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Research Article

Ecological Footprint Assessment for Environmental Sustainability at the University of Juba, South Sudan

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Abstract

Given the growing population of students and the new infrastructural development at the University of Juba, it is environmentally significant to investigate the ecological footprint of the University campus ecosystem in light of environmental sustainability. This study aims to assess and quantify the ecological footprint at University of Juba campus and compare them to the environmental sustainability. In this study cross sectional survey of 180 students and component based methods by Rees and Wackernagel were employed to obtain results of ecological footprint of water, food, land, transport, waste and energy at the University of Juba. Considering Ecological Footprint of students and staff on campus, Biocapacity was 1.16, ecological footprint remainder was 1.06 and ecological footprint index was 0.92. While the ecological footprint of Water, food, transportation, waste, energy and built-up land footprint were 0.04, 0.03, 0.03, 0.01, 0.0003 and 0.0002 gha/capita respectively. The result of the environmental sustainability practices on the campus revealed that 11 out of 44 environmental sustainable programs were not practiced on campus implying 27.7% of the university operation was unsustainable. Although, University of Juba was found to be environmentally sustainable, reducing its ecological footprint per capita by 0.89 gha/capita. Based on the study result, the Ecological Footprint per capita of water, energy, transportation, food, waste and build-up land at the University were environmentally sustainable (0.11 gha/capita). If, all people were living the lifestyle of the University of Juba, we would require only one planet Earth.

Keywords

Ecological Footprint, Environmental Sustainability, University of Juba, Biocapacity, Ecological Footprint Index

1. Introduction

The word Ecological Footprint (EF) was conceptualized by Wackernagel and Rees and defined as a tool used to assess environmental sustainability and effects that a society has on its environment [1]. Whereas Environmental Sustainability is

the use of environment that meets the needs of the present generation without compromising the environment of the future generation [2, 3]. Ecological footprint compares human demand with Earth's ecological capacity to regenerate resources and provide services [1].

EF represents the amount of biologically productive land and sea area needed: (a) to regenerate the resources a human population consumes and (b) to absorb the corresponding waste and render it harmless. The concept of EF is based on the principle that land is a fundamental factor on which all societies depend, since it provides living space, products and services, and a sink for wastes. Productive land is, therefore, a proxy for the demands societies place on the environment [4].

EF has often been regarded as a reliable indicator of anthropogenic pressure on the environment since it does not ignore tradeoffs among different types of environmental exploitation [5, 1, 3]. It can be used as an indicator of sustainability. It is used to estimate how much of the Earth or how many planet Earths it would take to support humanity if everybody lived a given lifestyle [1]. In 2017, World average EF per person was 2.7 global hectare (gha) per capita meanwhile due to covid-19, in 2019 and in 2021 global EF reduced to 1.5 gha. As compared to continents; North America has EF of 8.04 gha, Australia 7.1 gha, Europe 4.7 gha, South America 2.6 gha, Asia 2.6 gha and Africa has 1.2 gha per capita [6, 7].

In 2022, Global Footprint Network (GFN) calculated EF of countries including Qatar =14.7 gha, USA= 8.04 gha, Australia= 7.2gha, UK= 4.2 gha, China= 3.71 gha, Libya= 3.4 gha, Sudan= 1.33 gha, Uganda= 1.04 gha, DRC = 0.01 gha. If everybody on the earth lived like the lifestyle of USA, we would require 8.04 earths to sustain our life. In Africa the highest EF in 2022 is Libya with 3.4 gha [6-8]. However no assessment of South Sudan EF has been investigated.

So many EF analysis has been carried out by students at different universities in some countries around the world to calculate the impact students and staff place on their campus ecosystem and formulate ways to reduce their ecological footprint hence promoting environmental sustainability [9, 10]. It also helped students to broaden their experiences in environmental sustainability to be used in their respective societies [11]. In 2013 San Jose State University had EF of 4.46 gha, Polito University had 0.19 gha 2021, Leuven University had 0.35 gha [12, 13].

However, the ecological footprint of University of Juba was not studied. Given the growing population of students and the new infrastructural development at the University of Juba, it was therefore environmentally significant to investigate the ecological footprint on the University campus ecosystem in light of environmental sustainability.

The objective of this study was to assess, quantify ecological footprint of water, energy, food, transportation, land and waste in light of sustainability at the university of Juba campus.

This study measured and quantify the EF at the university of Juba using primary and secondary data to obtain information about the components (food, waste, energy, transportation, land and water) and compare them with Biocapacity, which is the maximum allowed resource consumption rate and waste discharge that can be sustained in definitely in a given region without gradually impairing the functional integrity and productivity of the relevant ecosystem per capita in regards to sustainability.

2. Materials and Methods

University of Juba (UoJ) is a public university located in Juba city, South Sudan which is located at a latitude 4°50'28"N, longitude 31°35'24" E and 487.07 meters above sea level. It is one the largest University in the Country. University of Juba campus has a total area of 569,945 square meters (101 hectares). The estimated population of students and staff was 38,000 and 2,000 respectively [14, 15]. The University buildings were spread on two campuses, main and custom campus with male and female hostels in the center of the two campuses. The main campus have open spaces for football and basketball at Eastern part of the campus as well as packing area are scattered on the campus. Administration complex, Office spaces, library, halls, laboratories, restaurants, University clinic, University power house, University waste store, and mechanical workshop are concentrated on the main campus. The University landscape comprised of trees including Neem *(Azadirachta indica)*, Mahogany *(Swietenia mahoni),* Mango *(Mangifera indica)* and some ornamental plants. Custom campus comprised of mostly large halls, library, physics laboratory and scattered ornamental plants. New construction activities were taking place at the campus.

