



# Population Pressure on Land Resources in Nigeria: The Past and Projected Outcome

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## Authors' contributions

*This work was carried out in collaboration among all authors. Author HIE designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors RNE and ESE managed the analyses of the study and literature searches. All authors read and approved the final manuscript.*

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## ABSTRACT

**Aims:** This paper assesses the population pressure on land resources in Nigeria: The past and projected outcome.

**Study Design:** 1967 to 2068 time series data were used. The data sets were resorted to due to lack of complete national data.

**Place and Duration of Study:** Past (1967-2017) and projected (2018-2068) five decades in Nigeria.

**Methodology:** The time series data were obtained from the United Nations Population Division, Department of Economic and Social Affairs, National Population Commission, International Energy Statistics and Food and Agriculture Organization (FAO) on population levels, renewable and non renewable resources in Nigeria. Others such as transformity were adapted from Odum (1996) and Odum (2000) for specific objectives. Data collected were analyzed using modified ecological footprint/carrying capacity approach, descriptive statistics and Z-statistics.

**Results:** Results showed that the mean annual pressure on land resources in the past five decades (1967-2017) was 9.323 hectares per capita, while the projected pressure in the next five decades

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(2018-2068) was 213.178 hectares per capita. Results also showed that about 73.08 percent of the pressure per capita in the past five decades emanated from arable land consumption (6.813ha), while 75.91percent of the pressure is expected to emanate from fossil land in the next projected five decades due to crude oil and mineral resource exploration and exploitation. The carrying capacity of land resources in the past five decades was 6.4091 hectares per capita, while that of the projected five decades was 1.667 hectares per capita, an indication of ecological overshoot in both periods.

**Conclusion:** Population pressures on land resources per capita in the past and projected five decades are higher than the carrying capacity of these resources in the country. Citizens lived and are expected to live unsustainably by depleting and degrading available land resources. Arable land consumption is the major contributor to the total pressure on land resources in the past five decades, while the consumption of fossil land due to exploration and exploitation of crude oil and mineral resources is expected to contribute majorly to the total pressure on land resources in the next five decades. Limiting affluence (per capita consumption of resources) and improving technology will not only ensure sustainable use of arable and fossil lands but place consumption within the limits of these resources for a sustainable future.

*Keywords: Population pressure; carrying capacity; land resources; energy; emergy; Nigeria.*

## 1. INTRODUCTION

The alarming pace at which land resources are degrading in recent times has been recognized at the international and sub-global levels [1,2]. Land resources are clearly under stress [3], and face strong pressures owing to inappropriate practices and overuse [4], as short-term economic gains are made at the expense of long-term damages. The Sustainable Development Goal (SDG) 15, one of the 17 SDGs decided at the Rio+20 conference in 2012, is specifically geared to protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss [5]. Sustainable use of land resources can only be enhanced if provisions are made for mitigation, remediation, compensation and/or rehabilitation especially when biodiversity loss results from overuse [6]. The key drivers are increased population, per capita consumption and endless growth economy [7,8,9].

Increase in population raises the demand for land resources above the regenerative capacity of these resources [10]. According to the Food and Agriculture Organization [11], by 2030, the global production of grain would have reached 2.1 billion tons, while the world demand for grain would have increased up to 2.7 billion tons. The rising demand for food and other land resources arise due to the current rate of population growth. Although the population growth is expected to be much slower in the coming decades, the global food production needs to increase by at least 50% by 2050 to feed the growing population [12].

The global population is more than 7.7 billion people (despite the declining global Total Fertility Rates (TFRs)), and is projected to rise to 9.8 billion by 2050 and 11.2 billion by 2100 [13]. Total Fertility Rate (TFR) plays a significant role in accelerating or decelerating population level. The decreasing trend of total fertility rate is linked to the increase in female literacy [14]. Increasing female education changes the dynamics of family formation as it shortens the total reproductive life of a woman leading to a decreased Total Fertility Rate [15]. Fertility can decline when women are given freedom to control their fertility via family planning [16]. If family planning and contraceptives are made universally available, the evidence is that population would stabilize and then start to decline [17].

Continued rapid population growth is a primary driver behind many ecological and even societal threats [18]. Rise in population increases the level of pressure on land resources. Cutting more forest for farmland, unsustainable intensification of farmland, killing more 'bush meat' (wild animals) for food and over-fishing the rivers and seas are indications of overpopulation [7]. Forests are reduced and trees are cut down or burned in order to meet the demands of the growing population [19]. The growing pressure stresses the ecosystem and translates to economic problem [20], as humans overshoot the global bio-capacity and live unsustainably by depleting stock of natural resources [21]. Overshoot (ecological deficit) occurs when carrying capacity is exceeded by increasing consumption of earth's finite resources by its inhabitants [22] and if the carrying capacity is larger than the population pressure or

consumption, ecological remainder occurs [23].

