 19305.50 ha (12.92 % composition) and 31519.40 ha (21.09 % composition), correspondingly. In year 2018 the impervious land cover increased to 60759.70 ha (40.66% composition) while mangrove forest and non-mangrove vegetation consisted of 35062.2 ha (23.46% composition) and 23019.2 ha (15.40% composition), correspondingly. Water bodies declined to 30607.10 ha (20.48% composition) following the consumption of water in hydro-electrical and agricultural expansion proximal to the Rufiji Delta.

3.2 Quantification of LULC changes present in form of gains, losses and net change

By graphing the gains and losses of each LULC using two images collected at different epoch enabled a rapid quantitative assessment of LULC change in 19998 - 2008, 2008-2018 and 1998 -2018. Using **Error! Reference source not found.** and **Error! Reference source not found.** in the period between year 1998-2008 mangrove forest lost about 11276 ha and gained about 18817 ha with net loss of about 7441 ha. The observed loss in area under mangrove forest land cover was resulted from progressive agricultural conversion from forest in Rufiji. A net loss of about 17529 ha of impervious were observed following the loss and gain about of 27108 ha and 9579 ha in year 1998 to 2008 while a net loss of 3239 ha of water bodies were recorded following the gain and loss of about 5080 and 1842 ha. In year 1998 to 2008, a net gain of about 13227 ha of non-mangrove vegetation were recorded following a loss of about 0 and gain of 13227 ha.

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Table 3: Area of LULC categories in (ha) and % composition for year 1998, 2008 and 2018

LULC category	Area (ha) in year 1998	% composition	Area (ha) in year 2008	% composition	Area in year 2018	% composition
Water bodies	42506.10	28.44	31519.40	21.09	30607.1	20.48
Mangrove forest	38060.40	25.47	36646.20	24.52	35062.2	23.46
Impervious	53413.40	35.74	61977.00	41.47	60759.7	40.66
Non-mangrove	15468.50	10.35	19305.50	12.92	23019.2	15.40
TOTAL	**149448.40**	**100.00**	**149448.10**	**100.00**	**149448.20**	**100.00**

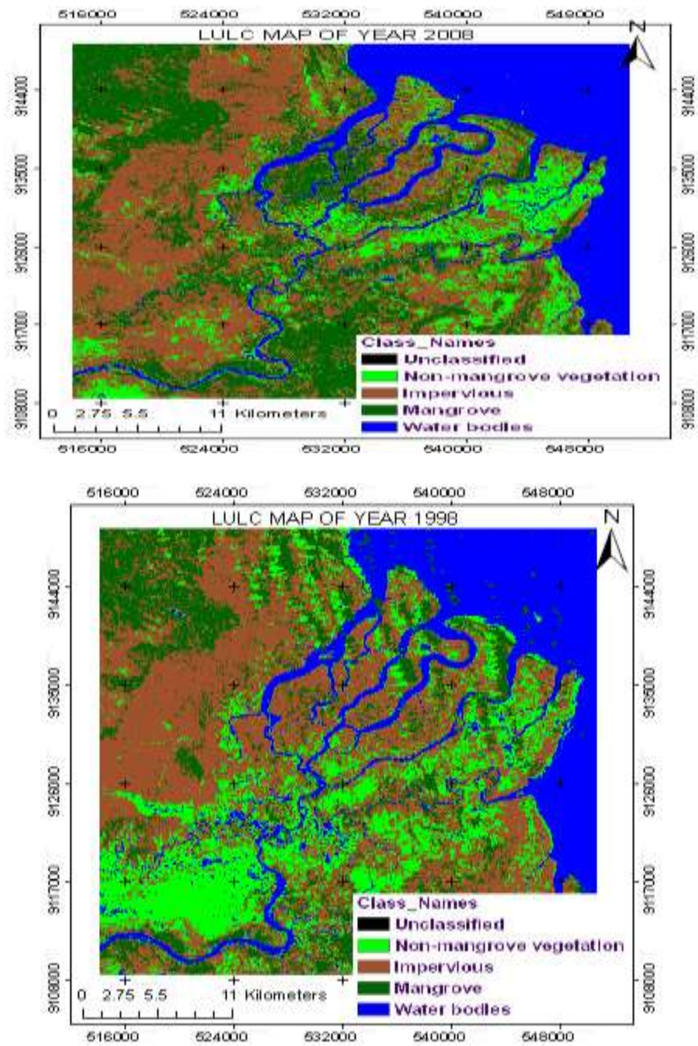

Figure 2: LULC map of year 1998 and 2008 in “A” and “B”, correspondingly.

