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ASSESSMENT OF WETLAND DEGRADATION CONDITION AND TREND BASED ON LAND USE/COVER IN WAMI-RUVU RIVER BASIN USING MULTI-TEMPORAL LANDSAT IMAGES

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ABSTRACT

The understanding of wetlands' distribution and their level of susceptibility is important to enhance management and conservation efforts. The study aimed to map wetlands and assess their distribution pattern and their degradation based on the LULC by the years 2000, 2010 and 2020. Wetland types i.e., marshes, ponds, lakes, fens, rivers, floodplains, swamps, and open water bodies with other land use such as agriculture land, built-up and natural vegetation land were classified and mapped using random forest algorithm in Arc Map. Multi-temporal Landsat satellite data including thematic Mapper Landsat (+ETM) and Operational Land Imager (OLI) images were used for LULC mapping. The random forest classifier technique is used to analyse the satellite imagery for detecting the LULC changes during the whole study period. To assess the wetland area degradation three aspects were used in this study for the analysis; wetland area change rate, annual land cover change and annual land cover change rate. The study found about -34.41Km2/y of wetlands potentially are degraded annually due to human and natural stressors in 20 years of our study however the basin experienced a higher rate of wetland degradation in the second epoch of 2010-2020 where the basin experience -42.8Km2/y degradation which results to the total loss of -687.75 km2 total coverage of wetland area in the basin. This information could be used to improve wetland planning and management by wetland managers and other stakeholders.

Keywords: land use/cover, Remote sensing, Wetland degradation, GIS, Driving factors.

1. INTRODUCTION

Wetlands are ecosystems that arise when inundation by water produces soils dominated by an anaerobic process and forces the biota, particularly rooted plants to exhibit adaptations to tolerate flooding (Davidson *et al.*, 2018). Wetlands are areas where water is at, near, or above the surface of the ground often enough for hydric soils to form and/or for wetland plants to grow. The wet conditions make wetlands the most biologically productive ecosystems, (Thawe, 2008). Wetlands are not only vital mechanisms of the global system only about 6% of the earth's surface area is covered by them but are also one of the most important living environments for humans (Beuel et al., 2016). Wetlands have a multitude of unique ecological functions including water conservation, wastewater purification and climate regulation such that they are referred to as the "kidney of the earth" (Islam et al., 2021, Lefebvre et al., 2019). In addition, the wetland is one of the important carbon pools nearly 35% of the total carbon stock of the terrestrial ecosystem, which plays a significant role in the global carbon cycle (Twumasi & Merem, 2006;).

During the last decade, around 50% of the earth's wetlands have already been converted to industrial, agricultural and residential use (Davidson, 2014; Gardner et al., 2015) These lands continue to disappear at a shocking rate without their values being understood. Numerous studies around the globe including India, china and north America have been conducted using remote sensing and GIS on wetland mapping to detect temporal land use/land cover changes (Guo et al., 2017; Jamal & Ahmad, 2020; Mao et al., 2021).

Numerous studies have conducted and reveal that climate change, human economic development, population growth, are the main challenges that have changed the natural hydrologic management in most of Africa's river basins, including the Sokoto Rima River basin the Didessa Sub-basin the Ouémé River basin the Draa basin and the Mara River Basin.(Assefa et al., 2021; Beuel et al., 2016; Kogo et al., 2021; Thamaga et al., 2022)

Wetland ecosystems in Tanzania have been under constant threat of degradation, mainly due to anthropogenic pressure driving changes in land use patterns (John Mwita, 2016; Mombo et al., 2011; Mugo et al., 2020; Mwakaje, 2009; Ngondo et al., 2021; Ntongani et al., 2014).

Wami Ruvu river basin in Tanzania is rich in wetlands, a total of 2,482 km^2 of the area is covered by wetlands both floods plain, marsh and swamp which make up approximately 4% of the total area of the Wami-Ruvu river basin (NLUFP Volume III, 2009). The Large size of wetlands is found in the central part of the Basin in Kilosa and Mvomero districts. Due to climate change, social and economic development, and irrational utilization, the total area of wetlands has been decreasing (Hu, 2020), leading to increasingly severe degradation, desertification and salinization, decreased river runoff and declined biodiversity.(Keshta et al., 2022; Ngondo et al., 2021; Twisa & Buchroithner, 2019)

Several studies have been conducted in the Wami-Ruvu river basin been exploring on dynamic of LULC change for various times and its implication on coastal water resources caused by rapid population increase (Ngondo et al., 2021; Twisa & Buchroithner, 2019) also a study has been conducted in the Ruvu riverine on analysing the drivers and economic consequence of wetland degradation (LIBERATH & A, 2017) but details on area extent magnitude and rate of change of wetland in the whole Wami ruvu river basin is still not well known. Which drivers are the dominant influencing the degradation of wetland degradation in the basin and to what extent rate are causing the degradation is also still not well known hence more information on wetland degradation is needed to be explored in Wami-Ruvu river basin

Due to the short-term nature of data availability, this study intended to detect wetland degradation based on the wetland elements by using long-term remote sensing data series.

This study is expected to map the extent and identifying wetland degradation in the Wami Ruvu river basin and to shed light on wetland loss and future development.

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2.MATERIALS AND METHODS

2.1 Description of the Study Area

The Wami-Ruvu Basin is located in 6 regions and 21 districts making it one of the largest river basins in the country, the basin includes the country's largest city of Dar es Salaam and the relatively larger city of Morogoro, Kibaha, dakawa, Gairo, and Dodoma. Located within 5°S-7°S and 36°E-39°E, The basin covers an area of approximately 66294.5 km2 made by seven sub-catchments of which are Kinyasungwe, Mkondoa, Ngerengere, Wami, Upper Ruvu, Lower Ruvu, and the Coast it consists of two major rivers flowing its water to Indian ocean which are Wami river flowing its water from the mountain Chenene Hills, north to north-east of Dodoma, Ukaguru Mountain north of Wami., Rubeho Mountain west of Kilosa, and Nguru Mountains north of Kilosa, and Ruvu river flowing its water from Uluguru Mountains in West Part of Ruvu River (Nhamo et al., 2017). According to Shen et al., (2019), the current population of the Wami/Ruvu Basin can be estimated at approximately 10.6 million based on the 2012 national population census. The average rainfall in the basin is approximately 500–780 mm per year in the western semi-arid highlands near Dodoma, and 900–1300 mm in the central areas near Morogoro and the estuarine and coastal regions. Most of the rain in the basin falls between March and May with a shorter rainy season from October to December. The annual mean temperature ranges from 12 to 32 ◦C. the basin was established in July 2002, and it operates under the Wami/Ruvu Basin Water Board. Wami-Ruvu river basin was selected as the study area as one of the largest river basins in the country to propose a new method for wetland loss identification to the other river basin in the country and another river basin in the continent.

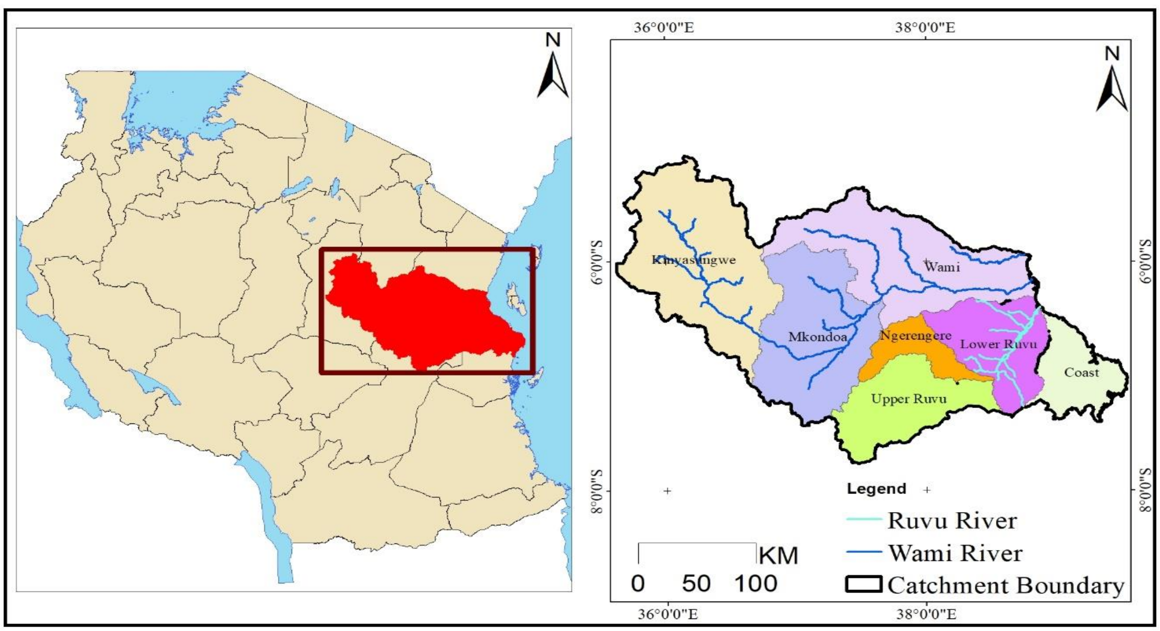

Figure 1: Location of the study area, Wami–Ruvu Basin (WRB), Tanzania

2.2 Data Sources

The analysis of the study was conducted using Landsat satellite imagery data. The analysis was developed for two decades in the study area, covering two epoch periods which are 2000, 2010, and 2020. At a spatial resolution of 30 m and were acquired in the same season of the year (July–September) with minimal cloud cover (<10%). The datasets downloaded were surface reflectance for Landsat 5 TM images acquired in 2000, Landsat 7 ETM + for 2010 and Landsat 8 OLI images for 2020. These Landsat images were acquired along WRS-2 paths 166 to 168 and row 64 and 65, downloaded from Earth Explorer (usgs.gov). A total of 18 Landsat scenes covering the study area were collected. Thereafter, the corrected Landsat images were mosaicked into a single composite image and subset to study the area boundary. Detailed information on the Landsat images is presented in the Table below.

