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Land Use Land Cover Dynamics of Upper Benue River Basin, Nigeria

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Abstract

This study examined land use land cover (LULC) dynamics in Upper Benue River Basin, Nigeria. The study makes use of primary and secondary data. Landsat Imageries for the years 1981, 2001 and 2021 were used in the study. Supervised approach with maximum likelihood classifier was adopted for the classification and generation of LULC maps. Markov Cellular Automata model was used to predict the status of LULC of the catchment for year 2070. The findings of the study reveal remarkable changes in the land use land cover of the Upper Benue River Basin. The land cover has witnessed downward trend in the percentage area covered by vegetation and bare surface resulting in 15.4% and 2.6% losses respectively. The result of the findings reveals that the built-up area and rock outcrop has shown significant gains of 15.2% and 2.9% of the study area respectively. Water body has been stable with 0% change, though, it witnessed a marginal decline in 2001. The land use land cover change observed in the Upper Benue River Basin was as a result of anthropogenic factors characterized by deforestation, expansion of agricultural lands, overgrazing among others. Based on the findings, the study recommended controlled grazing activity, deforestation and indiscriminate fuelwood exploitation and improved agronomic practices in the basin.

Keywords

Anthropogenic, Drainage Basin, Land Use Change, Landsat Imageries & River Benue

1. Introduction

The most significant component taken into account in studies of global change is land use change (Loveland et al., 2000; Tsarouchi & Buytaert, 2018; Rolando et al., 2017). The term "land use" refers to how humans utilize land resources

(Pielke, 2005). The quickest conversion of forest area to agricultural use during the last 20 years was in the Sub-Saharan African region (Nkonya et al., 2013). Nigeria consistently lost 410,100 hectares of vegetative cover annually between 2005 and 2010, at a rate of 3.12% per year, making it one of the countries with the highest rates in the world (Ozor & Odo, 2008). Agriculture, logging, grazing, urbanization, road development, and mining have been the primary factors contributing to this predicament in the nation (Ozor & Odo, 2008; MacDicken, 2015).

Land use change, particularly in arid areas, can alter hydrological processes at both temporal and spatial dimensions (Foley et al., 2005; Nian et al., 2014). The essential information needed to create various thematic maps and create a baseline for monitoring operations is provided by identifying different types of land cover (Macarringue et al., 2022).

Moreover, for the best management of natural resources, it is important to comprehend how changes in land use and land cover (LU/LC) affect the hydrologic cycle. The hydrologic cycle may be affected globally more by LU/LC change than by recent climate change (Vörösmarty et al., 2004). There is growing awareness of the effects of LU/LC change on the atmospheric parts of the hydrologic cycle (regional and global climate) (Pielke, 2005; Shi et al., 2013; Pitman et al., 2004). Less is known about the effects of LU/LC alteration on subsurface hydrologic cycle components, and this area has not been thoroughly investigated in the study region. More than half of the world's landscape is affected by human activity or is undergoing some kind of anthropogenic development, and from ancient times, many natural resources have been intensively utilized or, in the worst situations, depleted (Foley et al., 2005; Goldewijk et al., 2011).

These vast LULC changes have a variety of effects on the ecosystem, including climate change, changes to the hydrological cycle, increased water extraction, deteriorated water quality, nutrient degradation in the soil, increased surface erosion, and loss of biodiversity (Turner et al., 2007; Paiboonvorachat, 2008). As a result, knowledge of land use and land cover, evolving patterns, and best use of land resources have become predetermined criteria for land use planning and successful management of a region's natural resources. This study assesses the land use/land cover changes within the Upper Benue River basin from 1981-2021.

2. Materials and Methods

This study makes use of primary and secondary data. The secondary data used include the Shuttle Radar Topographic Mission (SRTM) data, Landsat Thematic Mapper, Enhanced Thematic Mapper plus+, and the Operational Land Imager (OLI-TIRS) for Land Use/Land Cover classification and transition modelling as well as an input for a spatially-enabled regression analysis. The SRTM data and the Landsat imageries (TM, ETM+, and OLI from 1981-2021) were downloaded from the United State Geological Survey (USGS) website (https://earthexplorer.usgs.gov) using the path/row (185-188/56-61) covering the Upper Benue River Basin. Landsat images and SRTM of the study area was downloaded and downscale to cover the upper Benue Basin using the study area map. The images downloaded include the following:

1) Landsat thematic mapper image of 1981

2) Enhance thematic mapper plus image of 2001

3) The operational land imager image of 2021.

The images for 1991 and 2011 were not used for this study because it had some stripes and even after orthorectification it was not good for the analysis.

