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Sustainability Measurement Criteria for Ecological Footprint campus Worksheet of Debre Berhan University, Ethiopia, East Africa

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Abstract: Ecological footprint is a measurement tool to find out the land and water area any given human population requires for the production of their resources and the absorption of their wastes which is necessary for assessing the environmental impacts (Baboulet, O., &Lenzen, M. (2010)and their resource consumption.This tool is significant enough to identify the sustainable practices in the campus area of the university by calculating and analysing the Ecological footprint of the given area.It is imperatively an eco-friendly approach for the sustenance of environment and its resources on a long term basis.This methodology followed in this paper helps to identify,quantify the consumption of various resources and to evaluate the practices being followed in the university campus area.

Keywords: Yield factors, Equivalence factors, Ecological footprint, Sustainability

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I. INTRODUCTION

Ecological footprint analysis(Chambers, and Wackernagel,.2000)) is an environmental assessment tool utilized with specific objectives to quantify the resource waste output which in turn, helps to evaluate the waste management practices and to perform the sustainability analysis (Alshuwaikhat, H. M., & Abubakar, I. 2008)by choosing an appropriate methodology for the given area.This method cannot directly convert the resource consumption into global hectares.Rather,first the area covered under land or water is calculated in hectares by dividing the total amount of resources to the average resource yield of the given resource harvested area,multiplied with both yield factors and equivalence factors.Mathis Wackernagel and William Rees (Wackernagel, M. and Rees, W. 1996) introduced the concept of Ecological Footprint Analysis and this technique has evolved gradually in the last two decades.Sustainability analysis helps to achieve the long term sustainable goals by resolving social,economic (Bennett, M., Hopkinson, P., & James, P. 2006) or environmental issues.

II. MATERIALS AND METHODS

The study area is chosen in the Ethiopian regionalcontext with the deep rooted background of uneven resource utilization in this country of Sub-Saharan Continent.Natural resources are used in the given area beyond sustainable yield leading to negative environmental impacts. The city Of Debre Berhan is located in North Shewa Zone of Amhara Region, Ethiopia.The topography of the area is inundated with significant variations both in the elevation and temperature tributes within few miles of this city.The area is covered by 92% cropland and animal husbandry is the main occupation of this area heavily relying on the biomass resources including agricultural residue,wood wastes as well as livestock residues.The city is divided into various woredas whose number in total comes to be 500 and 307 woredas out of these are heavily utilizing woody biomass in excess of the sustainable yield. In the given background context of the city the study area of Debre Berhan University is well perceived to show environmental impacts which can be assessed by using the Ecological Footprint analysis methodology.Since the study area is well placed within the heart of the city and reserved within the boundary of the city it became easy to collect the data on regular basis.This method cannot directly convert the resource consumption into global hectares (Venetoulis, J. 2001).Rather,first the area covered under land or water is calculated in hectares by dividing the total amount of resources to the average resource yield of the given resource harvested area,multiplied with both yield factors and equivalence factors(Venetoulis, J. 2001).Mathis Wackernagel and William Rees introduced the concept of Ecological Footprint Analysis and this technique has evolved gradually in the last two decades.

1.2.1 RESEARCH DESIGN

The total area of productive land and hydrospace is estimated which is utilized for university campus resources' consumption(Conway, T. M., Dalton, C., Loo, J., &Benakoun, L.2008) and waste absorption over a period of one year. The consumption includes resources of various types like water use,fossil fuels,energy use, recyclable and non-recyclable material use in the university campus area.

1.2.2 DATA COLLECTION

The university population data is collected by taking personal interviews, questionnaires (both open-ended and close-ended) and specific departmental surveys.The administrative offices like University Registrar office and the Human Resource department provided ample information about the university population and other quantitative data.

1.3 THEORY/CALCULATION

1.3.1 INPUT FACTORS

Various consumption resources are used as input data into unit less values and this is converted in the form of consumption of land area of that country as given in **Table A.1**

The Equivalence factor is used to describe the productivity of any land type as compared to the world average productivity. Different land types are combined together taking single unit of measurement, common global hectare.These factors are multiplied by world average land productivity to measure the productivity of the land type(Hempel, L., Venetoulis, J., Gin, J. and Obazyae, S. 1998).

