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Ecological footprint for environmental sustainability in Ilorin Metropolis, Kwara State, Nigeria

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Abstract

Ecological footprint (EF) is an indicator that accounts for human demand in the environment compared with the sizes of the bio-productive land and sea areas. This research was carried out to determine the EF for environmental sustainability in Ilorin Metropolis. Empirical surveying, which involved systematic random sample technique, was used to select residential households in each community for this investigation. The EF indicators, which include food, energy and waste consumptions, were determined empirically. The bio-capacity (BC), ecological stress and deficit were determined, from the land used as environmental sustainable areas in Ilorin, using Google Earth Mapping. The results revealed that energy has the highest EF of 44%, followed by waste and food with the footprint of 25% and 5%, respectively. A deficit of 38% was obtained, and this requires eight times the BC to balance the EF of the population. This implies that people are consuming more of the energy and generating more wastes than they consumed food.

Keywords: ecological footprint, bio-capacity, deficit, food consumption, Ilorin

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1. INTRODUCTION

Ecological footprint (EF) has the potential to illustrate symbolically the links between topical environmental issues, such as climate change, and an individual's day to day, local life style practices and decision-making [13]. The EF analysis is widely used to support sustainable development of resources including the management of goods and services, industry, neighborhoods, cities, regions and nations [9, 12, 20]. It is a consumption-based indicator, and it includes all the natural capital that is directly or indirectly used or consumed by the local population. In accounting for the EF of a location, the knowledge of the ecological bio-capacity (BC) is essential [15]. The BC is measured in relation to five categories of land-use type, namely grazing land, cultivated land, forest, fishing areas and built-up land [21]. It is used to measure the available biological productive land type that can be obtained for food, fiber, timber and carbon dioxide consumptions. It is necessary to calculate a region's total area of ecologically productive land. The combination of the EF (equivalent to demand) and the BC (equivalent to supply) allows researchers to estimate whether or not humans overuse the biosphere's resources by

subtracting the EF from the BC for a given period of time to identify a deficit or surplus. The EF analysis has been widely used as an indicator of ecological overshoot and human demand on natural systems. It is used at different scales, such as countries [2], regions and cities [3]. The EF accounting has been used to support decision-making in recent years by providing information for policy makers who must integrate food security with ecological implications [5].

A regenerative capacity of 1.6 Earths is needed to meet the yearly requirement of the natural resources, based on the calculations from a five-category global land use and the carbon EF [23]. This indicates that humanity has already exceeded the global BC by depleting the stocks of the natural resources. Song *et al.* [19] reported that food, water, waste, carbon and footprint of every household in China have increased over the years due to an increase in income per capita base. The authors computed the EF of food consumption using local average productivities based on the land-use types. They, however, did not consider the total land area required to absorb the wastes and greenhouse gases generated from the production and consumption activities. The national footprint account in 2016 computed the EF of each

country using data spanning from 1961 to 2013 from the global footprint network, which ranked Nigeria at 165th given the EF to be 1.16gha/capita, BC of 0.7gha/capita and also the ecological deficit to be -0.47 [1]. Despite the level of success achieved in the previous studies, there are no reported cases of the EF for the environmental sustainability of Ilorin Metropolis, Kwara State, Nigeria. The EF values were often underestimated, and this may perhaps be responsible for the high level of the ecological deficit in most localities [1, 16]. The consequence of this is severe on the local population, and planning for the future needs of the people may be affected. Hence, there is a need to evaluate the EF of Ilorin Metropolis by considering the yield and equivalence factors for the land-use type. This is necessary to ensure an environmentally sustainable management of resources in Ilorin Metropolis. Thus, the objective of this research was to determine the EF, including the percentage of daily food consumption, water consumption, energy consumption housing and waste generation for the environmental sustainability of Ilorin Metropolis, Kwara State, Nigeria.

