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SPATIO-TEMPORAL ASSESSMENT OF LAND USE/LAND COVER CHANGE AND ITS IMPLICATIONS ON DONGA RIVER BASIN, TARABA STATE, NIGERIA

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ABSTRACT

Disturbances due to anthropogenic activities, especially Land use/ Land cover change; modifies runoff and sediment transport leading to adjustment in channel dimension. To this effect, the land use/land cover change of Donga River Basin was conducted with the aid of temporal satellite images of 1985, 2000 and 2020 downloaded from the United States Geological Survey (USGS) achieve. An unsupervised classification was carried out in ARCGIS 10.3 where seven classes were generated namely: built up area, cropland, forest, grassland, plantations, water body, woodland and bare surfaces. Descriptive statistics was further used to analyse the data. The analysis revealed that Built-Up Area, Cropland, Grassland, Woodland and Bare surfaces increased by +3.41, +12.37, +2.88, +3.05 and +3.75 respectively; while Forest, Plantation and Water Body decreased by -20.93, -2.47 and -2.1 respectively. The implications of such changes at basin scale are increase sediment generated during agricultural activities which are capable of entrainment by fluvial processes, siltation, flooding, cutoffs, narrowing of geomorphic threshold, loss of anchorage for bank materials making it prone to under cutting, bank collapse, channel widening and loss of life and properties. It was recommended that healthy agricultural practices should be encouraged so as to reduce the amount of sediments generated from farming activities especially on hill slopes. Overgrazing and annual bush burning should be check mated in order to reduce the effect of nutrient leaching and erosion of the top soil. There's also need for land use plan that is in line with ecological principles of the study area.

Keywords: Drainage Basin, Land use/Land cover, Sediments, Agricultural Practices

INTRODUCTION

Drainage basin form the ideal unit for the interpretation and analysis of environmental resources and fluvial landforms within the context of open system (Ijafiya, 2023). Recent scientific research have shown that upsurge in human population and their related activities in the drainage basins are responsible for changes in land use/land cover (LULC) (Twisa and Buchroithner, 2019; Mpanano, 2019; Boampong, 2020; Park, 2021; Younis and Ahmed, 2022; Dorji *et al.*, 2022). These activities includes: increased in human settlements, road construction, agricultural practices, charcoal production, firewood sales, timber collection, logging, lumbering and mining activities among others (Nduka *et al.*, 2022).

The study of land use and land cover change is crucial in understanding the hydro-geomorphic responses of a drainage basin (Leta *et al.*, 2021). Land use and land cover change of a particular drainage basin have unintended consequences on hydro-geomorphic processes through modification of runoff pattern and discharge. These may lead to flooding, sediments generation, channel enlargement and formation of chute and neck cutoffs (Ijafiya and Yonnana, 2018; Ashaolu *et al.*, 2019; Mukhtar *et al.*, 2020; Sayd and Yonnana, 2021). To this effects, Clark and Wilcock (2000) find out that area cleared for agriculture between the periods of 1830 to 1950 in Northeast Puerto Rico, experienced about 50% increase in runoff and sediments to the river channel. Waheed and Chukwuemeka (2010) find out that river channel width is greatest along Malali and Kigo road extension of Kaduna State due to changes in land use/land cover. Chilagane (2017) noted that increased in built-up area and agricultural activities was responsible for increased stream flow and sediment yield in Ruaha River Catchment, Tanzania. Chinweotito *et al.*, (2023) observed that loss of light and thick vegetation to built-up area and other land uses increased surface runoff and erosion in Isuikwuato Local Government of Abia State, Nigeria.

Observation over time suggest that the Donga River Basin and its riparian environment is continually depleted in terms of vegetal resources, through increased deforestation for farming activities, fuel wood collection, mining, and built up areas among others. This may increase the likelihood of erosion and flooding (Gabriel and Zemba, 2017; Chinweotito *et al.*, 2023). The understanding of land use and land cover changes of drainage basin will enhance the efficiency of planning and management of vital environmental resources and development in the study area. This research is therefore aimed at assessing the changes in land use/land cover for a period of 35 years (1985-2020); so as to make reference of such dynamics to hydro-morphological processes within the studied basin.

