ASSESSING THE RESPONSE OF BIOCAPACITY TO LANDUSE LANDCOVER DYNAMICS IN KADUNA STATE FROM 2000 TO 2020

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Abstract

The dynamics of Biocapacity (BC) of Kaduna State was determined over the last two decades between year 2000 and 2020. The BC per capita was also established and used to compare with national averages for BC and Ecological Footprint (EF). Land use Land Cover (LULC) classification data for the years 2000, 2010 and 2020 for Kaduna State was extracted from the global LULC data provided by the Global Land Analysis and Discovery (GLAD). Data was imported into the QGIS 3.3 environment and used to manipulate the data. Calculation factors for BC (yield factors and equivalence factors) were obtained from the Global Footprint Network (GFN) National Ecological Footprint and Biocapacity Accounts. The LULC analysis indicate steady decline in grassland (-19.3%) and forestland (-4.1%) covers over the entire period studied. Conversely, a steady increase in the amount of cropland (+37%) and infrastructure (91.6%) was recorded throughout the same period. Furthermore, results indicate a total BC of 3,604,738gha, 3,934,588gha, and 3,762,599gha for years 2000, 2010 and 2020 respectively. Moreover, for the same periods, the BC/capita were determined to be 0.73gha, 0.57gha and 0.4gha respectively. By comparing these values with the average national EF/capita of 1.18 (2000), 1.28 (2010) and 0.9 (2020), a deficit of -0.45 (2000), -0.71 (2010) and -0.5 were recorded for the state over the period under study. It is hoped that healthy population growth and properly managed infrastructural development will give a better outlook for the biocapacity of the state.

Keywords: Biocapacity, Ecological Footprint, Landuse-Landcover, GIS

INTRODUCTION

The survival and development of human societies as well as the sustenance of many ecosystem services depend greatly on the availability of many environmental resources such as soil, water, and vegetation (Lin et al., 2016, Vörösmarty et al., 2018). Human population have grown significantly over the last decades, growing from an estimated 2.5billion people in 1950 to about 8billion as at November, 2022 (United Nations, 2022). The sustenance of this growing population, and the increased human actions culminating from it, place significant demands on environmental resources (Abebe et. al., 2022). Human activities, heightened by population growth has contributed to the significant degradation of ecological systemsthrough pollution, landcover conversion, waste generation and the likes (Khan et al., 2021; Morshed et al., 2023). Moreover, it is estimated that by 2050, global human population would have risen to about9.7 billion (United Nations, 2022). This therefore buttresses the need for the sustainable use of resources in order to guarantee the future of generations to come.

One of the major indicators of the pressure humans place on the environment are recorded as Land-Use Land-Cover (LULC) across the landscape. These changes are quite significant in Africa (Belcakova & Diviakva, 2017), where in recent decades, African grassland, woodland, bushland and other vegetation covers have been declining due to rising demands for agricultural lands and human infrastructure (Wackernagel & Bayers, 2019). Achieving sustainable development therefore requires that our consumption of environmental resources be monitored so as to provide credible information that would aid or guide policy making and action (Lin et al., 2016). Monitoring these human impacts are very vital in global discourse and the Biocapacity and Ecological footprint are among the most effective measure of assessing the capacity of the environment to sustain life (Morshed et al., 2023).

The Biocapacity (BC) refers to the 'capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans, using current management schemes and extraction technologies' (Global Footprint Network [GFN], 2022). On the other hand, the Ecological footprint (EF) is a measure of the demand humans place on biocapacity through production, import, export, and consumption. Further, both the BC and EF are indicators of resource flows. Such flows are usually expressed in other units such as tonnes per annum. However, the BC and EF concepts change this by relating these flows to actual amount of land required to provide or regenerate such annual resource flows (Lin et al., 2016).These represent the productivity of a nation or geographical area's ecological assets which are majorly grouped under cropland, grazing land, fishing grounds (water bodies), built-up land, forest area and the carbon demand on land. When the EF of a population exceeds its biocapacity, it is considered to be in biocapacity deficit or ecological deficit and vice-versa. Estimating the BC becomes important since it provides insights into the ecogeographical wealth of any region (Burucke et al 2013).