Geometric and radiometric accuracy are a prerequisite for reliable change detection using satellite imagery. The orthorectification process corrects different viewing angles typical of multi-temporal datasets and also ensures that images and secondary products overlay perfectly with other GIS datasets. The first step involves the rescaling of LANDSAT imageries from digital numbers to the Top of Atmosphere (TOA) reflectance and using radiometric rescaling coefficients provided in the product meta-data (**Figure 1**). Cloud and haze free imageries were carefully chosen at the point of scene preview and selection. Where there is unavoidable haze and cloud cover above 10% of the scene, further atmospheric correction was employed. Delineation of the study area was carried out using the river catchment area under study. Landsat Imageries spanning the years 1981, 2001 and 2021 were pre-processed. Supervised approach with maximum likelihood

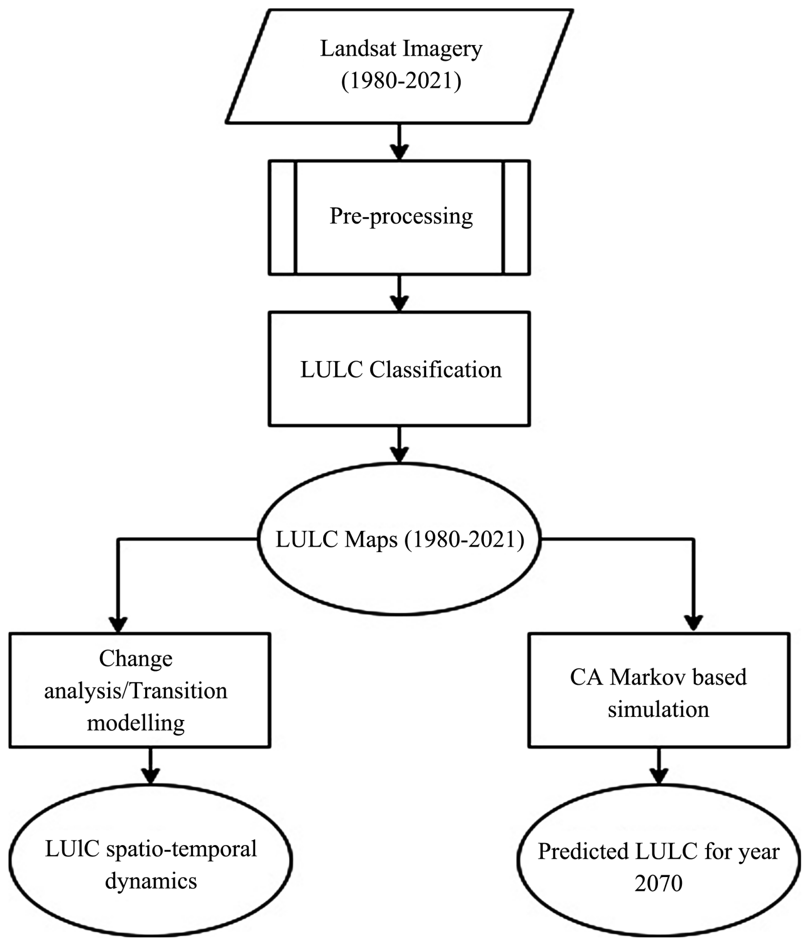


Figure 1. The rescaling of DN to TOP is done during the pre processing stage.

classifier was adopted for the classification and generation of LULC maps for the selected time periods to show the various LULC types across the study area. Using spatial transition modelling, the changes, gains and losses between LULC classes overtime were geo-visualized. The LULC first and last epoch was further subjected to Markov Cellular Automata model to predict the status of LULC of the catchment for year 2070. Multiple regression method was utilized to predict the impacts of land use dynamics.

3. Results of the Findings

3.1. Land Use and Land Cover Changes in the Upper Benue River Basin

The maps, tables and charts indicating the extents of the land use and land cover classification are presented in Figures 2-4 and Tables 1-3.

Table 1. LULC areal coverage for 1981.

LULC Class	Areal Coverage (Km^2)	Percentage (%)
Vegetation	22755.1	18.1
Water body	276.9	0.2
Built-up	245.1	0.2
Bare Soil	102105.0	81.3
Rock outcrop	170.6	0.1
Total	**125552.8**	**100**

Table 2. LULC areal coverage for 2001.

LULC Class	Areal Coverage (Km^2)	Percentage (%)
Vegetation	4808.5	3.8
Water body	192.1	0.15
Built-up	2884.1	2.3
Bare Soil	117112.0	93
Rock outcrop	556.1	0.4
Total	**125552.8**	**100**

Table 3. LULC areal coverage for 2021.

LULC Class	Areal Coverage (km^2)	Percentage (%)
Vegetation	3353.9	2.7
Water body	295.9	0.2
Built-up	19333.4	15.4
Bare Soil	98830.6	78.7
Rock outcrop	3739	3
Total	**125552.8**	**100**

