Ecological Footprint

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Ecological Footprint (EF) is one of the most scientific methods for the assessment of environmental performance. It is broadly applied to measure the sustainability grade of communities. EF is also an accounting tool for quantifying Herman Daly's (Nobel Prize winner for sustainable development) principles of sustainability, and it could provide the ability of natural resource consumption monitoring and present advice for the reduction of human pressure on the ecosystem.

Keywords: sustainable development ; Ecological Footprint Analysis (EFA) ; Biological Capacity (BC) ; environmental impacts ; green university campuses ; low carbon university campus

1. Introduction

A lot of tools and methods have been presented to assess ecological sustainability [1]. The footprint term is widely used to describe the sustainability level that is applied in various knowledge fields such as Carbon Footprint (CF) [2], Water Footprint (WF) [3], Material Footprint (MF) [4], and Urban Energy Density Footprint (UED_f) [5].

Mathis Wackernagel and William Rees from the University of British Columbia defined the Ecological Footprint (EF) concept for the first time in the early 1990s [6]. EF has been applied frequently as an index to control the quality of the environment in educational institutions [7] and as a policy guide as well as a planning measure to achieve sustainability [8]. It is also a proper tool to address the UNICEF's motto of "education for sustainability" [9].

Since EF is calculated based on the appropriation of land and all the impacting components, expressed in global hectares (gha), it is also called the land footprint [10]. EF compares the amount of natural resource consumption with the available Biological Capacity (BC) to indicate how human beings are using natural resources. BC is determined by inverting the concept of EF [11][12] and can be interpreted as the maximum allowed resource consumption rate and waste discharge that can be sustained indefinitely in a given region without gradually impairing the functional integrity and productivity of the relevant ecosystem [13].

EF is an accurate tool to measure the impact of all components resulted from human behaviors on a university campus. EF is calculated using two approaches, including the compound- and component-based models. In the compound approach (known as Wackernagel's approach) the human impact on each land type (fossil-energy land, arable land, pasture, forest, built-up land, and sea space) is considered for a given population [14]. In a component-based calculation, one starts with identifying all the individual items, i.e., goods and services, and accurate measuring of natural resources consumption as well as the produced waste by a given population in a given region. In the component-based model, the ecological footprint values are calculated using appropriate data belonging to the investigated region [15]. In this approach, one does not build up the total EF through an item-by-item methodology but starts from the overall consumption balance [16].

2. The Background of the Ecological Footprint Assessment for University Campuses

In recent years, Higher Education Institutions (HEIs) have been encouraged worldwide to boost their role to be an active part of the sustainable society, therefore, several research studies have been conducted to assess the sustainability level of HEIs [17][18][19][20]. As key actors in society, HEIs may educate thousands of students and staff for challenges connected to sustainable development. The fundamental purposes of EF accounting in HEIs can be summarized in 3 steps: (1) to have a clear intuition about the HEI's ecological impact, (2) to serve as a base for further policy planning, (3) to raise ecological awareness through education in the society [21].

EFA has been applied for several university campuses around the world and the specifications of this research are reviewed and summarized in **Table 1**. It shows both the total and the per capita footprint, the research period, the

percentage impact of each component, the component with the highest environmental impact (%), and the Ecological Footprint Index (EFI) of each university. However, few studies have calculated the EFI.

Table 1. Summarizing the EFA results of different universities.