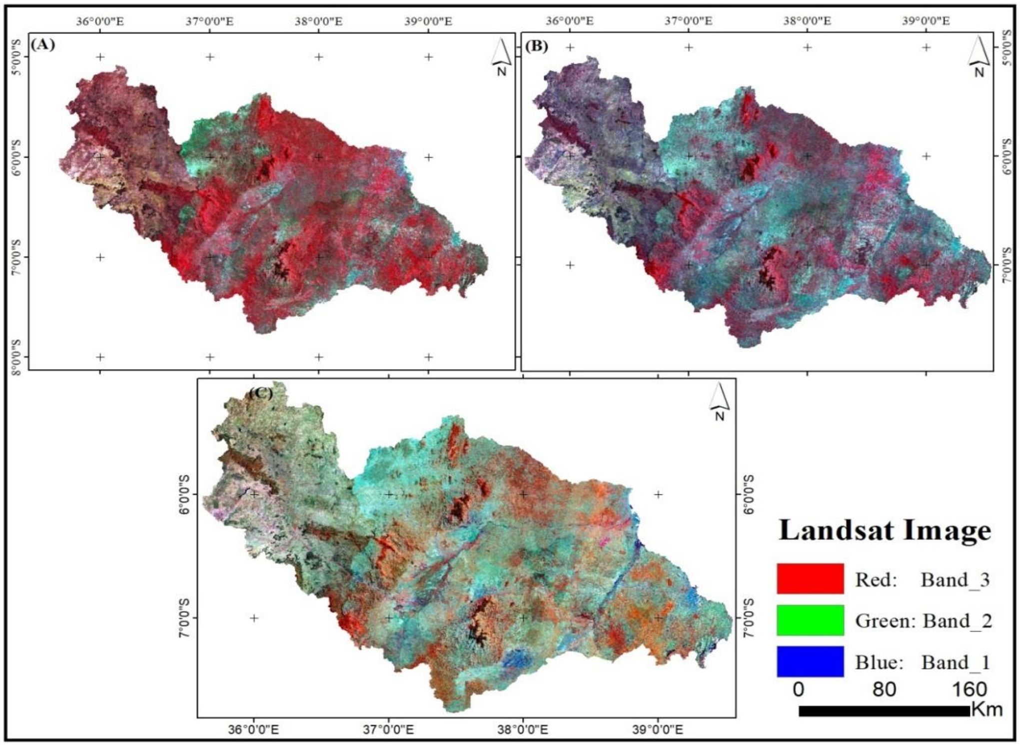

Figure 2: Composite Landsat images of 2000, 2010 and 2020 for the Wami Ruvu river basin

Table 1: Description of LULC classes used in the study

S/N	LULC Classes	Description
1	Built-up Area	Urban settlements, Rural/Trading centers, transportation networks, commercial and industrial areas
2	Water	Perennial water bodies, lakes, ponds and other water reservoirs, and flowing water confined in a channel
3	Bare land	Exposed field of land and sand fill area
4	Bush land	Shrubs, scrub and bushed
5	Agriculture land	Agriculture fields
6	Woodland	Open Crown trees
8	Forest	Evergreen and semi-evergreen forest cover.
9	Wetland	Covered with shallow water

Classification performed in the Wami-Ruvu river basin consist of eight major classes of land use/cover were identified which are forest, agricultural land, water body, forest, bare-land, bush-land, woodland, built-up area and wetland. To develop the accurate result of classification from Landsat images we applied an integrated image classification method which involves the combination of both spectral bands and various indexes approach. The common indices used are the normalized difference vegetation index and modified normalized difference water index which are widely used indices to retrieve the vegetation and water information from satellite image bands.

Table 2: Details description of Landsat images used

SN	Sensor	Date of acquisition	Path	Row	Resolution	Clouds Cover
3	**Landsat 5ETM**	11-07-2001	166	64	30 Meter	0%
4		11-07-2001	166	65	30 Meter	0%
5		07-07-2001	167	64	30 Meter	<5%
6		07-07-2001	167	65	30 Meter	<1%
5		06-07-2001	168	64	30 Meter	0%
6		10-10-2001	168	65	30 Meter	0%
	Landsat 7 ETM +	07-10-2011	166	64	30 Meter	0%
1		07-10-2011	166	65	30 Meter	0%
3		14-10-2011	167	64	30 Meter	0%
4		17-05-2011	167	65	30 Meter	0%
5		14-10-2011	168	64	30 Meter	0%
6		17-05-2011	168	65	30 Meter	0%
3	**LANDSAT 8-OLIS**	10-10-2021	166	64	30 Meter	<3%
4		06-07-2021	166	65	30 Meter	<5%
5		10-10-2021	167	64	30 Meter	<3%
6		06-07-2021	167	65	30 Meter	<5%
7		14-08-2021	168	64	30 Meter	0%
8		14-08-2021	168	65	30 Meter	0%

The research framework consisted of four parts: data preparation, classification of time series imagery, and wetland degradation analysis and wetland degradation driving factors analysis, initially remote sensing images, ancillary datasets, and reference datasets were collected and pre-processed. time series classification maps from 2000 to 2020 were produced through visual interpretation methods using Landsat imagery. Then, the historical dynamics of the different wetland types were analysed dataset used in the study and their sources are shown in the table below.

Table 3: Details description of the dataset used and their sources

S/N	Dataset used	Data source
1	Landsat TM/OLI	Earthexplorer.usgs.gov
2	Google Earth images	http://earth.google.com
3	Study area Boundary	the national bureau of statistics (NBS)
4	Population data	the national bureau of statistics (NBS)
5	Weather data	Climateengine.com/data

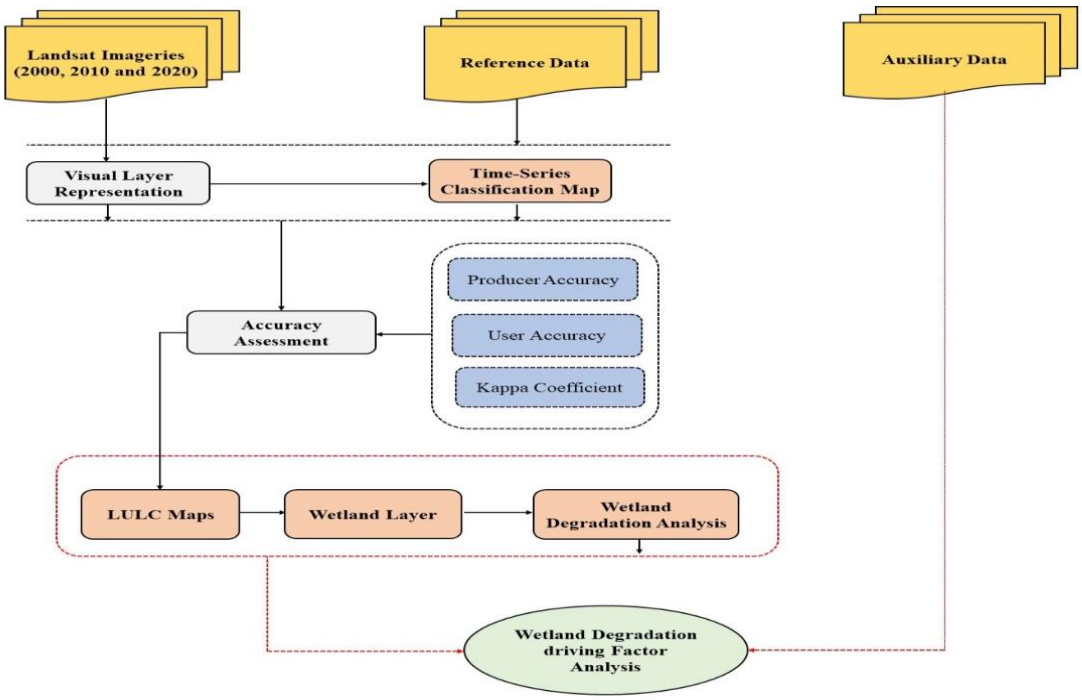

Figure 3: A general framework for the study design

2.3 Reference Datasets

Reference data for the three epochs years for this study were derived from visual interpretation of Google Earth historical images (http://earth.google.com). Through the above methods, the reference datasets for 2000, 2010 and 2020 were successfully established as shown below in figure 4.