2. MATERIALS AND METHODS

2.1. Description of study area

This study was conducted in Ilorin, the capital of Kwara State, Nigeria. Ilorin has a population of 847,000. It lies in the plain of the southwestern part of Nigeria. Kwara State has a population of 2.4 million people, and Ilorin is about 306 km from Lagos [11]. The city has three local government areas, namely Ilorin West, Ilorin East and Ilorin South local government areas, and about 19 wards as shown in Figure 1. This study took place in 19 heterogeneous communities in Ilorin such as Fate, Akerebiata, Oke-ose, Adewole estate, Kuntu, Gbagba, Agbooba, Irewolede, Asa-dam, Okelele, Sango, Adabata, Gaakanbi, Gomo, Gambari, Odota, Maraba, Saw-mill and also Baboko.

The satellite image of farm land near Egbejia, Ilorin, is shown in Figure 2a. It reveals that different farming activities are carried out including cultivating of soil, planting, harvesting of crops, feeding, rearing and management of animals, aquaculture, raising private aquatic animals (fish) floriculture and growing flowering plant. Figure 2b shows the satellite image of cluster forest and tree species as fuel wood indicating that the forest resources are indiscriminately exploited by the inhabitants who solely depend on it to earn their livelihood.

2.2. Conceptual analysis survey and data sources

Empirical surveying was carried out to determine the EF of food consumption in Ilorin Metropolis. The survey was in two stages, namely questionnaire administration and analysis. The questionnaire obtained necessary information about five different components, that is, food consumption, water consumption, housing, energy and waste generation footprint in the study area. The survey collected necessary information on mechanism that influences the resident habit to consumption of resources. Primary

information on food consumption was collected through a survey of households. In the survey, seven main categories of food items were identified and recorded: cereals, tubers, beverages, fish, fruits, vegetables, beef and meat as shown in Table 1.

Systematic random sample technique was used to select residential households in each community to answer the questionnaire. This involves selecting household at interval of 10 houses in each location. This was continued until the desired sample size was reached. This is a common approach for systematic random technique in the field and has been widely used [18]. Questionnaires that listed the main food items included in the questionnaire based on household socioeconomic data were distributed. Questions were posed to each household with respect to the amount of daily food consumption, water consumption, housing, energy consumption and waste generation. The average values obtained from these questions were then converted to EF. A total of 380 residential households were surveyed. During the survey, a correspondent of each household or a family member who was familiar with the household was asked to answer the questions. After reviewing the numerous literatures on EF, a research matrix from the findings of literature review was designed by addressing the required data, methodology, data collection process and data sources as shown in Table 2. The hourly climate condition of Ilorin city is presented in Table 3 [22]. This shows the average temperature, wind and weather conditions of the city at different times of the day.

2.3. Determination of EF

The EF of Ilorin Metropolis was determined based on the footprints of the consumption of food, water, housing, energy and waste production. The details on how this was carried out are discussed under the following headings.

2.3.1. Determination of the EF of food consumption

The footprint of the major food categories consumed within Ilorin Metropolis including cereals, beverages, confectionaries, tubers, meat, fish and poultry was determined. The total amount of the annual food consumed was determined from the empirical survey. This value was converted to consumption in kilogram by dividing the annual cost of consumed with the average amount of 1 Kg of food from the market survey, which is in this case 350 naira. The consumption in kilogram was also converted to consumption in tonnes by dividing it with 1000. The footprint in global hectare was thereafter obtained by dividing the consumption in tons with the yield factor of forest land (0.37) also by multiplying the resulting value with the national equivalence factor (1.28) and embodied energy, which was reported to be 70% of the food consumption in tons [10]. The EF per capita was therefore computed by dividing global hectare footprint with the population of 867,000 living within Ilorin Metropolis [4]. This gives the footprint in global hectare per capita as expressed in Eq. (1):

