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Ecological Footprint Assessment of Hospitals in Solan City of Himachal Pradesh

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Abstract

This study was carried out in selected hospitals of Solan Town of Himachal Pradesh to assess the ecological footprint which appraised the load of different components namely electricity, water, food, material, transportation and biomedical waste, imposed by the hospitals on the natural environment. The total ecological footprint of all four selected hospitals of Solan town viz., Regional Hospital, Shiva Hospital, City Hospital and Sai Sanjivni Hospital was found to be 1553.75 gha, 100.10 gha, 165.44 gha and 185.31 gha respectively during the year 2021. Transportation and material components registered the highest contribution towards the Ecological Footprint (EF) of the Hospitals and the lowest contribution was made by biomedical waste and electricity components. The maximum Ecological Footprint per area (6.02 gha) was exhibited by Sai Sanjivni Hospital and the minimum (0.75 gha) by the Regional Hospital. The sum Ecological Footprint for all the selected Hospitals was 2004.6 gha, whereas the average bio-capacity per capita was 0.0095 gha. It was concluded that the Ecological Footprint of all selected hospitals exceeded bio-capacity, resulting in un-sustainability. The hospitals had extremely poor bio-capacity, making it hard for them to keep up with the expanding footprints.

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Introduction

Consumption from human beings of natural resources consisting of water, air, food, and land arises spontaneously. Humanity depends upon the natural resources of the earth for supporting our lifestyle. Human activities consume resources and produce waste.[1] Development in living standards lead to population explosions. The population explosions have moved people from rural areas to cities, generating thousands of tonnes of garbage every day. As the living standard increases, the quantity of waste generated also increases.[2] To conduct our lives more sustainably while safeguarding our natural resources for future generations, an ecological footprint is a beneficial tool. The ecological footprint is a powerful model for measuring humanity's impact on the planet in order to reduce the harm we are causing before it is too late. Given current technological and economic processes, the Ecological *Footprint* (EF) is a tool measured in global hectares (gha) for estimating the biologically productive area required to sustain current consumption pattern.[3,4] The ecological footprint is a measure of biophysical limits and long-term sustainability. It provides an overall estimate of the ecological effect or a metric for measuring human environmental impact.[5] The EF can also be used to track how humans exploit and misuse potentially renewable natural functions and services. In order to achieve global sustainability, the total area of all impact of EF regional footprints must not exceed the biosphere's overall area limits.The biosphere's ability to meet human demand for resource consumption and waste disposal is referred to as Biological Capacity (BC). According to Galli,[6] humans are now demanding more than our planet's ecosystems will renew. By 2050, 2.6 Earths will be required to both provide us with the resources required and to manage our garbage. By 2050 it will take 2.6 Earth to supply us with sufficient resources while also absorbing our waste.[7] A biocapacity of 1.6 global hectares per person is estimated for the entire globe by dividing the 7.4 billion people who're now alive. In order to ensure global stability, the existing unsustainable living lifestyles and economical growth model needs must be addressed from various perspectives.

According to[5] Calcott and Bull,[8] despite housing more than half of the world's population, cities barely take up 2% of the planet's land cities. have more than half of the world's population but only occupy 2% of the Earth's surface region. However, these cities consumed roughly 75% of the country's capital and generate 75% of the waste. Bell,[9] looked at footprints and found that transportation, food use, and waste generation had the highest footprints, implying that universities are moving away from sustainability. According to WWF,[10] human demand for the planet's living resources, i.e., its ecological footprint, exceeds the planet's regenerative potential by 30% (to show the capacity of the planet which is exceeded day by day). But the problem is not just cities, because it is observed that urban dynamics emerge everywhere[11] and with that, the shift to urban lifestyles even in regular human settlements not very quantitatively populated and the emergence of a global problem. We must understand also that the urbanization rates diverge enormously between countries. A global perspective of the problem can be evaluated by checking the traces described by some relevant global indicators related to the urban population, economic growth, and environmental cost in terms of CO_2 emissions, where it is observed in the last decades most of the traces are moving in different directions at a different speed, showing a decoupling effect.[12] Breaking the connection between "environmental bads" and "economic goods" is referred to as decoupling. Decoupling indicators with an economic variable as the denominator and the pressured-related environmental variable as the numerator can be used to measure decoupling. In other cases, population increase or another factor may be the denominator or driving force.