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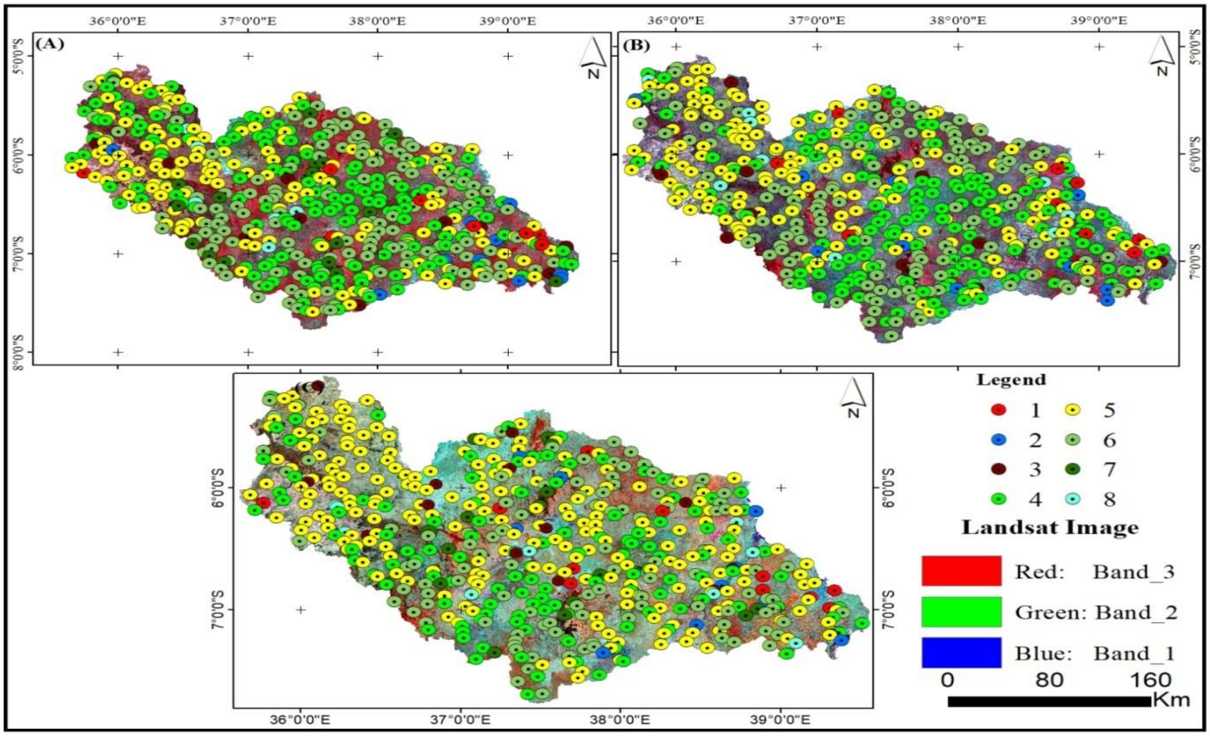

Figure 4: Ground truthing point for accuracy assessment of LULC

Key: *Where by* 1-*built-up,* 2-*water,* 3-*bare-land,* 4-*bushland,* 5-*agriculture,* 6-*woodland,* 7-*forest and* 8-*wetland*

2.4 Land Use/Cover Classification System

To better understand the wetland distribution in the Wami-Ruvu river basin, a land use/cover classification system was established based on the Ramras Convention and the results of the National Land Use Framework Plan Volume I, 2009 wetland survey. Considering the importance of vegetation growth and water content in wetland classification, the normalized difference vegetation index (NDVI), and modified normalized difference water index (MNDWI) were, used as rule layers to characterize vegetation and Water background, respectively in addiction Normalized Difference Built-up Index (NDBI) was used to separate and define the developed and bare land in the basin in our classification system.

Wami ruvu river basin classification was determined using three steps, the first step is the development of training datasets for various land use/cover the second one is classifiers selection and running of the model and the final stage is manual classification refinements. Each training dataset for existing cover for the study area was trained on a sample of 1000 permanent pixels for 2000, 2010 and 2020 from Landsat data and Google Earth images. Therefore, the training datasets were randomly selected.

In this classification system developed in the wami-ruvu river basin, the Random Forest classification technique was adopted for Landsat images in R software. Random Forest is a supervised classification technique method which is a non-parametric ensemble machine-learning algorithm developed by Breiman. The RF algorithm has been widely applied for solving environmental problems, like water resource management and natural hazard management. It can handle a variety of data, like satellite imagery, and numerical data. It is an ensemble learning method based on a decision tree, which combines with massive ensemble regression and classification trees.

An integrated classification method was used in this classification by incorporating three satellite indices which include normalized differential vegetation index (NDVI), modified normalized difference water index (MNDWI) and normalized differential built-up index (NDBI), which were calculated for this purpose. Each index was added as a single band in addition to the satellite bands to have a single complex composite image. The formulas for calculated indices are shown below. Where *NIR, Red and SWIR* are the spectral reflectance values in the TM ETM+ and OLI. These equations both produce values in the range from -1 to 1.

NDVI = (NIR – Red) / (NIR + Red) …………………………….……. (1)

NDBI = (SWIR – NIR) / (SWIR + NIR) ……………………………... (2)

MNDWI = (Green – SWIR) / (Green + SWIR) ……………………..... (3)

Several previous studies have reported that the different band combinations can be a crucial factor for identifying different land cover types. hence the above indices result and the combination can be very useful for classification in the wami-Ruvu river basin.

2.5 Analysis System for the Wetland Ecological Degradation Process

Wetland degradation forms the theoretical basis for the study and by using remote sensing techniques; the analysis of this study for the Wami Ruvu River Basin Wetland degradation process was constructed based on three different aspects (area degradation rate, annual land use/cover area change and land use/cover change rate).

2.2.1 Area change rate

The reduction in wetland area is the most direct index of wetland ecosystem degradation. The Wetland area change rate reflects the degree of change in wetland area across the enter basin across different years and describes the change in area as a percentage of the original wetland area, which can therefore reflect the wetland degradation rate (Shen et al., 2019).

Therefore, this study selected this index for the wetland area change rate to characterize the area degradation of the Wami-Ruvu river basin Wetlands. The Wetland area change rate is calculated as;

$$RAC = \frac{EA - IA}{IA} * 100$$

Where by

RAC Is wetland area change rate

EA is the end wetland area

IA is the initial wetland area that refers to the year with no or little change in the wetland area compared to the other years.

Two other indices were being annual land cover change area (ALCA) and annual land cover change rate (ALCR), were used to calculate the dynamic degree of land cover types changes. And were determined through the use of below formula;

$ALCA = (LC1 - LC0) * 1/T$ ……………………….……………….. Equation 1

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$ALCR = (LC1 - LCO)/LCO * 1/T) * 100\%$........................Equation 2

Where LC1 and LC0 represent the area of each land cover type at the beginning and the end of the study period, and T is the number of years. In the study, the time interval was divided into two stages (2000–2010) and (2010–2020).

3.RESULTS

3.1. Spatial-Temporal Changes of Land Use/ Cover Types in Wami-Ruvu river basin (2000-2020)

The LULC of the Wami Ruvu river basins were prepared through the interpretation of multispectral remote sensing satellite data of the years 2000, 2010 and 2020. Knowledge about the spatial distribution of LULC and the rate of change over some time is essential in the planning and management of land resources at local and regional levels (Akumu & Henry, 2018). The LULC changes in the Wami-Ruvu river basin were studied using historical Landsat imagery data from 2000, 2010, and 2020. The area under various land use/land covers, rate of change and per cent change during the periods of (2000–2010 and 2010–2020) were generated using thematic change analysis workflow in Envi 5.3 and are presented in the table below,

Table 4: Random Forest classification ALCA and ALCR analysis results of 2000, 2010 and 2020 in the Wami-Ruvu river basin.