In this study both qualitative and quantitative research method for collection of both primary and secondary data were used. Qualitative study design was used for collection of secondary data that involved review of related literature in books, reports, journals, and magazines in libraries and online. Questionnaires were also used to collect primary data from various respondents on campus. Face to face interviews, observations among others were used to determine ecological footprint at the University of Juba, main and custom campus. The data collection covered a period of one year coinciding with the first and second semesters when students and staff were full time on campus.

To assess and determine ecological footprint status of students and staff at University of Juba main and custom campus empirical surveying was carried out to determine the different components, that is, food consumption, water consumption, housing, energy and waste generation footprint in the study area. Questionnaires were distributed to each school with respect to the amount of daily food consumption, water consumption, transportation, energy consumption and waste generation. The average values obtained from these

questionnaires were then converted to EF. A sample size of 180 was selected from the study population using Yamane, 1967 formula (n = N/1+N*(e)^2). During the survey, 180 respondents answered the questions.

To measure and quantify the ecological footprint of water, energy, food, transportation, built-up land and waste in light of sustainability at the University of Juba, component approach of ecological footprint assessment was used. The six components, including energy (kWh), water (m^3), food consumption (ton), waste production (ton), built-up land (ha) and transportation (tCO$_2$/km), were analyzed in the period of one academic year 2023. The ecological footprint should be equal to the Biocapacity available per person which is 1.0 or less to be sustainable [1, 16].

2.1. Energy Consumption

For energy consumption category, the study considered the use of electricity at UoJ for several activities, among all: lighting, air conditioning, computers and other appliances for teaching and research. The data of energy including electricity consumption, were attained from the power management unit UoJ. To realize the accuracy of the calculation, the investigator also extracted detailed data from the monthly bills and daily bills of the local meter at the building level.

2.2. Water Usage

The data of the water usage was obtained from the directorate of engineering office, water management unit and assessed the number of water tankers on the campus. The water at the University of Juba is used for drinking, irrigation and sanitation purpose. The main sources of the water was underground water and surface water from river Nile transported by water tankers.

2.3. Food Usage

The quantity of food usage at the UoJ campus were provided by the restaurants and cafeterias. Interviews were done to obtain data from the University restaurants for period of one academic year. Food variables were divided into the following: meat, vegetables, processed and unprocessed foods. And also gardens on both campuses growing subsistent maize, beans, okra, tomatoes, groundnuts onions and cattle both for consumption and scientific research were quantified and analyzed.

2.4. Waste Production

The waste production data was obtained via interviews with university waste management officials, observation and questionnaires to all campus users. Since waste is collected daily at the University, the researcher estimated the amount of the waste in tons. The recorded reports of the waste management unit service office was applied in the estimations. The stores on the campus was used as field to study the types of wastes on the campus.

2.5. Transportation

The EF of transport linked to the walk trips and the University commuting of students, staffs and administrative staff were quantified using questionnaires, some data from transport unit and observation count of transport means entering the campuses in the morning from 7:00 - 9:00 PM, afternoon from 12:00 - 2:00 PM and evening from 5:00 - 7:00 PM on Monday, Tuesday and Friday every two weeks per month of January, February March, April, May, June, July, August, September, October, November and December.

2.6. Built-up Land

The built-up land footprint was calculated using GIS based on the area of land covered by human infrastructure, transportation, housing and other structures.

The land areas covered with buildings, water, trees, free areas, garbage areas and the land coverage of the University of Juba was determine using geographical information system (GIS).

The data of energy (kWh), water (m^3), food consumption (ton), waste production (ton), built-up land (ha) and transportation (tCO$_2$/km), were analyzed in the period of one academic year 2022 - 2023 and calculated according to [3, 13, 10, 17-19] in Table 1 and Figure 1.

2.6.1. Metric Conversions Factors to Calculate Several Components of the Ecological Footprint of UoJ

Table 1. Shows the conversion of units in this study.

UNIT	CONVERSION
1gram =	0.000001 ton
1kg =	0.001 ton
1ha =	1gha
1motorcycle emits =	119.6 CO$_2$ g/km
1Car emits =	192 CO$_2$ g/km
1 Bus emits =	171 CO$_2$ g/km
1kg =	0.001 ton
1m^2 =	0.01 ha
1kWh =	0.0036 Gigajoules

