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Research article

Land use and land cover changes implications on biodiversity in the Owabi catchment of Atwima Nwabiagya North District, Ghana

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ABSTRACT

This paper examined land use and land cover (LULC) change and implications to biodiversity in the Owabi catchment of Atwima Nwabiagya North District in Ghana from 1991 to 2021 using remote sensing, and geographic information systems (GIS), with participatory methods such as interviews and questionnaires with a sample size of 200 participants. The use of supervised classification with maximum likelihood algorithm in QGIS was employed to generate LULC maps of 1991, 2001, 2011, and 2021. Molusce Plugin in QGIS was applied to predict probabilities of LULC changes in 10 years (2021–2031). The results showed that high-density forest has disappeared from 1991 to 2021 while built-up has increased and remained the most dominant LULC from 2011 to 2021. There is a continual decline in the number of plant and animal species in and around the Owabi catchment. This can be attributed to the decline of high-density forests and increased built-up in the study area through human actions. The study identified the influence of human activities as the key forces of LULC change to biodiversity loss. This problem stemmed from the taste for housing and trading activities in the Kumasi Metropolitan Area which has resulted in an increasing demand for settlement because of its closeness to Kumasi and its environs. The study recommends that stringent preventive measures should be developed and enforced by various stakeholders including the Forestry Commission, Ghana Water Company Limited, Environmental Protection Agency, as well as the District/Municipal Assemblies to safeguard the forest from human activities. This recommendation will help these agencies to keep abreast with changes in LULC in the various communities and factors such as changes during the planning of the communities.

1. Introduction

Few areas on earth have not been altered or are currently being altered in some way by people [1]. The natural environment has been greatly influenced by man's existence on the earth and his use of land [2]. Land use and land cover (LULC) changes are influenced by human activities such as mining, deforestation, agriculture, construction, sand winning, and overgrazing, and are the necessary

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basic variables for environmental concerns that are gaining attention as the primary source of global environmental change [3]. Cities and their inhabitants have become key drivers of these changes [4,5] due to a significant increase in human-created impervious areas around the globe [4,6]. These have put a strain on the natural environment [7–9], transformed and fragmented ecosystems [10–12], as well as natural resources and human livelihoods [13,14].

Studies have shown that forests obscured a large portion of the earth's land area several decades ago [15]. However, due to rapid population growth, majority of world forests have been converted to urban areas [16]. Land use change driven by multiple interacting processes of various natural and socio-economic factors [17] have resulted in land cover changes affecting biodiversity, water and radiation budgets, trace gas emissions, and other processes that come together to affect biosphere [18,19]. Africa Ecological Footprint Report on Green Infrastructure for Africa's Ecological Security [20] reviewed that the continent has loss approximately 40% of biodiversity over the last four decades as a result of land use change. This could have serious implications for human well-being [21], due to its impact on people's livelihoods and services provided [14,22,23].

In Ghana, as in many other developing countries, the consequences of LULC changes are being recognized in the form of biodiversity loss [24]. The loss of biodiversity as a result of LULC change puts the ecosystem's long-term viability and functioning in jeopardy, as well as its economic and environmental value for human life [25]. Land use change is currently accelerating, resulting in extensive global environmental problems that must be investigated and mapped [1,26]. According to Maina et al. [19], land use refers to the physical and biological characteristics of the land that can be attributed to management whereas land cover refers to the physical features of the earth's surface, as captured in the distribution of vegetation, water, soil, and other physical features of the land, including those created entirely by human activities such as settlements [18].

The Owabi catchment for instance has experienced forest degradation over the past decades. These degradations have been attributed to a number of natural and human activities [1]. Despite the fact that some of the catchments is designated as a protected zone (inner site) [27], it faces serious interconnected issues such as population pressure, poaching, illegal logging, land tenure, and land-use practices such as local developments, all of which have an unavoidable impact on its management plan [28]. Farming activities, sand winning, indiscriminate dumping of waste and land acquisition for local development (e.g., home construction) are encroaching the area having a great effect on the quality and quantity of water provided by the Owabi dam [29,30].

Studies have been undertaken to quantify this damage on the Owabi catchment. For instance, Adubofour and Forkuo [31] used remote sensing and geographic information systems to survey the Owabi catchment and discovered a 34.46% decline in high-density forest between 1986 and 2007, which they attributed to an increase in human activities and the catchment area's population growth. Antwi-Agyei et al. [14] investigated on LULC change implications on livelihoods and management in the Owabi catchment and found that livelihoods of community members as well as the management of the area have been affected. Agyen-Brefo [32] investigated how encroachment affected the sustainable management of public lands in the study area and discovered that it had a detrimental impact on building regulations and land use planning, increased the cost of producing water, and decreased government revenue. A research work by Ameyaw and Dapaah [29] has recommended that the rate at which the resources in the Owabi catchment have been exploited, there is the need for stakeholders in charge of managing the area to actively engage in co-managing the resources to protect them from exploitation. LULC change and implication on biodiversity in the area has received limited research attention. Therefore, this paper addresses the research gap by investigating to find out the extent to which LULC changes have affected biodiversity in the area.

The objectives of the study were to: (1) evaluate LULC changes in the Owabi catchment from 1991 to 2021; (2) determine LULC change impacts on biodiversity; (3) identify the socio-economic and human induced drivers to forest degradation and biodiversity loss; and (4) Predict LULC changes in the Owabi catchment for 2031.

2. Study area

The Owabi catchment is found within the Atwima Nwabiagya North district. It is situated between latitudes 6°47.32″ and 6°41.32″N, and longitudes 1°44.81″ and 1°37.53.04″ in the Ashanti Region, roughly 19 km north-west of Kumasi [31]. The study area shares common boundary with the Offinso municipality to the north, the Amansie-West and Atwima Kwanwoma districts to the south, the Kumasi Metropolitan and Afigya Kwabre districts to the east and the Atwima Mponua district to the west [14]. It is part of the wet semi-equatorial climatic zone, with double maximum rainfall seasons ranging from 170 to 185 mm per year [14,33]. The main rainy season lasts from mid-March to mid-July, and the minor season lasts from September to mid-November [14,33]. Rain does not fall evenly throughout the year. Temperatures are reasonably constant, ranging from 27°C in August to 31°C in March, with a mean relative humidity of roughly 87% to 91% [28].

The Owabi dam is totally surrounded by the Owabi wildlife sanctuary, which is approximately 13 km^2 [29,34]. The dam was the only source of water in the Kumasi Metropolis and surrounding villages until the completion of the Barekese dam in 1971 [29]. The Owabi dam produces 20% of the total portable water requirement in the Kumasi Metropolis and adjoining communities [35]. The Owabi Wildlife Sanctuary is a Ramsar site under the Ramsar Convention of 1976 that contains many important plant and animal species [34,35]. The Sanctuary is a home to 193 vascular plant species, 161 bird species, belonging to 29 families [27,28,36], and a few other important mammals such as Mona's monkeys, Royal antelopes, and Cusimanses [36], thus providing important ecosystem services [29]. The figure below shows the map of the study area with the various communities used for the study.