LULC_Classes	Area (KM2)	Area (KM2)	Area (KM2)	ALCA(KM2)			ALCR (%)		
Year	**2000.0**	**2010.0**	**2020.0**	**2000-2010**	**2010-2020**	**2000-2020**	**2000-2010**	**2010-2020**	**2000-2020**
Built up	468.3	1184.0	2012.6	71.6	82.9	77.2	15.3	7.0	16.5
Water	279.1	235.8	227.2	-4.3	-0.9	-2.6	-1.6	-0.4	-0.9
Bare land	1675.6	1463.5	2029.4	-21.2	56.6	17.7	-1.3	3.9	1.1
Bush land	21636.7	19752.8	17143.1	-188.4	-261.0	-224.7	-0.9	-1.3	-1.0
Agriculture	19748.1	22003.3	28499.5	225.5	649.6	437.6	1.1	3.0	2.2
Woodland	19648.1	19491.0	14651.1	-15.7	-484.0	-249.9	-0.1	-2.5	-1.3
Forest	2757.1	2102.8	1944.8	-65.4	-15.8	-40.6	-2.4	-0.8	-1.5
Wetland	1209.1	949.0	521.3	-26.0	-42.8	-34.4	-2.2	-4.5	-2.8
TOTAL	67182	67182	67182						

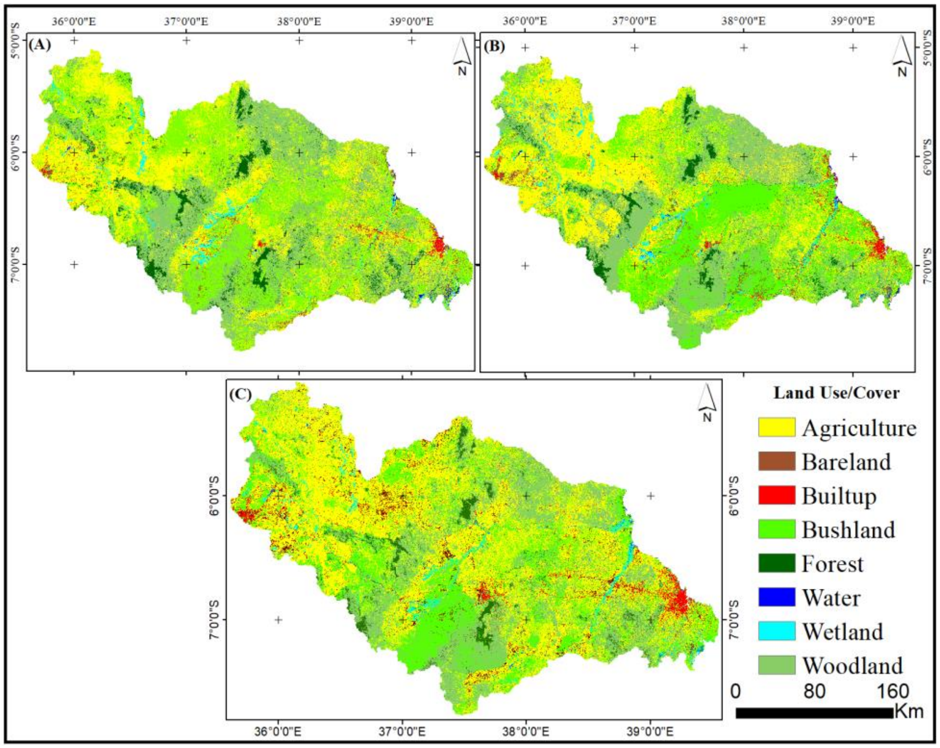

Figure 5: classified image of Landsat of (A) 2000, (B) 2010 and (C) 2020

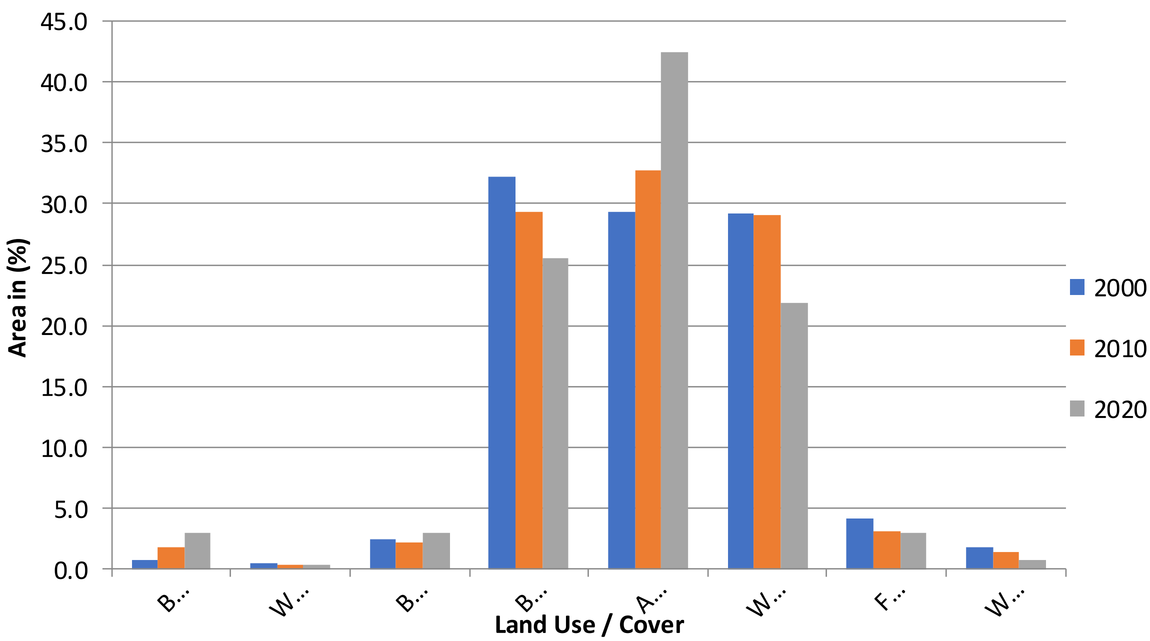

Figure 6: Area percentage of land use/cover for the Wami-Ruvu river basin in 1990, 2000 and 2020

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3.2. Spatial-Temporal Changes of Land Cover Types

Table 5: Spatial-Temporal Changes of Land Cover Types

Wami Sub Basin									
	Coverage			ALCA (km2/y)			ALCR(%/y)		
LULC	2000(KM)	2010(KM)	2020(KM2)	2000-2010	2010-2020	2000-2020	2000-2010	2010-2020	2000-2020
Built-up	140.70	399.03	650.12	25.83	25.11	25.47	18.36	6.29	18.10
Water	70.01	103.44	139.28	3.34	3.58	3.46	4.77	3.47	4.95
Bare land	779.67	792.24	1450.87	1.26	65.86	33.56	0.16	8.31	4.30
Bushland	13866.96	10728.04	11025.02	-313.89	29.70	-142.09	-2.26	0.28	-1.02
Agriculture	14432.42	17217.09	20477.11	278.47	326.00	302.23	1.93	1.89	2.09
Woodland	11760.62	12510.52	8325.24	74.99	-418.53	-171.77	0.64	-3.35	-1.46
Forest	1852.11	1451.95	1161.07	-40.02	-29.09	-34.55	-2.16	-2.00	-1.87
Wetland	839.84	540.01	513.00	-29.98	-2.70	-16.34	-3.57	-0.50	-1.95
Total	**43742.33**	**43742.31**	**43741.72**						

Ruvu Sub basin									
	Coverage			ALCA (km2/y)			ALCR(%/y)		
LULC	2000(KM2)	2010(KM2)	2020(KM2)	2000-2010	2010-2020	2000-2020	2000-2010	2010-2020	2000-2020
Builtup	125.2	263.8	422.2	13.86	15.84	14.85	**11.1**	**6.0**	**11.9**
Water	79.2	68.3	56.8	-1.09	-1.14	-1.12	**-1.4**	**-1.7**	**-1.4**
Bareland	631.1	442.0	533.2	-18.91	9.12	-4.89	**-3.0**	**2.1**	**-0.8**
Bushland	5963.1	6392.9	4802.9	42.98	-159.00	-58.01	**0.7**	**-2.5**	**-1.0**
Agriculture	3799.1	4330.3	6389.6	53.12	205.92	129.52	**1.4**	**4.8**	**3.4**
Woodland	6259.9	5539.1	4960.2	-72.08	-57.89	-64.98	**-1.2**	**-1.0**	**-1.0**
Forest	708.9	545.2	494.9	-16.37	-5.04	-10.70	**-2.3**	**-0.9**	**-1.5**
Wetland	222.6	207.1	129.3	-1.55	-7.78	-4.66	**-0.7**	**-3.8**	**-2.1**
Total	**17789.2**	**17788.8**	**17789.1**						