$$EF_f = \sum_{i=1}^7 \frac{C}{Y_c} \times E_f \times EE \quad (1)$$

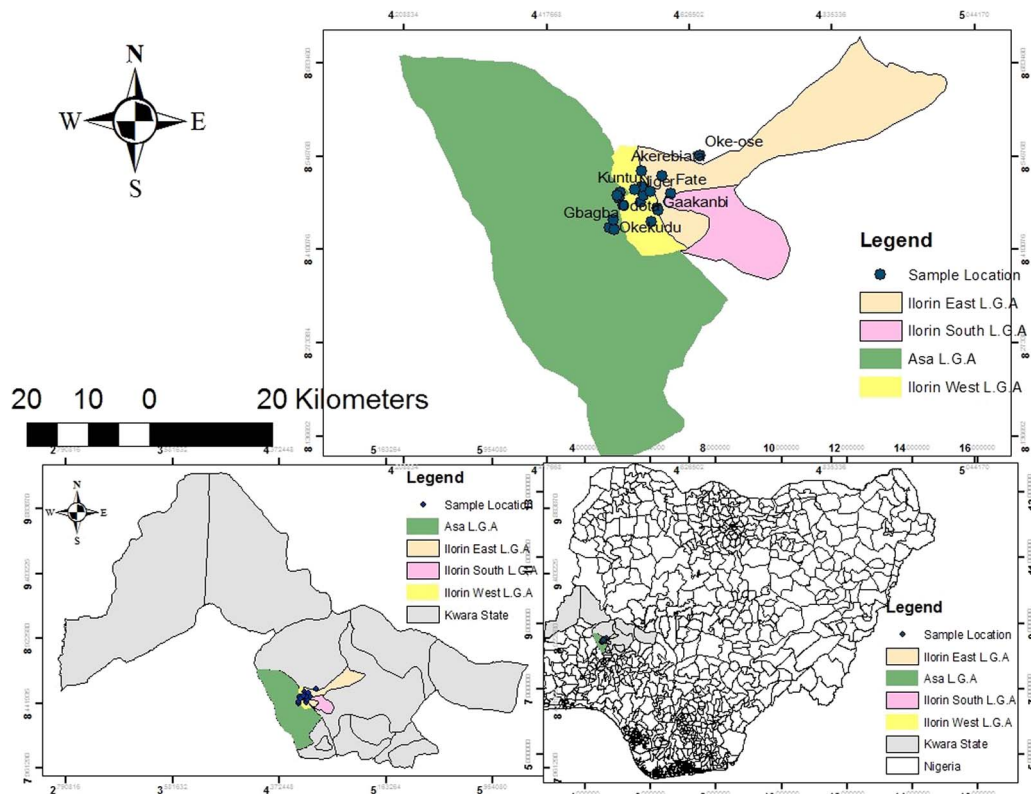


Figure 1. Map of Ilorin Metropolis showing the study area.



Figure 2. Satellite image showing (a) farm land near Egbejia, Ilorin, and (b) cluster forest land.

where

EF_f = EF of food (gha/capita);

C = food consumption in tons;

EE = embodied energy (MJ/kg); and

Y_f and E_f = yield and equivalence factor respectively collected directly through e-mail from [1, 10, 16]

2.3.2. Determination of the EF of water consumption

The annual amount of water consumption in liters used per household was determined from the empirical survey. The energy

value in kilowatt-hour (kWh) was determined since 1 L of water will give 0.0352 kWh provided the temperature is changing from 20 C to 50°C as the water enters the heat exchanger and also the circulating pump for both cold and hot domestic water (Greenhouse Gas Emission Standards, 2010). This temperature difference corresponds to the ideal temperatures of most water in Ilorin Metropolis according to the background information obtained from the Kwara State Ministry of Water Resources. However, the embodied energy for water reported was 2000 kWh/mg (Greenhouse Gas Emission Standards, 2010) which was later converted to mega joule per kilogram (MJ/Kg) by dividing 2000 kWh/mg

Table 1. Considered components for the derivation of ecological footprint.