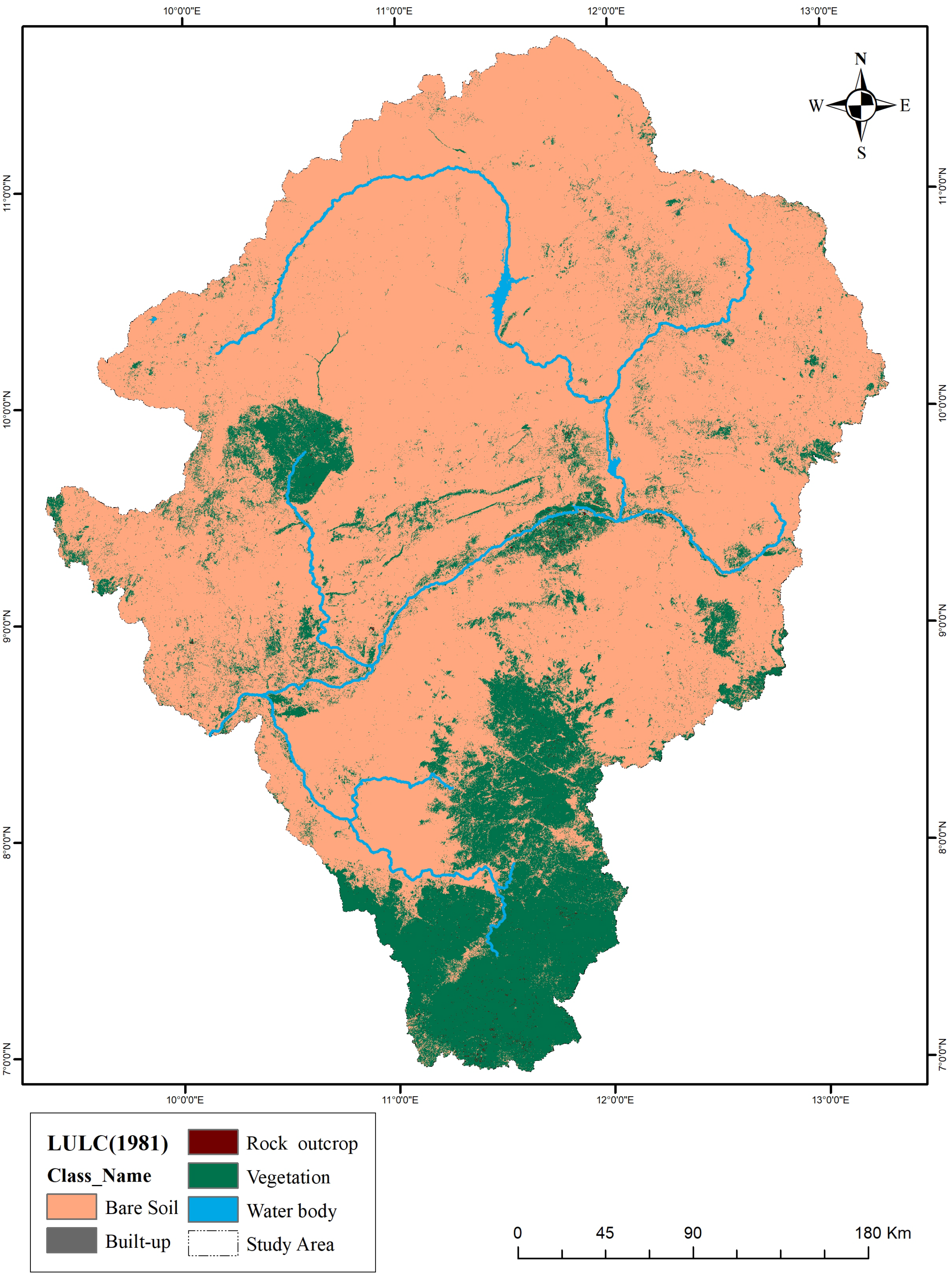


Figure 2. LULC for 1981 in the Upper Benue River Basin.