Coastal Sub basin									
	Coverage			ALCA (km2/y)			ALCR(%/y)		
LULC	2000	2010	2020	2000-2010	2010-2020	2000-2020	2000-2010	2010-2020	2000-2020
Built-up	189.3	287.0	521.9	9.8	23.5	16.6	5.16	8.19	8.79
Water	85.4	57.4	40.1	-2.8	-1.7	-2.3	-3.29	-3.00	-2.66
Bare land	232.9	227.1	128.7	-0.6	-9.8	-5.2	-0.25	-4.33	-2.24
Bush land	1420.8	1558.1	1120.5	13.7	-43.8	-15.0	0.97	-2.81	-1.06
Agriculture	1051.1	1158.4	1601.0	10.7	44.3	27.5	1.02	3.82	2.62
Woodland	1452.3	1321.2	1218.8	-13.1	-10.2	-11.7	-0.90	-0.77	-0.80
Forest	190.0	106.4	94.1	-8.4	-1.2	-4.8	-4.40	-1.16	-2.52
Wetland	141.3	47.9	37.9	-9.3	-1.0	-5.2	-6.61	-2.09	-3.66
Total	**4763.1**	**4763.4**	**4763.1**						

3.3 Classification Accuracy Assessment

Accuracy assessment plays an important role in image classification to validate the LULC. Many pixels remain misclassified because of the uneven distribution of the data. In this study, an accuracy assessment was conducted by summarizing and quantifying the data using an error matrix. Four different accuracy results were produced including producer accuracy, user accuracy, overall accuracy, and kappa coefficient index from overall accuracy assessment which provide a better understanding of the classification accuracy. The kappa values greater than 0.75 suggested that the maps agree reasonably with the reference data (Singh et al., 2020). The overall assessment results of each classified image from 2000 to 2020 are shown in the table below.

Table 6: Summary of LULC classification accuracies (%) from 2000 to 2020

SN	LU/LC Classes	2000		2010		2020	
	Accuracy	**User**	**Producer**	**User**	**Producer**	**User**	**Producer**
1	Built-up	70.0	77.8	60.0	66.7	71.4	83.3
2	Water	100.0	53.8	70.0	63.6	68.8	84.6
3	bare land	50.0	100.0	45.5	71.4	58.8	83.3
4	bush land	93.2	84.0	94.8	88.8	92.7	90.1
5	Agriculture	86.5	90.8	92.9	92.9	91.6	92.9
6	Woodland	96.8	94.9	96.2	94.9	96.0	92.4
7	Forest	85.7	100.0	83.3	93.8	88.2	83.3
8	Wetland	100.0	100.0	72.7	72.7	75.0	60.0
	Overall Accuracy	89.3		89.8		90.2	
	Kappa Statistics	85.7		86.5		87.0	

3.4 Land Cover/Use Temporal Changes Analysis

Land cover/use temporal changes of the Wami-Ruvu basin between 2000-2020 were analysed through annual area land cover change and Annual land cover change rate analysis as illustrated in the table above. The results show that the basin experience a gradual high rate of annual depletion of the wetland of a total area -26.01(km^2/y) to -42.8(km^2/y) between 2000-2010 to 2010-2020 with an annual land cove change rate of -2.15(%/y) to -4.51(%/y).

Other Land Use/Cover also experience gradual degradation such as Forest degraded from -65.4(km^2/y) to -15.8(km^2/y) with ALCR of -2.37(%/y) to -0.75(%/y) of loss, Bush land decrease by -188.4 (km^2/y) to -261.0 (km^2/y) in area of coverage with ALCR of -0.87 (%/y) to -1.32 (%/y), woodland loses -15.7(km2/y) to -484.0(km2/y) with -0.08(%/y) -2.48(%/y), bare land changed into other land uses by -21.2(km2/y) to 56.6(km2/y) with ALCR of -1.27 (%/y) to 3.87(%/y), open water in lakes and river within the basin degraded in area coverage from -43.3(km2/y) to -4.3(km2/y) with ALCR of -1.55(%/y) to -0.37(%/y) the degradation of these land cover occurred due to increase of various human activities such as human settlement (built-up) which increase in area coverage from 71.6 (km2/y) to 82.9(km2/y) with ALCR Of

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15.28(%/y) to 7.00 (%/y) the increase of human dominance in the basin result to the expansion of agriculture activities coverage area from 225.5(km2/y) To 649.6(km2/y) with ALCR of 1.14(%/y) To 2.95(%/y) .

3.5 In Sub-basin Level

Wami Sub-basin

Wami sub-basin covering 64% of the whole basin has experienced a high increase in human activities between 2 epochs of the study area, the sub-basin experience increase of built-up area from 141km^2 in 2000 to 650km^2 in 2020 with ALCA (km^2/y) of 25.8 (km^2/y) to 25.1 (km^2/y) with ALCR of 18.4(%/y) to 6.3(%/y) between 200-2010 to 2010-2020, agriculture expand from 14432km^2 in 2000 to 20477km^2 in 2020 with ALCA of 278.5(km2/y) to 3026.0 (km2/y), open water increase from 70km^2 in 2000 to 139km^2 in 2020 with ALCA of 3.3 (km^2/y), to 3.6(km^2/y), a bare-land increase from 780km2 to1451km2 with ALCA of 1.3 to 65.9 with ALCR Increase of 0.2 (%/y) to 8.3(%/y). Bush land and woodland land cover experience increase and decrease within 2 epochs of the study, as bush land decrease in the area of coverage from 13867km^2 in 2000 to 10728 km^2 in 2010 while increased in 2020 to 11025km^2 the loss between 2000 to 2010 is equal to -313.9 km^2/y with the rate of -2.3(%/y) and increase of 29.7(km^2/y) with the rate of 0.3(%/y) between 2010 to 2020.

And woodland increased from 11761km^2 in 2000 to 12511km^2 in 2010 with ALCA of 75.0(km^2/y) with a rate of increase of 0.6(%/y) while experiencing degradation of -418.5(km^2/y) at the rate of -3.3(%/y) between 2010 to 2020.

Wetlands in the Wami sub-basin experienced gradual degradation in area coverage from 840km^2 in 2000 to 513km^2 in 2020 with ALCA of -30.0(km^2/y) to -2.7(km^2/y) and with ALCR degradation of -3.6(%/y) to -0.5(%/y) between 200-2010 to 2010-2020, the same scenario happens to the forest which degraded from 1852km2 to 1161 km2 between 2000-2020 with ALCA loss of -40.0(km^2/y) to -29.1(km^2/y) with ALCR of -2.2-3.6(%/y) to -2.0-3.6(%/y) in 2000-2010 and 2010-2020.

3.5.1 Ruvu Subbasin

In the Ruvu sub-basin, the situation is the same it experienced gradual degradation of various land cover comparisons due to the increase of various major human activities. Agriculture as a dominant human activity in the basin expands twice between the study period of 2000 to 2020 it increased from 21.4% to 35.9% of coverage within the sub-basin which include expansion of both irrigation and rain-fed farms and become one of the dominant land uses in the basin. In Ruvu sub-basin Built-up experienced a gradual increase from 0.7% to 2.4% between 2000 to 2020 during the first epoch of ten years between 2000-2010 the built-up area increases higher in the other epoch period with ALCR and ALCA of 11.1(%/y) and 13.9(km2/y).

Wetland, Open water, forest, bare land and woodland were the major degraded land use/cover affected in the basin as Wetlands experienced a degradation rate of ALCR of -0.7(%/y) to -3.8(%/y) between 2000-2010 to 2010-2020, forest experience degraded with ALCA of 16.4 (km2/y) to 5.0(km2/y) where it marks the high rate of degradation in the between 2000-2010

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with ALCR loss of -2.3(%/y), open water found in river and dam within Ruvu river sub-basin experience slowly gradual change between the study period as it degraded its coverage area from 0.4% to 0.3% degraded from 2000-2020 with ACLA of -1.1 (km2/y) to -1.4(km2/y) between 2000-2010 and 2010-2020 also bare land experience steady degradation by 1.0% between 2000-2010 with ALCA of -18.9 (km2/y) and degradation rate of -3.0 (%/y)

While 2010-2020 the area for bare land increased by 0.5% with an ALCA of 9.1 (km2/y) with a rate of increase of 9.1(%/y). Woodland experience severe conversion/degradation in this sub-basin as it degraded from 6259.9 km2 to 4960.2 with ACLA loss of -72.1(km2/y) to -57.9(km2/y) between 2000-2010 to 2010-2020.