2.6.2. The Structure for the Calculation of Ecological Footprint and Biocapacity at the University of Juba
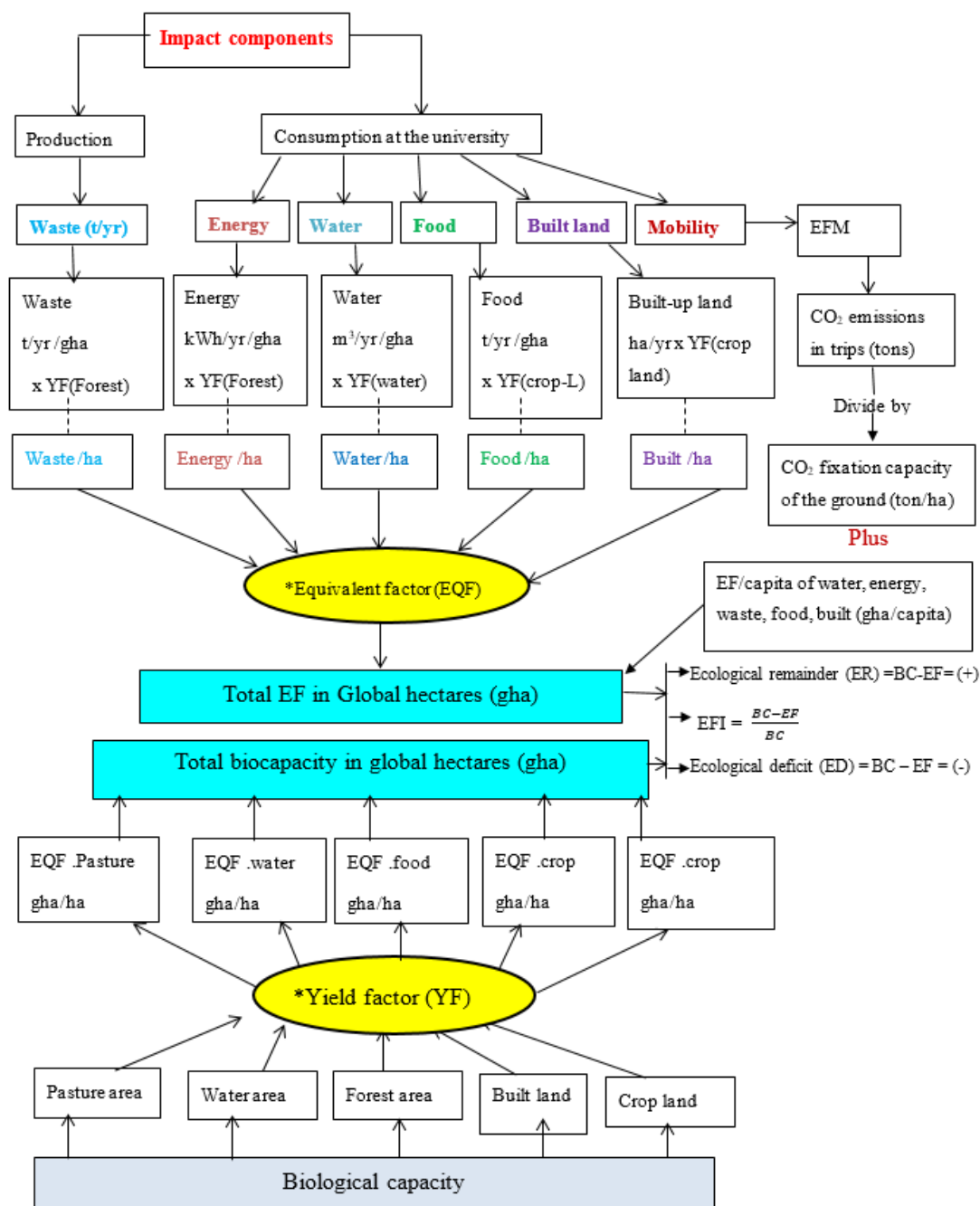

Figure 1. Flow chart for the calculation of ecological footprint.

3. Results and Discussions

3.1. Transportation on Campus

The most common means of transport on campus were bus, car, lorry, motorcycle, tricycle, bicycle and foot (walking) as depicted in Figure 2 below. Out of the several means of transport, bus constitutes 50% of the means of transport. This implies that majority of the respondents use bus to reach the campus making public transport such as buses significant in reducing the ecological footprint of a campus. They are more energy-efficient than personal vehicles and can reduce traffic congestion [36].
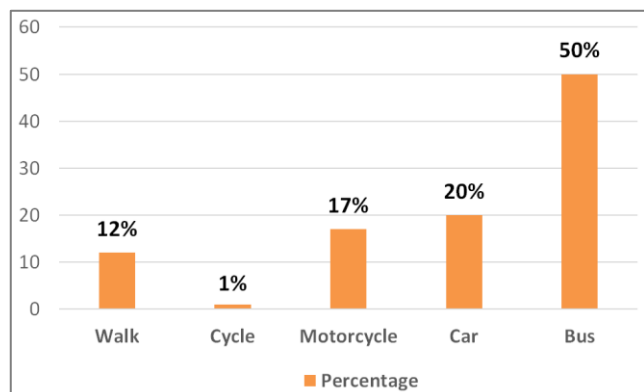
Figure 2. Shows means of transport used on campus.

3.2. Waste Production

The most common wastes found on campuses includes paper, plastic, electronics, leaves and food wastes. Figure 3, depicts that majority of the respondents (76%) accumulated less than 0.3kg of waste per day on campus while only 2% of the respondents accumulated 1.0-1.8kg per day per capita. This implies that waste footprint on campus is environmentally sustainable because most people produce only 0.3kg of waste per day/capita. High waste per day/person could lead to negative impact on the environment and the campus community. This would lead to water pollution, soil contamination, air pollution and health hazard when they were improperly disposed [20, 21]. The highest waste footprint was recorded in the month of April, May, June, September, October, and November has the highest footprint of (55.7 ton) when students and staff are fulltime on campus while the month of January, March, August and December has the low footprint recorded (31 ton) due to most students are on holidays. Whereas February has the least footprint of (28 ton) due to few number of working days in the month. It can lead to health risks for both humans and animals. Disease-carrying insects and vermin can spread diseases if they come into contact with waste [22]. This

can damage the University's reputation and negatively impact its relationship with the local community.
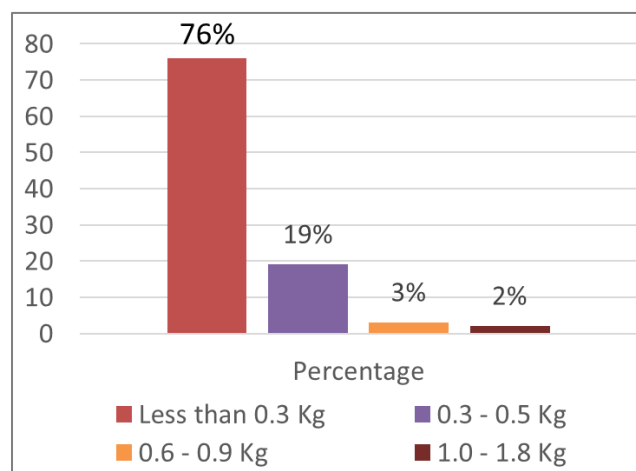

Figure 3. Shows waste accumulated per day per capita.