1.3.2 CALCULATION OF PAPER CONSUMPTION

Calculating Equation:

$$\frac{\boldsymbol{Consumption(reams)}}{\boldsymbol{435(\frac{reams}{tonne})}} * (\boldsymbol{1.32\ ha - \frac{yr}{tonne}})$$

As given in **Table A.2 of Appendix**

A tonne of virgin paper requires 1.8 m^3 of wood and the world average yield is 1.99 m^3 per ha per year [1](Chambers, Simmons, Wackernagel. 2000. Sharing Nature's Interest. London. p.93).

Total productive land for one tonne of paper: $\frac{1.8m^3}{\frac{1.99m^3}{ha-yr}} = 0.904\ ha - yr$

After conversion using the forest land equivalence factor,

ENERGYLAND = 0.9106 [*ha-yr/tonne*]

FOREST LAND 0.904×0.4569 =0.413 [*ha-yr/tonne*]

TOTAL = 1.32 [*ha-yr/tonne*]

Take as

1 ream = 2.3 kg

1 tonne = 1000 kg

1 tonne = 435 reams

Paper Reams (Bundles) =500×12×2kg=12,000kg

Newspapers=50gm×100=5000gm=5kg

EF= $[\frac{502}{435}] * 1.32 \Rightarrow$ **EF=1.52**

1.3.3 CALCULATION OF WASTE CONSUMPTION

Calculating Equation:

Paper waste [*kg*] × 0.0028 [*ha-yr/kg*] = EF [*ha-yr*]

Glass waste [*kg*] × 0.001 [*ha-yr/kg*] = EF [*ha-yr*]

Aluminum waste [*kg*] × 0.0094 [*ha-yr/kg*] = EF [*ha-yr*]

Plastic waste [*kg*] × 0.0036 [*ha-yr/kg*] =EF [*ha-yr*]

[1]Chambers, Simmons, Wackernagel. 2000. Sharing Nature's Interest. London. (p.93).

Derivation:
Ecological footprint of
Paper waste 2.8 ha-yr/tonne = 0.0028 ha-yr/kg
Glass waste 1.0 ha-yr/tonne = 0.001 ha-yr/kg
Aluminum waste 9.4 ha-yr/tonne = 0.0094 ha-yr/kg
Plastic waste 3.6 ha-yr/tonne = 0.0036 ha-yr/kg

EF OF WASTES (Chambers, Simmons and Wackernagel 2000. Sharing Nature's Interest. London. p.93).
Paper=7200kg×0.0028 =20.16
Glass=2232kg×0.001 =2.232
Al Cans=1086kg×0.0094 =10.2
Plastics=9722kg×0.0036 =34.99
Total EF =67.582

1.3.4 CALCULATION OF WATER CONSUMPTION

Calculating Equation:
$\boldsymbol{Consumption\ (m^3) \times 0.00008\ [ha - \frac{yr}{m^3}]}$**= EF [ha/yr]**

Derivation:
UTM's water consumption in m^3 can be obtained from Facilities Resources[10].

Ecological footprint for cold tap water is
0.08 m^2ha-yr/100 L (1 m^3 = 1000 L)
$\Rightarrow 1\left[\frac{1000\,l}{m^3}\right] \times 0.08\left[m^2 ha - \frac{yr}{100\,l}\right] \times 1\left[\frac{ha}{10000\,m^2}\right] = 0.00008[ha - \frac{yr}{m^3}]$

⇒**EF**=46153.85×12×0.00008=44.308 (ha-yr)

⇒EF=44.308(ha-yr)

1.3.5 CALCULATION OF ENERGY CONSUMPTION

Total mix of energy consumption as Footprint is given in **Table A.3 of the Appendix.**
Conversion factor equation:

$$Conversion\ factor = \left\{\begin{matrix} (fraction\ hydroelectric) * (footprint\ for\ hydroelectric) + \\ (fraction\ natural\ gas) * (footprint\ for\ natural\ gas) + \\ \left(fraction\ \frac{coal}{oil}\right) * (footprint\ for\ \frac{coal}{oil}) \end{matrix}\right\}$$

(Green fleet, Diesel conversion factor , 2005)
⇒EF=717+94+754+120.78+10=1695.78
⇒EF=1695.78