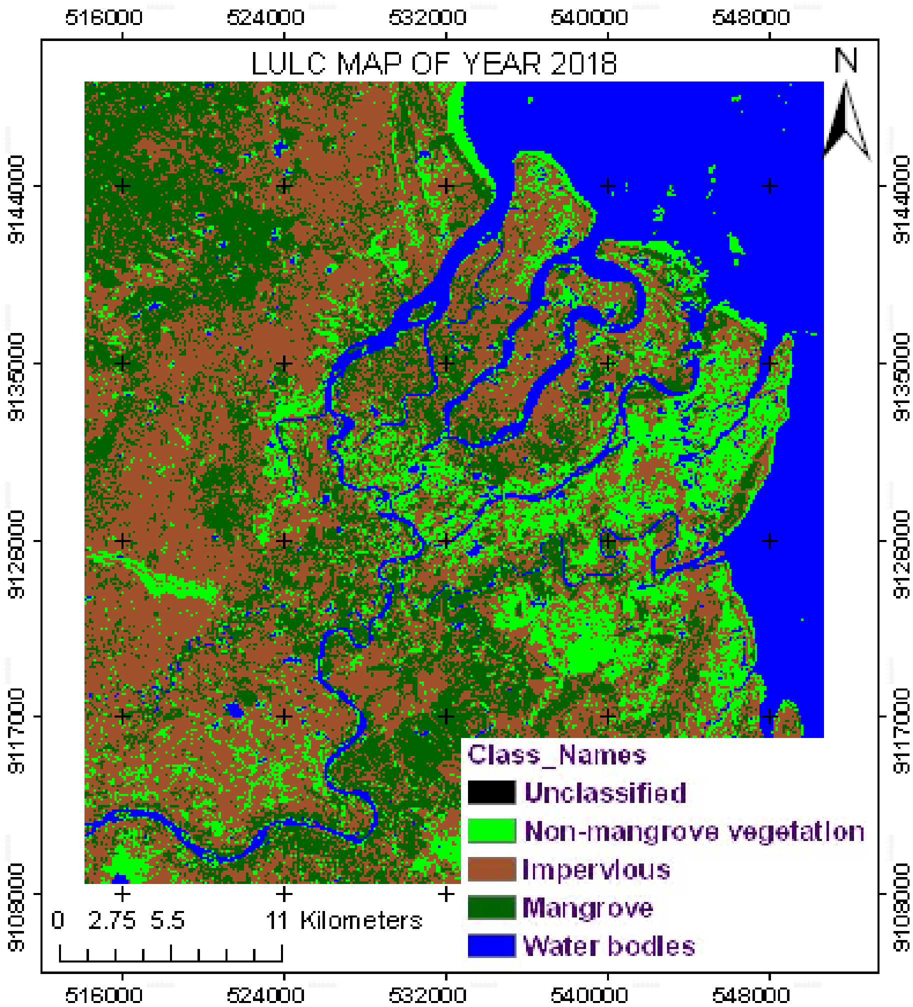

Figure 3: LULC map of year 2018

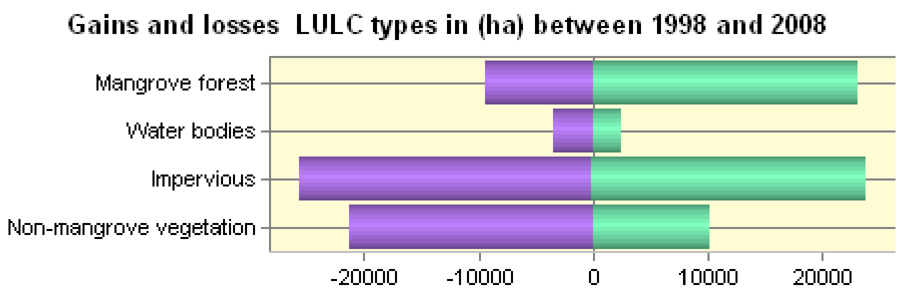

Figure 4: Graph of gains and losses of LULC types (in ha) between 1998 and 2008

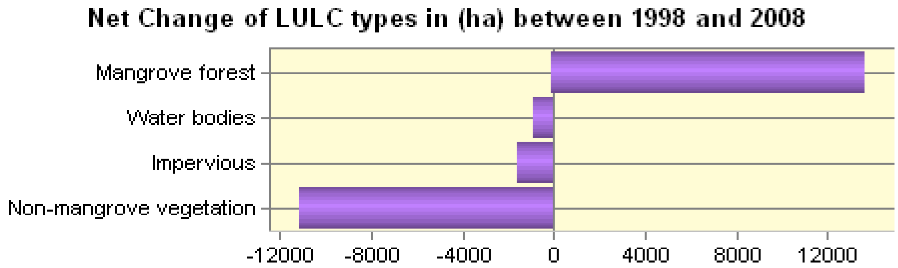

Figure 5: Net change of LULC types (in ha) between 1998 and 2008

In year 2008 to 2018, a net gain in area covered by non-mangrove forest by 3065 ha following the loss and gain of about and 4932 and 7998 ha, respectively as per Figure (6 &7). A net loss of 1931 ha of mangrove forest following a loss of about 11420 ha and gain of about 9429 ha. A net loss of 300 ha of impervious class following a loss of about 13425 ha and gain of about 13126 ha. A net loss of 774 ha of water bodies following a loss of about 2118 ha and gain of about 1344 ha.