MATERIAL AND METHOD

Study Area

The Donga River Basin is the major hydro-geomorphic system that transverse the Mambilla Plateau from several hills such as Tsabga, Koba, Njeke, Yirum, Kusuku, Kwamen, Wairi, and Dorofi among others. This catchment is located betweeen Lat 6^{o}45'0"N to 7^{o}30'0"N and Long 9^{o}45'0" E to 11^o 15'0"E and has an area of 13,228km^2 and is fed by several tributaries of the sub-basins and terminate where River Donga form a confluence with River Suntai at Bantaje; before flow downstream to join River Benue (Fig.1).

The geology is made up of Basement Complex rock which covered most of the highland areas; while Granite Gneiss, Shale and Limestone dominates parts of the middle and the lower course. The soils are made up of sandy textural classes: such as sand, sandy loam, sandy clay loam and loamy sand which makes the banks to be susceptible to fluvial erosion and transportation even during low flow. The area cut across the Alpine or highland climate on the Mambila Plateau and the savannah climate at the lower surrounding areas. Two distinctive seasons are prevailing; the rainy season, which last from April to October and the dry season November to March (Oyatayo *et al.*, 2017). The distributional pattern of rainfall shows significant decrease as one progress from the North to the South; for instance, places around Maisamari have the highest record of about 2000mm, while the southern parts like Mbanga record 1600mm (Adebayo and Umar 2005; Gabriel and Zemba, 2017). While the low lying areas have total rainfall that is between 755.4 to 2354.1 Elevation ranged from 19m above sea level at the lower reaches to 3000m on the Mambilla Plateau.