Despite the importance of the Owabi catchment to the socio-economic development of Ghana, the area has been encroached upon by numerous human activities [14,32,35] affecting flora and fauna species in the area [29]. This has been worsened by land tenure between landowners and Ghana Water Company Limited especially on the catchment area [14,28], as a result of misunderstanding of management responsibility for the outer Sanctuary [27]. Land owners of the catchment area have been complaining that government has taken their lands for the construction of the Owabi dam without any compensation [1,14,37] and since their only source of livelihoods depend solely on their land, they have resolved clearing the forest for farming purposes, illegal allocation of lands for sand winning, construction of houses and illegal exploitation of natural resources as a means of livelihood until compensation is pay to them [27,28]. These have completely cleared most of the forest cover which in effect affected plant and animal species in the area [31].

Four towns, namely, Bokankye, Esaase, Owabi and Ohwim, were selected for the study, and of these four towns, a sample of 200 interviews were conducted to investigate the consequences of land use and land cover (LULC) change on biodiversity. Table 1 shows the population data for the four communities used for the study.

2.1. Materials and method

The study combined both interview (community and expert), Field Observation, Mammals data, related literatures and Landsat images to analyze LULC changes and implications to biodiversity in the Owabi catchment.

2.1.1. Image acquisition and data preprocessing

Landsat images of 1991 (Landsat 5), 2001 (Landsat 7), 2011 (Landsat 7), and 2021 (Landsat 8) were downloaded from the United States Geological survey's website. The selection of the satellite images was influenced by availability of the images, the spatial resolution, and the overall quality of the images in terms of those with low cloud and scene cover [38]. To be compatible with QGIS Imagine files, the raw data satellite images were transformed from zip files using WinRAR which extracted the images into various bands and stored for further processing [39]. The images were resampled to a 30*30 m spatial resolution and are chosen from the same season to avoid seasonal fluctuation [30,40].

Radiometric correction was performed for 2011 Landsat-7 ETM+, which had scan lines to improve interpretability and quality of remote sensed image [39,41]. The corrected image of 2011 (Landsat-7 ETM+) together with 1991 landsat-5 TM, 2001 Landsat-7 TM and 2021 Landsat-8OLI_TIRS were subjected to atmospheric correction with the help of Semi-Automatic Classification Plugin in QGIS 3.12.2. Atmospheric correction was then performed to extract the surface reflectance of the individual bands in the Landsat images to improve accuracy of the classification [39,42]. The individual bands in the Landsat images were layer stacked and projected to Ghana Meter Grid [38]. A shape-file of the Owabi catchment received from the District Assembly within the catchment area was used to sub-set the area of interest from the Landsat images. Table 2 shows the summary of the satellite images downloaded from the USGS website.

2.1.2. Landsat image classification

Supervised classification was chosen based on prior knowledge of the study area and the findings of the researchers' field survey (see Fig. 1). The supervised classification was carried out using maximum likelihood algorithm in QGIS 3.12.2 which examined the probability function of each class and assigned each pixel to the class with the highest likelihood [43,44]. Band combinations, visual interpretation, GPS Essential, and Google Earth were used to identify LULC classes in the Landsat images. These helped to arrive at six LULC classes which is shown in Table 3. Land use and land cover (LULC) maps were developed and class statistics were generated for each LULC class for the years of 1991, 2001, 2011, and 2021 in ArcGIS 10.5 as shown in Fig. 2. The land cover classes for the study are described in Table 3.

2.1.3. Post-classification

This stage includes change detection and accuracy assessment techniques. A change detection technique was used to detect changes in LULC in the Owabi catchment [42]. Using "-from, -to" information, a pixel-based comparison was employed to obtain change information on a pixel basis and so analyze the changes more quickly [39]. This method allows the determination of the difference between independently classified images from each of the years in question and it is the only approach in which "from" and "to" classes can be evaluated for each changed pixel [39]. Cross-tabulation was used to compare classified image pairs from two separate decade data in order to assess qualitative and quantitative features of the changes for the years 1991–2021. With the help of QGIS 3.12.2 software, a change matrix [45] was created. Between 1991 and 2021, quantitative areal data on overall LULC changes, as well as gains and losses in each category, were compiled. Google earth and GPS essentials during field survey, were used to collect ground truth points to validate the accuracy of the classified images. Using a sample of 97 of the ground control points and from Google Earth imagery for each year, the study validated the classified images. This was achieved by calculating and analyzing the accuracy and Kappa statistic of each classified image [38,46].

Table 1
Characteristics of the study communities.

Community	Population	Source
Esaase	3918	[1]GSS
Bokankye	4944	Atwima Nwabiagya North Assembly
Ohwim	20,780	GSS
Owabi	80	GSS
Total	29,722	

[1]Ghana Statistical Service.

Table 2
Landsat data used for the study.

Landsat Products	Acquisition date	Path/Row	Spatial Resolution	Source
Landsat [2]TM 5	31/12/1991	192/056	30 m	[3]USGS
Landsat TM 7	31/12/2001	192/056	30 m	USGS
Landsat 7 [4]ETM+	31/12/2011	192/056	30 m	USGS
Landsat 8 [5]OLI_TIRS	31/12/2021	192/052	30 m	USGS

[2]Thematic Mapper.
[3]United States Geological Survey.
[4]Enhanced Thematic Mapper Plus.
[5]Operational Land Imager and Thermal Infrared Sensor.

Table 3
Description of LULC classes used for the study.

LULC types	Descriptions
Built-up	An area highly populated by houses or other structures that grow in intensity over time.
High density forest	This refers to the Owabi dense forest cover which protects the Owabi dam, its reservoir and waters covering other areas within the area of study
Low density forest	These are sparsely spread trees of various ages, plants, and underbrush that cover a considerable portion of the study area.
Water	The Owabi Dam is the study area's principal water source.
Bare-ground	This is a sand and gravel-covered section of land.
Wet-Land	The Ramsar Convention defines wetlands "as areas of marsh, fen, peat land, or water, whether natural or manufactured, permanent or temporary, with static or flowing water, fresh, brackish, or salt, including areas of marine water with a depth of less than 6 m at low tide" (Ramsar Convention, 1971, Ministry of Lands and Forestry, 1999).