3.5.2 Coastal Sub-basin

In the coastal sub-basin, built-up and agriculture experienced an increase annually and become the major human activities in the basin, built-up increased in the basin by 7% between 2000-2020 with a major increase between 2010- 2020 where the major expansion of urban area occurred by 5% of land use in the basin with ALCA of 23.5(km2/y) and rate of (8.2 km2/y). While agriculture increased by 11.5% within the study period with ALCA of 10.7(km2/y) to 44.3(km2/y) and ALCR of 1.0(%/y) To 3.8(%/y), the major increase was noticed in second epoch of 2010-2020 where the increase rate was 3.8(%/y) with ALCA of 44.3(8.2 km2/y). Bush land experienced a gradual increase of area coverage where woodland and forest were converted to bush land hence it increases its area by 11.5% of the total area with ALCA of 10.7(km2/y) to 44.3(km2/y) between 2000-2010 to 2010-2020.

The Coastal sub-basin experienced major degradation of other major land use/cover found in the basin. During 2000-2010 wetlands degraded by -9.3 (km2/y) with a rate of -6.6(%/y) with slow degradation in the second epoch of 2010-2020 with ALCA of -1(km2/y) And ALCR of -2.1(%/y). Open water degraded by 1% within the study area with an ALCA of -2.8(km2/y) to -1.7(km2/y). Woodland and forest experienced major area reduction in the coastal sub-basin whereby forest area degraded by half of its coverage area from 4.0% in 200o to 2% in 2020 while woodland experienced a small conversion by 9.9% of its area into other land use/cover in 2020 agriculture and built increase result to deduction of bare land by 2.2% of total coverage area between 2000-2020 with ALCA of -0.6(km2/y) To -9.8(km2/y) and ALCR of -0.3(%/y) To -4.3(%/y).

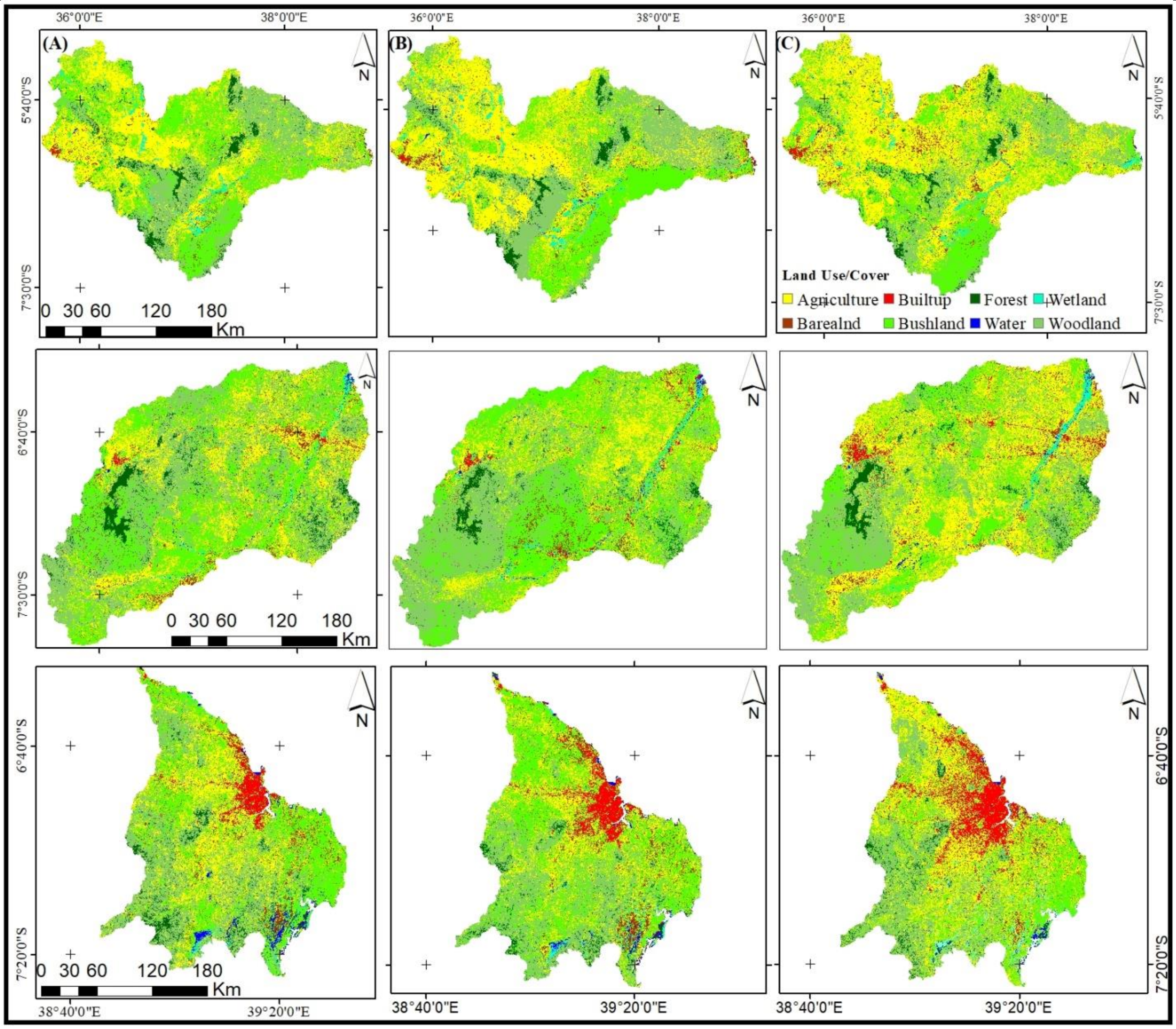

Figure 7: The classification results in sub-basin levels A (2000), B (2010), and C (2020)

3.6 Wetland Area degradation process

The result of the wetland area change rate for the years 2000, 2010 and 2020 for the Wami-Ruvu river basin was well calculated and the results are shown in table 7 respectively. The negative values indicate that the wetland area was degraded and it was observed that the Wami-Ruvu river basin experienced a severe rate of wetland degradation in the year between 2010-2020. The wetland area change rate was negative for all periods of study in the basin. Only the Wami sub-basin shows a decrease in wetland area change in the year between 2010-2020 the wetland area for other sub-basin gradually increased in degradation across the study period concerning the temporal aspect, the most severe wetland degradation occurred in 2010 in the basins.

In terms of spatial distribution in degradation rate Ruvu sub-basin, the second largest in terms of the area of coverage experienced a larger degradation rate in all two epochs. Followed by the

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Coastal sub-basin with a highly moderate rate of wetland degradation. Wami-sub-basin experienced a low rate of wetland degradation except for the year between 2000-2010 when it experiences a higher rate of degradation than the Ruvu sub-basin. The severity of wetland degradation is shown in the table below.

Table 7: Statistical results of wetland area degradation rate (%)

Sub-basin	2000	2010	2020
Coastal	-27.67576982	-75.45235473	-80.58019361
Ruvu	-61.45959532	-64.1446514	-77.61372681
Wami	-11.93805194	-43.37741657	-46.20897984

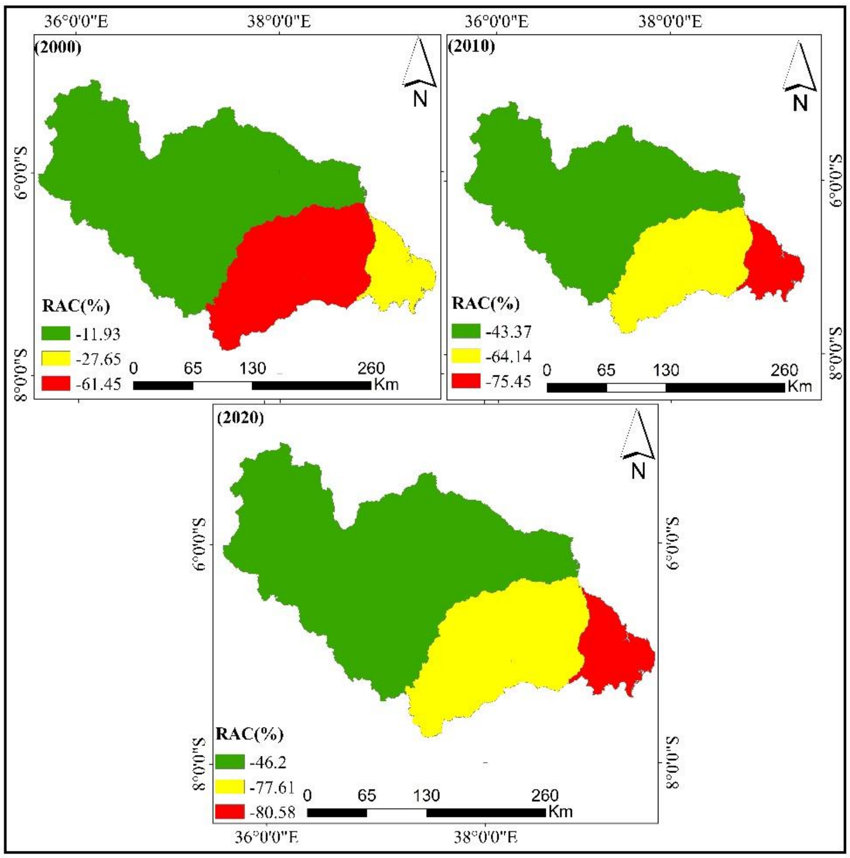

Figure 8: Wetland area change rate in Wami-Ruvu river sub-basins

3.7 Driving forces of wetland degradation in the Wami-Ruvu basin

According to the spatial-temporal classification analysis, the driving factors for dynamic wetland degradation were mainly caused by rapid economic development and natural environmental factors. To reach a well sympathetic of the drivers of wetland degradation, relationships between various driving factors both climate change, socioeconomic factors and land use change are

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analysed. The relationships were established Through the use of the quantitative correlation between wetland areas and each factor contributing to wetland degradation. Agriculture and settlement area increase is an important factor in the analysis of driving forces in the Wami-Ruvu river basin.