Most computations of the EF and BC have been at the global, regional or national level. However, a number of studies have attempted to assess the EF and BC at the subnational level such as Wang et al,.(2014) in Wuhan city, Galli et al. (2020), for Portuguese cities, while Marzouki et al. (2012), compared the EF of ecotourism and mass tourism by studying cases in Seychelles and Tunisia. Others assessed the EF of academic institutions (Venetoulis, 2001; Cetin et al., 2021) and of building construction (Gonzalez-Vallejo et al., 2015). In Nigeria, Otto et al. (2022) assessed the EF of consumption in Ijebu Ode, and Abd'Razack et al (2021) assessed EF of a housing estate in Minna. Most of these studies focus majorly on the EF and only introduce the BC as a part of the calculation both at regional, national and subnational level (Morshed et al., 2023). To the best of our knowledge, studies on EF and BC in Nigeria are quite few and majority focus more on the EF of small cities or of residents. We have sought to bridge this gap by assessing the BC of Kaduna State using geospatial techniques.

MATERIALS AND METHODS

Study Area

Kaduna State is located in the Northwestern part of Nigeria and lies between Latitudes 090 02'N and 110 32'N, and between Longitudes 060 15'E and 080 38'E(See Figure 1). The state is characterized by two marked seasons; the wet season which begins about May through mid-October, and the dry season which lasts from mid-October through April of the following year. Average annual rainfall across the state is about 1322mm but higher amounts may be recorded in the southern part of the state, while lesser amounts are recorded in the Northern part(Abaje et al., 2015). The state is located within the guinea savanna belt of Nigeria which is characterized by large expanses of grasslands and shrublands (Iloeje, 2001). A few forested areas also abound including the AfakaForest Reserve, the KamukuNational Park, the KachiaForest Reserve among others. The state currently has a population of over 9million people making it the third largest in Nigeria. Furthermore, Kaduna, the state capital is largely a metropolitan area with a lot of commercial and administrative activities. Over 50percent of the population engage in some form of agriculture either for subsistence or commercial purposes (Kaduna State Government, 2023)