Carrying capacity of land resources is an important index for assessing the capacity for sustainable development [24]. Carrying capacity is the ability to absorb the demands/needs of rapid population growth without causing significant crash [25]. Carrying capacity is a tool for measuring human impacts on the natural environment, and maximum value of resource use without affecting natural, social, economic and cultural development [26]. Economic and general environmental damages occur if population exceeds the carrying capacity. According to Wackernagel et al. [27], it is possible to exceed global bio-capacity (carrying capacity) because trees can be harvested faster than they re-grow, fisheries can be depleted more rapidly than they restock, and CO<sub>2</sub> can be emitted into the atmosphere more quickly than ecosystems can sequester it. There are many factors that can impact the carrying capacity of land resources. For example, the degree of resource utilization serves to be the essential element that influences the carrying capacity to a considerable measure [28]. Carrying capacity can be determined based on the energy requirements for a given population or the energy intensity of a given economic development. The carrying capacity of an environment is determined by that environment's ability to supply the required energy [29].

Emergy (spelled with an 'm') is the energy of one type required in transformations to generate a flow and storage. Emergy is the available energy of one kind previously used up directly and indirectly to make a service or product [30]. The amount of emergy required directly and indirectly to generate a unit of energy in unit of solar emjoule per joule (sej/J), which constitutes the ratio of emergy to available energy is called transformity [31]. Transformity is an indicator of past environmental contributions that have combined to create a resource, and is, in theory, an indicator of the potential effect on a system that will result from the resource use [32]. Transformity can be used to convert a given energy into emergy, by multiplying the energy by its transformity [23].

This paper employs the modified ecological footprint approach. The methodology takes a holistic look at the pressure placed on land resources, given the level of production and consumption in the country and the carrying

capacity for each year. Ecological footprint approach and emergy accounting have made substantial headway, especially in evaluating rational use of natural resources. As a helpful, best policy and planning tool, modified ecological footprint approach offers a rapid resource appraisal method for nations or regions to compare the demands of a given population with the carrying capacity. The methodology is a unified thermodynamic metric for objectively evaluating resource depletion, environment degradation and ecological overshoot.

### 1.1 Objectives of the Study

This paper assessed the population pressure on Land Resources in Nigeria: The Past and Projected Outcome. The specific objectives were to;

- i. Estimate the level of population pressure on land resources in the past (1967-2017) and projected five (2018-2068) decades in Nigeria.
- ii. Estimate the carrying capacity of land resources and sustainability gap in the past (1967-2017) and projected five (2018-2068) decades in the country and make policy recommendations.

### 1.2 Hypotheses of the Study

The null hypotheses tested were that;

- i. The population pressure on land resources in the past five decades (1967-2017) is not different from the expected pressure in the next projected five decades (2018-2068) in the country.
- ii. The carrying capacity of land resources in the past five decades (1967-2017) is not different from the expected carrying capacity in the next projected five decades (2018-2068) in the country.

## 2. METHODOLOGY

### 2.1 Study Area

Nigeria where this study was carried out is located in West Africa on the Gulf of Guinea and has a total area of 923,768 km<sup>2</sup> [33]. The country is bordered in the south by approximately 800km of the Atlantic Ocean, on the West by the Republic of Benin, on the North by the Republic of Niger and Republic of Cameroun on the East [34]. Nigeria lies between Latitudes 4° and 14°N

and Longitudes 2° and 15°E [35]. There are 36 states and the Federal Capital Territory Abuja. The states are aggregated into six geopolitical zones: North West, North East, North Central, South East, South South and South West [36]. The country's population is about 201.3 million persons [37]. Nigeria has two major seasons, namely, the rainy and dry seasons. The rainy season in Nigeria varies across the agro-ecological zones. In the south, rain begins in March/April, with the peak of rainfall occurring in June/July and peak dry season occurs between November and January. In the north, the rainy season starts in April, with a peak in June/July, and the dry season occurs between early to mid-October and mid-April [38]. At one time Nigeria was the world's largest exporter of groundnuts, cocoa and palm oil, and a significant producer of coconuts, citrus fruits, maize, millet, cassava, yams and sugar cane [39]. According to the World Bank [40], Nigeria is classified as

a mixed economy emerging market and has already reached lower middle income status. The country's oil reserves have played a major role in its growing wealth and influence [41].

## 2.2 Analytical Techniques

### 2.2.1 Population pressure on land resources in the past five decades

The population pressure on land resources was estimated using the modified ecological footprint approach. Following Zhao et al. [23], the approach involves estimating the emergy densities for the earth and the country, ecological footprint analysis and carrying capacity estimation. The emergy densities for the earth and the country were estimated using the Emergy Density Indices stated as in Zhao et al. [23]:

$$\rho_1 = \frac{\text{Total emergy of the earth in one year (measured in sej)}}{\text{Area of the earth (measured in } M^2)} \quad (1)$$

and

$$\rho_2 = \frac{\text{Total emergy of the country in one year (measured in sej)}}{\text{Land Area of the country (measured in } M^2)} \quad (2)$$

Where,

$\rho_1$  = emergy density of the earth (Sej/ $M^2$ )  
 $\rho_2$  = emergy density of the country (Sej/ $M^2$ )  
 Sej = Solar emergy emjoules  
 $M^2$  = Meter square