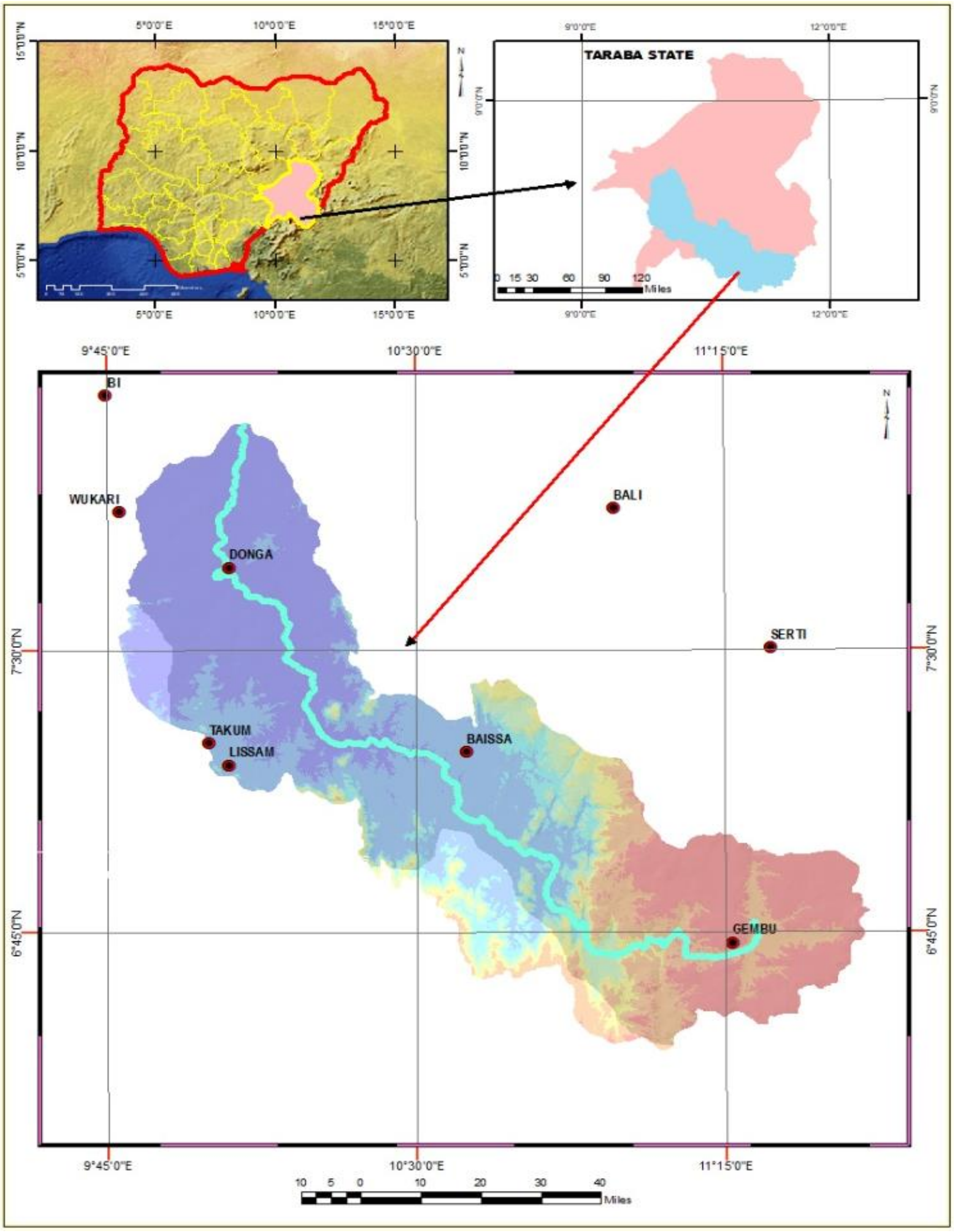

Figure 1: The Study Area
Source: Analysed from SRTM DEM

Data used in this research were sourced from United State Geological Survey (USSG) spatial portal (Earth explorer). The first epoch (1985) was captured by Landsat 5 aircraft using multispectral sensors (MSS); while the second (2000) and the third (2020) were captured using enhanced thematic mapper plus (ETM+) and OLI_TIRS sensors respectively.
Composite image was created using a combination of 4 bands for 1985, 5 bands for 2000, and 7 bands for 2020. The

variation in number of bands was due to the availability of bands in each epoch's collection. It was discovered that, the more the number of bands in a composite image, the better the distinctions in reflective signatures of the image pixels. A strand of band in an image collection comes stretched in black and white; therefore composite mapping is geared towards combining a minimum of three bands to achieve an RGB color combination using sensors reflectance. The operation was performed in ArcMAP's Toolbox where the 'Create Composite' tool was used in the Raster Data Management section. The clipped images in the folders from each scenes workspace were respectively stacked in each folder to produce composite images of each division.

An unsupervised classification was conducted due to the granularity and complexity of the study area. With the researcher's firsthand knowledge of the study area, and the help of Google Earth software; ground truth exercise was conducted to ascertain the different land use/land cover classes and equally compare them with the spectral signatures of the composite images. The classification of land use/cover of the study area was performed in the image classification tool bar of ArcGIS by utilizing the maximum likelihood classifier scheme where the signature files created during training sampling were equally registered. The class categories generated are bare surfaces, built up area, croplands, forest, grassland, plantations, water bodies and woodlands. The seven (7) classes' generated gives an insight on the existing land use/land cover of the entire study area.

Accuracy assessment of LULC is the most significant and final step in image classification. This analysis was conducted to quantitatively assess how effectively the pixels were assigned to the correct LULC classes. This was done using the create accuracy assessment points under spatial analyst tool in ARC tool box. A total of 162, 184 and 182 points were created on the classified LULC maps for 1985, 2000 and 2020 respectively; and a stratified random statistic were also used to show the distribution of these points in ARC GIS. The attribute table which contained the classified field and ground truth column of the classified images was displayed and verified using Google Earth Images of the study area. This was done by converting the displayed point on the LULC map to KML, which was later overlaid on the Google Earth Images to ascertain the pixels assigned to each cover type and computing the confusion matrix in ARC GIS environment.

RESULTS

The land use and land cover (LULC) classes generated are built up area, cropland, forest, grassland, plantations, water body, woodland and bare surfaces (Figs 2-4 and Table 1). The kappa value for accuracy assessment stood at 0.911737, 0.888943 and 0.901367 for 1985, 2000 and 2020 respectively.