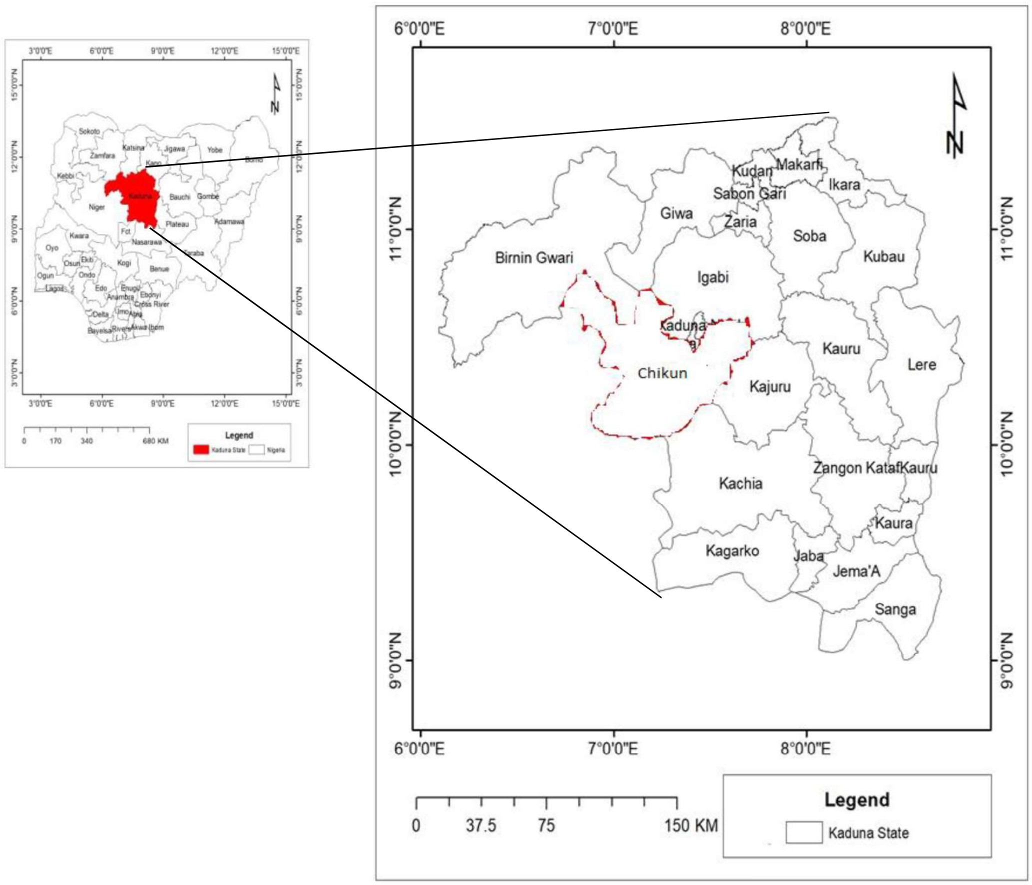


Figure 1: Map of Kaduna State
Source: Modified from Abaje (2015)

Methodology

Data Types and Sources

The LULC data for the years 2000, 2010 and 2020for Kaduna state was extracted from the global LULC data provided by the Global Land Analysis and Discovery (GLAD). This dataset is freely available at https://storage.googleapis.com/earthenginepartners-hansen/GLCLU2000-2020.To calculate BC, the landcover sizes are related to the yield and equivalence factors. These factors are obtained from the GFN public dataset. The population data for

Kaduna State for the year 2000, 2010 and 2020 was used to determine the per-capita BC in the state. The population data was obtained from the website of the Kaduna State government.

Nigeria's national EF and BC values were obtained from the GFN National Ecological Footprint and Biocapacity Accounts (York University Ecological Footprint Initiative & Global Footprint Network, 2023). QGIS 3.3 and Microsoft Excel were used to aid with the analysis.

Determination of Biocapacity (BC)

The BC is the measure of the biologically productive land required to sustain a population's demand for resources and to also absorb the waste it generates therefrom, under prevailing management practices and technological level. Biocapacity can change from year to year due to climate, management, and also what portions are considered useful inputs to the human economy (GFN, 2022). The landcover types and their basic description are provided in Table 1. Biocapacity is usually expressed in global hectares (gha) and for each land type, we determined the BC using Equation 1 below:

$$\mathbf{BC} = A * YF * EQF$$ ……………………. Eq. 1

Where:

BC = biocapacity of a given land use type, gha

A = Area of a given land use type within a country, nha

YF = Yield factor for a given land use type within a country, wha nha-1

EQF = Equivalence factor for given land use type, gha wha-1

Table 1:LULC Types Used for BC and EF Accounting

Cropland: Cropland is the most bioproductive of all the land-use types and consists of areas used to produce food and fiber for human consumption, feed for livestock, oil crops, and rubber.
Land for Forest Products: Forests provide for two services. The forest product Footprint, which is calculated based on the amount of lumber, pulp, timber products, and fuel wood consumed by a country on a yearly basis. It also accommodates the Carbon Footprint.
Fishing grounds (surface water): Inland waterbodies that serve as source of fish for a variety of purposes including animal feeding

Grazing land: Grazing land is used to raise livestock for meat, dairy, hide, and wool products.	
Built-up land: The built-up land Footprint is calculated based on the area of land covered by human infrastructure — transportation, housing, industrial structures, and reservoirs for hydropower. In absence of better evidence, it is typically assumed that built-up land occupies what would previously have been cropland.	