The population pressure on land resources was estimated using the ecological footprint model. This model on the other hand measures the level of resource use. The model is represented explicitly as:

$$ef_t = \sum_{i=1}^n \frac{c_i}{\rho_2} \quad (3)$$

This can also be stated as:

$$ef_t = \sum_{i=1}^n \frac{[\text{consumption}_i(J) \times \text{Transformity}_i(\frac{sej}{J})]}{\rho_2(\frac{sej}{m^2})} / N \quad (4)$$

Where,

$ef_t$  = Population pressure per capita for the time period t (ha/cap).  
 $c_{it}$  = emergy amount of the  $i^{\text{th}}$  land resource per capita for the period t (sej)  
 $\rho_2$  = emergy density of the country (sej/ $m^2$ )  
 $N_t$  = Population size for the time period t (number)  
 $n$  = Number of resources.

In this case, the annual per capita pressure on each consumption item was analyzed using the following model, stated as:

$$\pi_{it} = \mu_{it} + \gamma_{it} - \tau_{it} \quad (5)$$

and

$$\omega_t = \frac{\sum_{i=1}^n \pi_{it}}{N_t} \quad (6)$$

Where,

$\pi_{it}$  = Consumption of  $i^{\text{th}}$  resource (food production, livestock production, fisheries, forestry, electricity, natural gas, oil, coal, and other mineral resources per capita) for the time period, t (Joules)

$\mu_{it}$  = Production of the  $i^{\text{th}}$  resource for the time period t (Joules)

$\gamma_{it}$  = Imports of the  $i^{\text{th}}$  resource for the time period t (Joules)

$\tau_{it}$  = Exports of the  $i^{\text{th}}$  resource for the time period t (Joules)

$N_t$  = Population size for the time period t (number)

$n$  = number of consumption resources (number)

$\omega_t$  = per capita consumption for the time period t (Joules)

$i$  = level of consumption resource (numbers)

### 2.2.2 Carrying capacity of land resources in the projected five decades

The carrying capacity of land resources was estimated using the carrying capacity model. The model is stated as:

$$cc_t = \frac{e_t}{\rho_1} \quad (7)$$

Where,

$cc_t$  = Carrying capacity per capita for the time period t (ha)

$e_t$  = Renewable resource energy amount per capita for the time period t (sej).

$\rho_1$  = Earth energy density (sej/m<sup>2</sup>), as derived from equation (1)

#### 2.2.2.1 Decision rule

The sustainability gap was based on the value of the carrying capacity of land resources in the country, if:

$$a. \left[ \frac{e_t}{\rho_1} \right]^* \geq \sum_{i=1}^n \frac{c_{it}}{\rho_2}$$

This implies that the population pressure on land resources is below the carrying capacity of these resources (i.e Sustainable use of land resources or Resource Remainder).

$$b. \left[ \frac{e_t}{\rho_1} \right]^* < \sum_{i=1}^n \frac{c_{it}}{\rho_2}$$

This implies that the population pressure on land resources is above the carrying capacity of these resources (Unsustainable use of land resources or Resource overshoot).

### 2.2.3 Test of hypotheses

The following null hypotheses were tested:

**Hypothesis I:** The null hypothesis that the population pressure on land resources in the past five decades (1967-2017) is not different from the expected pressure in the next projected five decades (2018-2068) in the country was realized using the Z-statistics. The model is stated as:

$$Z = \frac{\bar{G}_1 - \bar{G}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}} \quad (8)$$

Where,

$Z$  = Value to be tested

$\bar{G}_1$  = Mean of the population pressure on land resources in the past five decades (ha/cap)

$\bar{G}_2$  = Mean of the population pressure on land resources in the projected five decades (ha/cap)

$S_1^2$  = Variance of the population pressure on land resources in the past five decades

$S_2^2$  = Variance of the population pressure on land resources in the projected five decades

$n_1$  = Number of observation of population pressure in the past five decades

$n_2$  = Number of observation of population pressure in the projected five decades

**Hypothesis II:** The null hypothesis that the carrying capacity of land resources in the past five decades (1967-2017) is not different from the expected carrying capacity in the next projected five decades (2018-2068) in the country was realized using the Z-statistics. The model is stated as:

$$Z = \frac{\bar{B}_1 - \bar{B}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (9)$$

Where,

Z = Value to be tested

$\bar{B}_1$  = Mean of the carrying capacity of land resources in the past five decades (ha/cap)

$\bar{B}_2$  = Mean of the carrying capacity of land resources in the projected five decades (ha/cap)

$S_1^2$  = Variance of the carrying capacity of land resources in the past five decades

$S_2^2$  = Variance of the carrying capacity of land resources in the projected five decades

$n_1$  = Number of observation in the past five decades

$n_2$  = Number of observation in the projected five decades

### 3. RESULTS AND DISCUSSION

#### 3.1 Level of Population Pressure on Land Resources

##### 3.1.1 Emery amount of the earth and Nigeria

Table 1 shows the emery amount of the earth. This is derived from the sum of the indicators such as the emery of solar insolation, deep earth heat and tidal energy. Results showed that the total emery amount of the earth was 1.58E+25 Sej/a. This implies that a total energy of 1.58E+25 sej was used up directly and indirectly to provide for the available renewable resources or the ecosystem services of the earth in one year. The emery density of the earth (3.10E+10sej) shows that a total energy of 3.10E+10 sej was dissipated per meter square of productive land and sea areas of the earth in one year. It implies that a total energy of 3.10E+10 sej was used up per meter squared of the total global hectares, to provide for the ecosystem services of the earth in one year. This emery amount estimation was based on literature, as a given amount of energy must be dissipated in

order to allow for resource transformation. This also implies that for a given amount of the rain, wind or sun that shines for land resource transformation, a certain amount of energy must first be dissipated.