3.3. Water Usage

Results are shown in the Figure 4, indicates the much water used to be supplied during working days (80,000 L) and used to be used all in the same day whereas only (60,000 L) used to be supplied during weekends and could be used all. This implies that water footprint was not sustainable on campus because the water supplied per day was used all, this means there was high water demand to be supplied to satisfy the campus users' needs. A high water usage can lead to water scarcity issues as emphasized by [23, 24, 45]. This can affect the University's ability to maintain its operations and can lead to conflicts with local communities, hence increased cost of water bills for the University.
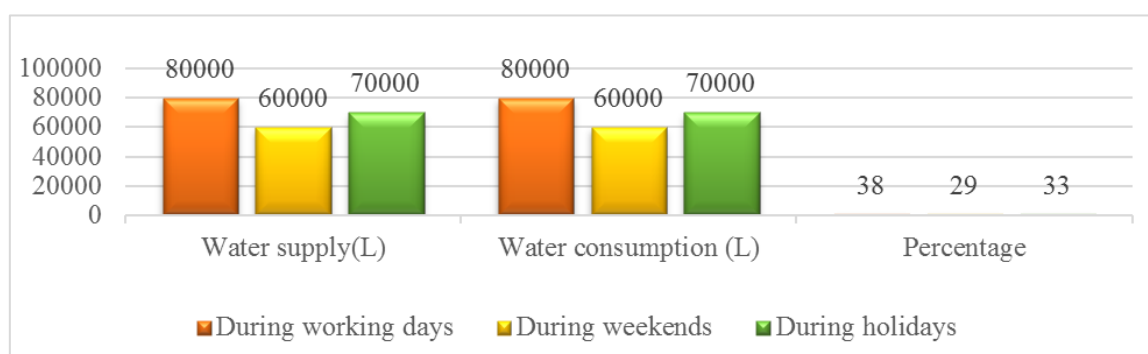

Figure 4. Shows water usage.

3.4. Food Consumption

The main categories of food on campus were meat, vegetables and mixed feeding. As shown in the figure 5, depicts that large proportion meat (18.1%), vegetables (9.9%) used to be cooked, compared to only (4.5%) of beans used to be cooked on campuses per day. This implies that food footprint was unsustainable on campus due to high cooked meat on campus which used to be consume all. This is in unison with [10, 25], proposed that animal products such as meat has

significant impact on the environment at the University campus this include climate change by emissions of greenhouse gases in production of animal, it requires large amount of water which can lead to water scarcity issues. Large amount of land which can lead to deforestation, habitat loss, and soil degradation. The disposal of animal products also generate waste including manure and packaging materials and animal dung, comports with emphasizes that, this wastes can contribute to air, and water pollution, negatively impacting the campus environment [26].
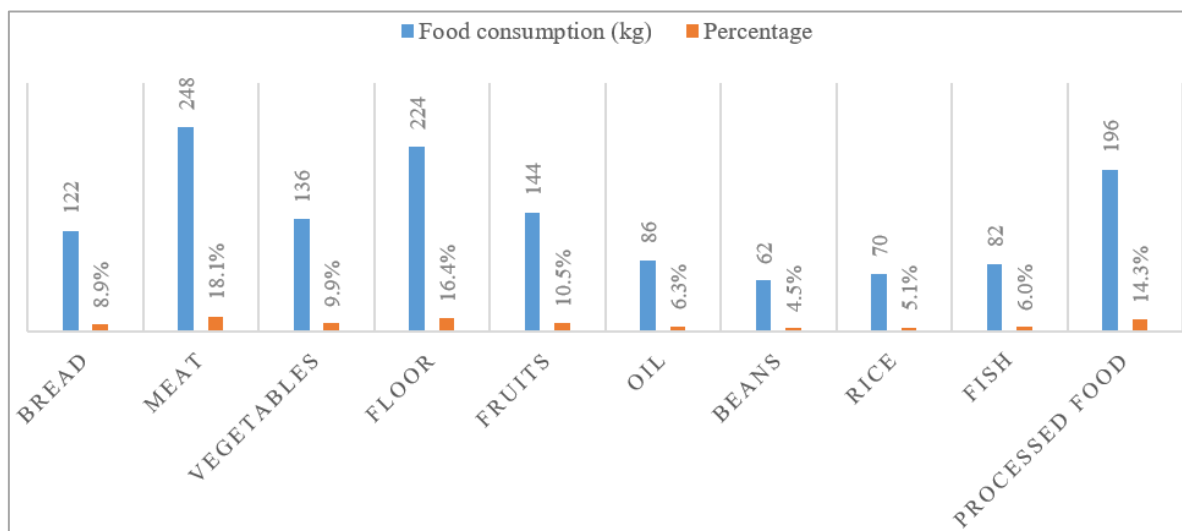

Figure 5. Shows food consumption per day.