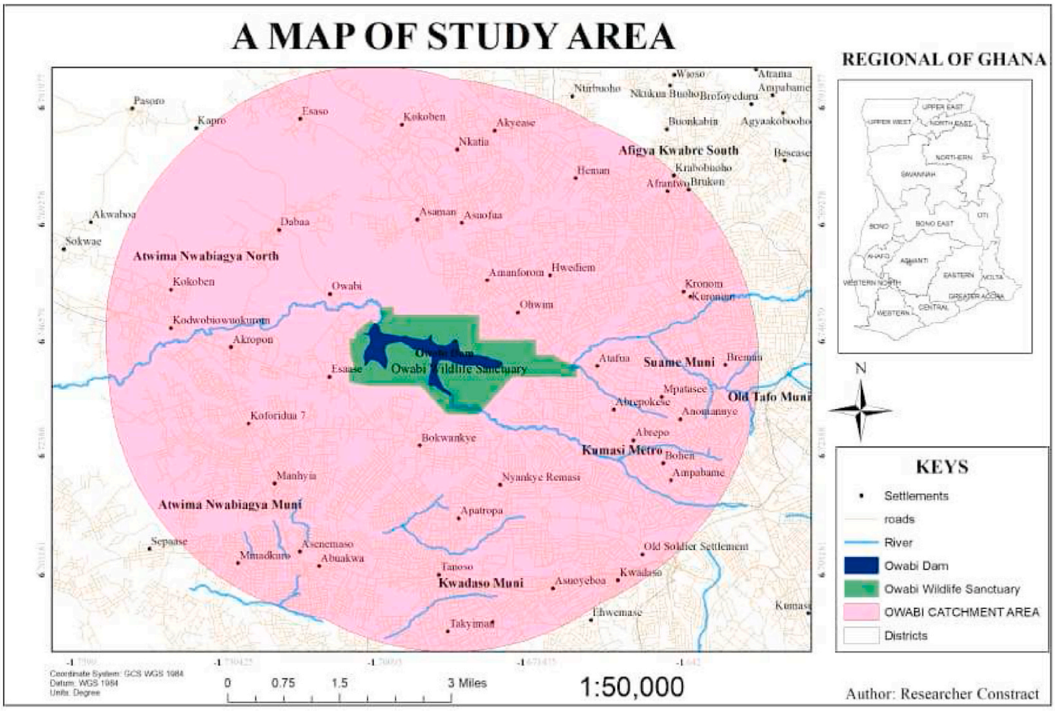

Fig. 1. Map of the study area showing the study communities.
Source (Field Survey, Owabi Catchment, Ghana, 2022).

2.1.4. Interviews

To understand the impact of LULC change to biodiversity in the Owabi catchment, community members of the study area were interviewed to know their perceptions about the consequences of LULC change on biodiversity in the Owabi catchment area. In all, 200 household interviews were conducted between September and November 2021 in the various four communities. The interview

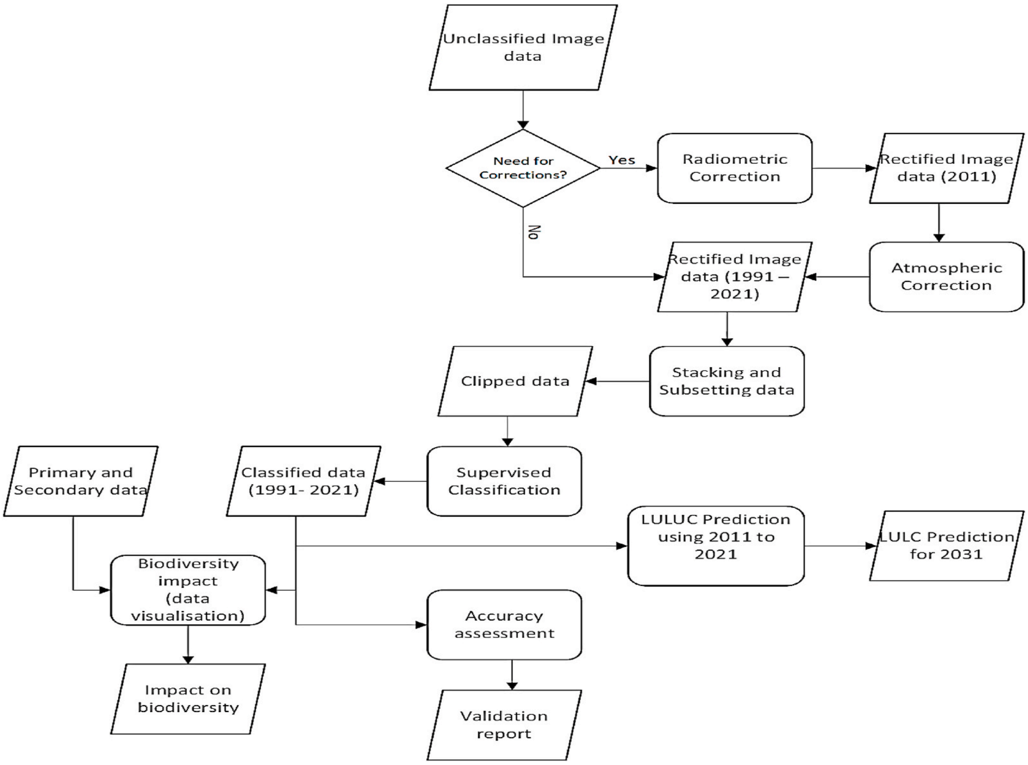

Fig. 2. Methodological flowchart of the study.

involved questionnaires which were largely closed-ended and supplemented with a few open-ended ones. For the study, stratified random sampling procedure was used. This enables the work obtain a sample population that best represents the entire population being studied. To ensure that each relevant subgroup is represented, fifty (50) individuals were chosen from each community, namely Owabi, Bokankye, Esaase, and Ohwim that best represents the whole population being examined. Socio-economic characteristics of respondents such as status in the community, number of years lived in the community, were used to choose the respondents for the interviews to better understand their responses and inquire deeper for explanations. Ninety-one (91) respondents representing 45.5% of the sample size were indigenes while one hundred and nine (109) representing 54.5% were strangers. These include both males and females. People who have lived in the study area between the years of 31–40 and 40+ are dominating the area as it shown in Table 4. The sample size was calculated based on the Mathematical formula

$$n = \frac{N}{1 + N(e)^2} \tag{1}$$

where n = Sample Size; N = Number of participants selected; e = margin of error (confidence interval); 1 = Probability of an event occurring by Yang and Miller, 2008.

Table 4
Socio-economic characteristics of respondents.

Status in the community		
	Frequency	Percent
Indigene	91	45.5
Stranger	109	54.5
Total	200	100.0
Number of years stayed in the community		
	Frequency	Percent
1–10	11	5.5
11–20	17	8.5
21–30	44	22.0
31–40	67	33.5
41+	61	30.5
Total	200	100.0

However, the questions were read out in the Asante Twi dialect to allow respondents to respond appropriately. The questionnaires focused on key variables such as status in the community, number of years lived in the community, services derive from the study area, frequency of use of the services, the level of dependency on the services, the current state of biodiversity in the area, drivers of forest degradation and biodiversity loss, the impact of LULC change on forest degradation and biodiversity loss and what can be done to ensure the sustainability of plants and animal species in the study area. Expert interview was also conducted with the staff of the Owabi Wildlife Division. These staffs were chosen based on their capacity to exhibit in-depth agro-ecological knowledge of the communities concerned. Two expert interviews were held.