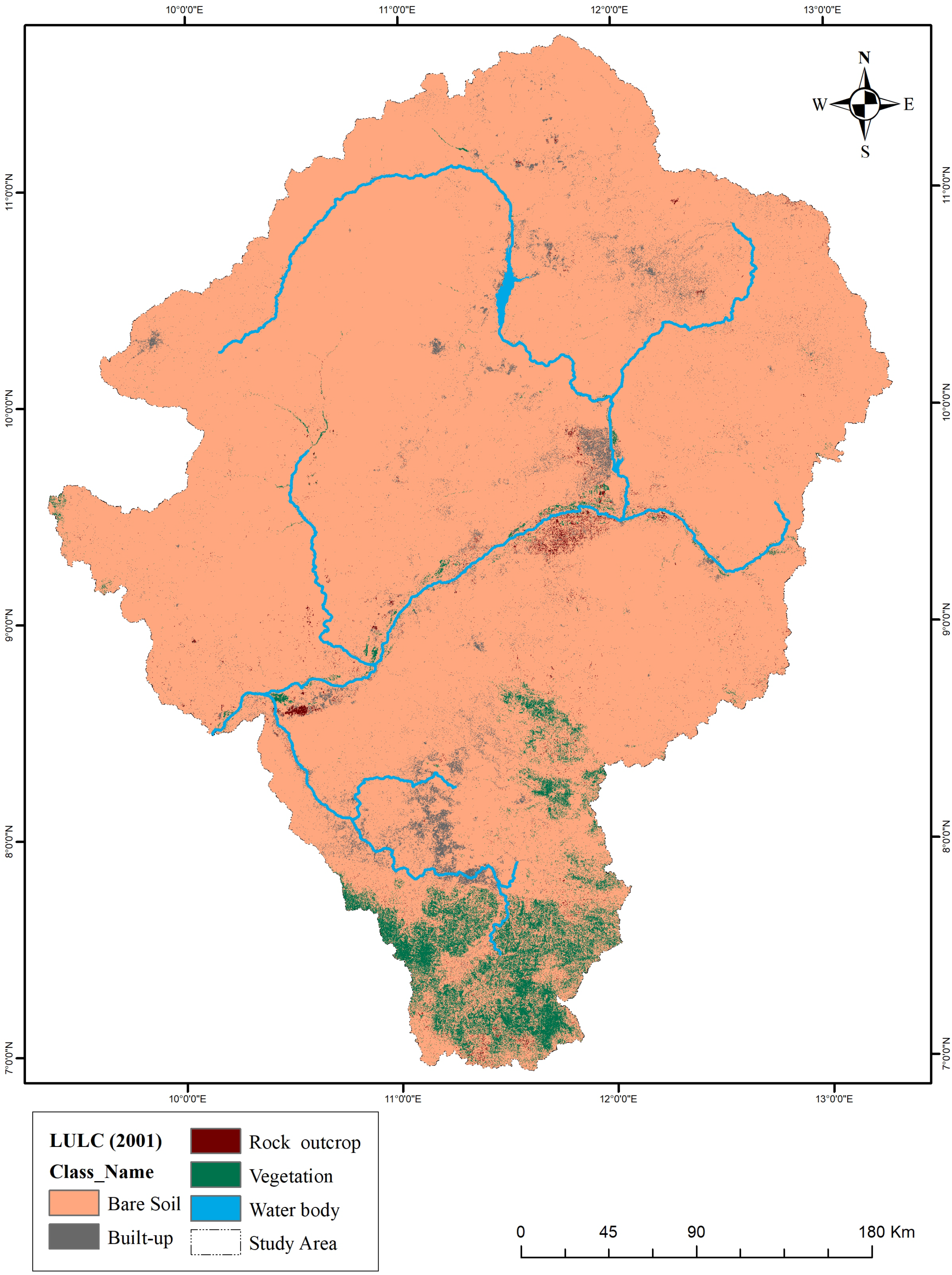


Figure 3. LULC for 2001 in the Upper Benue River Basin.