University (Country)	Newcastle (Australia)	Redlands (USA)	Holme Lacy (UK)	Kwantlen (Canada)	Ohio State (USA)	SRM (India)	Northeastern (China)	Toronto at Mississauga (Canada)	Otago (New Zealand)	East Anglia (UK)	Illinois (USA)	Algarve (Portugal)	Leuven (Belgium)	Tianjin (China)	UOK (Iran)
Reference	Flint [22]	Venetoulis [23]	Dawe et al. [24]	Burgess and Lai [25]	Janis [26]	Thattai [27]	Li et al. [28]	Conway et al. [29]	Bell et al. [30]	Wright et al. [31]	Klein-Banai and Theis [32]	Nunes et al. [33]	Lambrechts and Van Liedekerke [21]	Liu et al. [34]	This study (2021)
Year	1998–1999	1998–1999	2001–2002	2005–2006	2006–2007	2006–2007	2003–2004	2005–2006	2008–2009	2007–2008	2008–2009	2013–2014	2010–2011	2014–2015	2013–2016
Study Period	One academic year	One academic year	One academic year	One academic year	One academic year	One academic year	One academic year	One academic year	One academic year	One academic year	One academic year	One academic year	One academic year	One academic year	Four academic years
Population	19,200	2727	524	10,376	77,120	10,000	23,345	8100	———	18,000	36,640	4950	7611	30,000	9982
Area (ha)	135	57	240	62	710.5	30	110	90	———	129.5	97	20	2.22	200	101
Total EF (gha)	3592	2300	296	3039	650,665	30,606	24,787	8744	217	13,160.59	97,601	5049–9999	2663.70	4659	16,484
Total EF/Area	27	40	1.23	49	916	1020	225	97	———	102	1006	252–500	1200	23.30	163.21
EF per capita	0.19	0.84	0.56	0.29	8.66	3.06	1.06	1.08	———	0.73	2.66	1.02–2.02	0.35	0.16	1.69
Energy (%)	———	50.26	55.20	28.91	21.81	1.72	68.28	69.40	22	28.96	72.66	51–89.6	17.83	7.8	70.73
Food (%)	5.97	———	72.80	9.64	———	98.02	21.91	9.14	7.13	———	2.60	3.3–5.9	4.77	48.28	1.28
Mobility (%)	42.66	32.57	69.20	52.96	74.14	0.25	0.08	16.07	38	10.28	12.60	41–41.9	44.22	———	———
Built-up land (%)	43.73	———	20.40	1.10	———	———	———	1.14	6.38	1.01	———	0.07–0.14	———	———	———
Waste (%)	———	12.50	74.90	———	4.06	———	5.77	4.03	26.38	59.50	11.83	0.14–0.25	0.05	16.56	26.87
Water (%)	———	4.67	3.60	0.16	———	4.2	1.98	0.23	0.11	0.25	0.14	2.1–3.7	0.01	27.37	1.12
Goods & Services (%)	3.97	———	———	7.24	———	———	1.99	———	———	———	———	0.29–0.49	23.69	———	———
Infrastructure (%)	3.67	———	———	———	———	———	———	———	———	———	———	———	9.43	———	———
Component with the highest impact (% of EF)	Built-up land (43.73)	Energy (50.26)	Waste (74.90)	Mobility (52.96)	Mobility (74.14)	Food (98.02)	Energy (68.28)	Energy (69.40)	Mobility (38)	Waste (59.50)	Energy (72.66)	Energy (51–89.6)	Mobility (44.22)	Food (48.28)	Energy (70.73)
EFI	———	———	———	———	———	———	———	———	———	———	———	———	———	0.61	−0.82

One of the major defects in the reviewed research is related to the short period of the assessment time (an academic year) of the calculated EF. To assess the EF of university campuses accurately, selecting a longer period is fundamental. The impact of humans on the environment may alter over the years because of temporary activities at campuses such as the number of national or international conferences or building constructions. For example, if the EF measurement is conducted in a year in which a university organized several international conferences (impact of guests) or during the same year engaged with new building construction, definitely the EF in that year is radically higher than normal. Therefore, analyzing the EF during one academic year is not reliable.

Furthermore, the assessment of the EF at a campus scale, as conducted in the reviewed literature, does not provide detailed information. Understanding which part of a university such as colleges, cafeterias, libraries, sports centers, etc. behaves unsustainably is essential to outline sustainable policy plans.

3. Conclusions

Global warming and other negative impacts of humans on the environment are the main challenges of the world. Consequently, the concept of sustainable development has been frequently investigated to address these challenges. In recent years, the Ecological Footprint Assessment (EFA) tool has played a significant role in evaluating sustainable development performance, especially in academic institutes. Applying EFA helps the planners to explore which part of a community and to what extent has a higher impact on the environment. This information forms the foundation of future sustainable action plans to diminish the environmental impacts.

The methodology for the assessment of the EF was developed in terms of the longer period of the study, data cleaning, visualization, and conducting the assessment simultaneously at both community and individual building levels.

Based on the EFA, a range of strategies and actions are suggested to diminish the impact of fossil fuel energy, reduce the water footprint, and decrease the impact of food components on the campus environment.

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