Variable Food	Cereals	Beverages	Components Fish	Fruits	Vegetables	Beef
Water	-	-	-	-	-	-
Housing	-	-	-	-	-	-
Energy	Electricity	Charcoal	Gas	Firewood	Generator	-
Waste	Paper	Ferrous metal	Non-ferrous metal	-	-	-

Table 2. Ecological footprint data requirements and data sources.

s/n	Data type	Data source
1	Demographic data	National Population Census (NPC), 2006
2	Consumption-related data (household level): food, water, housing, energy and waste	Questionnaire survey
3	Unit price electricity	Ibadan Electricity Distribution Company IBEDC
4	Gas cylinder characteristics and price	Energy filling station, Basin road, Ilorin
5	Current fuel price	Total filling station, Agric road, Ilorin (direct interview)
6	Ilorin city water supply	Kwara State Water Board (2018)
7	Waste management system	Kwara State Environmental Protection Agency (KWASEPA)

Table 3. Hourly climate condition in Ilorin.

S/n	Time	Temperature	Wind	Weather
1	23 h	25°C	8Km/h SSE	Mostly cloudy
2	0 h	24°C	6Km/h SSE	Cloudy
3	1 h	23°C	8Km/h SSW	Cloudy
4	2 h	22°C	8Km/h S	Cloudy
5	3 h	23°C	8Km/h S	Scattered thunderstorms
6	4 h	22°C	8Km/h SSE	Thunderstorms
7	5 h	22°C	9Km/h SSW	Scattered thunderstorms
8	6 h	23°C	9Km/h SSW	Isolated thunderstorms
9	7 h	23°C	9Km/h SSE	Scattered thunderstorms
10	8 h	23°C	11Km/h SSW	Cloudy

Weather Atlas [22]

with 0.2778 kWh (equivalent to 1 MJ) and 1000 mg (equivalent to 1 Kg). The energy value in kWh was thereafter obtained by multiplying the embodied energy with the annual liter of water consumption 20,556,800 L from the empirical survey. The resulting value in kWh was converted to MJ by dividing it with 0.2778 kWh. The carbon dioxide (CO₂) emission in Kg/MJ was also obtained by multiplying the CO₂ emission in kilogram with the embodied energy in MJ/Kg and 0.2778 kWh [11]. The EF in global hectare was thereafter obtained by dividing the energy value in MJ with the national yield factor for inland water (0.38) also multiplying the resulting value with the equivalence factor (0.38) and CO₂ emission in Kg/MJ [10]. The EF per capita was therefore computed by dividing the footprint in global hectare with the population of 867,000 as expressed in Eq. (2):

$$EF_w = \sum_{i=1}^7 \frac{EV}{Y_f} \times E_f \times CO_2 \text{gas emission} \left(\frac{\text{kg}}{\text{MJ}} \right), \quad (2)$$

where

EF_w = EF for water consumption;

EV = energy value;

Y_f and E_f = yield and equivalence factor respectively collected through e-mail from [10]; and

$CO_2 \text{ emission}$ = carbon dioxide emission [10, 11].

2.3.3. Determination of the EF of housing

The method for estimating the housing footprint of the study was adopted by using the standard bedroom flat conversion into square feet (ft²), the average conventional house and room size used in Ilorin were considered and used to obtain the footprint of housing. The average standard was 516ft² being equivalent to a one-bedroom flat, 936ft² represent a two-bedroom flat, 1356ft² is equivalent to a three-bedroom flat and 2334ft² representing a four-bedroom flat. The square feet for each bedroom flat was therefore converted to meters square (m²) of which one square meter being equivalent to 0.929m². Thereafter, the EF of the study area for housing was computed by multiplying the average housing in m² with yield factor of forest land (0.26) and the equivalence factor 1.28 and also dividing the resulting value with one hectare (10,000m²) to give the footprint in global hectare per capita [10]

as expressed in Eq. (3):

$$EF_h = \frac{A_h \times Y_f \times E_f}{1000}, \quad (3)$$

where

EF_h = EF of housing;

A_h = average housing of the study area;

Y_f and E_f = yield and equivalence factor respectively collected through e-mail from [10]; and

10000m² = one hectare [16].