Source: York University Ecological Footprint Initiative & Global Footprint Network (2023)

Global hectare (gha)

This is the fundamental unit for the expression of BC and EF of a given area. It is determined based on the average biological productivity of a given hectare of land in any particular year and serves as the standardized basic unit for Biocapacity and Ecological Footprint accounting. It tends to normalize the variation in bio-productivity at the local, regional or global scale so that BC and EF values are comparable globally(Lin et al., 2016).

Yield Factor (YF)

The YF is a normalizing factor which accounts for the variations in productivity of a given landcover types across different countries. When the size of a given land type (in hectares) is multiplied by the YF and equivalence factor (discussed later), the product is a landmass expressed in global hectares (gha) (Miller et. al. (2022). For each landcover type in Nigeria, the yield factors utilized were obtained from the 2023 report of theGFN's National Ecological Footprint and Biocapacity Accounts (NFBAs) and same is presented in Table 2.

Table 2: Yield Factors of Various Land Types in Nigeria

YEAR	LAND TYPE	YIELD FACTOR
2000	Crop Land	0.657511
2000	Grazing Land	1.45557
2000	Inland Fishing Grounds	1
2000	Forest Land	0.262785
2000	Infrastructure	0.709082
2010	Crop Land	0.7125
2010	Grazing Land	1.45557
2010	Inland Fishing Grounds	1
2010	Forest Land	0.262785
2010	Infrastructure	0.756329

2020	Crop Land	0.573703
2020	Grazing Land	1.45557
2020	Inland Fishing Grounds	1
2020	Forest Land	0.262785
2020	Infrastructure	0.808719

Source: York University Ecological Footprint Initiative & Global Footprint Network (2023)

Equivalent Factor (EQF)

The EQF aids in the grading of productivity of any given landcover type, aiding to convert same into a standardized unit of biologically productive area (the global hectare, gha). It should be noted that EQFs for various countries of the world are the same for any given year – variations are only recorded intertemporally(Johannesson, 2017). The EQF used for the current study was obtained from the 2023 report of the GFN's National Ecological Footprint and Biocapacity Accounts and used for computations of BC. The equivalence factors utilized are as presented in Table 3.

Table 3: Equivalence Factors (EQF) of Different Land Types

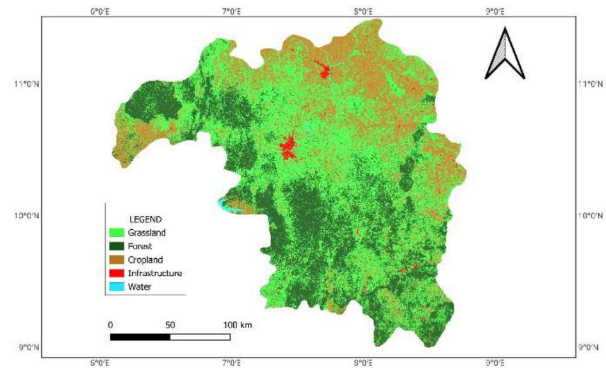
LAND TYPE	**YEAR**		
	2000	**2010**	**2020**
Cropland	2.535	2.528	2.497
Forest Land	1.304	1.292	1.267
Grazing Land	0.457	0.453	0.461
Inland Fishing Grounds	0.368	0.364	0.371
Infrastructure	2.535	2.528	2.497

Source: York University Ecological Footprint Initiative & Global Footprint Network (2023)

RESULTS AND DISCUSSION

Interdecadal LULC Characteristics of Kaduna State (2000 – 2020)

The LULC characteristics in Kaduna is shown are shown in Figures 2a, 2b and 2c. The progressive expansion of the croplands in the Northern, Western and South-western parts of the maps from 2000 to 2020 is rather obvious. Also visible is the expansion of infrastructure, majorly taking up lands initially covered by grasslands and cropland. But for a few areas in the southern fringes, the forest cover across the state appear to remain somewhat unperturbed throughout the period under consideration.