1.3.6 CALCULATION OF FOSSIL FUEL CONSUMPTION(TRANSPORTATION GROUND VEHICLES)

Calculator Equation:
Consumption [*L of diesel/yr*] × 0.000867 [*ha-yr/L*] = EF [*ha-yr*]
Consumption [*L of unleaded gasoline/yr*] × 0.000774 [*ha-yr/L*] = EF [*ha-yr*]

Derivation:
<u>Diesel</u>
Diesel emissions[2] 2.69 kg of CO_2/L
Uplift factor[3] 1.45
CO_2 sequestration land[4] 0.00019 ha-yr/km
Equivalence factor for forest land 0.4569

[2]Greenfleet. Diesel conversion factor taken from "Technical Information." Retrieved July 7, 2005 from http://www.greenfleet.com.au/
[3]Wackernagel and Rees. 1996. Our Ecological Footprint. Canada. (Box 3.7, p.107).
[4]Chambers, Simmons, Wackernagel. 2000. Sharing Nature's Interest. London. (p.93).

And then we get

$$2.69\left[kg\frac{of\,CO_2}{L}\right]\times 1.45\times 0.00019\left[ha-\frac{yr}{kg}of\;CO_2\right]\times 0.4569=0.0003386[ha-\frac{yr}{L}]$$

Unleaded gasoline

Emissions[5]	2.4 kg of CO_2/L
Uplift factor [6]	1.45
CO_2 sequestration land[7]	0.00019 ha-yr/kg of CO_2
Equivalence factor for forest land	0.4569

$$\mathbf{2.4\left[kg\;of\frac{CO_2}{L}\right]\times 1.45\times 0.00019\left[ha-\frac{yr}{kg}of\;CO_2\right]\times 0.459=0.000302[ha-\frac{yr}{L}]}$$

Consumption [24000L of diesel/yr] 0.0003386 [ha-yr/L] = 8.126 EF [ha-yr]
Consumption [6000L of unleaded gasoline/yr] 0.000302 [ha-yr/L] = 1.812 EF [ha-yr]

TOTAL EF=9.938

1.3.7 CALCULATION OF CAR-DROP OFFS

Calculating Equation:

$$Distance\;of\;car-km\times 0.12\left[\frac{L}{car}-km\right]\times 2.4\left[kg\;of\frac{CO_2}{L}\right]\times 1.45\times 0.00019\left[\frac{ha-yr}{kg\;of\;CO_2}\right]\times 0.4569\times 5$$

Distance of car-km × 0.00018126[ha-yr/km]

Total distance travelled is given in **Table A.4 of Appendix**
Average fuel consumption [8]= 0.12 L/car-km
Emissions [9]= 2.4 kg of CO_2/L
Uplift factor [10] = 1.45
CO_2 sequestration land[11] = 0.00019 ha-yr/kg of CO_2
Equivalence factor for forest land = 0.4569
Ten passenger car equivalence factor = 5

Car Km Travel= (130×2×250)+35,000=100,000Km
⇒EF (ha-yr/km)=100,000×0.00018126=18.13
⇒EF=18.13

1.3.8 CALCULATION OF BUILT UP LAND AREA WITHIN CAMPUS

Calculator Equation:

$$Consumption[m^2]\times 0.000006\left[ha-\frac{yr}{m^2}\right]=EF\;[ha-yr]$$

Derivation:
Campus built-up land includes the area of buildings, parking lots, road space, and all impermeable surfaces.
Equivalence factor for built-up land = 0.060

$$Consumption[m^2]\times 0.0001\left[\frac{ha}{m^2}\right]\times 0.060=0.000006[ha-\frac{yr}{m^2}]$$

⇒ EF =40hactares= 40×10000=400,000km^2
⇒EF=400,000×0.000006=2.4(ha-yr)
⇒EF=2.4
Sum of Total of All EF=1839.65 Ha-Yr=4599.145acres
(Kitzes, J., Peller, A., Goldfinger, S., &Wackernagel, M.2007)

III. RESULTS

[5] Government of Canada. 2004. Your Guide to the One Tonne Challenge.
[6]Wackernagel and Rees. 1996. Our Ecological Footprint. Canada. (Box 3.7, p.107).
[7]Chambers, Simmons, Wackernagel. 2000. Sharing Nature's Interest. London. (p.93).
[8]Wackernagel and Rees. 1996. Our Ecological Footprint. Canada. (p.107).
[9] Government of Canada. 2004. Your Guide to the One Tonne Challenge.
[10]Wackernagel and Rees estimate that the equivalent of 15% of the fuel energy use is needed to manufacture and maintain a vehicle with an extra 30% for the construction and maintenance of the road infrastructure (p.85, Sharing Nature's Interest).
[11]Chambers, Simmons, Wackernagel. 2000. Sharing Nature's Interest. London. (p.93).