3.5. Energy Consumption

The types of energy found on campuses were renewable from solar panels and none-renewable energy from national grid and backup generators. University of Juba Power Management Unit were the sole operator of electricity on the campuses. With high output of energy noted from nonrenewable energy. Figure 6, indicates that mega energy (50%) used to be recorded during working days from Mondays to Fridays while 25% energy was recorded every weekends and holidays. A high energy footprint per day on campus can lead to a larger ecological footprint for several reasons [27]. Firstly, the energy came from non-renewable sources such as fossil-fuels, which contribute to greenhouse gas emissions and climate change [28]. Secondly, energy consumption can lead to other forms of pollution, such as air pollution and noise pollution from generators. The combustion of fossil fuels releases large amount of greenhouse gases, such as methane, sulfur dioxide, nitrogen oxide and carbon oxide into the atmosphere which can lead to respiratory and other health issues [29], as well as causing climate change from the emission

of greenhouse gases [25, 30].
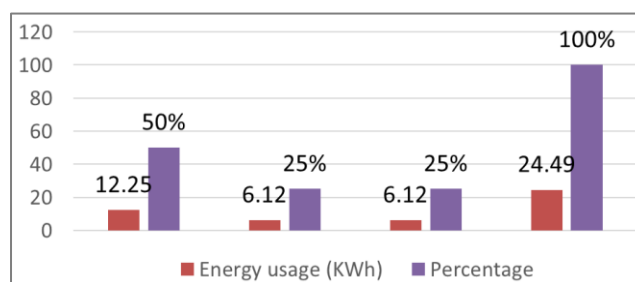

Figure 6. Shows energy consumption per day.

3.6. Build-up Land

Figure 7 below reveals that the total area of the University of Juba is 101 hectares. The build areas was 69.39 hectares while 31.61 hectares were empty spaces.
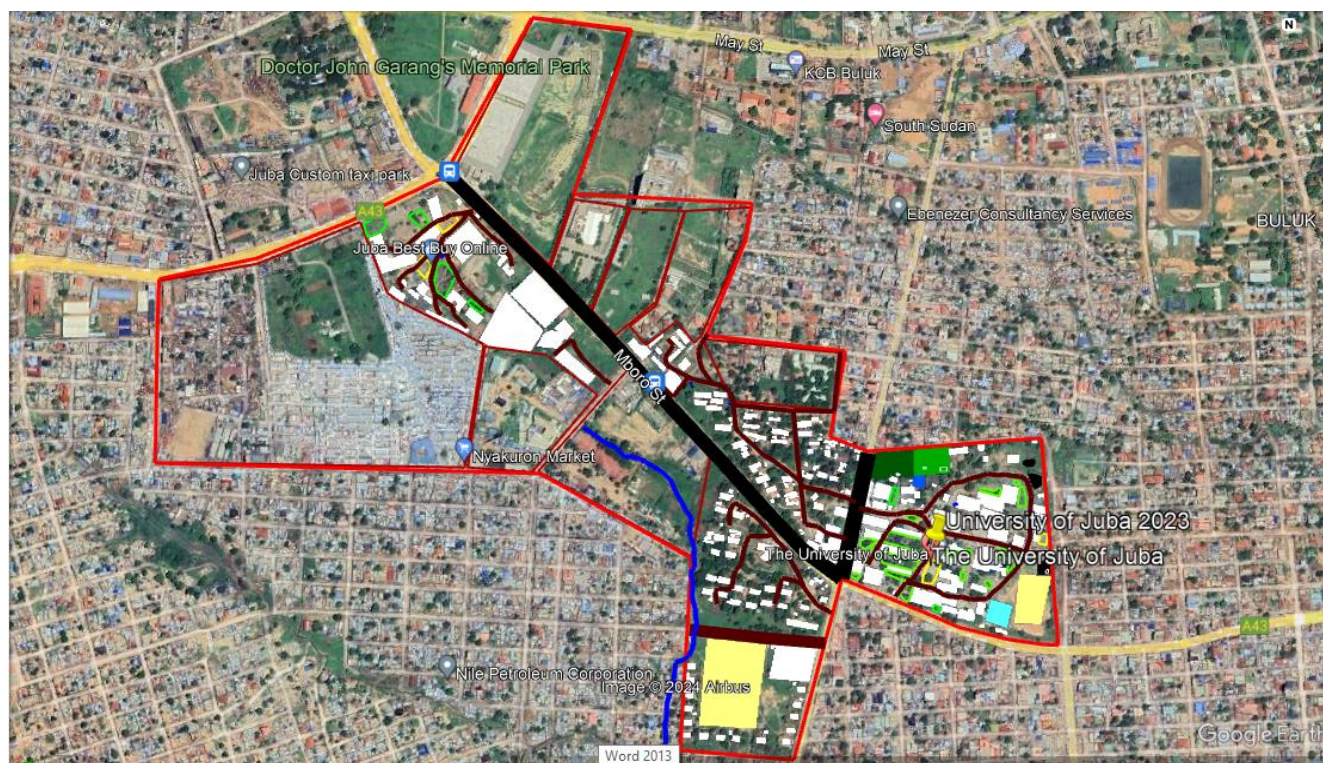
Figure 7. Shows the area of the University of Juba.

4. Biocapacity Calculation at the University of Juba

Biocapacity (BC) has a fundamental role in ecological sustainability. To calculate the BC for the UoJ campus, first, the necessary data such as cropland, grazing land, water area, forest land and built-up land were obtained from FAO [31]. The BC for the state of Central Equatoria State (1,826,936.812) was calculated and then the BC per capita was determined (1.16). The state BC extrapolated for the UoJ campus was based its mean population. The BC per capita for Central Equatoria State was calculated and the results are presented in Table 2.