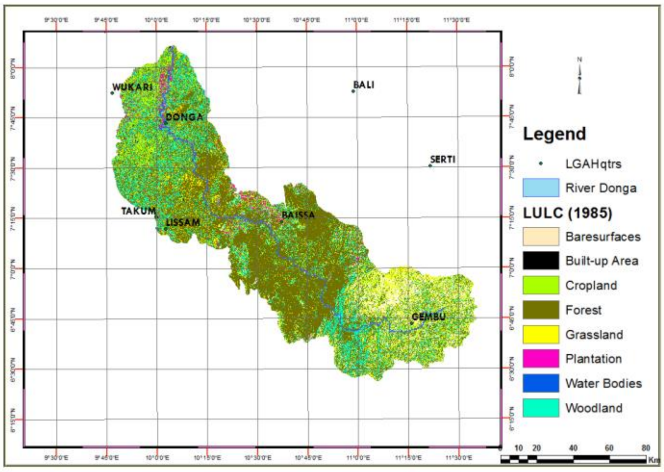

Figure 2: LULC of Donga Catchment

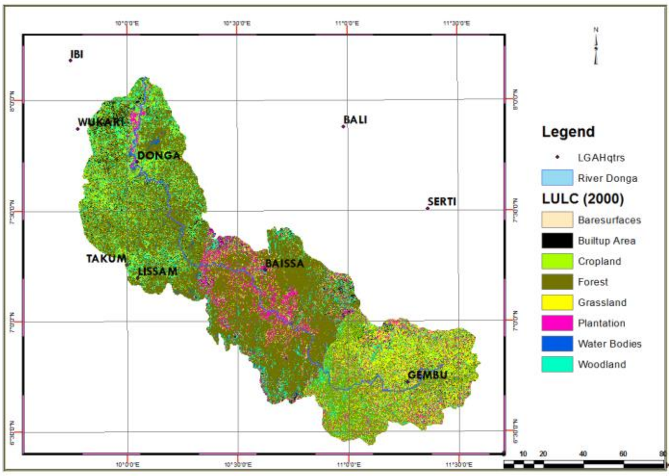

Figure 3: LULC of Donga Catchment

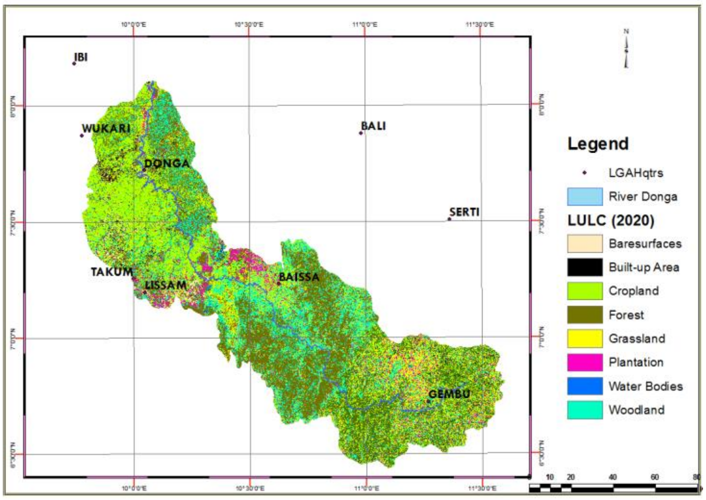

Figure 4: LULC of Donga Catchment

Table 1: Land use/ Land cover Classification and Change Detection Analysis for 1985, 2000 and 2020 in Hectares (Ha)

S/N	**Land use**	**1985 Ha**	**2000 Ha**	**2020 Ha**	**1985 to 2000**	**2000 to 2020**	**1985 to 2020**
1	Built-Up Area	21697.72303	34728.21242	66807.66717	13030.4894	32079.45475	+45109.94415
2	Cropland	134784.7274	206610.6542	298469.1996	+71825.92674	+91858.5454	+163684.4721
3	Forest	689258.6579	575086.673	412493.383	-114171.9849	-162593.29	-276765.2749
4	Grassland	117529.7565	120538.7532	155721.0932	+3008.996728	+35182.34001	+38191.33674
5	Plantation	94001.53543	100725.7315	61362.55493	+6724.196084	-39363.17659	-32638.9805
6	Water Body	42367.18769	15568.49116	14620.80609	-26798.69653	-947.6850718	-27746.3816
7	Woodland	208064.8223	228250.8242	248436.8262	+20186.00194	+20186.00194	+40372.00388
8	Bare surfaces	15089.77197	41284.84252	64882.65206	+26195.07055	+23597.80954	+49792.88009
	Total Area (Ha)	13,22794.182	13,22794.182	13,22794.182			
	Land use	**1985 Percentage Area Ha**	**2000 Percentage Area Ha**	**2020 Percentage Area Ha**	**1985 to 2000 Percentage Change** Ha	**2000 to 2020 Percentage Change** Ha	**1985 to 2020 Percentage Change** Ha
1	Built-Up Area	1.64	2.63	5.05	+0.99	+2.42	+3.41
2	Cropland	10.19	15.62	22.56	+5.43	+6.94	+12.37
3	Forest	52.11	43.48	31.18	-8.63	-12.3	-20.93
4	Grassland	8.89	9.11	11.77	+0.22	+2.66	+2.88
5	Plantation	7.11	7.61	4.64	+0.5	-2.97	-2.47
6	Water Body	3.21	1.18	1.11	-2.03	-0.07	-2.1
7	Woodland	15.73	17.26	18.78	+1.53	+1.52	+3.05
8	Bare surfaces	1.16	3.13	4.91	+1.97	+1.78	+3.75
	Total Area (%)	100	100	100			