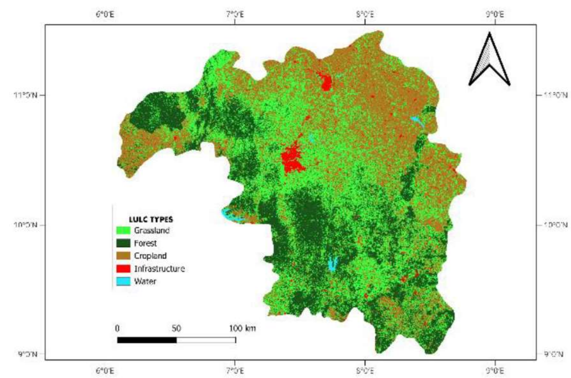


Figure 2a: 2000 Figure 2b: 2010

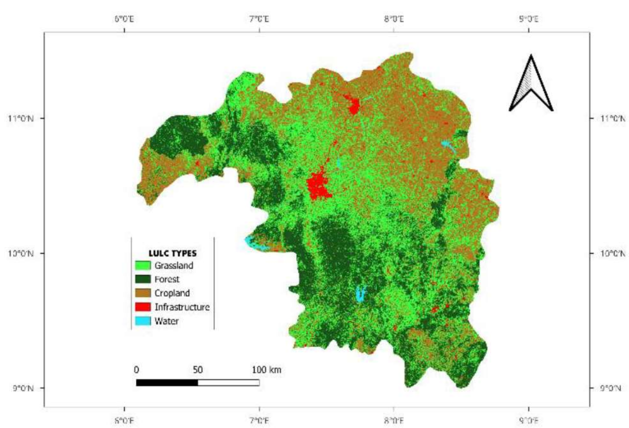


Figure 2c: 2020

Source: Adapted and Modified from GLAD Data Set

LULC Dynamics in Kaduna (2000-2020)

Figure 3 presents the LULC characteristics for the years 2000, 2010 and 2020. The change statistics are also presented in Table 4. For the years under consideration, grassland remained the dominant landcover type in the area.This is expected since the state is located within the guinea savanna region where grasslands are the dominant vegetation. More so, a steady decline in grassland was also recorded from 2000 to 2020.

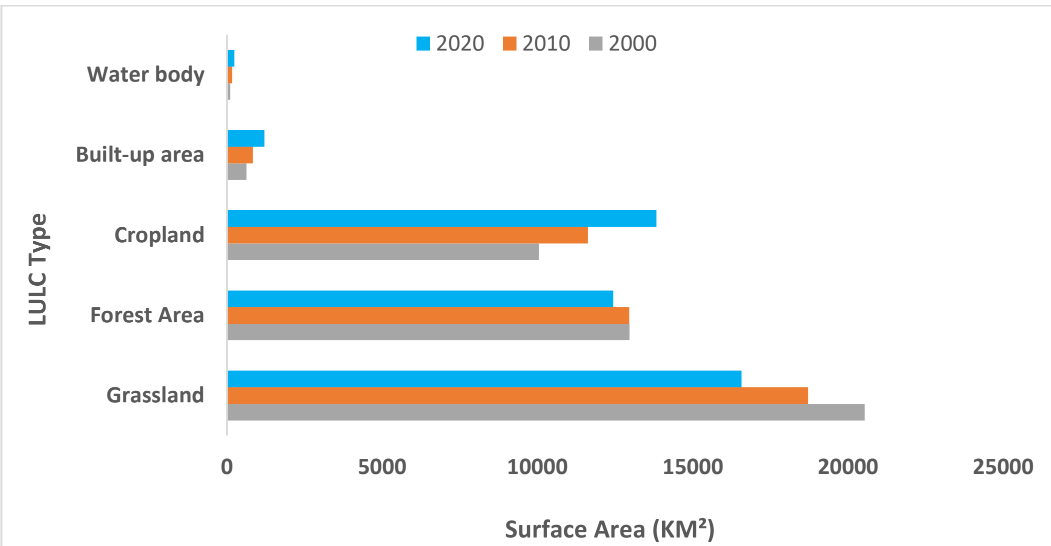


Figure 3: LULC Dynamics of Kaduna State from 2000 to 2020

Source: Author's Analysis (2023)