The Total Ecological Footprint of the University Campus Area is calculated by finding out the individual categories of footprint as Hydroprint,Waste print, Electricity print, Fossil fuel print, Paper print, Built-Up Land Area print. This helps to find out Per Capita Foot print in Acres or hectares-year.The sum total of all the Ecological foot prints is 4599.145 acres. The Per capita university footprint is 0.34 as given in **Table A.5 of the Appendix.**The Campus Footprint Component ha-yr is depicted in **Fig.A.1** while percentage component is depicted in **Fig.A.2**

3.1 SUSTAINABILITY OF UNIVERSITY

The Footprint comparison for campus footprint per person and recommended footprint is given in **Table A.6** and shown in **Fig.A.3** of the Appendix.

3.1.1 SUSTAINABILITY ANALYSIS

The university land space is 255 acres and the hydrospace is 84 acres which gives the value of 339 acres for Ideal sustainability (Venetoulis, J. (2001).Strong sustainability is 1.6 acres per capita on world average and weak sustainability is 3.4 acres per capita on world average.This is given in **Table A.7.**of the Appendix and sustainability of Debre Berhan University is shown in **Fig.A.4**

IV. DISCUSSION

The Ecological foot prints of various resource consumptive materials in the university campus area like Hydro print, Waste print, Electricity print, Fossil fuel print, Paper print, Built up Land area print are calculated in the result section and the total Ecological footprint of the university area is evaluated which is 1839.65hac or 4599.145 acres.

(1 hectares =2.5 acres).Since this footprint score of the university is 18 times the university area of 255 acres, the per capita university footprint space is 0.34 acres.In comparison to the available footprint space per person in the country 1.0123 acres(Monfreda, C., Wackernagel, M., &Deumling, D. 2004), this value of per capita university footprint is three times short. While if we compare this score of 0.34 acres with the world average footprint per capita of 5 acres, then it is almost 15 times short of the recommended space. This score is used to evaluate and analyse the sustainability of the university on ecological basis. The criteria followed is the quantitative evaluation of ecological footprint and sustainability of the score which is used for scoring on qualitative terms. The Ideal Sustainability is the sum total of university area (255) and hydrospace (84) which is 339 acres. Strong sustainability is the world average per capita of 1.6 acres which in university acres is 21,660 (1.6*13,538)while the Weak Sustainability is 3.4 acres which in university acres is 46,029 (3.4*13,538).To be ideally sustainable the university footprint per capita should be less than or equal to the sum total of 339 acres. Since the campus ecological footprint space is 4599.145 acres which is five times less than the required Ideal sustainability space, so it proves the Strong sustainability of the university space. However, in this research paper only few footprint spaces of the campus are included while other factors like pavements are not included which might change the sustainability criteria.

V. CONCLUSIONS

The ecological footprint analysis reveals the consumption pattern of natural resources with minimum impacts on the nature which seems to be impossible by using conventional approaches or environmental techniques. The consumption gap is widely viewed by using the current state of technology. This helps in the community awareness and decision making process for the university management.