+ indicate increase in land use/ land cover and – indicate decrease in land use/ land cover
Source: Satellite Image Analysis (2020)

DISCUSSION

Spatial Extent and Pattern of Land Use/Land Cover Change in the Study Area

The spatial distributional pattern of LULC type in 1985 revealed that forest which dominates the study area spread across the entire catchment; places like Baissa, Abong, Kendu, Kwanda and other settlements along the riparian zone have this land cover in their pristine stage. The upper course around Gembu, Kara, Banga, Titong, Warwa and Lame have patches of original dense forest and sparse vegetation spread across the entire landscape. The vegetation of places found in the lower course revealed that forest cover is sparsely distributed. Grassland mostly dominates areas found on the hill slopes of the Mambila Plateau such as Likitaba, Mbamga, Gembu, Ngalbin and Kara among other; this land cover type provide fodder for cattle rearing on the Plateau. Other places of the study area especially at the middle and lower courses dominated by grassland are as a result of clearance of original forest for anthropogenic activities such as lumbering, farming, hunting, grazing and fuel wood for domestic usage. Woodland shows a sparsely distribution in the study area. The highland areas around Tepkwar, Mbar, Ku and Chuwa revealed a cluster of woodland. Places found along the middle and lower course shows a sparsely distributed pattern. Built-up area found along the river channel (Riparian Settlements) in the lower course are Donga, Akite, Ngbebe, Ajetola, Agame, Tshokundi, Kwatan Boya and Bantaje among others. Clusters of built-up area at the middle course are also found around Mararaba, Kumbo, Manya and Baissa. At the upper course, built-up area includes; Gembu, Titong, Kara, Warwar, Chuwa, Likitaba, Ku, Mbamga, Mbar, Kakara and Dorofi among others. Cropland mostly dominates area of the lower course and is widely spread around Ghenda, Chobga, Akabo, Zanbe, Yiwamba and Bantaje among others. At the middle course, cropland are found in-between forest cover and riparian areas especially places that are cleared for farming activities; these includes, Kwanda, Mayan, Kendu, Gayama, Donga, Ayaboro etc. The upper course shows a very sparsely distributional pattern of cropland all around the river channel; while bare-surface are found to be numerous especially in the northern part of the study area.

Temporal Changes in Land use/Land cover

Under a simple random process of change, land use/ land cover is expected to gain or loss area it previously occupied. In the light of this statement, the land use/ land cover of Donga catchment have undergone series of changes in the last 35 years. The temporal change detection analysis revealed that forest cover which is the dominant land cover in the study area decreases throughout the study period (Figs. 5). The overall decrease from 1985 to 2020 stood at -20.93% (Table 1).