Table 2 shows the estimated average emery amount of the country. The emery was derived from the energies from the sun, rain, wind and earth cycle. The maximum emery from these renewable resources was captured as the total emery of the country. This is to avoid double counting or duplication in the analyses. Results showed that the earth cycle had the highest emery (5.36E+22sej). This implies that the total emery of the country was 5.36E+22 Sej/annum. Using the emery density index, it was found that the emery density of the country was 5.80E+10sej/m<sup>2</sup>/year. This implies that with the interaction of renewable resource flows, a total energy of 5.80E+10sej/m<sup>2</sup>/year was expended in the transformation of land resources in one year. It also shows that a total energy of 5.80E+10 sej was dissipated per meter square of the land area of the country in one year, to provide land resources and other needs of her citizens.

In the line of agricultural production a given level of energy is expended from breaking of seed dormancy period to formation of a given food crop. However, in the livestock production, a certain amount of energy is also dissipated in order to contribute to livestock growth and development. This also applies to land resources such as coal, crude oil, and other mineral resources. A given level of energy is used up in order to form these resources. Table 2 shows a total of 5.80E+10 sej was expended per meter square of the land area of the country in order to provide these land resources in one year.

##### 3.1.2 Population pressure on land resources in the past (1967-2017) and projected five decades (2018-2068)

Tables 3 and 4 show the estimated average population pressure on land resources in hectares per capita in the past (1967-2017) and projected five decades (2018-2068) in Nigeria. Results showed that in the past five (5) decades between 1967 and 2017, the mean annual population pressure on land resources was 9.323 hectares per capita, while the projected pressure in the next five (5) decades between 2018 and 2068 was 213.178 hectares per capita. This implies that an average citizen of the country consumed about 9.323 hectares of land and sea

**Table 1. Estimated energy amount of the earth**

| Energy items     | Energy (Joule) | Solar transformiy (Sej/J) | Solar Energy (Sej) |
|------------------|----------------|---------------------------|--------------------|
| Solar Insolation | 3.93E+24       | 1                         | 3.93E+24           |
| Deep earth Heat  | 6.72E+20       | 1.20E+04                  | 8.06E+24           |
| Tidal energy     | 5.20E+19       | 7.39E+04                  | 3.84E+24           |
| Total            |                |                           | 1.58E+25           |

Emergy density of the Earth ( $\rho_1$ ) 3.10E+10 sej/m<sup>2</sup>

Source: Adapted from [42]

**Table 2. Estimated average emergy amount of the country**

| Renewable resources      | Values (Joules/a) | Transformity (Sej/J)* | Total emergy (Sej) |
|--------------------------|-------------------|-----------------------|--------------------|
| Sun                      | 5.41E+21          | 1                     | 5.41E+21           |
| Rain, chemical potential | 3.27E+17          | 3.05E+04              | 9.97E+21           |
| Rain, geo-potential      | 1.67E+17          | 4.70E+04              | 7.85E+21           |
| Wind                     | 3.87E+17          | 2.45E+03              | 9.48E+20           |
| Earth cycle              | 9.24E+17          | 5.80E+04              | 5.36E+22***        |

Emergy density of the country ( $P_2$ ) 5.80E+10sej/m<sup>2</sup>

\*Transformities were taken and modified from [43]

\*\*\*Maximum emergy

Source: Computed Results, 2018

in the past five decades (1967-2017) and is expected to consume about 213.178 hectares of land and sea in the next five decades (2018-2068). Results also showed that 73.08% of the total pressure in the past five decades (1967-2017) emanated from the demand for arable land (6.813ha), while it is expected that 75.91% of the total pressure in the next five decades (2018-2068) will emanate from fossil land due to exploration and exploitation of crude oil and other natural capital in the country. The increase in population pressure on arable land in the past five decades (1967-2017) could be linked to the corresponding increase in population, as Josephat [44] reported that population growth increases demand for agricultural land. Kadir et al. [45] asserted that population pressure on agricultural land that exceeds the ability of land can lead to a decline in the ability of land for agriculture. This is also an indication that the level of resource use in today's agriculture is resulting in high erosion rate, pollution and soil degradation as reported by Tesfaye et al. [46] that Sub-Saharan Africa, Nigeria inclusive is significantly affected by land degradation due to poor land management and conversion of fragile natural habitats into fields for crops.