2.1.5. Ethical concerns

The recruitment of participants for this study, the respect shown for their rights, and the care used to protect record confidentiality were all ethical concerns for the study. Indigenous peoples have a special right known as Free, Prior, and Informed Consent (FPIC) which enables them to approve or reject studies that could have an impact on them or their lands [47]. FPIC requires that consent be sought from participants before the research begins [48]. The purpose of the research was explained to respondents and permission was sought before the interview was conducted. Permission was obtained to compare the effects of LULC changes on biodiversity and to produce maps to that effect for publication. This involved using the data gathered during the study (both primary and secondary data). Respondents from the various communities were asked to select people who have in-depth agro-ecological knowledge concerning how LULC changes over the period have affected biological diversity in the study area. No attempts were made to influence the decision of the respondents to take part in the study. Before using and administering the study questionnaires, verbal consent from the respondents was requested. After receiving their agreement, respondents have the option to stop taking part at any time. None of the respondents, however, withdrew from the data gathering procedure after providing consent. The study's communities and the Owabi Wildlife Division agreed that the study results would be made public. Descriptive statistics were utilized to evaluate the qualitative data in IBM SPSS Software Version 23 and Microsoft Excel Software. Thematic analysis of qualitative data was used to uncover the primary themes that emerged from the interview. The interview and structured questionnaires yielded themes, which were then thematically assessed.

3. Results

3.1. Land use and land cover analysis in the Owabi catchment from 1991 to 2021

In 1991, high-density forest represented the most prominent LULC type with a surface area of 9945.50 ha representing 72.34% found in the north, south, west and some portion of east within the Owabi catchment (Fig. 3). The second dominant LULC type was low-density forest, covering a land surface area of 1958.75 ha representing 14.24%, followed by Built-up with a coverage of 1387.52 ha (10.09%), wetlands with 314.62 ha (2.29%), bare-ground with 89.61 ha (0.65%), and water with 51.75 ha (0.38%) (see Table 5).

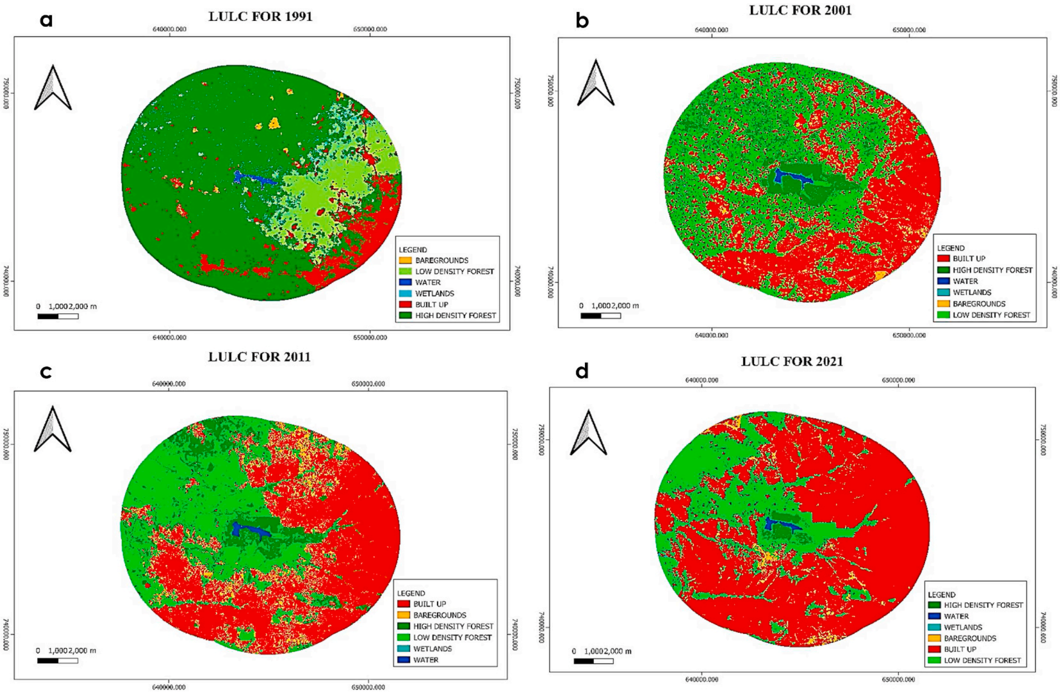

Fig. 3. Classified Maps of the Owabi catchment in 1991 (a), 2001 (b), 2011 (c) and 2021 (d).

The 2001 classified map shows reduction of land cover classes as compared to the classified image of 1991. With the exception of built-up with 6102.00 ha (44.39%), low-density forests with 6112.83 ha (44.46%) and bare-ground with 215.27 ha (1.57%). High-density forest lost its land surface area, with only 1205.05 ha remaining, accounting for 8.77% of the study area. The water decreased to 51.61 ha (0.38%), wetland decreased to 61.04 ha (0.44%). High-density forest was only occupied around the water within the catchment as shown in Fig. 3.

The 2011 classified map disclosed that considerable changes have taken place in the study area with built-up areas absorbing 6713.43 ha (48.83%) of the land, followed by low-density forest with a land coverage of 4604.77 ha representing (33.49%) found in the north-eastern, south-western and north-western parts of the catchment area respectively. The area of high-density forest reduced to 1196.21 ha representing 8.70%, wetland reduced to 5.88 ha (0.04%), and water increased and stood at 57.58 ha (0.42%) of the study area.

The 2021 classified map of the study area shows that built-up occupied 9653.68 ha, representing 70.22%. Low-density forest also occupied a significant portion of the land representing 3586.96 ha (26.09%). Bare-grounds reduced to 276.62 ha representing 2.01%, water reduced to 45.69 ha representing 0.33%, and wet-land also reduced to 5.33 ha representing 0.04%. Fig. 3 and Table 5 show that high-density forests have been primarily transformed into other LULC classes, particularly low-density forest and built-up. High-density forest was 179.58 ha representing only 1.31% of the surface area of the identified pixels as shown in Table 5 and Fig. 3.

3.2. Land use and land cover change patterns in the Owabi catchment from 1991 to 2021

LULC change trend analysis of the Owabi catchment demonstrates a shift in the size of the six classes over the study's 30-year period. The classification shows that built-up areas had the greatest positive change, whereas high-density forests had the greatest negative change as illustrated in Table 6.

3.3. Accuracy assessment

GPS essentials was used to collect point's data in geographic coordinates from field survey along with samples extracted from google earth for the assessment. In all, 97 sample points were picked for the assessment and presented in a form of error matrix as shown in Appendix 2. The accuracy of the classification is validated in Table 7 to show the kappa coefficients and the overall accuracies achieved. The kappa values for all the periods represent almost perfect reliability since they fall within 0.81–1 [49].