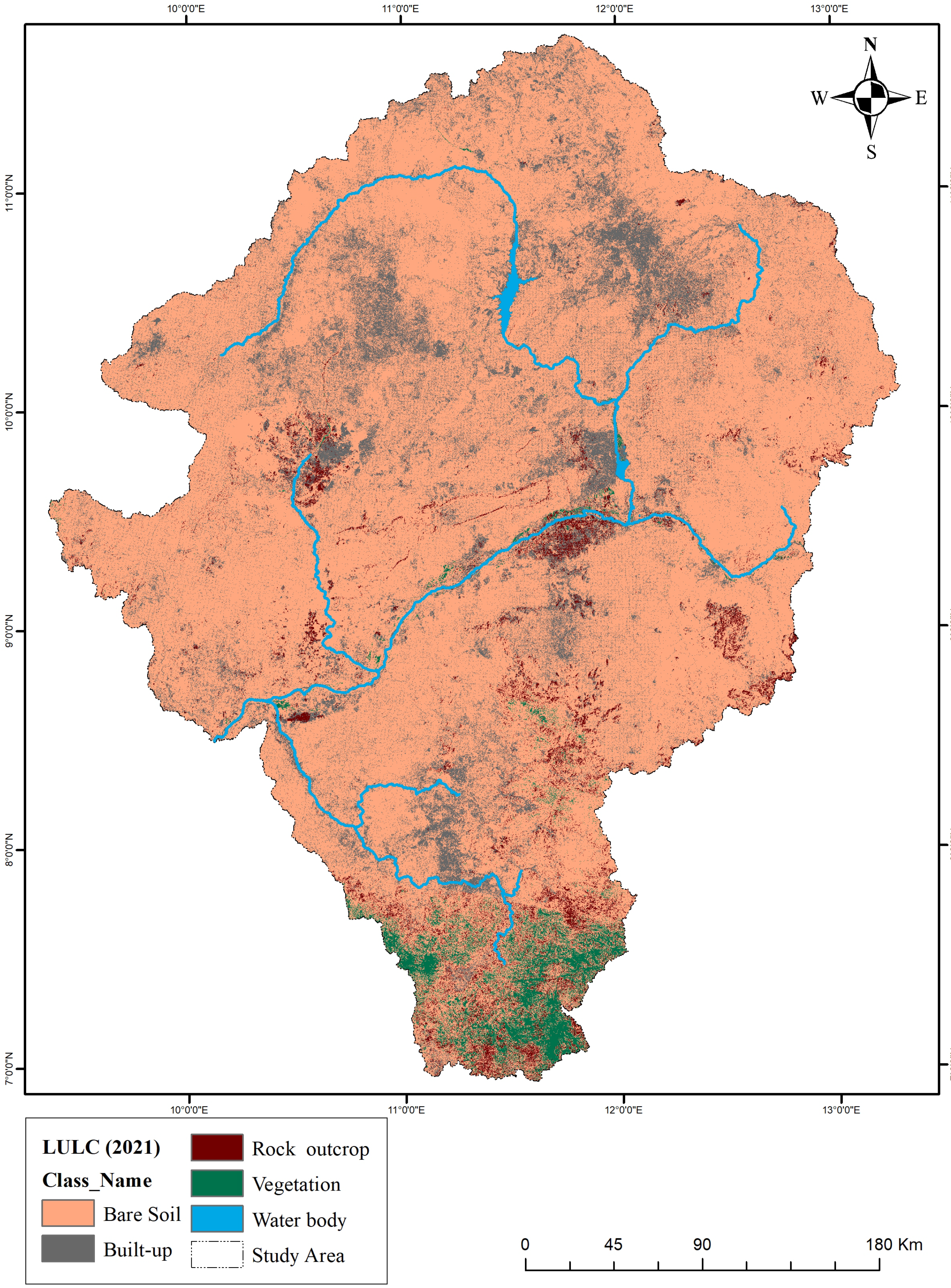


Figure 4. LULC for 2021 in the Upper Benue River Basin.

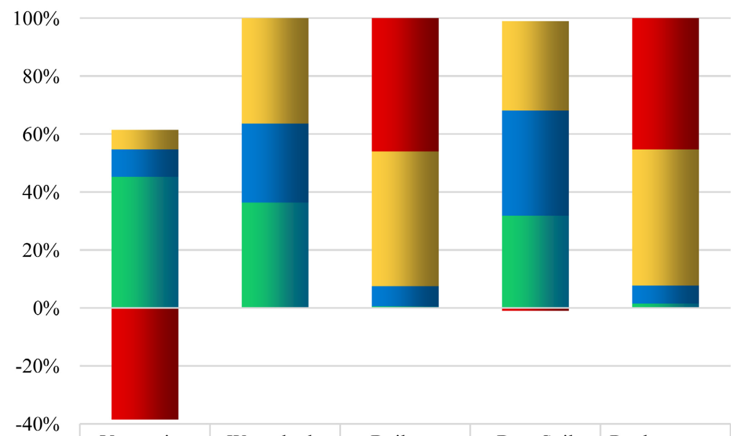
The findings of the study from **Figure 2** and **Table 1** reveal that, as at 1981, the land use class with highest area coverage was bare soil with an area of 102,105 Km^2, which makes up 81% of the study area. This was followed by vegetation with an area of 22755.1 Km^2, making 18.1% of the study area. Water body, Built-up and Rock outcrop had area percentages of 0.2%, 0.2% and 0.1% respectively. Furthermore, the basin shows a lot of vegetation along the river courses, more noticeable on the southern edge of the basin. This can be attributed to the flow dynamics and the slope of the basin. This result agrees with Huang, Zhang, & Chen (2019) that groundwater depth is an important environmental factor affecting vegetation growth and landscape dynamics in arid environments. Because of its direct and indirect effects on water recharge, vegetation is crucial in the interactions between groundwater and surface water systems; the long-term pattern of net groundwater discharge is influenced by the following factors: plant diversity, altitude, soil type, and river geometry (Alaghmand, Beecham, & Hassanli, 2013).

As presented in **Figure 3** and **Table 2** for the year 2001, bare soil retained its leading position with 117,112 km^2 coverage (93%) of the study area. This was followed by Vegetation which covered 4808.5 km^2 (3.8%) of the study area. Built-up ranked 3rd with 2884 km^2 coverage (2.3%) while rock outcrop covered 0.4%. Water body had the lowest percentage of 0.15%. It is clear from the result above that 20 years later, most of the vegetation along the river channels were beginning to decline except those in the southernmost part of the basin. The decline of the vegetation along most parts of the basin can be attributed to anthropogenic factors.

As presented in **Figure 4** and **Table 3** for the year 2021 which marks the last epoch, bare soil shows a marked decline, but still had the highest coverage of 98830.6 km^2 (78.7%) of the basin. This was followed by built-up which covered 19333.4 km^2 (15.4%) of the study area and Rock outcrop taking up 3%. Vegetation and Water body had lowest coverage of 2.7% and 0.2% respectively. The decline in bare soil in the basin can be attributed to the joint effects of increasing built-up areas, and the increase in rock mining activities which has caused most of the larger boulders to be disintegrated into smaller pieces giving opportunity for possible growth of some plants when environmental conditions in the area improve. The results of the land use change presented in **Figure 5** agree with the result of the findings of Siddik et al. (2022) which observed that the seasonal changes in Land Use and Land Cover (LULC) have a substantial influence on groundwater recharge.