Urban expansion (urban population growth) and the increase of other social economic activities in the basin such as the increase of expansion of agricultural land were the main drivers' factors for wetland degradation from 2000 to 2020. Annual mean precipitation and temperature were selected because they have a direct impact on biomass productivity, which determines the development of vegetation and were considered natural factors causing wetland degradation. Linear correlation was established between wetlands and above mention factor and used to examine their relationship. According to the linear correlation of socio-economic factors, both human settlement and agricultural activities have a greater impact on wetland degradation than climatic factors.

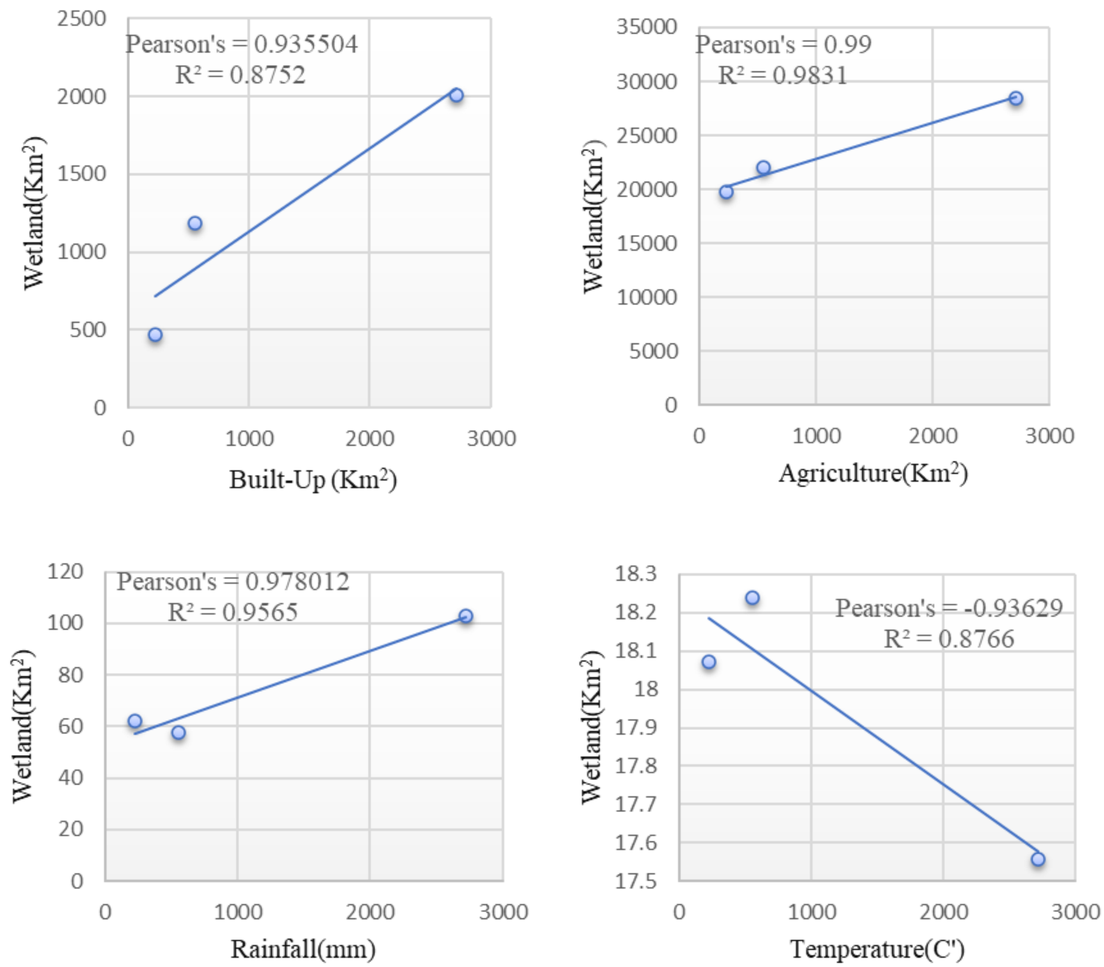

Figure 9. The relationship between the wetland and four variables (Total precipitation, Mean temperature, Built-up, population Size, Agriculture

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4.DISCUSSION

This study aims to assess and map the extent, condition and trends of wetlands found in Wami Ruvu river basin using land use/cover changes as an indicator factor for influencing wetlands degradation. Through the results of study, a trend of land use/cover changes is showing annual shrinking of wetlands and it is identified that the wetlands, bush land and woodland are the most affected by anthropogenic activities. mainly because they provide the most arable land in the basin for cultivation and for human settlements, due to the fact that these areas have secure water annually and provide security to farmers especially who depend on rainfall cultivation. Through the analysis of land use/cover changes between 2000-2010 it shows larger changes where by the basin experience extremely increase of human agriculture activities and hence mark a higher level of agriculture land expansion. While between 2010-2020 the basin experience extremely urban sprawl with expansion and conversion of various land use/cover into urban land in all urban and village centre.

Generally, between the period of 2000-2020 the basin undergoes major transformation cause by human activities especially agriculture by almost half percentage coverage of the whole basin hence making the dominant land use. Through the analysis of land use/cover changes between the study period Vegetation land cover such as woodland, bush land, forest and water were the dominant affected through the expansion of human development activities. The worsen is that 34.4km^2 of wetland is lost every year in wami-ruvu river basin which is equal to 680km^2 for 20 years have been lost. And 515.2km^2 of vegetation cover have been converted to human activities.

In this study, we use RAC, ALC and ALCR the results obtained using these methods, for an assessment of basin wetland degradation was established, and a picture of annual wetland degradation status has been realized. Hence The applicability of a model is fundamental to its wide application for other basins at national and regional (Lu et al., 2019; Shen et al., 2019)

Wetlands degradation increase has been observed in other several wetlands in other basins in the country such as in Eastern Usangu, which experience a higher rate of degradation due to human development without taking any efforts by the government to protect the wetland it could have been completely depleted by now,(John Mwita, 2016). Also, Lake Victoria wetlands, have suffered significantly from degradation. Infestation of water hyacinth since the 1990s, resulting from increased nutrients due to pollution from various sources in the lake, illegal fishing practices, farming in the fringes of the wetland and the ever-growing needs of the population continue to threaten the lake ecosystem (Mkanda, 2002; Mugo et al., 2020; Verschuren et al., 2002).

The laws and policies governing environmental resource use and management are in place but are not in practice, the government should enforce them, there is Poor enforcement of policies and laws in the Wami - ruvu basin with political interference and hence accelerated the degradation of resources in the basin. Also lack awareness on proper usage of wetlands by local people become a key factor for the increase of wetland degradation and jeopardizing their future existence. Awareness creation on wetlands through various media such as radio and Television programs, newspapers and the use of extension officers to educate farmers and livestock keepers can also contribute to active involvement and greater public participation in issues related to the conservation and management of wetlands (H, 2001).

5.CONCLUSIONS

This study has been carried out to assess and analyse the spatial and temporal changes in wetland areas and land use/cover in the Wami-Ruvu basin using GIS and Remote sensing techniques. The results show that the area for built-up, agriculture and bare lands has been gradually increasing at the expense of a decrease of open water, wetland, forest, woodland, and bush land between the years 2000-2020. This gradual decrease in wetland area is contributed mainly by the increase of human activities within the wetland and surrounding the wetland boundaries which is well observed in classified land use/cover images with kappa statistics above 75%.

This study demonstrates successfully that remote sensing and geographical information system techniques that we used are useful as baseline scaling up to the regional and continental level in assessing the loss and degradation of wetlands and other land use/cover loss. The methods and results from this study can help our understanding of wetland changes and their driving forces in a wide area. These conclusions can be used as a guide for the bilateral government policymakers in formulating the conservation and rehabilitation plans for these wetlands for effective protection and management of wetlands for sustainable development.