3.4. Land use and land cover change detection in the Owabi catchment (1991–2021)

In 1991–2021, land cover change matrix shows relative changes with the areas covered by high density forest transformed to built-up, bare-ground, low density forest, wetland and water. Also, low density forest lost it land area to built-up, bare ground and water. Water and wetland areas also change into bare ground, build up and low-density forest as shown in Table 8.

3.5. Land use and land cover change impact on biodiversity

To analyze LULC change impact on biodiversity, communities that fall within the study area were interviewed about the extent to which land use change has affected plant and animal species. Out of the total percentage of the respondents, 69.5% agreed that trees are the most affected plant species followed by shrubs (27%) and the least being grass (3.5%). For animal species that have been affected as a result of land use change, 67% of the respondents agreed mammals are the most affected animals followed by birds (23.5%), fish (6%) and reptiles (3.5%) as shown in Figs. 4 and 5.

The Owabi wildlife sanctuary made available data of mammal species from 2013 to 2020 based on number of counts according to the department (see Appendix 1). According to the department, although there have been precedence of LULC changes in the Owabi catchment but data of plant and animal species over the years were not all documented with the exception to that of mammals which were recorded from 2013 to 2020. Due to this, the study was limited to mammals. However, since most mammals dominate in high-density forest, the decline of this land cover type may not be sufficient to ensure the long-term survival of animals that need vast

Table 5
Spatial extent of LULC change in the Owabi catchment after classification.

Land use/Land cover	Year							
	1991		2001		2011		2021	
Area	Ha	%	Ha	%	Ha	%	Ha	%
Built up	1387.52	10.09%	6102.00	44.39%	6713.43	48.83%	9653.68	70.22%
High density forest	9945.50	72.34%	1205.05	8.77%	1196.21	8.70%	179.58	1.31%
Low density forest	1958.75	14.24%	6112.83	44.46%	4604.77	33.49%	3586.96	26.09%
Water	51.75	0.38%	51.61	0.38%	57.58	0.42%	45.69	0.33%
Wet Land	314.62	2.29%	61.04	0.44%	5.88	0.04%	5.33	0.04%
Bare grounds	89.61	0.65%	215.27	1.57%	1169.93	8.51%	276.62	2.01%
Total Area	13,747.8	100.00	13,747.8	100.00	13,747.8	100.00	13,747.8	100.00

Table 6
LULC change trend from 1991 to 2021.

	Year							
Land use/land cover	1991–2001		2001–2011		2011–2021		1991–2021	
Area	Ha	%	Ha	%	Ha	%	Ha	%
Built up	4714.48	34.29%	611.43	23.39%	2940.25	21.39%	8266.16	60.13%
High-density forest	−8740.45	−63.58%	−8.84	−0.06%	−1016.63	−7.39%	−9765.92	−71.04%
Low-density forest	4154.08	30.22%	−1508.06	−10.97%	−1017.81	−7.40%	1628.21	11.84%
Water	−0.14	−0.2%	5.97	0.04%	−11.89	−0.09%	−6.06	−0.04%
Wet Land	−253.58	−1.84%	−55.16	−0.40%	−0.55	−4.00%	−309.29	−2.25%
Bare grounds	125.66	0.91%	954.66	6.94%	−893.31	−6.50%	187.01	1.36%

Table 7
Accuracy Assessment of 1991, 2001, 2011 and 2021 classified images.

Year		1991		2001		2011		2021
LULC	[6]PA	[7]UA	PA	UA	PA	UA	PA	UA
[8]B-up	95%	90%	100%	78%	100%	62%	100%	87%
[9]H-D F	100%	100%	95%	86%	80%	70%	65%	100%
[10]L-D F	88%	96%	95%	86%	75%	79%	100%	72%
Water	100%	90%	95%	100%	100%	100%	100%	100%
[11]W-L	86%	70%	70%	75%	71%	100%	83%	100%
[12]B-G	81%	90%	70%	100%	73%	100%	85%	100%
Overall	0.93		0.86		0.74		0.89	
Kappa	0.91		0.82		0.86		0.86	

[6]Producer Accuracy.
[7]User Accuracy.
[8]Built-up.
[9]High-density forest.
[10]Low-density forest.
[11]Wet-land.
[12]Bare-ground.

Table 8
LULC change conversions (change detections) 1991–2021.

1991	2021							
	Class Names	Built-up	High density forest	Low density forest	Water	Wet Land	Bare- ground	Total Area (ha)
	Built up	1328.78	1.30	39.16	0.74	1.56	15.13	1386.67
	High density forest	6434.03	155.78	3116.26	0.16	3.78	228.76	9938.77
	Low density forest	1587.85	12.33	341.06	0.16	0.00	25.23	1966.63
	Water	0.00	0.28	10.11	41.29	0.00	0.08	51.76
	Wet land	220.13	9.89	77.40	3.34	0.00	3.63	314.39
	Bare-ground	85.70	0.00	0.42	0.00	0.00	3.46	89.58
	Total Area (ha)	9656.49	179.58	3584.41	45.69	5.34	276.29	13747.8

expanses of space to support thriving populations [50–52]. This has affected the lives of mammal species in the catchment area since percentage of forest cover had the greatest influence on species richness [50]. In Figs. 6 and 7 the research indicates that the number of Dwarf Mongoose and African Civet have reduced to 8 and 12 in 2020 respectively. In Appendix 1, data on mammals indicate that Maxwell Duiker increased from 47 in 2013 to 54 in 2014, but its number declined from 2015 to 2020. Also, Royal Antelope declined to 37 in 2014, increased in 2015 and further declined again from 2016 to 2020. A study conducted by Alhassan [27] in the study area found that the amount of bush meat and fish being harvested in the Owabi catchment each year is 2000, which is 12 times more than what is being produced. This is viewed as not being sustainable [27]. According to the Forest Commission [28], bush-meat trade is thriving in the area. Some chop-bar owners admitted receiving carcasses of duikers and other ungulates from hunters within the villages around the reserve. It is possible some of them may have originated from the Owabi forest reserve; others were probably hunted from the fallow areas and secondary thickets around the Owabi catchment. Nunoo et al. [34], conducted similar work in the Owabi catchment and discovered that fishing resources at the reservoir were over-exploited, as shown by low catches recorded by fishermen during the study. The environment is a home to endangered mammals, whose population is declining [27].