3.2. LULC Change Transition Pattern

The results of the land use change analysis (**Figure 5**) reveal a downward trend in the percentage area covered by vegetation in the study area as well as a loss of 15.4 %. Subsequently, there has been a decline in bare soil which recorded a loss of 2.6%. However, the built-up area and rock outcrop has shown significant



	Vegetation	Water body	Built-up	Bare Soil	Rock outcrop
Observed Change(%)	-15.4	0	15.2	-2.6	2.9
2021	2.7	0.2	15.4	78.7	3
2001	3.8	0.15	2.3	93	0.4
1981	18.1	0.2	0.2	81.3	0.1

Figure 5. Observed land use and land cover changes (1981-2021).

gains of 15.2% and 2.9% of the study area respectively. Water body has been stable with a 0% change, though, it witnessed a marginal decline in 2001. Land use land cover of the Upper Benue River Basin has experienced a high rate of dynamism as a result of anthropogenic factors characterized by steady encroachment into vegetated areas. This result is in agreement with the findings of Jothimani et al. (2021) which identified the decrease in forest cover over Northeastern Ethiopia and Savari & Eskandari (2022) which observed diminishing bare land of the LULC in Western Iran. Similarly, it agrees with the studies of Enoguanbhor et al. (2019) in Abuja city and that of Mukhtar (2020) in Kano State which observed increase in built-up areas and decrease in bare surfaces.

Figure 6 and **Figure 7** show the spatial and temporal extent of transition between land use classes and land cover of the study area over the period 1981-2021. During the period under study, the persistent area, largely bare soil which witnessed no transition was 89680.3 km^2, while the total area that experienced transition was 35568.5 km^2. Furthermore, the built-up gained the highest and was a major contributor to 16006.2 km^2 loss in bare soil, and 3274 km^2 loss in vegetative cover. Bare soil gains were also a major contributor to 12640.3 km^2 loss in vegetation. While the montane vegetation losses made way for rock outcrop exposure by 3568.5 km^2, interestingly, built-up areas encroached into surface water ways by 30.2 km^2.

3.3. LULC Markovian Prediction for 2070

The result of the findings of the study on prediction of the extent of LULC for 2070 based on existing changes is presented in **Figure 8**.

From **Figure 8** and **Table 4** LULC prediction for 2070 indicates that it is likely that bare soil increase will be minimal, having a highest coverage of 100490.4 km^2