APPENDIX

Tables

Table A.1 : Equivalence Factors for Ecological Footprint Consumption Per Capita Ethiopia-2013

Land Category	Equivalence Factors[18]
Fossil energy (carbon)	0.08276
Built-up area	0.060226
Crop land	0.299086
Fishing ground	0.001896
Forest, including deforestation	0.456929
Grazing Land	0.111458

Table.A.2 Total Energy Supply-2014(International Energy Agency)

Energy Type	**% of Energy Mix**	**Energy of GJ out of 25 GJ**	**GWh** (1 GWh = 3600 GJ)	**Ha-yr per GWh**[12]	**Land (ha-yr)**
Water	1.6	0.4	0.000111	717	0.07969
Renewable	0.1	0.025	0.0000069	120.78	0.0008334
Biomass	92.2	23.05	0.0064	10	0.064
Natural gas	6	1.5	0.0004167	94	0.03917
Coal/oil	6.1	1.525	0.000424	754	0.3197
			TotalLand for 1 tonne:		0.9106

Table A.3 Total Electricity mix consumption as Energy Footprint

Electricity type	**Footprint (ha-yr/GWh)**
Hydroelectric	717
Natural gas	94
Coal/oil	754
Renewable	120.78
Biomass	10

Table A.4 Total distance travelled in Km for Transport Footprint

Distance category	Distance of 1 round trip (estimate) [km]	Total distance in 1 year (140 days) [km]
0-2 km	4	**560**
2-5 km	10	**1400**
5-10 km	20	**2800**
> 10 km	30	**4200**

Table A.5 Ecological Footprint Per Capita of University Campus Area

	Footprint Component(ha-yr)	**Percentage of total**	**Per capita foot print(ha-yr)**
Hydro print	44.308	2.41	0.0033
Waste print	67.582	3.67	0.005
Electricity print	1695.78	92.17	0.125
Fossil fuel print	28.068	1.52	0.0021
Paper print	1.52	0.083	0.0001
Built up Land area print	2.4	0.13	0.0002
Total	1839.85ha-yr/4599.145acres	100.00	0.34

Table A.6 Comparisons of Footprint per capita

Campus Footprint (acres)	Recommended footprint(acres)	Footprint space per person in Ethiopia (acres)	World Footprint space per person (acres)	Campus Footprint per person (acres)
4599.145	21,660	1.012	5	0.34

Table A.7 Sustainability Analysis in Acres of Ecological Footprint

Ideal Sustainability (acres)	Strong Sustainability (acres)	Weak Sustainability (acres)	Campus Footprint (acres)
339	21,660	46,029	4599.145

[12]Chambers, Simmons, Wackernagel. 2000. Sharing Nature's Interest. London. (p.83). Median/Mean values were used in the case of hydroelectricity and natural gas/oil.