Table 2. Central Equatoria State per capita BC in 2023 [31].

Table 2. Shows the Central Equatoria State BC in 2023 by FAO.

Land type	Area (ha)	Equivalent Factor (EQF)	Annual Production (ton)	Yield Factor (YF)	Biocapacity (BC)
Crop land	654.9	2.49	353.646	0.54	880.578
Grazing land	1,261,740	0.46	1,261,740	1	580,400.4
Forest land	2,277,630	1.26	979,380.9	0.43	1,234,019.934
Water area	13,480	0.37	13,480	1	4,987.6
Built-up land	13,350	2.49	2,670	0.2	6,648.3
TOTAL					1,826,936.812

To find, annual production (tons) = YF*A   (1)

Total BC of Central Equatoria State (CES) = 1,826,936.812
Population of CES = 1,574,700

The BC is assessed by multiplying the land area available annually for production of each product, by the appropriate yield and equivalence factors as shown in equation 3 [18, 3, 32]. A region's BC (gha) for any land type is calculated as follows;

$$BC \ (gha) = A. \ YF. \ EQF \qquad (2)$$

Where, A is the available area for a given land use type (ha), YF is the yield factor that is different for everywhere, and EQF is the equivalent factor [13, 18]. Where Biocapacity per area is calculated as;

$$\text{Biocapacity per capita} = \frac{Total \ biocapacity \ area}{Total \ population} \qquad (3)$$

Therefore,

$$\text{Biocapacity per capita (gha)} = \frac{1,826,936,812}{1,574,700} = 1.16$$

4.1. Yield Factor

$$\text{Yield Factor (YF)} = \frac{Annual \ production \ (ton)}{Area \ (ha)} \qquad (4)$$

Yield factor is a factor that varies from everywhere. It is presented in the Table 3.

Table 3 Yield Factors specific to the South Sudan footprint accounts for 2023 [33].

Table 3. Shows yield factors of Biocapacity in South Sudan.

Area type	Yield Factor (World ha/ha)
Crop land	0.54
Forest land	0.43
Grazing land	1
Water area	1
Built-up land	0.2

4.2. Equivalent Factor

Due to the fact that most human settlement are located in a very fertile land areas of the world [18] crop land and built area are equal in the amount of EQF [13].

The equivalent factor for various land type are presented in table 4 [18, 44]. Table 4 Equivalent factor used in the South Sudan footprint accounts for 2023 [33].

Table 4. Shows Equivalent Factors of BC in South Sudan.

Land type	Equivalent Factor (EQF)
Crop land	2.49
Grazing land	0.46
Forest land	1.26
Water area	0.37
Built-up land	2.49

5. Ecological Footprint Calculation at the University of Juba

There are many formulas used to calculate EF as given in the below equations.

Equation 5 for calculation of EF components [18, 13, 44].

$$\text{Total EF (gha)} = \sum_i \frac{Ci.efi}{Pi} \qquad (5)$$

Total EF (gha) was determined through weighted sum of the total natural resources consumption components and waste production divided by land productivity (ha/ton/year). Where, C_i (amount /year) is the amount of the consumed resources or waste production in a year, efi (gha/ha) is a constant coefficients, and Pi (ha/ton/year) is the land productivity. In regard to the six components, including energy (Gigajoules), water (m^3), food consumption (ton), waste production (ton), built-up land (ha) and transportation (tCO_2/km), were analyzed in the period of one academic year 2023. The data of the following components were collected and analyzed as follow. Given the values of EF at the University of Juba in 2023 in the Table 5.

Table 5. Shows the analyses of Ecological Footprint Calculation at the University of Juba Campus.

EF Components	Total/day	Total/year (365days)	Hectares (ha)	Global hectares (gha)
Water (m^3)	11.500	4,197.5	4197.5	1,553.075
Waste (tons)	2.34	854.1	367.263	462.751
Food (tons)	2.74	1,000.1	540.054	1,344.7446
Energy (GJ)	0.0666	24.309	10.452	13.16952
Built-up land (ha)	69.39	69.39	37.4706	93.301794
Mobility (tCO_2/km)	55.6767	20,322	635.0625	800.17875

EF Components	Total/day	Total/year (365days)	Hectares (ha)	Global hectares (gha)
TOTAL				4,257.220664

5.1. Transport (Mobility) Footprint Calculation

First and foremost, the total emission corresponding to each respondent of the transport and observation count was calculated by considering the emission factor of the mode of transport utilized, which is the amount of CO_2 (ton) that given mode of transport per kilometer travelled. In the case of car travel, the carbon footprint of a medium petrol car was 192 grams of CO_2 per kilometer, a medium diesel bus carbon footprint was 171 grams of CO_2 per Kilometer, and motorcycle emits 119.6 grams of CO_2 per kilometer [1, 34, 35], while bicycle and on foot are non-emitting transport mode, had a factor of 0 [35-37]. As presented in the Table 6.

Table 6. Shows transport (Mobility) Footprint Calculation.

Means of transport	Percentage	Users	tonCO$_2$/year
Walk (on foot)	12%	4,800	0
Cycle (on bicycle)	1%	400	0
Motorcycle	17%	6,800	2,950.66
Car	20%	8,000	4,963.24
Bus	50%	20,000	12,408.1
TOTAL	100%	40,000	20,322

The equation below was used to calculate ecological footprint of transport [36, 35].

$$\text{Mobility} = \frac{CO2\ emissions\ in\ (tons)}{CO2\ fixation\ capacity\ of\ the\ ground\ (\frac{ton}{ha})} \quad (6)$$

In this component of mobility, the results obtained in 2023 survey and observation count are presented. UoJ students and staff performed 12,840,000 journeys in the year covering 125,960,600 km/year in total in 2023, amounting to a direct emission of 20,322 tons of CO_2 in the atmosphere. EFM was 635.0625 ha of local forest land and 644.3892 gha, corresponding to 6 times the total area occupied by UoJ or 10 times its Biocapacity to absorb the gases (the forest land at the UoJ is 1.6 ha). The EFM equals 18.79% of the total EF of UoJ in 2023.