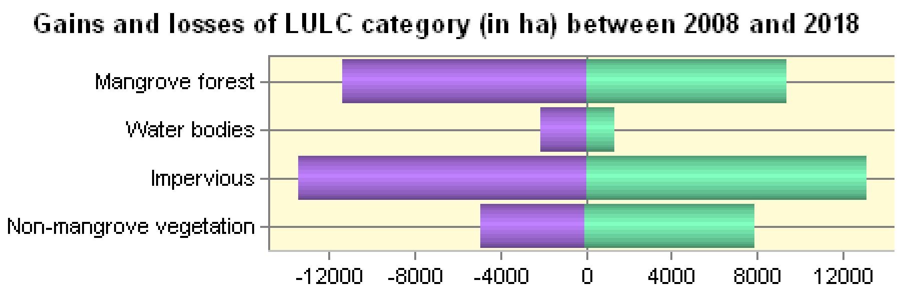

Figure 6: Graph of gains and losses of LULC types (in ha) between 1998 and 2008

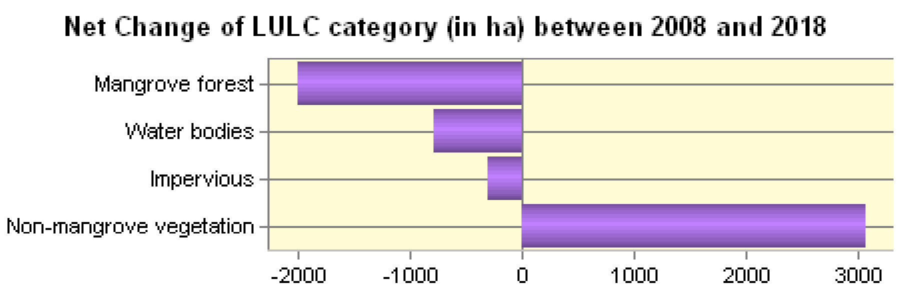

Figure 7: Net change of LULC types (in ha) between 2008 and 2018

In year 1998 to 2018, a net gain in area covered by mangrove forest by 7541 ha was recorded following the loss and gain of about and 11246 and 18817 ha, respectively as per Figure (8 & 9). A net gain of 13227 ha of non-mangrove forest were recored following a gain of about 13227 ha and loss of about 0 ha from year 1998 to 2018. A net loss of 17529 ha of impervious class following a loss of about 27108 ha and gain of about 9579 ha. A net loss of 3239 ha of water bodies was recorded following a loss of about 5080 ha and gain of about 1842 ha.