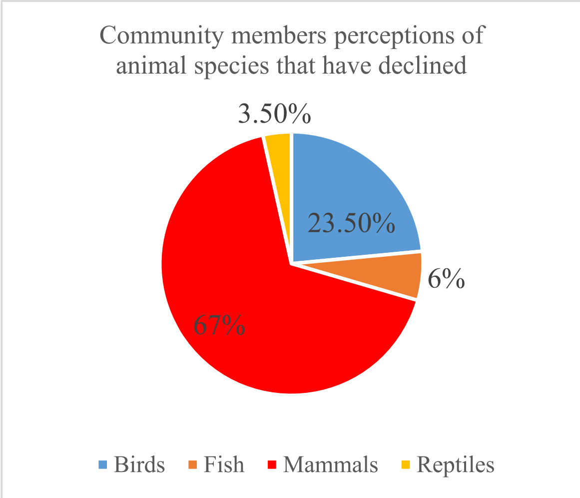

Fig. 4. A pie chart showing LULCC impact on animal species based on community members perception.

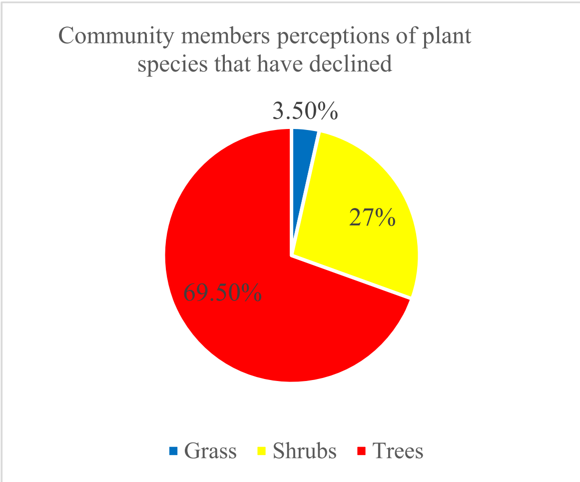

Fig. 5. A pie chart showing LULCC impact on plant species based on community members perception.

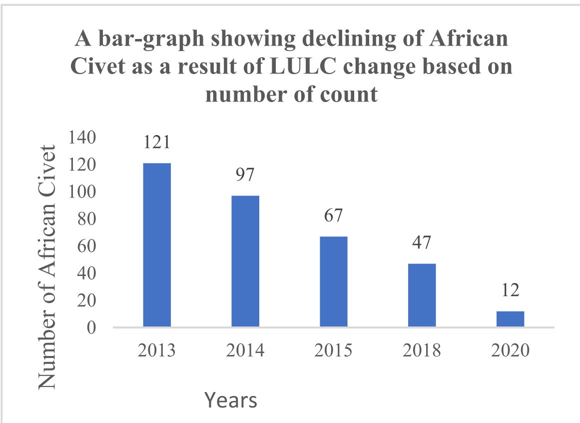

Fig. 6. A bar graph showing the state of African Civet.

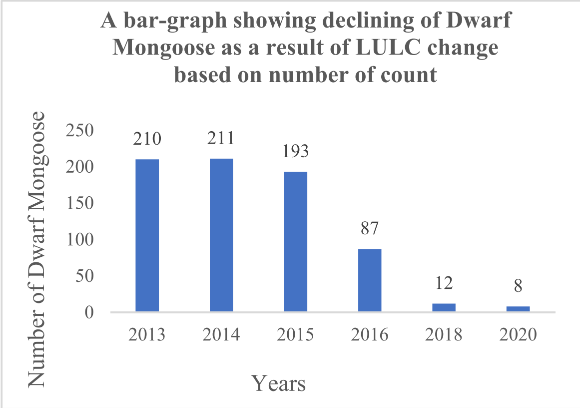

Fig. 7. A bar graph showing the state of Dwarf Mongoose.

3.6. Socio-economic and human-induced drivers to forest degradation and biodiversity loss

Regarding the socio-economic and human-induced drivers to forest degradation and biodiversity loss. Community members in the catchment area were interviewed about what they perceived as drivers of LULC change to forest degradation and biodiversity loss. The result shows that, 146 (73%) of the respondents perceived activities (for example, expansion of built-up as a result of population growth and illegal logging) as the main drivers to forest degradation and biodiversity loss. Twenty-one (10.5%) attributed the cause to poaching. While 17 (8.5%) and 16 (8.0%) of the respondents said it is bad farming practices and sand winning respectively. Investigations have revealed that population growth, illegal logging, and agricultural development are the main forces behind changes in LULC [53]. Population growth, land use practices and local development are exerting increasing pressure on the Owabi forest reserve and the dwindling resource base of the surrounding area [28]. Experts who had the background expertise to contribute to the research goals were included. During the expert interview, it was revealed that over-exploitation, climate change, industrialization, over-grazing, urbanization and population growth are among these drivers. These are major drivers contributing to LULC change [54] which increase pressure on biodiversity [55].

The result is shown in Table 9.

3.7. Land use and land cover prediction in the Owabi catchment for 2031

Fig. 8 shows LULC prediction map for 2031 in the Owabi catchment with the corresponding area of coverage shown in Table 10. Application of Molusce Plugin in QGIS 2.18.25 software procedures yielded a prediction land cover map for 2031. Built-up occupies the highest area coverage of 10184.4 ha representing 74.08%. Spatial extent of the remaining land cover classes is high density forest, occupying 176.7 ha representing 1.29%, low density forest occupying 2996.3 ha representing 21.80%, bare-ground with 348.2 ha (2.5%), wetland occupying 2.6 ha (0.02%) and water with 46.5 ha representing (0.33%). The study predicted LULC change in the Owabi catchment for 2031 using classified Landsat images of 2011 and 2021 together other spatial variables such as aspect, slope, distance to rivers and roads of the study area [56]. The system underwent changes involving artificial neural network learning for the prediction as shown in Fig. 8 and Table 10.

4. Discussion

4.1. Land use and land cover change in the Owabi catchment from 1991 to 2021

The Owabi catchment presents a unique landscape comprising of forest covers, water bodies and a distinctive plant and animals' species [28]. Yet, the landscape of the catchment area is changing by human activities [14,30,31 and 37]. Classified images of 1991, 2001, 2011 and 2021 have shown significantly reduction of high-density forest to low-density forest and built-up. High-density forest,

Table 9
Drivers for land use and land cover change.