Table 7. Shows EFM and EFM per capita.

EFM Components	CO$_2$ emissions (tCO$_2$/year)	EFM (ha)	EFM (gha)	EFM gha/capita
UoJ Campus	20,322	635.0625	800.17875	0.02832

$$\text{Total EF/Area} = \frac{\text{Total Ecological Footprint (gha)}}{\text{Area (ha)}} \quad (7)$$

Solution

$$\text{Total EF/Area} = \frac{4,257.220664}{101} = 42.150\ \text{gha}$$

$$\text{EF per Capita} = \frac{\text{Total EF (gha)}}{\text{Population}} \quad (8)$$

Solution

$$\text{EF per Capita} = \frac{4,257.220664}{40,000} = 0.106 \approx 0.11\ \text{gha/capita}$$

Breakdown of Ecological Footprint Components Using Equation 8

i) Water footprint $= \frac{1,553.073}{40,000} = 0.0388$ gha/capita

ii) Waste footprint $= \frac{462.751}{40,000} = 0.011568$ gha/capita

iii) Food footprint $= \frac{41344.7446}{40,000} = 0.0336$ gha/capita

iv) Energy footprint $= \frac{13.16952}{40,000} = 0.000329$ gha/capita

v) Built-up land $= \frac{93.3017}{40,000} = 0.000233$ gha/capita

Vi) Transportation footprint $= \frac{800.17875}{40,000} = 0.02832$ gha/capita.

5.2. Ecological Deficit and Ecological Remainder

The Ecological Deficit (ED) indicates that the ecological resilience capacity is sufficient, whereas the Ecological Remainder (ER) indicates that the ecological capacity is surplus, i.e., more than the resource consumption and the amount of waste neutralization [13, 18].

ED is when EF is bigger than BC

ER is when EF is smaller than BC.

BC and EF are used to determine whether a region is located in an ecological remainder or ecological deficit. They are calculated as follow in equation 9 and 10 [18, 24].

$$ER = BC - EF = (+) \tag{9}$$

$$ED = BC - EF = (-) \tag{10}$$

ER - ED = BC − EF {(ER > 0 =sustainable, ED < 0 = unsustainable)}

ER and ED depicts the given states with footprints bigger and smaller than their Biocapacity, respectively. To show how much they are sustainable.

Therefore, from the equation;

ER and ED = BC − EF, where BC = 0.16 and EF = 0.11 gha/capita.

Solution, ER and ED = 1.16 − 0.11 = 1.05 ER.

The Ecological Remainder = 1.05 meaning sustainable, Biocapacity is bigger than the EF.

5.3. The Ecological Footprint Index

The EFI is the percentage difference between the ecological resilience capacity (BC) and the ecological footprint (EF) and shows the level of sustainability of a given region. From the equation (11) of EFI. The interpretation of EFI and its relationship with the sustainability level are presented in Table 9 [1, 3, 13].

$$EFI = \frac{BC - EF}{BC} \tag{11}$$

Where BC = 1.16, and EF = 0.11

Solution, $EFI = \frac{1.16 - 0.09}{1.16}, = \frac{1.06}{1.16} = 0.91$

Therefore, EFI = 0.92

5.4. Environmental Sustainability Practices at the University of Juba Campus

1. Building construction and renovation based on green design principles i.e. (relying on clean energy includes: solar, wind, hydroelectric, green roof, renovation),
2. Energy conservation practices (including turn off light, unplug devices and appliances not in use, skylight, walking, ventilation, window etc.),
3. Waste Reduction practices (such as e- communication, waste collection, double- sided copying, and waste free lunch program),
4. Recycling of solid waste (including paper, plastic metal, e- waste etc.),
5. Sustainable food program (such as local organic, or fair-trade food),
6. Water conservation practices (including efficient toilets, minimal irrigation, harvested rainwater etc.),
7. Sustainable landscaping (integrated pest management, native plants, trees in pots, porous pavers, compound grasses, biodiversity, minimizing lawn etc.),
8. Sustainable transportation program (including bicycle/pedestrian friendly system, carpool, bus pass programs, biodiesel programs),
9. Green purchasing from environmentally and socially responsible companies (products are non-toxic, water and energy conserving, etc.),
10. Reduction of toxic materials and radioactive waste [38, 39], presented in Figures 8, 9, 10, 11, and 12.

Based on the above practices, remarks were given based on the present practices as; Total Remarks = 44, Present practices = 33, None present practices = 11, Total rate = 44 x 4 = 176.

Figure 8. Shows sustainable landscaping.

Figure 9. Shows energy conservation practices (solar panels).

Figure 10. Shows waste reduction practices.

Figure 11. Shows sustainable food program.

Table 8. Shows the Analyses of the Environmental Sustainability Practices at the University of Juba Campus.

Rate	Code	Total	Remarks	Percentage
None	1	12	Unsustainable	27.27
A little	2	14	Slightly sustainable	31.81
Quite a bit	3	17	Moderately sustainable	38.63
Great deal	4	1	Greatly sustainable	2.27
TOTAL	76	44	4	100%

Figure 12. Showed building construction and renovation based on green design principles (LEED).