2.3.4. Determination of the EF of energy

The energy footprint was computed using the five categories of energy source such as electricity, generator, gas, charcoal and firewood by adopting the method of greenhouse gas conversion standard (2010) [18]. In this investigation, amount of the energy source from the empirical survey was evaluated in kWh. Now, since 1 kWh is rated 25 naira [8], the total amount for each energy source was converted to energy value in kWh by dividing the amount with 25 naira while for electricity, the energy value was obtained in MJ by dividing the energy value in kWh with 0.2778 kWh. However, the embodied energy in MJ per kilogram and carbon dioxide emission in kilogram per MJ were obtained from the updated greenhouse gas emission of the various fuels of 2019. The footprint in global hectare was thereafter computed by dividing the energy value in MJ with the national yield factor for forest land (0.26) and also multiplying the resulting value equivalence factor CO₂ emission in kilogram per MJ which was therefore divided the population of 867,000. This gives the footprint in global hectare per capita as expressed in Eq. (4):

$$EF_e = \sum_{i=1}^5 \frac{EV}{Y_f} \times E_f \times CO_2 \text{ gas emission} \left(\frac{\text{kg}}{\text{MJ}} \right), \quad (4)$$

where

EF_e = EF for energy by mode of energy usage (gha/capita);

EV = energy value (MJ/kg);

CO_2 emission = carbon dioxide emission (kg/MJ) [10]; and

Y_f and E_f = yield and equivalence factor respectively collected through e-mail from [7, 10].

2.3.5. Determination of the EF of waste

Adopting the methodology of the 2006 guidelines for national greenhouse inventions, the overall measurement of the bin or garbage from the empirical survey was collected and the weight was estimated using 2.2 Kg to be equivalent to one bin or garbage of waste production per household given total of 131400 kg. This value was converted to kWh and MJ by multiplying the generated waste with 0.214 kg of CO₂ which is equivalent to 1 kWh [17]. The energy value in MJ was obtained by dividing the energy value in kWh with 0.2778 (equivalent to 1 MJ) given 101222.4622 MJ. Organic energy normally generates energy in form of biogas or liquefied petroleum gas [17]. Hence, the embodied energy for

liquefied petroleum gas (LPG) was reported to be as 13750kWh/-ton. This value was converted to MJ/Kg by multiplying with 0.2778 kWh and dividing with 1000 to give 3.81975 MJ/Kg. The CO₂ gas emission of the biogas generated in the form of LPG has been reported to be to be 0.214 Kg/kWh. Therefore, converting this to MJ/Kg, it was simply divided by 0.2778 kWh to give 0.7703Kg/MJ. The footprint in global hectare was computed 101222.4622 MJ with the national yield factor of forest land (0.26) and also multiplying the resulting value with equivalence factor (1.28) and 0.770308373 as expressed in Eq. (5):

$$EF_{wg} = \sum_{i=1}^7 \frac{W}{Y_f} \times E_f \times EE, \quad (5)$$

where

EF_{wg} = EF of waste generated (gha/capita);

W = annual waste generated in tones (i.e. paper, ferrous metal, non-ferrous metal, glass, organic wastes);

EE = embodied energy (MJ/kg); and

Y_f and E_f = yield and equivalence factor respectively collected directly through e-mail from [10, 17].

2.3.6. Determination of Ilorin Metropolis land use and land cover

The image class distribution were assessed based on the classified land cover of the study area into 10 categories (public infrastructure/land, orchard/garden, mixed vegetation, cluster trees, farmland or open space, aquatic vegetation, low-density residential area, rivers or wetlands, high-density residential area and water bodies or dams). In this process, by adopting the method of [6], a detailed land-cover map with multiple references by cross-checking the land-use land-cover map of the detailed area plan was validated in Ilorin Metropolis with Quickbird imagery, Google Earth imagery and land sat satellite images of Kwara State for the year 2019. For this purpose, a land use map of the study area which provided baseline information for the study area was downloaded and brought to Universal Transverse Merator in ArcGIS [6] The whole study area was divided into a grid to ensure a readable and manageable file size (the smaller grid size produces more accurate values, but it creates a larger file). Thus, based on the purpose of the study, 15 × 15 ft grids (creating a 15 × 15 ft resolution image) were selected, and accordingly data were cross-checked and updated to generate a precise land-cover and land-use map.