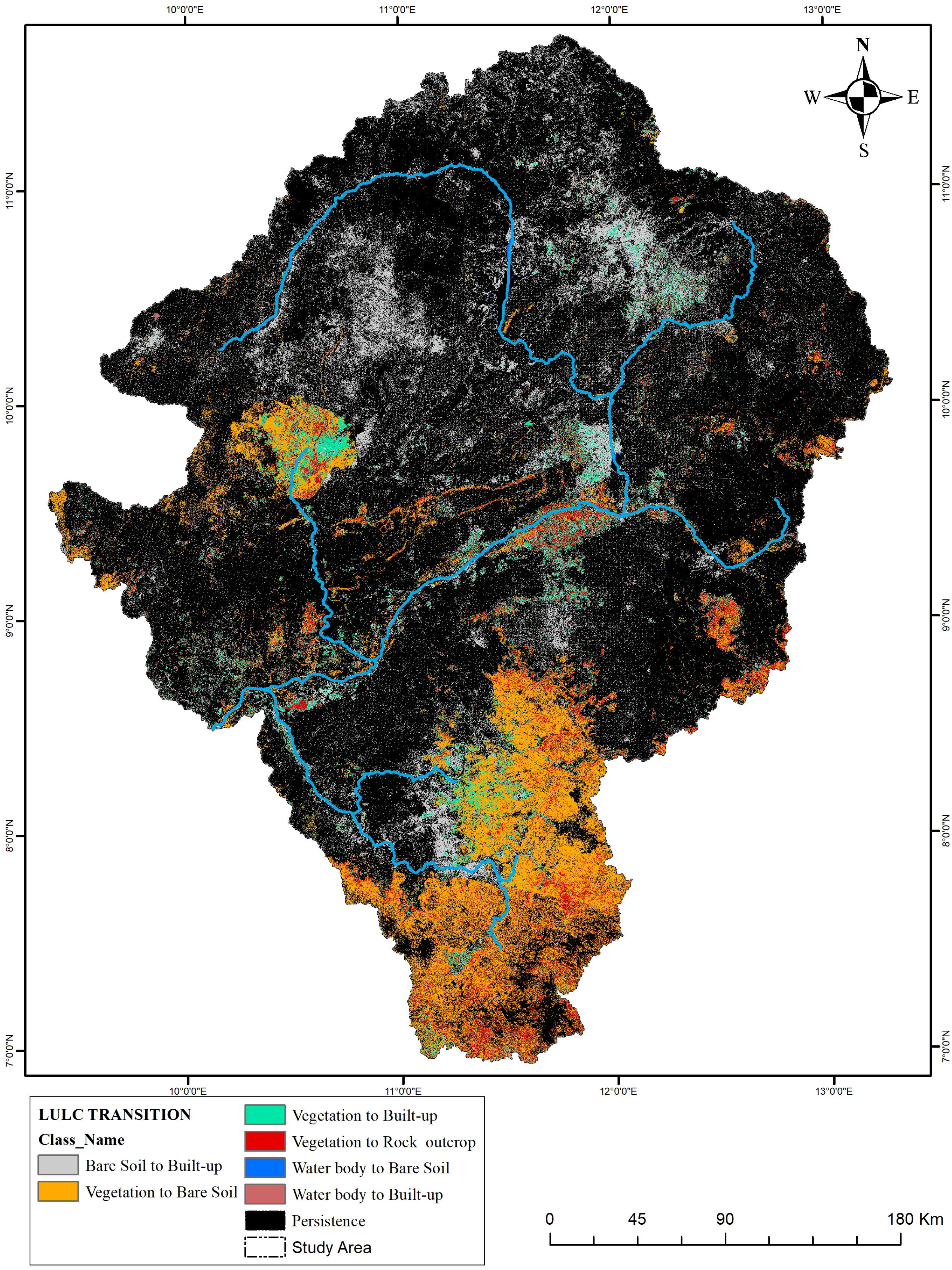


Figure 6. LULC transition between 1981-2021.

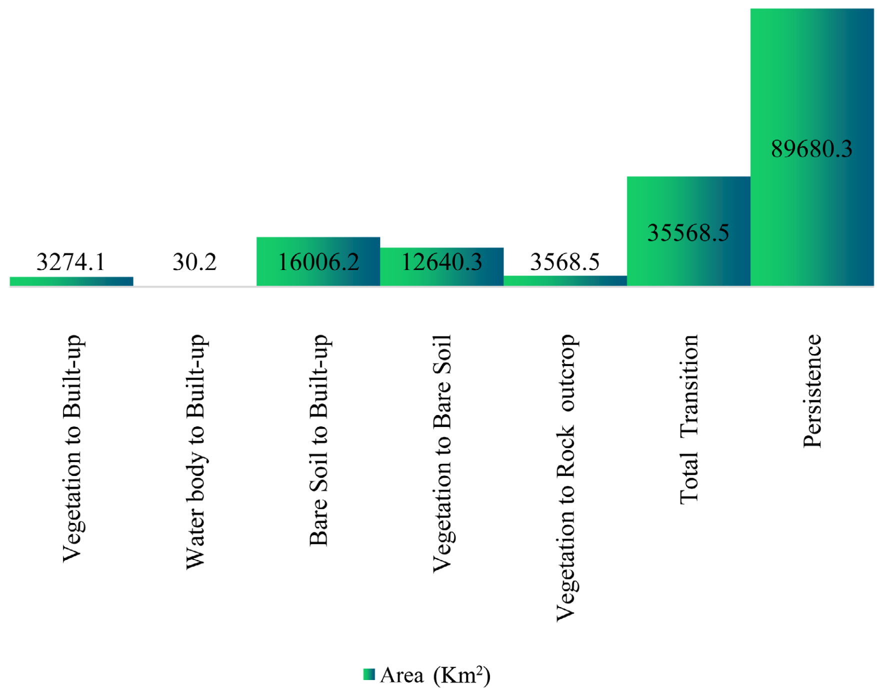


Figure 7. LULC transition.

Table 4. LULC prediction for 2070.

LULC Class	Areal Coverage (km^2)	Percentage (%)
Vegetation	30	0.02
Water body	173.16	0.13
Built-up	19474.1	15.1
Bare Soil	100490.4	80
Rock outcrop	5387.2	4.2
Total	**125552.8**	**100**

(80.0%) of the study area from 78.7% in 2021 in a space of 49 years. This is a marginal increase of 1.3%. This is followed by built-up areas which will cover 19474.1 km^2 (15.1%) and Rock outcrop taking up 4.2%; Vegetation and Water body in the prediction reduces further and has the lowest coverage of 0.02% and 0.13% respectively. This suggests that if necessary steps are not taken to reduce deforestation, both the groundwater potential and vegetation in the Upper Benue Basin may suffer significantly in the next 50 years, while anthropogenic changes may compound these problems since bare surface will expand. This further means that the vegetation that relies on groundwater will go into extinction. This result agrees with the study of Naumburg et al. (2005) which had similar result in the Great Basin of USA. Earlier in 2021, Ojeh & Semaka (2021) had observed that climate change will pose a challenge in the accessibility to water by households in the Upper Benue River Basin.