Results also showed that the per capita pressure on land increased across the two periods except for forest land and fossil land (coal). The pressure on forest land decreased from 0.3155hecares per capita in the past five decades (1967-2017) to 0.1734 hectares per

capita in the projected five decades (2018-2068). This indicates that an average citizen in the next five decades (2018-2068) will devise alternative sources of forest extracts such as wood, paper and fibers, in order to satisfy his/her changing tastes and lifestyle. This shows that in the next five decades (2018-2068), the citizens of the country are expected to switch from forest goods to synthetics, example switching from wooden doors to iron or synthetic fiber doors. This therefore will decrease the pressure each citizen mounts on forest land by 0.1421 hectares per capita in the next five decades. The per capita pressure on fossil land (coal) also decreased from 0.00274 hectares of fossil land in the past five decades (1967-2017) to 0.000109 hectares of fossil land in the projected five decades (2018-2068). This could be linked to the improvements in technology which reduces the pressure on fossil land or use of coal as major source of energy especially for electricity generation, steel production and cement manufacturing in the country by 0.002631 hectares of fossil land in the next five decades in the country.

Table 5 shows the Z-test of the significant difference in population pressure per capita in the past (1967-2017) and projected five decades (2018-2068) in the country. Results showed that the Z-value was 4.9237 and significant 1% level. Therefore, the null hypothesis that the population pressure on land resources in the past five decades (1967-2017) is not different from the expected pressure in the next projected five

**Table 3. Estimated population pressure on land resources in hectares per capita in the past five decades (1967-2017)**

| Land resources | Values (Joules) | Transformity (Sej/J)* | Total emergy (Sej) | Emergy per capita (Sej) | Emergy per emergy density (P2) per capita | Population pressure (Hectares per capita) |
|----------------|-----------------|-----------------------|--------------------|-------------------------|---|---|
| Food crops     | 1.378E+18       | 3.22E+05              | 4.44E+23           | 3.95E+15                | 6.81E+04                                  | 6.813 arable land                         |
| Livestock      | 2.40E+16        | 3.22E+06              | 7.74E+22           | 6.14E+14                | 1.06E+04                                  | 1.0596 pasture land                       |
| Fisheries      | 6.94E+15        | 3.22E+06              | 2.24E+22           | 1.82E+14                | 3.14E+03                                  | 0.3138 water area                         |
| Forestry       | 8.24E+17        | 2.21E+04              | 1.82E+22           | 1.83E+14                | 3.16E+03                                  | 0.3155 forest land                        |
| Petroleum      | 4.94E+17        | 8.53E+04              | 4.21E+22           | 3.97E+14                | 6.85E+03                                  | 0.6846 fossil land                        |
| Natural Gas    | 1.57E+17        | 5.88E+04              | 9.21E+21           | 7.74E+13                | 1.33E+03                                  | 0.1334 fossil land                        |
| Coal           | 1.81E+15        | 6.40E+04              | 1.16E+20           | 1.59E+12                | 2.74E+01                                  | 0.00274 fossil land                       |
| Electricity    | 2.91E+13        | 3.22E+05              | 9.38E+18           | 8.24E+10                | 1.42E+00                                  | 0.00014 built-up land                     |
| Total Pressure |                 |                       |                    |                         |   | 9.323                                     |

*\*Transformities were taken and modified from [43]  
Source: Computed Results, 2018*

**Table 4. Projected population pressure on land resources in hectares per capita in the next five decades (2018-2068)**

| Land Resources | Values (Joules) | Transformity (Sej/J)* | Total Emergy (Sej) | Emergy per capita (Sej) | Emergy per emergy density (P2) per capita | Population pressure (Hectares per capita) |
|----------------|-----------------|-----------------------|--------------------|-------------------------|---|---|
| Food crops     | 2.75E+19        | 3.22E+05              | 8.85E+24           | 1.74E+16                | 3.00E+05                                  | 29.986 arable land                        |
| Livestock      | 3.46E+17        | 3.22E+06              | 1.11E+24           | 2.26E+15                | 3.90E+04                                  | 3.902 pasture land                        |
| Fisheries      | 1.23E+18        | 3.22E+06              | 3.97E+24           | 1.00E+16                | 1.73E+05                                  | 17.283 water area                         |
| Forestry       | 1.79E+18        | 2.21E+04              | 3.96E+22           | 1.01E+14                | 1.73E+03                                  | 0.1734 forest land                        |
| Petroleum      | 5.98E+20        | 8.53E+04              | 5.10E+25           | 8.08E+16                | 1.39E+06                                  | 139.264 fossil land                       |
| Natural Gas    | 1.39E+20        | 5.88E+04              | 8.15E+24           | 1.31E+16                | 2.26E+05                                  | 22.567 fossil land                        |
| Coal           | 2.70E+14        | 6.40E+04              | 1.73E+19           | 6.32E+10                | 1.09E+00                                  | 0.000109 fossil land                      |
| Electricity    | 4.40E+15        | 3.22E+05              | 1.42E+21           | 2.44E+12                | 4.20E+01                                  | 0.00420 built-up land                     |
| Total Pressure |                 |                       |                    |                         |   | 213.178                                   |