The Table 8, indicates that the campus was sustainable. 38.63% and 31.81% moderately and slightly sustainable respectively. Most of the environmental sustainable practices were available on campus such as energy conservation, water conservation, bus pass and carpool, local food, sustainable Land scape among others [40-42, 44].

5.5. Comparing Ecological Footprint of Different Universities around the World to the EF of University of Juba

The Table 9, indicated that the highest ecological footprint per capita was recorded at the University of Kurdistan (1.69) in 2016 – 2021, while the least ecological footprint per capita was recorded at the University of Juba in 2023. The lower ecological footprint result at the University of Juba was due to low consumption when compared to high consumption in developed countries. Most studies have found strong correlations between living standards at lower consumption levels (developing countries), and decoupling at higher levels (industrialized countries) [13, 22, 24].

Table 9. Shows comparison of Ecological Footprint of different universities around the world to the EF of University of Juba.

University	Kurdistan	Tianjin	Leuven	East Anglia	Newcastle	Redland	Juba
Country	Iran	China	Belgium	UK	Australia	USA	South Sudan
Reference	Vaisi	Liuet al.	Lambrechts	Wright et al.	Flint	Venetoulis	Morris
Year	2016 – 2021	2014 – 2015	2010 - 2011	2007 - 2008	1998 - 1999	1998 - 1999	2022 – 2023
Study period	Four academic years	One academic year	One academic year	One academic year	One academic year	One academic year	One academic year
Population	9,982	30,000	7,611	18,000	19,200	2,727	40,000
Area (ha)	101	200	2.22	129.5	135	57	101
Total EF/ (gha)	16,484	4659	2663.7	----	3,592	2,300	4,199.85
Total EF/ Area	163.21	23.3	1200	102	27	40	41.58
EF per capita	1.69	0.16	0.35	0.73	0.19	0.84	0.11
Energy (%)	70.73	7.8	17.83	28.96	----	50.26	0.3
Food (%)	1.28	48.28	4.77	----	5.97	---	31.58
Mobility (%)	----	----	44.22	10.28	42.66	32.57	18.79
Built-up (%)	----	----	----	1.01	43.73	----	2.19
Waste (%)	26.87	16.56	0.05	59.5	----	12.5	10.86
Water (%)	1.12	27.37	0.01	0.25	----	4.67	36.48
Goods & Services (%)	----	----	23.69	-----	3.97	----	---
Infrastructure (%)	-----	-----	9.43	-----	3.67	----	---
Components with highest impact (%)	Energy	Food	Mobility	Waste	Built-up land	Energy	Water
	-70.73	-48.28	-44.22	-59.5	-43.73	-50.26	-36.48
EFI	-0.82	0.61	----	----	----	----	0.92
Environmental Sustainability	Unsustainable	Very Sustainable	Very Sustainable	Sustainable	Very Sustainable	Sustainable	Very Sustainable

The study therefore, brings to light the status of the ecological footprint of the University of Juba and it adds to the existing body of knowledge. The anticipated limitations includes lack of knowledge about the term ecological footprint by the respondents and unwillingness of respondents to share information in the process of data collection, bad weather conditions especially high temperature up to 34 ℃ and heavy rainfall, distance and transport complication to the research site, lack of personal computer and inability to include indirect consumption of components of ecological footprint of students in their homes due to lack of funds. However, further studies is needed in transportation footprint, energy footprint and food footprint at the University of Juba while including their indirect consumption of the components from homes. Moreover, this studies need to be carried out in the counties, states, South Sudan as a nation and other higher institutions and organizations in South Sudan.

6. Conclusions

This study aimed to assess and quantify the ecological footprint of water, waste, transportation, food, energy and build-up land at University of Juba campus and compare them to the environmental sustainability. Based on the study result, the Ecological Footprint per capita footprint of Water, food, transportation, waste, energy and built-up land footprint were 0.04, 0.03, 0.03, 0.01, 0.0003 and 0.0002 gha/capita respectively which were environmentally sustainable (0.11 gha/capita). If, all people were living the lifestyle of the University of Juba, we would require only one planet Earth. Therefore, it's recommended that University of Juba maintains and improves on its ecological footprint status to enhance its environmental sustainable goals. More emphasis should be put on reducing water, food and transportation footprint and maintaining the other components. To

improve and maintain ecological footprint at University of Juba in regards to sustainability, this study recommended the University of Juba administration to establish University Environmental Sustainability Office (ESO). Recommending environmental coordinator to continuously audit the environment and encourage behavior change at the University of Juba.

Abbreviations

EF	Ecological Footprint
GFN	Global Footprint Network
ESO	Environmental Sustainability Office
gha	Global Hectare
UoJ	University of Juba
EFI	Ecological Footprint Index
BC	Biological Capacity
ha	Hectares
GIS	Geographical Information System
USA	United States of America
UK	United Kingdom
DRC	Democratic Republic of Congo
CES	Central Equatoria State
LEED	Leadership in Engineering and Environmental Design
ER	Ecological Footprint Remainder
ED	Ecological Footprint Deficit
FAO	Food and Agriculture Organization
EFM	Ecological Footprint of Mobility
YF	Yield Factor
EQF	Equivalent Factor
kWh	Kilowatt Hours
Kg	Kilogram
A	Area
t	Ton
m^2	Meter Square
m^3	Meter Cube
Km	Kilometer
CO_2	Carbon Dioxide
GJ	Gigajoule

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Authors Contributions

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Conflicts of Interest

The authors declare no conflicts of interest.

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