Forested areas appeared to remain constant between 2000 and 2010 and then slightly declining for about 4percent between 2010 and 2020. Cropland is also a major landcover which has seen a steady increase in the last two decades, having increased by about 38percent throughout the period.

Table 4: Interdecadal LULC change statistics (2000-2020)

Land Type	2000 – 2010 (KM^2)	Percentage Change	2010-2020 (KM^2)	Percentage Change	Overall (2000-2020)	Percentage Change
Grassland	-1822	-8.9	-2143	-11.4	-3965	-19.3
Forest Area	-11	-0.1	-516	-4.0	-527	-4.1
Cropland	1576	15.7	2210	19.0	3786	37.7
Infrastructure	202	31.9	377	45.2	579	91.6
Water body	59	58.0	73	45.2	132	129.4

Source: Author's Analysis (2023)

Though making up a little part of the entire landcover, the infrastructure also experienced steady increases over the years. This is likely a reflection of the population growth in the state which has necessitated the need for more residences and social infrastructure to cater to the needs of the burgeoning population. Overall, the loss of about 19% of grassland cover and about 4% forest area between 2000 and 2020, is explained by the obvious changes captured in Table 4 where about 4500km^{2}was collectively lost by grassland and forested areas, while about 4300km^2 was collectively gained by cropland and infrastructure. It is worth noting that the area occupied by bare-ground was not captured here as it is considered unproductive and thus not relevant in the calculation of BC.

Biocapacity of Kaduna state

The BC of Kaduna state is presented in Figure 4 across various LULC type. The statistics of the change of BC in response to LULC changes are also presented in Table 5. It can be observed that the highest BC was recorded in 2010 while the least was in 2000. The major contributor to BC for all the three epoch is cropland followed, closely by grassland.

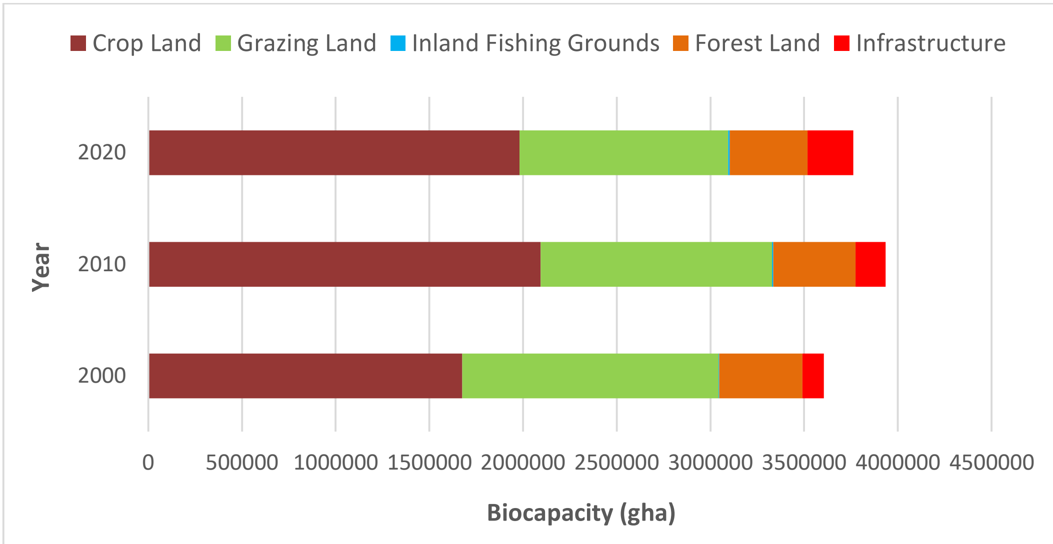


Figure 4: LULC dynamics of Kaduna State from 2000 to 2020
Source: Author's Analysis (2023)