*\*Transformities were taken and modified from [43]  
Source: Computed Results, 2018*

**Table 5. Z-Test of the significant difference in population pressure per capita in the past (1967-2017) and projected five decades (2018-2068)**

| <b>Items</b>       | <b>1967-2017 (Past five decades)</b> | <b>2018-2068 (Projected five decades)</b> |
|--------------------|--------------------------------------|---|
| Mean Pressure      | 9.323                                | 213.178                                   |
| Standard deviation | 2.11867                              | 295.7015                                  |
| Standard error     | 0.29667                              | 41.40649                                  |

Z-Value 4.9237\*  
 \*significant a 1%  
 Source: Computed Results, 2018

**Table 6. Estimated carrying capacity of land resources in hectares per capita in the past five decades (1967-2017) in Nigeria**

| <b>Renewable resources</b> | <b>Values (Joules)</b> | <b>Transformity (Sej/J)</b> | <b>Total emergy (Sej)</b> | <b>Emergy per capita (Sej)</b> | <b>Emergy per emergy density of the earth capita per (P1)</b> | <b>Carrying capacity of land resources (Hectares per capita)</b> |
|----------------------------|------------------------|-----------------------------|---------------------------|--------------------------------|---|--|
| Sun                        | 5.41E+21               | 1                           | 5.41E+21                  | 5.93E+13                       | 1.91E+03  | <b>0.1911</b>  |
| Rain, chemical potential   | 3.22E+17               | 3.05E+04                    | 9.82E+21                  | 1.06E+14                       | 3.42E+03  | <b>0.3425</b>  |
| Rain, geo-potential        | 1.58E+17               | 4.70E+04                    | 7.43E+21                  | 8.03E+13                       | 2.59E+03  | <b>0.2591</b>  |
| Wind                       | 4.3E+19                | 2.45E+03                    | 1.05E+23                  | 1.15E+15                       | 3.72E+04  | <b>3.7226</b>  |
| Earth cycle                | 9.24E+17               | 5.80E+04                    | 5.36E+22                  | 5.87E+14                       | 1.89E+04  | <b>1.8937</b>  |
| Total                      |                        |                             |                           |                                |   | 6.4091   |

Source: Computed Results, 2018

**Table 7. Estimated carrying capacity of land resources in hectares per capita in the projected five decades (2018-2068) in Nigeria**

| <b>Renewable resources</b> | <b>Values (Joules)</b> | <b>Transformity (Sej/J)</b> | <b>Total emergy (Sej)</b> | <b>Emergy per capita (Sej)</b> | <b>Emergy per emergy density of the earth (P1) per capita</b> | <b>Carrying capacity of land resources (Hectares per capita)</b> |
|----------------------------|------------------------|-----------------------------|---------------------------|--------------------------------|---|--|
| Sun                        | 5.42E+21               | 1                           | 5.42E+21                  | 1.54E+13                       | 4.95E+02  | <b>0.0495</b>  |
| Rain, chemical potential   | 3.32E+17               | 3.05E+04                    | 1.01E+22                  | 2.88E+13                       | 9.29E+02  | <b>0.0929</b>  |
| Rain, geo-potential        | 1.63E+17               | 4.70E+04                    | 7.66E+21                  | 2.18E+13                       | 7.03E+02  | <b>0.0703</b>  |
| Wind                       | 4.3E+19                | 2.45E+03                    | 1.05E+23                  | 2.99E+14                       | 9.64E+03  | <b>0.9637</b>  |
| Earth cycle                | 9.24E+17               | 5.80E+04                    | 5.36E+22                  | 1.52E+14                       | 4.90E+03  | <b>0.4902</b>  |
| Total                      |                        |                             |                           |                                |   | 1.667  |

Source: Computed Results, 2018

**Table 8. Sustainability gap of the estimated average carrying capacity of land resources and population pressure in Hectares per capita in the past and projected five decades**

| Period    | Average carrying capacity of land resources (Hectares per capita) | Population pressure (Hectares per capita) | Sustainability gap (Mean difference) | Remark                    |
|-----------|---|---|--------------------------------------|---------------------------|
| 1967-2017 | 6.409   | 9.323                                     | -2.914                               | Overshoot (Unsustainable) |
| 2018-2068 | 1.667   | 213.178                                   | -211.511                             | Overshoot (Unsustainable) |

Source: Computed Results, 2018

decades (2018-2068) in the country was rejected. We therefore accepted the alternative hypothesis and concluded that the population pressure on land resources in the past five decades (1967-2017) is different from the expected pressure in the next projected five decades (2018-2068) in the country.