2.3.7. Determination of ecological BC in Ilorin Metropolis

The method described by [18] was used to compute the ecological bio capacity in Ilorin Metropolis. The method involves multiplying the total bio productive area in hectare for each land use type in Ilorin Metropolis with the yield and equivalence factor of the land-use type as reported in the global footprint network [10] bulletin and expressed in Eq. (6):

$$EBC = \sum_{i=1}^n (A \times Y_f \times E_y)_i, \quad (6)$$

where

EBC = bio-capacity;

A = area available for a given land-use type; and

Y_f and E_f = yield and equivalence factor respectively for each area, year and land-use type.

The yield and equivalence factor for all land-use type for Nigeria have been collected from global footprint network [10] directly through e-mail [18].

2.4. Statistical analysis

The data collected was subjected to analysis to be able to understand the underlying factors that causes EF to be verified. The data was analyzed using the statistical package for Social Scientist (SPSS) version 17. The data was analyzed using both descriptive and inferential statistics, namely frequency table, percentage and Analysis of Variance. Analysis was also presented using the pictorial variable such as histogram pie-chart and graphs.

3. RESULTS AND DISCUSSION

3.1. EF of food consumption in Ilorin Metropolis

EF of different food categories in global hectare per capita of Ilorin Metropolis is shown in Figure 3. The result revealed that cereal have the highest footprint of 0.010996 followed by meat and poultry, while the least is vegetable probably because the people of Ilorin Metropolis consume more of cereal than vegetable as a result of consuming more of *ogi* (pap). This result agrees with the work of [18] on the consumption and ecological stress in an urban area at Khulna city showing the food footprint of cereal to be the highest with 0.0182 gha/capita followed by meat (0.0182 gha/capita) and the least being vegetable (0.0153 gha/capita). This also agrees with the work of [16] on measuring the sustainability and appraisal of resource consumption pattern on the ecological EF of Bida, Nigeria, showing unprocessed non-animal food items to be the highest with 0.184, followed by processed non-animal food items to be 0.058 and the least was animal based food items to be 0.141. EF analysis based on changing food consumption in a poorly developed area of China in 2017 by Lin and Binzhen [14] disagrees with this studies carried out, revealing that meat, egg and milk (0.4037) have the highest footprint, followed by cereals (0.1232) and the least being vegetable and melon which could probably be as a result of integrating grain to green program that reduced the cultivation of cereal production and then making the people consume more meat.

3.2. EF of energy consumption

EF of energy consumption in Ilorin Metropolis is shown in Figure 4. It reveals that generator have the highest footprint of 0.1655, followed by charcoal (0.01597) and the least being electricity (0.0000523). This could probably be due to rate at which generator is been mostly used in most areas within Ilorin Metropolis and it emitting greenhouse gases because of low rate of electricity supply. It also reveals that charcoal have a high footprint

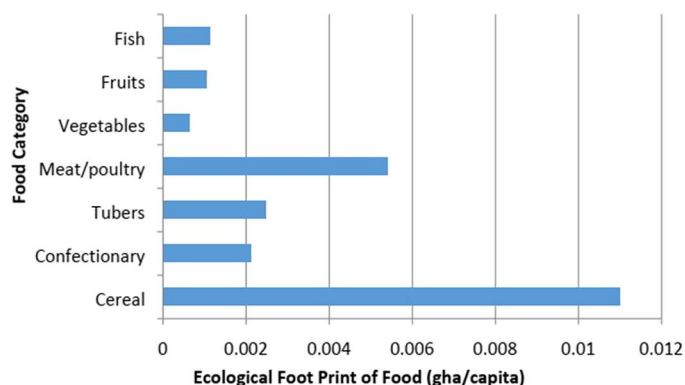


Figure 3. EF of food consumption.