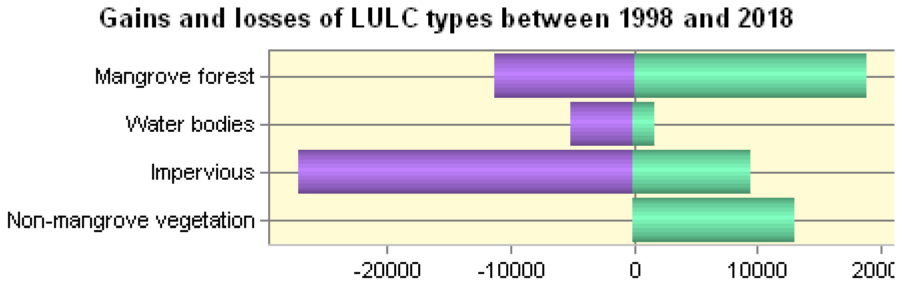

Figure 8: Graph of gains and losses of LULC types (in ha) between 1998 and 2018

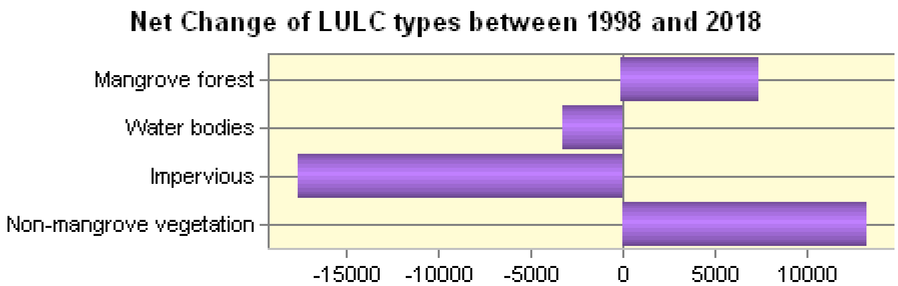

Figure 9: Net change of LULC types (in ha) between 2008 and 2018

IV. CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

This research study used **Landsat Data for Quantifying Impacts of Land and Land Cover Changes on Water resources of Rufiji Delta.** The overall objective of this research study was to quantify the impacts of LULC changes in the water resources of Rufiji Delta. The research study generated the past, current and future information on LULC dynamics in Rufiji Delta using Landsat data and LCM. The capability of Landsat data in capturing the earth data has been utilized in determination of the magnitudes of the LULC classes have emerged and existed from year 1998 to 2018 while LCM has enabled quantification of LULC classes in Rufiji Delta. The research study has revealed declining in water resources following expansion of non-mangrove vegetation and impervious class.

4.2 RECOMMENDATIONS

i. The observed decreasing trends in mangrove forest and water bodies from year 19998 to 2018 require multi-sector intervention through community agro forestry farming is highly recommended in Rufiji district.

ii. The observed increasing in areas covered by impervious and non-mangrove forest from year 1998 to 2018 calls for agricultural technologies that increase crop production yield per unit area and without confronting other LULC categories.

iii. Local Government Authority (LGA), research organization and other stakeholders should develop and promote nursery of trees for evaluation, multiplication and dissemination of agro forestry seeds, seedlings/propagating material among community members is highly recommended to research and agricultural extension services of Rufiji district.

iv. Biological and chemical environmental effects of rapid expansion of anthropogenic activities and its associated heavy application of herbicides and pesticides is still unclear, hence further research is required to investigate environmental effects associated with agricultural expansion in Kilombero district.

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