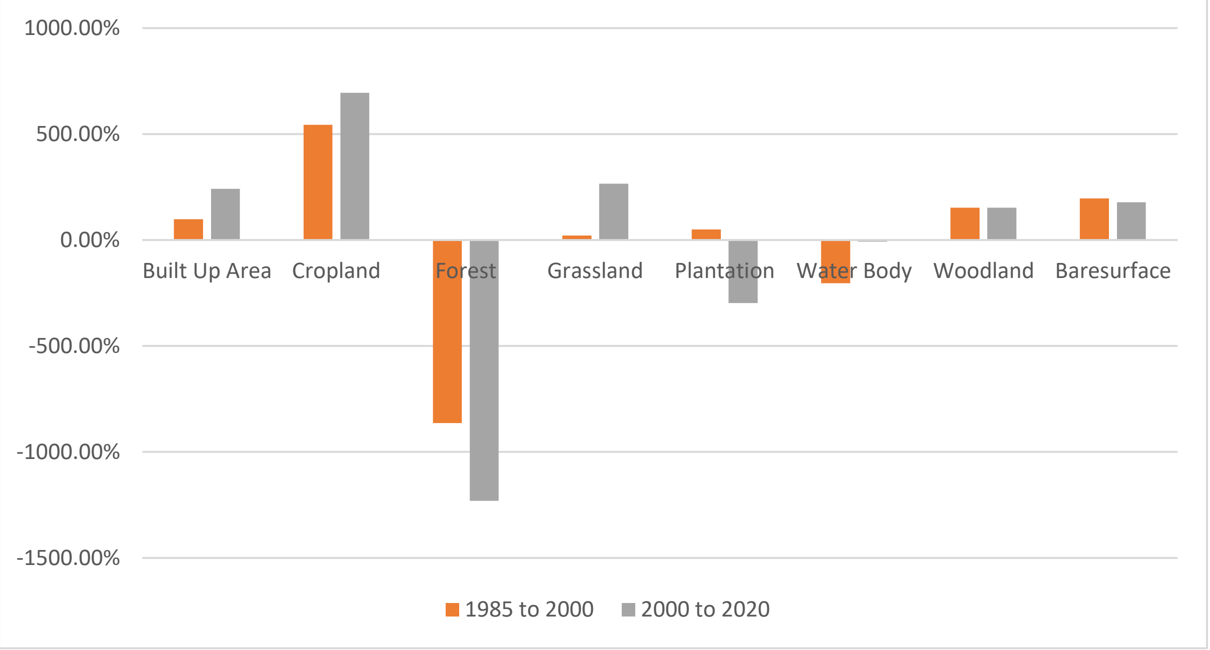

Figure 5: Land Use/Land Cover Change of Donga Catchment

This observation can be simply attributed to increased anthropogenic pressure on forest resources through incessant falling down of trees for various economic reasons; such as Madrid tree exploitation, clearing of land for agricultural purposes, charcoal production, increased human settlements, sand mining and gravel mining among others. The result of this analysis agrees with the work of Mishra *et al.*, (2019) who find out that open forest decrease by -13.98% in the Sikkim Himalaya, India. The finding is also in consonant with the work of Maina *et al.*, (2020) who made similar observation of decreasing forest cover by 45.94% in Kieni, Central Kenya for a period of 30 years (1987-2017). The implication of such decrease in forest cover on river morphology is that surface and bank cohesion is reduced and sediment generated through the impact of raindrop and slope processes will make the river become unstable and migrate.

Woodland which is the second largest cover type of the study area increased within the study period. The percentage increase of this land cover from 1985-2020 is +3.05%. The result of this analysis showed a gradual increase in woodland from the inception of this study; which is as a result of gradual regeneration process with limited anthropogenic interference especially in government owned forest reserved. This observation was similarly made by Suleiman *et al.*, (2017) in Falgore Game Reserve, Kano, Nigeria; where moderate woodland increased from 46% in 1985 to 57% in 2005. Aabeyir *et al.*, (2017) also made similar observation in Kintampo Monucipality of Ghana where woodland increased from 70.4% in 1985 to 80.4% in 2001. Also, Yirsaw, *at el.*, (2017) who in their study of land use/ land cover change in Su-Xi-Chang Region of China observed increasing trend of woodland from 0.23% to 2.29% and 0.48% between 1990-2000, 2000-2010 and 2010-2020 respectively.

Built up area gained 3.41% from places that were once occupied by forested land cover (Figs. 1-3 and Table 1). The outcrop of new settlements emerges in places around Sarkin Kudu, Gidan Madaiki, Kendu and area of Gembu could be the reason for the observed increased in built up area. The emergence of these new settlements increased pressure on forest resources so as to build houses, gather wood for fuel and exploitation for other economic reasons such as lumbering and Pharmaceutical uses. Plate 1 shows a new emerging rural settlement at Sarkin Kudu, Kurmi Local Government Area of Taraba State. Disturbance to river channel and ecosystem due to urbanization have led to serious consequence of flood, loss of life and properties, channel adjustment and disruption in the normal functioning of the ecosystem. The result of this analysis is in consonant with the work of Nabegu (2014) who find out that channel enlargements are common in urban areas under impervious surface in Jakada catchment of Kano metropolis of Kano State, Nigeria. Sayd and Yonnana (2021) also observed that channel width around urban land use are wider than their agricultural and abandoned agricultural counterpart in River Kilange, Adamawa State, Nigeria.