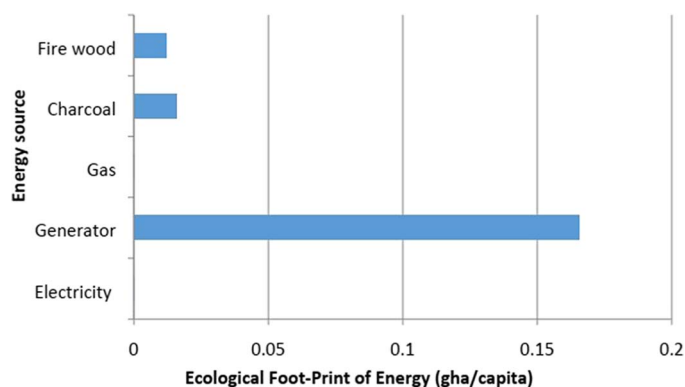


Figure 4. EF of energy consumption.

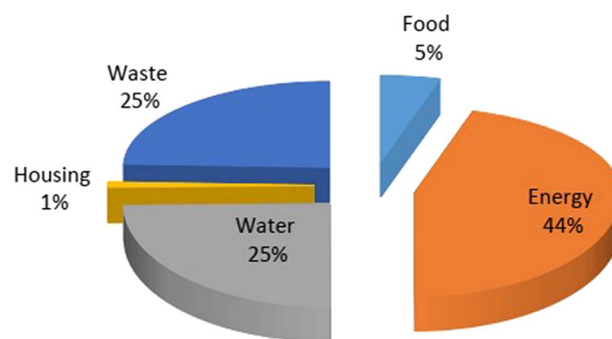


Figure 5. Summary of EF indicators in Ilorin Metropolis.

probably because it is mostly used as a source of energy to cook and also because people see it as cheap, fast and emitting less smog unlike firewood. Gas footprint is low probably because the study population felt it is expensive to purchase a gas cylinder and also refilling it. Electricity appears to be the lowest footprint from the result obtained due low supply of electricity.

3.3. Comparison of EF of all parameters in Ilorin Metropolis

The summary of the EF in Ilorin Metropolis is shown in Figure 5. The analysis indicates that energy has the highest footprint of

Table 4. Image class distribution for selected area of land use and land cover in Ilorin Metropolis.

S/n	Image classification LULC	Number samples	Area (ha)	Percentage
1	Public infrastructure/land	10,667	960.030	4.65
2	Orchard/garden	3,300	297.000	1.44
3	Mixed vegetation	44,445	4,000.050	19.38
4	Cluster trees	4,477	402.930	1.95
5	Farmland/open space	21,407	1,926.630	9.34
6	Aquatic vegetation	5,193	467.370	2.26
7	Low-density residential area	88,734	7,986.060	38.70
8	Rivers/wetlands	11,609	1,044.810	5.06
9	High-density residential area	31,004	2,790.360	13.52
10	Water bodies/dam	686	761.740	3.69
	Total	221,522	20,636.98	100