Figures

Fig.A.1

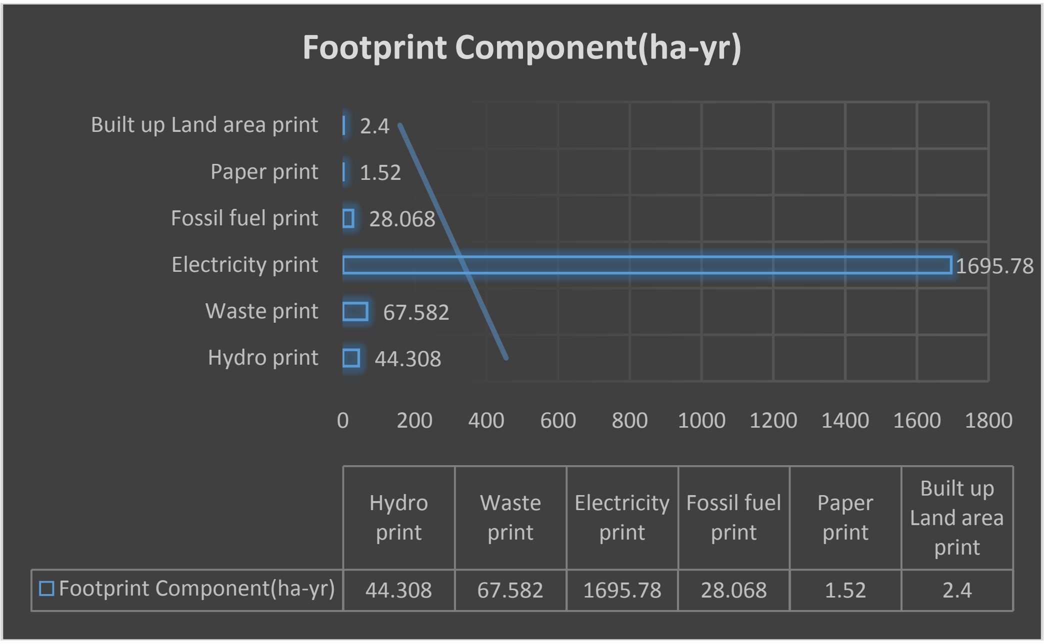


Fig.A.2

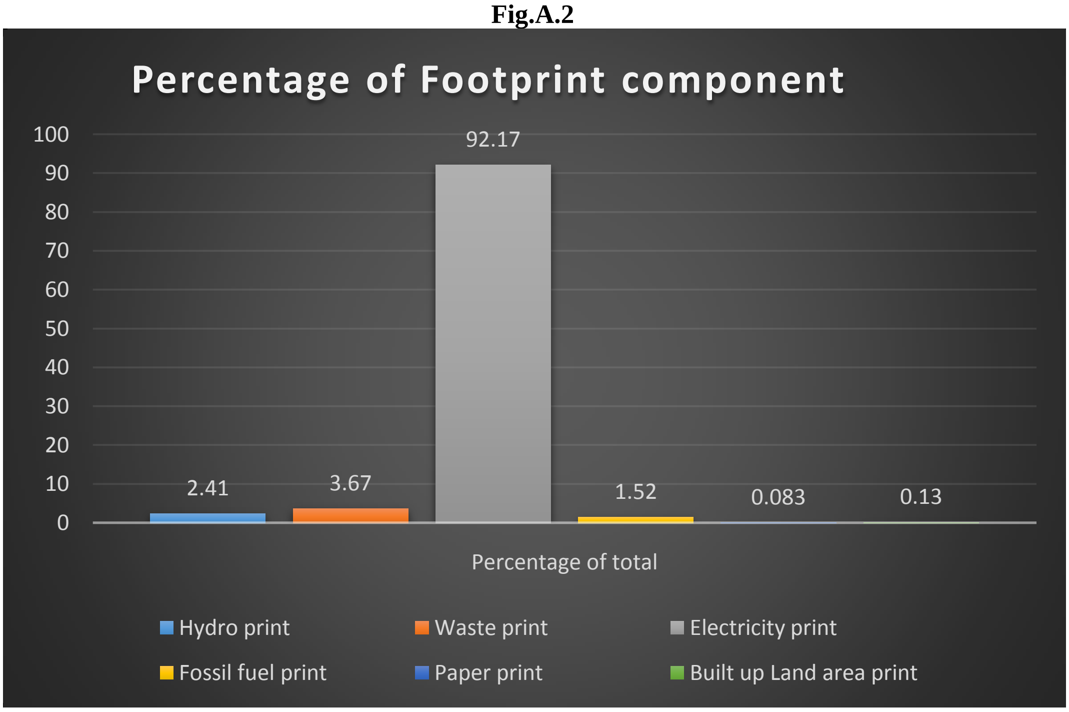


Fig.A.3