Plate 1: New Emerging Farming Settlement along Riparian Corridor of River Donga

The LULC analysis also revealed the dynamics of anthropogenic activities in the study area in which cropland increased throughout the study period. Generally, the change dictation analysis of the study period revealed that cropland increased by 12.37%. This is as a result of increased pressure on food security due to upsurge of human population in the study area and beyond. The influence of people migrating from Cameroon to Nigeria due to political reasons have led to increased demand for food crops. This is obvious in places like Dorofi, Tamnya, Tepkwar, Hainare, Antere, Amba and Titong who share international boundary with Cameroon. The implication of such changes at a basin scale is that significant amount of sediments are loosed during agricultural activities (i.e. clearing, harrowing, ridging, cleaning, grazing, cropping, irrigation) and entrained by fluvial processes, which may cause changes in river channel morphology of the study area. The finding of this study is in agreement with the work of Merten *et al.,* (2016) which revealed that smaller agricultural watershed of Yazoo River Basin (YRB) had greater suspended sediment yield than Iowa River Basin (IRB) due to more erodible soil, high rainfall erosivity and overland flow. The morphological differences and channel down-cutting is higher in the YRB than IRB which can led to expansion of smaller tributaries at the upper course. The observation is also conformity with Maina *et al.,* (2020), who found out that cropland in Kieni, Central Kenya increased from 12.54% in 1987 to 32.66% in 2017. Similarly, Mesfin *et al.* (2020) also observed a tremendous increased in cropland of 38.78% in Central Rift Valley of Ethiopia. The reflectance's of grassland from satellite image analysis revealed that this cover type increased over the study period. Anthropogenic activities such as deforestation and bush burning exposed the landscape to solar radiation; which by implication lead to the transition of deforested and burnt areas to grassland. This new land cover, gained 2.88% of the area earlier occupied by forest over the study period. The result of this is in consistent with the findings of Aabeyir *et al*., (2017) who observed that grassland increased consistently between 1985-2001 and 2001-2014.

At the early period of this study from 1985 to 2000, plantation gained an area earlier occupied by other land cover which could be a result of increased emphasis on the production of oil palm for exportation to other countries. In the later period from 2000 to 2020, this land use lost 2.97% to other LULC types. This could be attributed to change in agricultural practices from plantation to farming so as to cope with the challenge of food security. The increased in plantation observed from 1985-2000 is in agreement with the work of De Alban e*t al.,* (2018) who observed an expansion of Rubber and oil palm plantation in the northern and Southern Tanintharyi Region of Southern Myanmar.

Water body experienced significant decrease in this study. The total changes in the entire study period from 1985 to 2020 is -2.1; which could be a result of increase in built up area and agricultural activities in places earlier occupied by small water bodies in the study area. The result of this analysis is in conformity with Yirsaw, *at el.,* (2017) who in their study of land use/ land cover change in Su-Xi-Chang Region of China observed that water body decreased from -3.38%, to -2.85% and -2.17 between the period of 1990-2000, 2000-2010, 2010-2020 respectively.

The increased rate of bare surface observed in the study area within the study period could be a result of deforestation, unhealthy agricultural practice, crustal thickening by animal trampling, urbanization and reduction in water bodies. This land cover gained 3.75% within the period of 35 years. Bare surface increase with increase in cropland and built up area. However, the same land cover increase with decrease in forest cover and water bodies in the study area. The result of this analysis is in consonant with the findings of Mesfin *at al.* (2020) who in their study observed a 40% increase in bare surface in the Central Rift valley of Ethiopia. The implication of this result is that the land is exposed to the erosive force of raindrop which aid loosing of soil through rain plash erosion and contributes large amount of sediment to the river channel; which is capable of causing changes in river channel morphology.

CONCLUSION

The study concludes that increase and decrease in the various land uses and land covers, may lead to flooding of the riparian areas, loss of life and properties, channel adjustment and increase in the amount of sediment generated during agricultural activities. This is capable of causing, channel bed siltation, meander migration, chute and neck cutoffs, narrowing of geomorphic threshold and other changes in channel morphology of the drainage basin. There's need for land use plan that is in line with ecological principles of the study area; so as to avert the impact of such changes on channel adjustment.

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