Driving forces	Frequency	Percent
Bad farming practices	17	8.5
Expansion of settlement	116	58.0
Illegal logging	30	15.0
Poaching	21	10.5
Sand wining	16	8.0
Total	200	100.0

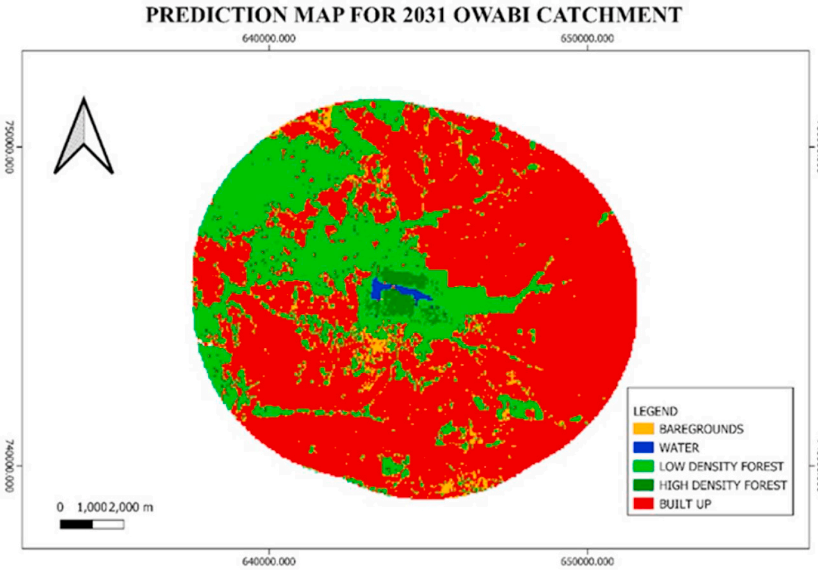

Fig. 8. LULC prediction map of the Owabi catchment for 2031.

Table 10
LULC prediction table for 2031.

LULC Class	Areas (hectares)	Percentages (%)
Wetland	2.6	0.02
Bare-ground	348.2	2.50
Water	46.5	0.33
Low density forest	2996.3	21.80
High density forest	176.7	1.29
Built-up	10184.4	74.08

the most dominant land cover type which accounts for 72.34% of the catchment area in 1991 reduced to 1.31% in 2021. In 2001, there was a major extension of low-density forest with noticeable conversion of high-density forest into low density forest. This increase in low density forest is directly caused by expansion of agriculture and demand for farmlands [57]. When agricultural based population increases near forested areas, deforestation occurs, since people destroy forest to pave way for farming activities [58]. This is also supported in a similar study by Peters [42] that roughly 65% of new agricultural lands comes from intact forest, 35% from disturbed forest, and 5% comes from shrubs. This backs with the claim made by the Max Planck Institute for Meteorology [59] that agriculture and pastures have replaced forest cover in many places of the world. Similarly, surface areas of water bodies in the study area were subjected to decreasing trend. In 1991, water area was 51.75ha (0.38%). In 2001, it reduces to 51.61 ha (0.38%) but increases to 57.58 ha (0.42%) in 2011 and later reduces again to 45.69 ha (0.33%) in 2021. The increased surface area of water in 2011 can be ascribed to excellent rainfall conditions and the fact that there were fewer human encroachment operations within the catchment as a result of the Ghana Water Company Limited and the Wildlife Conservation Division's rigorous restrictions [1]. These figures show a relative decrease in water in the study area over the 30-year period. However, wetlands in the area were subjected to the same decline. Wetland surface area was 314.62 ha (2.29%) in 1991 but it started declining from 2001 with 61.04 ha (0.44%), 5.88 ha (0.04%) in 2011, and 5.33 ha (0.04%) in 2021. As a result of population pressure, unplanned urban sprawl is wreaking havoc on water bodies in the area [60], stifling the growth of plant and animal species.

There is a striking rise of built up in the study area which had increased steadily from 44.39% in 2001 to 70.22% in 2021 as a result of urbanization and population growth in the Kumasi Metropolis. In 2011 and 2021, built up became the most dominant LULC type in the study area. The increase in built-up is a sign of urban expansion, which is reflected in the population growth of the Kumasi Metropolitan Area [61]. As a result of lack of economic opportunities and social amenities in rural areas, rural-urban migration has resulted in a considerable population increase in many Sub-Saharan African cities [42]. It is confirmed in other studies that urbanization is the principal cause of LULC changes in Ghana's wet and forest regions [62]. The conversion of forests and wetlands to other land uses, predominantly built-up, has increased in the twentieth century [63].

4.2. Impact of land use and land cover change on biodiversity

The study examines whether changes in LULC have affected biodiversity in the Owabi catchment area. Evidence from the LULC analysis in Tables 5 and 6 indicate that LULC have changed in the study area over the 30-year period of examination. The predominant change was conversion of high-density forest to low-density forest and built-up. Analysis of community members' perceptions of the current state of plants and animal species in the study area has shown that mammals, birds, fish, reptiles, trees, shrubs and grass have declined. Mammals' data received from the Owabi Wildlife Division shows evidence of decreasing mammal species such as Dwarfs Mongoose, Tree Pangolin, Maxwell Duiker, Bay Duiker, Africa Civet and others (see Figs. 6 and 7 and Appendix 1). The analysis of community members' perceptions of the current state of biodiversity, mammals' data and LULC changes (1991–2021) show a clear linkage between LULC change and biodiversity loss in the Owabi catchment. Urban sprawl, with a continuous increase in built-up have resulted in the loss of natural lands in the study area [64]. This is a threat to the existence and functionality of biodiversity [65].

The increasing problem of the forest deforestation for built-up has eroded most of the forest cover in the Owabi catchment [14,31]. This loss of forest cover is responsible for drastic reduction in biodiversity especially a large-sized animals [66,67] which are more sensitive to land use changes [68]. Human activities are changing the natural landscapes which in effect affecting the abundance, richness and spatial distribution of biodiversity in the area [1]. The broad expansion of built-up in the Owabi catchment has provided access for land encroachment [69]. This has served as a threat to plants and animal species in the area. Due to the fact that removing the forest cover has an impact on the diversity, quantity, and geographical distribution of plant and animal species [70]. This confirms that species diversity, richness, and range are decreasing, while dangers to species diversity are increasing [71].

According to Alhassan [27], one of the biggest risks to Ghana's biodiversity is LULC change. This has been supported by a research work from the forestry commission [28]. Between 1991 and 2021, about 80% of forest covers in the Owabi catchment were converted to built-up. This is affecting the security of the sanctuary/ramsar site since large areas of the outer portion of the catchment have been encroached [28]. These have major implications on plant and animal species [72]. This threats to biodiversity in the study area needs to be properly checked, so that the biodiversity in the study area can be sustainably manage and conserve to meet the needs of the future generations, but if not, land use activities will completely wipe off the biological diversity in the catchment in the nearby future.

4.3. Identifying the socioeconomic and human-induced drivers to LULC changes and biodiversity loss

Basommi et al. [73], highlighted that climate change, population expansion, urbanization, economic, socio-political, cultural, and religious factors, as well as scientific and technological advancements, are all factors that contribute to the extinction of plants and animals' species on the natural landscape. According to Neo-Malthusian' theory of environmental decay, when the number of available resources in a country is less than the size of the population, there will be an increasing number of depleted vegetation since greater number of them will be converted into other land uses [24]. However, Boserupian school of thought argued that population growth is rather not a curse but blessing or an asset. Their reasoning was that as a country's population grows, agricultural advances rather than forest conversion emerge [74]. While the Brundtland Report [WCED] [24,75] views poverty as a primary driver of forest degradation, an emerging empirical literature known as the Environmental Kuznets Curve contends that forest degradation is caused by development rather than poverty [24]. In a related literature on LULC mapping by Pandy and Nathawat [76] in the Yamunanger District of India noted that changes in climate and physical circumstances were the factors of LULC changes. It shows that neither population growth nor poverty are the main causes of forest degradation and biodiversity loss. People's responses to economic opportunities, international commerce, and agro-climatic conditions, as well as institutional factors cause forest degradation and biodiversity loss [77].