REFERENCE

Akumu, C. E., & Henry, J. (2018). *Digital Scholarship @ Tennessee State University Inland wetlands mapping and vulnerability assessment using an integrated geographic information system and remote sensing techniques*. *4*(4), 387–400. https://doi.org/10.22034/gjesm.2018.04.001

Assefa, W. W., Eneyew, B. G., & Wondie, A. (2021). The impacts of land-use and land-cover change on wetland ecosystem service values in peri-urban and urban area of Bahir Dar City, Upper Blue Nile Basin, Northwestern Ethiopia. *Ecological Processes*, *10*(1). https://doi.org/10.1186/s13717-021-00310-8

Beuel, S., Alvarez, M., Amler, E., Behn, K., Kotze, D., Kreye, C., Leemhuis, C., Wagner, K., Willy, D. K., Ziegler, S., & Becker, M. (2016). A rapid assessment of anthropogenic disturbances in East African wetlands. *Ecological Indicators*, *67*, 684–692. https://doi.org/10.1016/j.ecolind.2016.03.034

Davidson, N. C. (2014). How much wetland has the world lost? Long-term and recent trends in global wetland area. *Marine and Freshwater Research*, *65*(10), 934–941. https://doi.org/10.1071/MF14173

Gardner, R. C., Barchiesi, S., Beltrame, C., Finlayson, C. M., Galewski, T., Harrison, I., Paganini, M., Perennou, C., Pritchard, D., Rosenqvist, A., & Walpole, M. (2015). State of the World's Wetlands and Their Services to People: A Compilation of Recent Analyses. *SSRN Electronic Journal*, *June*. https://doi.org/10.2139/ssrn.2589447

Guo, M., Li, J., Sheng, C., Xu, J., & Wu, L. (2017). A review of wetland remote sensing. *Sensors (Switzerland)*, *17*(4), 1–36. https://doi.org/10.3390/s17040777

H, J. G. K. (2001). Minireview Restoration and management of mangrove systems - from the East African region. *South African Journal of Botany*, *67*(3), 383–389. https://doi.org/10.1016/S0254-6299(15)31153-4

Hu, T. (2020). *Evaluation of historical and future wetland degradation using remote sensing imagery and land use modeling*. *July 2019*, 65–80. https://doi.org/10.1002/ldr.3429

Islam, H., Abbasi, H., Karam, A., Chughtai, A. H., & Jiskani, M. A. (2021). *Geospatial analysis* *of wetlands based on land use / land cover dynamics using remote sensing and GIS in*. *104*(2), 1–22. https://doi.org/10.1177/00368504211026143

Jamal, S., & Ahmad, W. S. (2020). Assessing land use land cover dynamics of wetland ecosystems using Landsat satellite data. *SN Applied Sciences*, *2*(11), 1–24. https://doi.org/10.1007/s42452-020-03685-z

John Mwita, E. (2016). Monitoring Restoration of the Eastern Usangu Wetland by Assessment of Land Use and Cover Changes. *Advances in Remote Sensing*, *05*(02), 145–156. https://doi.org/10.4236/ars.2016.52012

Keshta, A. E., Riter, J. C. A., Shaltout, K. H., Baldwin, A. H., Kearney, M., El-din, A. S., & Eid, E. M. (2022). *Loss of Coastal Wetlands in Lake Burullus , Egypt : A GIS and Remote-Sensing Study*. 1–16.

Kogo, B. K., Kumar, L., & Koech, R. (2021). Analysis of spatio-temporal dynamics of land use and cover changes in Western Kenya. *Geocarto International*, *36*(4), 376–391. https://doi.org/10.1080/10106049.2019.1608594

Lefebvre, G., Willm, L., Campagna, J., & Redmond, L. (2019). *Introducing WIW for Detecting the Presence of Water in Wetlands with Landsat and Sentinel Satellites*. 10–14.

LIBERATH, G., & A. (2017). *Analysis of Drivers and Economic Consequences of Wetland*. 1–97.

Lu, C. Y., Ren, C. Y., Wang, Z. M., Zhang, B., Man, W. D., Yu, H., Gao, Y. Bin, & Liu, M. Y. (2019). Monitoring and assessment of wetland loss and fragmentation in the cross-boundary protected area: A case study of Wusuli River Basin. *Remote Sensing*, *11*(21). https://doi.org/10.3390/rs11212581

Mao, D., Tian, Y., Wang, Z., Jia, M., Du, J., & Song, C. (2021). Wetland changes in the Amur River Basin: Differing trends and proximate causes on the Chinese and Russian sides. *Journal of Environmental Management*, *280*(August), 111670. https://doi.org/10.1016/j.jenvman.2020.111670

Mkanda, F. X. (2002). *Contribution by farmers ' survival strategies to soil erosion in the Linthipe River Catchment : implications for biodiversity conservation in Lake Malawi / Nyasa*.

Mombo, F., Speelman, S., Huylenbroeck, G. Van, & Hella, J. (2011). *Ratification of the Ramsar convention and sustainable wetlands management : Situation analysis of the Kilombero Valley wetlands in Tanzania*. *February 2016*.

Mugo, R., Waswa, R., Nyaga, J. W., Ndubi, A., Adams, E. C., & Flores-Anderson, A. I. (2020). Quantifying land use land cover changes in the lake victoria basin using satellite remote sensing: The trends and drivers between 1985 and 2014. *Remote Sensing*, *12*(17), 1–17. https://doi.org/10.3390/rs12172829

Mwakaje, A. G. (2009). Wetlands, livelihoods and sustainability in Tanzania. *Africafile:///C:/Users/User/Downloads/Local_Knowledge_on_the_Influence_of_Land_Use Cover_.Pdfn Journal of Ecology*, *47*(SUPPL. 1), 179–184. https://doi.org/10.1111/j.1365-2028.2008.01067.x

Ngondo, J., Mango, J., Liu, R., Nobert, J., Dubi, A., & Cheng, H. (2021). Land-use and land-cover (Lulc) change detection and the implications for coastal water resource management in the wami–ruvu basin, tanzania. *Sustainability (Switzerland)*, *13*(8). https://doi.org/10.3390/su13084092

Nhamo, L., Magidi, J., & Dickens, C. (2017). *Determining wetland spatial extent and seasonal variations of the inundated area using multispectral remote sensing*. *43*(4), 543–552.

Ntongani, W. A., Munishi, P. K. T., More, S. R., & Kashaigili, J. J. (2014). Local Knowledge on the Influence of Land Use/Cover Changes and Conservation Threats on Avian Community in the Kilombero Wetlands, Tanzania. *Open Journal of Ecology*, *04*(12), 723–731. https://doi.org/10.4236/oje.2014.412062

Shen, G., Yang, X., Jin, Y., Xu, B., & Zhou, Q. (2019). Remote sensing and evaluation of the wetland ecological degradation process of the Zoige Plateau Wetland in China. *Ecological Indicators*, *104*(May 2018), 48–58. https://doi.org/10.1016/j.ecolind.2019.04.063

Singh, S., Bhardwaj, A., & Verma, V. K. (2020). Remote sensing and GIS based analysis of temporal land use / land cover and water quality changes in Harike wetland ecosystem , Punjab , India. *Journal of Environmental Management*, *262*(March), 110355. https://doi.org/10.1016/j.jenvman.2020.110355

Thamaga, K. H., Dube, T., & Shoko, C. (2022). Evaluating the impact of land use and land cover change on unprotected wetland ecosystems in the arid-tropical areas of South Africa using the Landsat dataset and support vector machine. *Geocarto International*, *0*(0), 1–22. https://doi.org/10.1080/10106049.2022.2034986

Town, M. M. (n.d.). *REMOTE SENSING APPROACH IN WETLAND AND LAND DEGRADATION ASSESSMENT : A SCENARIO OF*. *1959*, 247–256.

Twisa, S., & Buchroithner, M. F. (2019). Land-use and land-cover (LULC) change detection in Wami river basin, Tanzania. *Land*, *8*(9). https://doi.org/10.3390/land8090136

Twumasi, Y. A., & Merem, E. C. (2006). GIS and remote sensing applications in the assessment of change within a coastal environment in the niger delta region of Nigeria. *International Journal of Environmental Research and Public Health*, *3*(1), 98–106. https://doi.org/10.3390/ijerph2006030011

Verschuren, D., Johnson, T. C., Kling, H. J., Edgington, D. N., Leavitt, P. R., Brown, E. T., Talbot, M. R., & Hecky, R. E. (2002). *History and timing of human impact on Lake Victoria , East Africa*. *September 2001*, 289–294. https://doi.org/10.1098/rspb.2001.1850