### 3.2 Carrying Capacity of Land Resources over Time in Nigeria

#### 3.2.1 Carrying capacity of land resources in the past five decades (1967-2017)

Table 6 shows the estimated carrying capacity of land resources in hectares per capita in the past five decades (1967-2017) in the country. It shows the carrying capacity of land resources per capita given the available renewable resources such as sun, rain chemical potential, rain geo-potential, wind and earth cycle and the ecosystem life support services in the Nigeria between 1967 and 2017. Results showed that the estimated mean renewable resources available per capita in the past five decades (1967-2017) were sun (0.1911 ha), rain chemical potential (0.3425 ha), rain geo-potential (0.2591 ha), wind (3.7226 ha) and earth cycle (1.8937 ha). Results also showed that the total carrying capacity of land resources was 6.4091 hectares per capita. This implies that the available renewable resources or mean carrying capacity of land resources that supported citizens of the country in the past five decades (1967-2017) were 6.409 hectares per person. This is an indication that the available resource flows that supported the resource needs of each citizen in the past five decades (1967-2017) were 6.409 hectares of land and sea. According to Qian et al. [47], land carrying capacity explains whether the local land resources are effectively used to support economic activities and/or human population. The implication is that 6.409 hectares was the limit of pressure per person on land resources in

the past five decades (1967-2017) and sustainable use of land resources in the past five decades would have been achieved if consumption of or pressure on land resources fell within this limit of 6.409 hectares. This also indicates that in the past five decades, resource management and planning policies that would have moved the country to the next stage of development would have been 6.409 hectares or below per capita. This is an indication that sustainable development or sustainable resource use would have been achieved in the past five decades if the use of resources such as arable land, pasture land, forest land, fossil land and built-up land did not exceed 6.409 hectares per capita.

#### 3.2.2 Carrying capacity of land resources in the projected five decades (2018-2068)

Table 7 shows estimated carrying capacity of land resources in hectares per capita in the projected five decades (2018-2068) in the country. It shows the carrying capacity of land resources per capita given the available renewable resources such as sun, rain chemical potential, rain geo-potential, wind and earth cycle; and the ecosystem life support services in the Nigeria between 2018 and 2068. Results showed that the estimated mean renewable resources available per capita in the projected five decades (2018-2068) were sun (0.0495 ha), rain chemical potential (0.0929 ha), rain geo-potential (0.0703 ha), wind (0.9637 ha) and earth cycle (0.4902ha). Results also showed that the total carrying capacity of land resources in the projected five decades (2018-2068) was 1.667 hectares per capita. This implies that the available renewable resources or mean carrying capacity of land resources that will support the population in the next five decades (2018-2068) is 1.667 hectares per person. This implies that 1.667 hectares per capita of land resources is the expected limit that can support the resource needs of each citizen in the next five decades

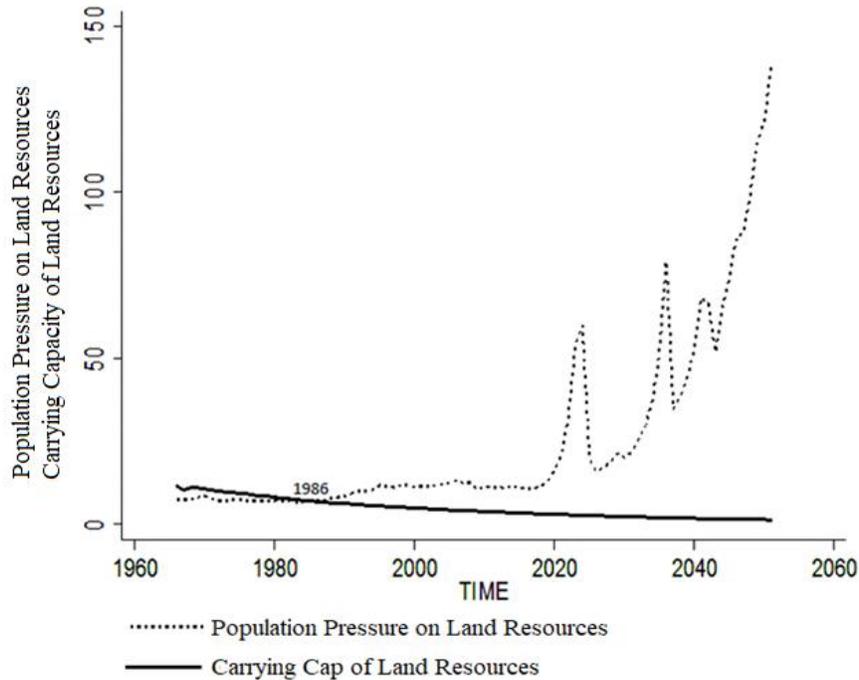
(2018-2068). This is an indication that 1.667 hectares is the expected limit of pressure per person on land resources in the past five decades (2018-2068); and in order to ensure sustainable use of land resources in the next five decades, consumption of arable land, pasture land, water area, forest land, fossil land and built-up land per capita should not exceed 1.667 hectares.