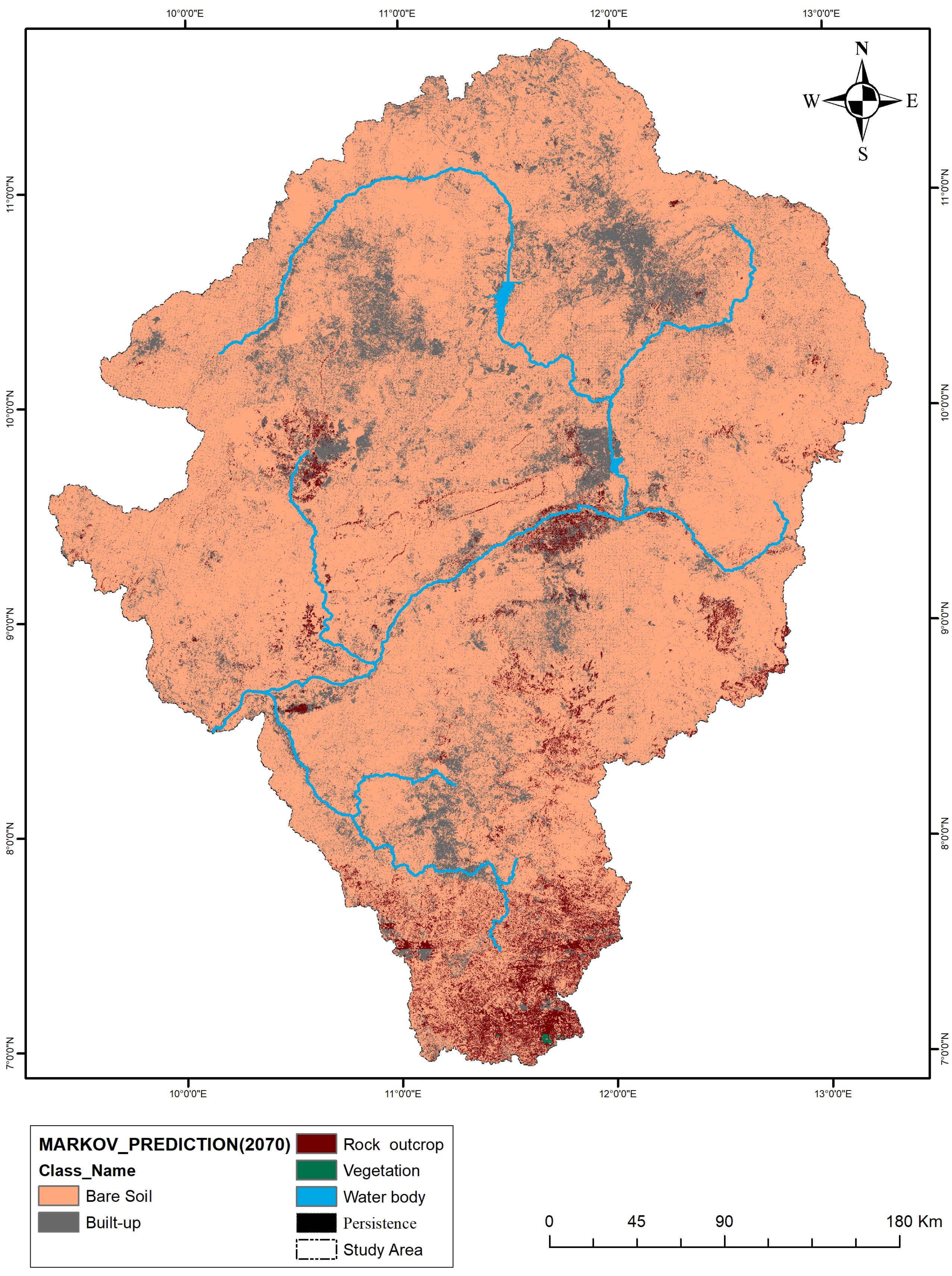


Figure 8. Markov prediction for 2070.

4. Conclusion

This study has examined the land use land cover dynamics of Upper Benue River Basin, Nigeria. This study used Landsat Imageries for the years 1981, 2001 and 2021 supervised classification to generate LULC maps of the study area. The findings of the study reveal that the land cover in the Upper Benue River Basin witnessed downward trend in the percentage area covered by vegetation resulting in 15.4% loss. Also, there has been decline in bare soil which recorded a loss of 2.6%. However, the built-up area and rock outcrop has shown significant gains of 15.2% and 2.9% of the study area respectively. Water body has been stable with 0% change, though, it witnessed a marginal decline in 2001. The land use land cover change observed in the Upper Benue River Basin was as a result of anthropogenic factors characterized by steady encroachment into vegetated areas. The study concludes that if necessary steps are not taken to reduce deforestation, both the groundwater potential and vegetation in the Upper Benue River Basin may suffer significantly in the next 50 years.

5. Recommendations

Based on the findings of the study, the following recommendations are made:

1) Controlled grazing activity in the basin to reduce pressure on the vegetation resources of the basin.

2) Control deforestation and indiscriminate fuelwood exploitation in the basin.

3) Improved agronomic practices and extension services in the basin.

4) Vegetation monitoring of the basin should be mainstreamed into existing laws establishing the UBRBA to prevent further degradation.

5) Afforestation of the basin is of urgent importance to help more water infiltration into the basin and sustain the ground water recharge and potential in the future. Since the projected trend shows that the northern part of the basin is most likely to be adversely affected in the future, there is need for policy to protect the land and conserve vegetation, reduce forest degradation in this zone of the basin.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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