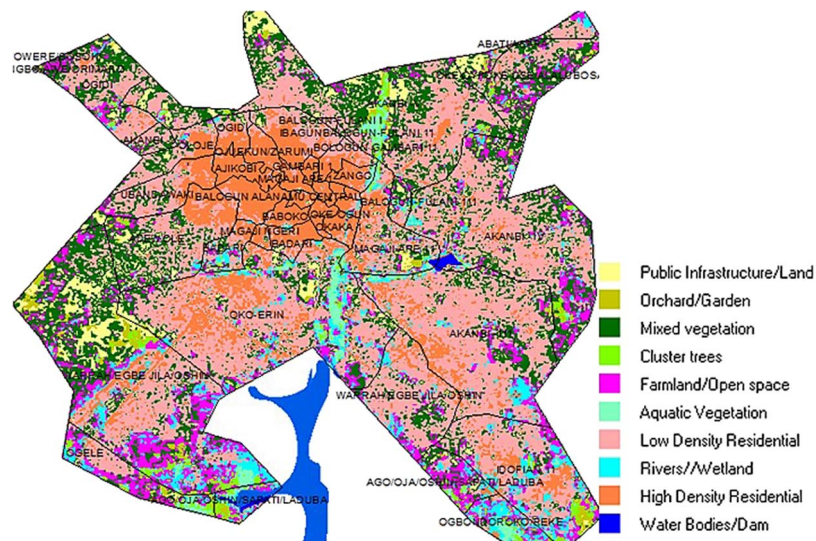


Figure 6. *Land use/cover map.*

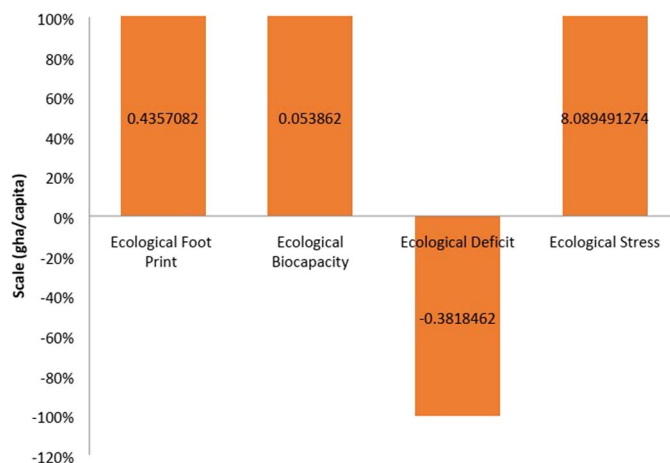


Figure 7. Comparison of EF and BC in relation to the ecological deficit and stress for Ilorin Metropolis.

44% (0.194), followed by water and housing with the footprint of 25% each (0.108 and 0.107 respectively), food has the footprint of 5% (0.024), while the least is housing with the footprint of 1%

(0.0034). This could be probably because people consume more of energy than water and also due to income and affordability level. This implies that the more residents tends to consume more of energy, the more there is going to be in for EF which is not sustainable compared to bio productive land in Ilorin put at 0.054 gha. This is in line with the result of [18] on household consumption and ecological stress in an urban of Khulnan city revealing the EF of energy to be the highest (25%).

3.4. Land-use cover distribution and ecological BC

The results of the land-use and land-cover distribution as derived from the maps are presented in [Figure 6](#) and [Table 4](#). Based on the different available methods, a knowledge-based classification was performed to attain the most updated and reliable land-cover classification for the study area. This reveals that the low-density residential area occupies the highest percentage of 38.70% followed by the mixed vegetation 19.38%, while the orchard or garden area occupied the lowest percentage of 1.44%.

Figure 7 shows the relationship among the footprint, bio capacity and ecological deficit and ecological stress of the consumption

level of food, energy, water, housing and waste generation from the same location. It shows that Ilorin consumption is unsustainable as the ecological bio-capacity (the available bio productive land, 0.054 gha) tend to be lower than the EF (0.436gha) placing Ilorin Metropolis at a deficit of -0.382 and ecological stress of 8.089 indicating that the residents of Ilorin are using resources faster than they can be replenished and using the planet unsustainably.

4. CONCLUSIONS

The EF of Ilorin is very important; this will aid check and balance on the town's resource consumption habit against the earth share available per capita. Ilorin's EF was estimated to be 0.436 gha, this is a close value to the Nigeria EF which was reported to be 0.6 gha. The major difference between the Nigeria national footprint and Ilorin's local footprint is linked with the amount of BC available for use. Nigeria has a bio capacity of 1.1 gha per capita, while Ilorin have a BC of 0.0539 gha per capita which is far less than the one available at the national setting. The derived value for both the EF and BC reveals that Ilorin is unsustainable in its resource consumption when compared with the BC available. This trend, if not checked will keep Ilorin at a large deficit of 0.3818 gha that will keep nothing for posterity. The derived value for ecological stress (8.089 gha/capita) means that it will require eight times the BC to sustain the population. Hence, this calls for a more environmentally sustainable management to resource consumption in Ilorin Metropolis. It is therefore recommended that the residents of Ilorin imbibe a more sustainable fuel consumption approach. Also, decisionmakers should look inward and encourage inter-regional developments that will, in the long run, keep Ilorin on a sustainable path.

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