However, the results of the interviews (both community and expert) brought forth the drivers influencing LULC changes and biodiversity loss in the Owabi catchment. Expansion of settlement, illegal logging, sand wining, and bad farming practices are the drivers changing the natural landscape of the study area as perceived by the community members. Analysis of the classified Landsat images of 1991–2021 sees expansion of built-up and low-density forests (farmlands) as the primary cause of forest degradation and biodiversity loss. This is in support to a study conducted by Musetsho et al. [78], which discovered expansion of built-up and increased in agricultural land as the most dominate LULC classes to biodiversity loss in South Africa. Expert interview with the staff of the Owabi Wildlife Division revealed that overexploitation, urbanization, industrialization, and population growth are among these drivers. Urbanization is regarded as one of the most intensive and rapid human-induced factors that threat biodiversity [65]. When urban land replaces natural habitat, it permanently alters the type of habitats available along with their spatial configuration and level of interconnectedness, resulting in significant changes in the abundance and composition of species assemblages [79]. Since industrialization can lead to urbanization and climate change, these could have significant impact on both human societies and the environment [80,81]. Population growth, land use practices and local development are exerting increasing pressure on the Owabi forest reserve and the dwindling resource base of the surrounding area [28].

Nunoo et al. [35], conducted a research in the Owabi catchment and discovered that fishing resources at the reservoir were over-exploited, as shown by low catches recorded by fishermen during the study. Osei-Wusu et al. [24], revealed similar observation where LULC changes have endangered species such as antelopes, monkeys, deer, crocodile, crab and odum found in the lake Bosomtwe. According to the staff of the Owabi wildlife sanctuary, most Mammals' species have been overexploited through poaching. Noise creation from logging activities have destroyed most of the natural habitats of the animals' species contain in the forest [14].

4.4. Predicting land use and land cover changes in the Owabi catchment for the year 2031

The 10-year spatial prediction of LULC change in the Owabi catchment from 2021 to 2031 shows an increase in built-up covering an area of 10184.4 ha representing 74.08% of the land area (Table 10 and Fig. 8). The analysis shows that other LULC classes have reduced to built-up area. The closeness of the Owabi catchment to the Kumasi Metropolitan Area which has seen an increasingly demand for land for settlement makes this prediction a possibility. Communities surrounding the Owabi catchment have also seen the expansion of settlement. These LULC predicted changes are apparent considering the demand to stay near and access of activities within the Owabi catchment. Since everyone wants to live close to activity centers like trading center, administrative areas, schools, home, workplaces, and so on, there is always spread of human population in such areas. This rapid change could be mitigated through active decision makers to decentralize activity centers and to develop efficient road network distribution. Farming activities within the catchment area and its environs are also reducing and therefore 21.80% of land predicted for low density forest is predictable. Since forest covers have been degraded to pave way for built-up during this period, the lives of the biodiversity in the study area will still be at stake if proper measures are not put in place.

In 1988, Ghana signed the Ramsar Convention, which led to the designation of the Owabi watershed as a protected site and the subsequent passage of the Forest and Wetlands Management (Ramsar sites) Regulations 1999 [82]. Nonetheless, the observation in this study indicates that the Owabi catchment, which is a protected area, is losing its significance. The prediction also presupposes that the Forestry Commission's Wildlife Division and Ghana Water Company Limited, which are mandated to protect the Owabi catchment, have largely failed to improve biodiversity conservation and sustainable use in the study area, despite raising awareness about the importance of forest conservation and restoration. There is therefore the need to tighten the conservation measures and improve on the measures requires to protect the forest degradation and subsequent loss of biodiversity.

5. Conclusion

The study uses Landsat satellite images of 1991, 2001, 2011, and 2021 to examine LULC change and implications to biodiversity in the Owabi catchment from 1991 to 2021. Analysis of the Landsat images shows substantial reduction of high-density forest to built-up. High-density forest which accounts for 72.34% of the Owabi catchment in 1991 has reduced to 1.31% in 2021. Similarly, the surface area of water-bodies have reduced in the area, while built up areas have increased steadily from 2001 to 2021. These changes can be linked to urbanization which is reflected in the population growth of the Kumasi Metropolitan Area. The demand for land for built-up in different parts of the catchment area due to increasing population have resulted to the loss of forest cover and water-bodies in the area.

The study also indicates that plant and animal species in the area have reduced. One would agree that as forest cover which form the habitat for plant and animal species decline, there is a major threat to biodiversity. The main fear is that the Owabi catchment could suffer a significant loss of biodiversity if forest cover in the area continue to decline. The study revealed expansion of built-up and increase in low-density forest (farmlands) as the primary causes of forest degradation and biodiversity loss in the study area. The Owabi catchment has experienced increasingly encroachment from settlement expansion and other human activities. The spatial prediction of LULC map shows that by the year 2031, a significant proportion of forest covers and water bodies in the Owabi catchment will give way to built-up. High density forest will reduce to 1.29%. It is also predicted that built-up area will cover an area of 10184.4 ha (74.08%) of the land area. These changes in LULC are likely to affect the lives of biodiversity in the study area if proper measures are not put in place to reverse it.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendices.

Names of Mammals	2013	2014	2015	2016	2017	2018	2019	2020
MONA MONKEYS	247	271	261	254	243			224
DWARF MONGOOSE (Ahwea)	210	211	193	87		12		8
Tree Pangolin (Apra)	43	45	23	17	10	7		3
African Civet (Kankane)	121	97	67			47		12
MAXWELL DUIKER (Otwee)	47	52	56	52		11		3
ROYAL ANTELOPE (Adowa)	57	37	42			42		13
GIANT SQUIRREL (Opro)	86	92	67	52		17		35
Bay Duiker (Oyuo)	37			23	25			12
Bush Buck (Wasane)	52	54		28		23		25

Appendix 1. Mammals data in and around the Owabi catchment from 2013 to 2020

Source: Owabi wildlife Sanctaury

Appendix 2. Error Matrix for 2021 classification

Classified	Built-up	High density forest	Low density forest	Water	Bare-grounds	Wet lands	Classified Total
Built up	20	0	0	0	3	0	23
High-density forest	0	13	0	0	0	0	13
Low-density forest	0	7	21	0	0	1	29
Water	0	0	0	10	0	0	10
Bare-grounds	0	0	0	0	17	0	17
Wet lands	0	0	0	0	0	5	5
Reference Total	20	20	21	10	20	6	97

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