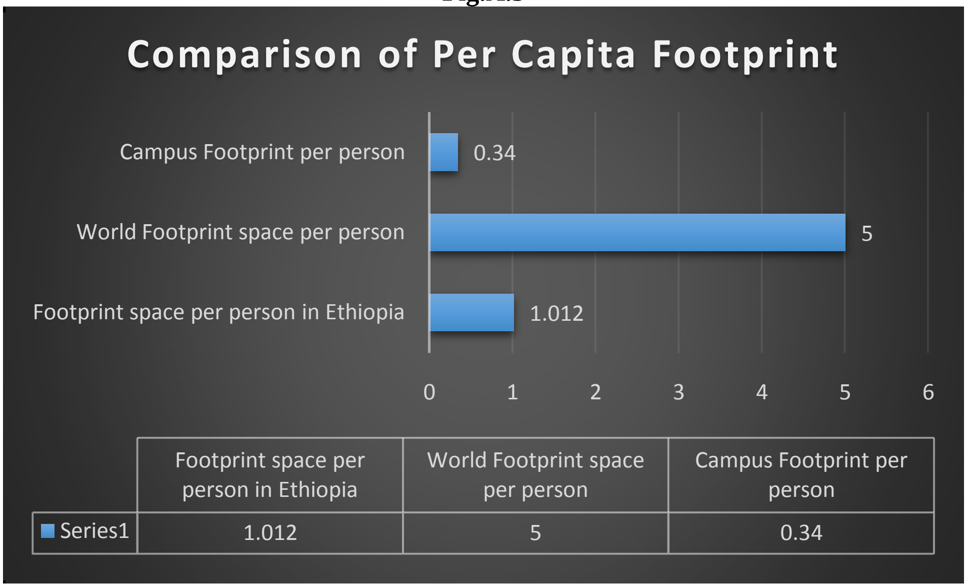
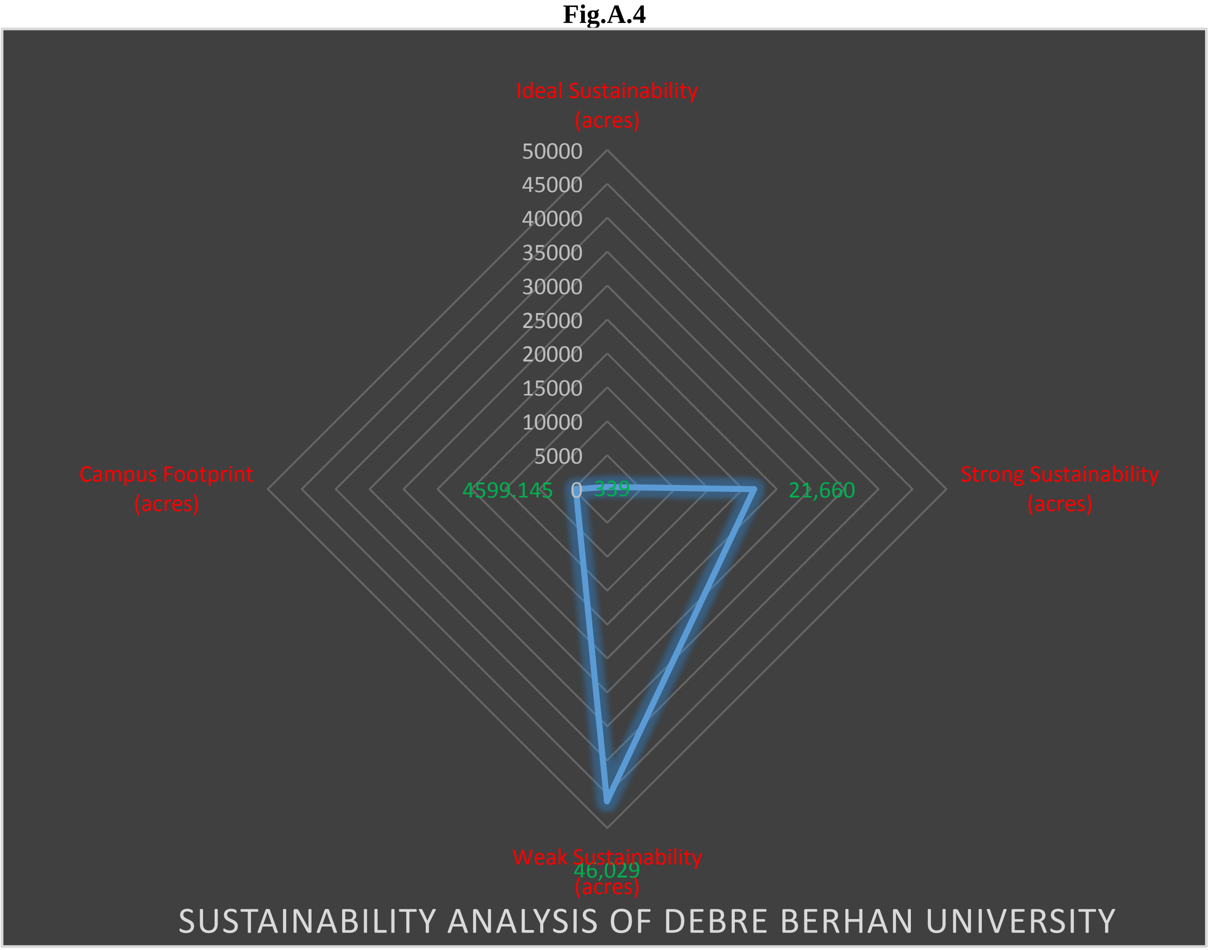


Fig.A.4



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