Water bodies have the least, almost insignificant contribution to the BC of the state. While forest contribution to BC seems fairly constant, we observe a continuous rise in the contribution of infrastructure to BC, increasing by about 115 % over the last two decades. More so, between 2000 and 2020, the individual contributions of grasslands and forest lands to the BC of the state have declined by about 19% and 7% respectively. The fishing grounds also registered significant increase in its contribution to the BC of the state having increased by about 131% throughout the period.

Table 5: Interdecadal Biocapacity change statistics (2000-2020)

Land Type	2000 – 2010 (gha)	Percentage Change	2010-2020 (gha)	Percentage Change	2000-2020 (gha)	Percentage Change
Crop Land	419349.2	25.0	-112521	-5.4	306828	18.3
Grazing Land	-133051	-9.7	-121797	-9.9	-254848	-18.6
Inland Fishing Grounds	2125	56.5	2811	47.8	4936.254	131.3
Forest Land	-4453	-1.0	-25626	-5.8	-30079	-6.8
Infrastructure	45879	40.3	85144	53.3	131023	115.2

Source: Author's Analysis (2023)

Determining Kaduna State Per-capita BC

Table 6 summarizes the BC per capita determined for Kaduna state. Generally, a continuous decline in the BC is observed over the last two decades, from 0.86gha in 2000 to about 0.5gha in 2020.

Table 6: Comparison between Kaduna BC/capita and National averages

Parameter	2000	2010	2020
Total Kaduna State BC	3604738	3934588	3762599
Total Population	4,930,300	6,929,027	9,476,053
Kaduna State BC/capita	0.73	0.57	0.4
Nigeria BC/Capita	0.86	0.73	0.5
Nigeria EF/Capita	1.18	1.28	0.9
Kaduna Reserve/Deficit*	-0.44886	-0.71216	-0.50294

*Utilized national average EF values to be derived

Source: Adapted and modified from York University Ecological Footprint Initiative & Global Footprint Network (2023)

This pattern is similar to that of Nigeria's average BC per capita. Although the current study did not determine the EF of Kaduna state, using the national averages of EF in the last two decades, we observe an increasing ecological deficit for Kaduna state over the period considered.

Discussion of Findings

The LULC dynamics in the state has been shown to favor an increasing number of croplands and infrastructure as also identified by Wackernagel & Bayers (2019). Such increase came at the detriment of a declining grassland and forest covers and is most likely a consequence of population expansion which places demand on more infrastructure. With the population of Kaduna state expected to reach about 13million in the year 2030 (Herbert, n.d.),this pattern of LULC changes may not abate. More so, the drive towards agriculture by the last administration in the country and the significant rise in value of farm produce might have, to a large extent, influenced the increase in cropland cover and its subsequent increased contribution to the BC of Kaduna. As observed from table 6, it is worth noting that currently, average per capita BC of the country is 0.5 and this places the BC/capita of Kaduna state below this national average. Even more concerning is the fact that the per capita EF in Nigeria is currently 0.9gha. This implies that an 'extra' Kaduna state is required to properly accommodate the demand placed on the environment by the state's population since about 0.5gha of BC/capita will be required. A burgeoning population and poor land management practices could even place more demands. Responsible actions must thus be taken to ensure that development is pursued sustainably.

Conclusion

The biocapacity and ecological footprint of Kaduna state has again established the challenge of increasing population growth over resources that are already overburdened. With the deficit in BC established for the state, the growth of population and infrastructural development, if not properly managed would continually threaten the sustainability of future generations. This calls for action from relevant stakeholders if our future in a flourishing earth is to be guaranteed.

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