Table 8 shows the sustainability gap of the estimated average carrying capacity of land resources and population pressure on land resources in hectares per capita in the past and projected five decades in Nigeria. The carrying capacity of land resources per capita in the past (6.409ha) and projected (1.667ha) five decades, and population pressure per capita in the past (9.323ha) and projected (213.178ha) five decades had mean difference of -2.914 ha and -211.511ha, respectively. This implies that the population pressure per capita in both periods is higher than the respective carrying capacity of land resources in the country. This shows that each person's consumption or use of land resources in the past five decades exceeded the available resources by 2.914 hectares, and it is expected that in the next five decades, per capita consumption or pressure on land resources will exceed the carrying capacity of these resources by 211.511 hectares. As reported by Eriogun *et al.* [48], the consumption per capita in Nigeria exceeded the available resources. This is also an indication of unsustainable use of land resources, ecological overshoot and high level of degradation and overexploitation. Population pressure is the most fundamental driving force for land conversions [49]. Land conversions result from the need to satisfy the growing demand for food. In this case, Wily [50] reported that pasturelands and the natural vegetation are converted to farmlands and commercial investments. This however creates an imbalance in the ecosystem. According to Ruževičius [51], the growing pressure on ecosystems creates disintegration and extinction of natural habitats and threatens the biological diversity and wellbeing of humanity. This leads to natural resource depletion, carbon accumulation in the atmosphere, fisheries collapse, deforestation, and biodiversity loss. This shows that demand outpaces the regenerative and absorptive capacity of the biosphere, as the biosphere's future ability to provide for humanity is at risk as reported by Ruževičius [51].

Fig. 1 illustrates the trend in population pressure and carrying capacity of land resources in the

country overtime. It shows that between 1960 and 1985, the population pressure on land resources was below the carrying capacity of land resources. This implies that the population lived within the limits between 1960 and 1985. This is also an indication that the resource needs of the then population between 1960 and 1985 were sustainable and within the regenerative capacity of these resource. The Fig. 1 also shows that the population pressure on land resources started to outpace the decreasing carrying capacity of land resources in 1986, as reported by Ewing [52] that humanity was living within the Earth's ecological limits until around 1986, whereas after 1986 these limits have increasingly been exceeded every year. The argument between population growth and subsistence goes back to the classical theory of Malthus [53]. The Malthusian theory speculates the negative impact of population on development, as the growth of human population always tends to outstrip the productive capabilities of land resources. Malthus was of the opinion that the influence of population is indefinitely greater than the control of the earth to produce subsistence for man [54]. According to this theory, the arithmetic increase of subsistence could not feed the exponential growth of population. This is an indication that as human number grows, food supply becomes insufficient to feed the emerging population as reported by Bremner [55].

According to Bekele [56], the adjustments and adaptations towards increasing population and land scarcity were initially possible through land extensification, but as opportunities for land expansion disappeared, agriculture encroached into fragile ecosystems, often without the necessary resource amendments and led to soil degradation, deforestation, and loss of biodiversity. Consequently, Malthus suggested positive and preventive checks to balance the rising population with the existing subsistence. The positive checks included increase of mortality as a result of disease, famine, malnutrition and war while preventive checks were fertility reduction through female literacy, delayed marriage and others [55]. Neo-liberalists believe that strong economy supports population growth whereas radical ecologists argue for stabilization or even reduction of human population in order to preserve the earth's carrying capacity [57]. Makuria [53] asserted that these paradigms have in-placed different views towards population growth in relation to human needs. On the other hand, Boserupian theories



**Fig. 1. Illustration of the trend in population pressure and carrying capacity of land resources in the country between 1967 and 2068**  
 Source: Author's Computation and STATA, 2018

**Table 9. Z-test of the significant difference in carrying capacity of land resources in the past (1967-2017) and projected five decades (2018-2068) in the country**

| Items              | 1967-2017 | 2018-2068 |
|--------------------|-----------|-----------|
| Mean               | 6.4091    | 1.667     |
| Standard deviation | 2.442797  | 0.646757  |
| Standard error     | 0.34206   | 0.090564  |
| Z-Value            | 13.5875*  |           |

\*significant at 1%

Source: Computed Results, 2018

counteract the contention of classical theory by justifying the growing population would respond to their food demands through land use intensification, increasing farm yield through new agricultural technologies [58]. However, an increase in population growth may not be the problem as it can be a threat or an opportunity depending on economic growth, expansion of infrastructure, technological innovation, settlement patterns and potentials of environments as opined by Awulachew et al. [59].

Table 9 shows the Z-test of the significant difference in the carrying capacity of land resources in the past five decades (1967-2017) and projected five decades (2018-2068) in the country. Results showed that the Z-value was

13.5875 and significant at 1% level. Therefore the null hypothesis that the carrying capacity of land resources in the past five decades (1967-2017) is not different from the expected carrying capacity in the next projected five decades (2018-2068) in the country was rejected. We therefore accepted the alternative hypothesis and concluded that carrying capacity of land resources in the past five decades (1967-2017) is different from the expected carrying capacity in the next projected five decades (2018-2068) in the country.

#### 4. CONCLUSION

Population pressures on land resources per capita in the past and projected five decades are higher than the carrying capacity of these

resources in the country. Citizens lived and are expected to live unsustainably by depleting and degrading available land resources. Arable land consumption is the major contributor to the total pressure on land resources in the past five decades, while the consumption of fossil land due to exploration and exploitation of crude oil and mineral resources is expected to contribute majorly to the total pressure on land resources in the next five decades. Limiting affluence (per capita consumption of resources) and improving technology will not only ensure sustainable use of arable and fossil lands but place consumption within the limits of these resources for a sustainable future.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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