The ecological footprint assessment (EFA) tool provides footprint reduction options for a more sustainable future and proper environmental protection, both of which are required to solve humanity's current catastrophic impacts on natural habitats. Humans have overrun the planet's ecological or human carrying capacity (CC), according to the EF study.

Although the footprint concept is used to calculate ecological CC, global CC is only a heuristic. This disparity (EF>CC), also referred to as "*overshooting*," may be perfect for increasing overall satisfaction. Tsuchiya[13] stated that the sub-national Ecological Footprints of Japan's 47 territories were obtained using a standard top-down scaling strategy devised by the Global Footprint Network. Japan's national

Ecological Footprint was 67.97% of total household consumption. Household consumption accounted for 67.97% of Japan's overall Ecological Footprint at the national level.

Healthcare facilities are at the heart of service delivery, ensuring that people's health is protected, patients are treated, and lives are saved. It contributes significantly to the climate crisis. If the health industry was an emitter, it would be the fifth largest on the globe.[14] The health sector contributes to environmental damage, putting human health at risk and causing a variety of environmental problems with negative consequences.

Healthcare accounts for 5% of the national CO_2 footprint in OECD nations, China, and India, making it equivalent to the food sector in value. The average per capita health carbon footprint in 2014 was 0.6 t CO_2, ranging from 1.51 t CO_2 per cap in the United States to 0.06 t CO_2 per cap in India. Furthermore, according to Lenzen,[15] depending on which measure is used, health care has worldwide environmental impacts that vary from 1% to 5% of overall global environmental impacts, and are more than 5% for particular national impositions. In addition, because the pandemic has highlighted the abuse of single-use personal protective equipment, healthcare organizations must track and quantify their environmental impact over time. Eckelman,[16] argued the outflow emissions from the health economy category care sector calculated, as well as their possible negative effects on public health. The National Health Expenditures (NHE) economic input-output model showed negative public health outcomes over a ten-year period. This industry is responsible for a number of global environmental problems, including the precipitation of acid rain (12%), GHG emissions (10%), smog formation (10%), pollutants in the air (9%), stratospheric ozone depletion (1%), and mutagenic and non-carcinogenic air toxics (1-2%). Inadequate medical waste management culminates in an undesirable odour, the expansion of insects, rats, and warms, as well as the spread of numerous diseases. Despite the fact that even though hospitals save and preserve lives, the waste products they produce have a huge negative impact on the environment.[17] Gain,[18] found that clinical practice accounts for a large portion of a hospital's environmental footprint. The evidence base on hospital sustainability also has substantial gaps. According to Joshi,[19] the number of healthcare centres in Nepal is steadily growing, although healthcare waste is also rapidly increasing. All garbage becomes potentially toxic when bio-medical waste and municipal waste are combined. In 2001, Nepal generated about 1.7 kilogramme of hospital waste per person day, compared to healthcare-associated waste at 0.48 kg per person per day. According to Syrovatka,[20] humanity's ecological footprint (20.6 billion gha) was greater than bio-capacity (12.2 billion gha), implying that human consumption has outpaced the planet's regenerative and assimilative ability. This means that there is a global environmental unsustainable situation.

The city of Solan is a fast-growing city in Himachal Pradesh and has a municipal corporation recently upgraded. The city has a government-run Zonal Hospital as well as many a number of private hospitals (8-9), all of which consume natural resources and produce various wastes. As a result, a physical inventory of the facilities used by hospital employees is critical. This method enables us to make better use of natural resources and envisions more sustainable possibilities. The purpose of the current research was to evaluate the ecological impact of the city's hospitals. The current study was conducted to assess the ecological footprint of hospitals in the city.

Material and Methods

Study Area

Solan is known as India's "Mushroom City" and "City of Red Gold" because the large quantity of tomatoes is produced around the city (Fig 1). It is the second-largest municipal corporation in Himachal Pradesh after Shimla and is situated around a standard elevation of 1550 metres, 45.5 kilo metres south of Shimla, the state capital. In the Shivalik Himalayan peaks, the city is situated halfway between Shimla, the state capital, and Chandigarh, the combined capital of Punjab and Haryana. Solan Town has an area of about 33.43 km² and a population of about 806,645 (Aadhar uidai.gov.in). The climate of the Solan district is warm and temperate. The district's average annual temperature is 25.1°C. With an average temperature of 30.2°C in June and 16.1°C in January, respectively, they are the warmest and coldest months of the year. The average rainfall in this district is 1262 mm, with

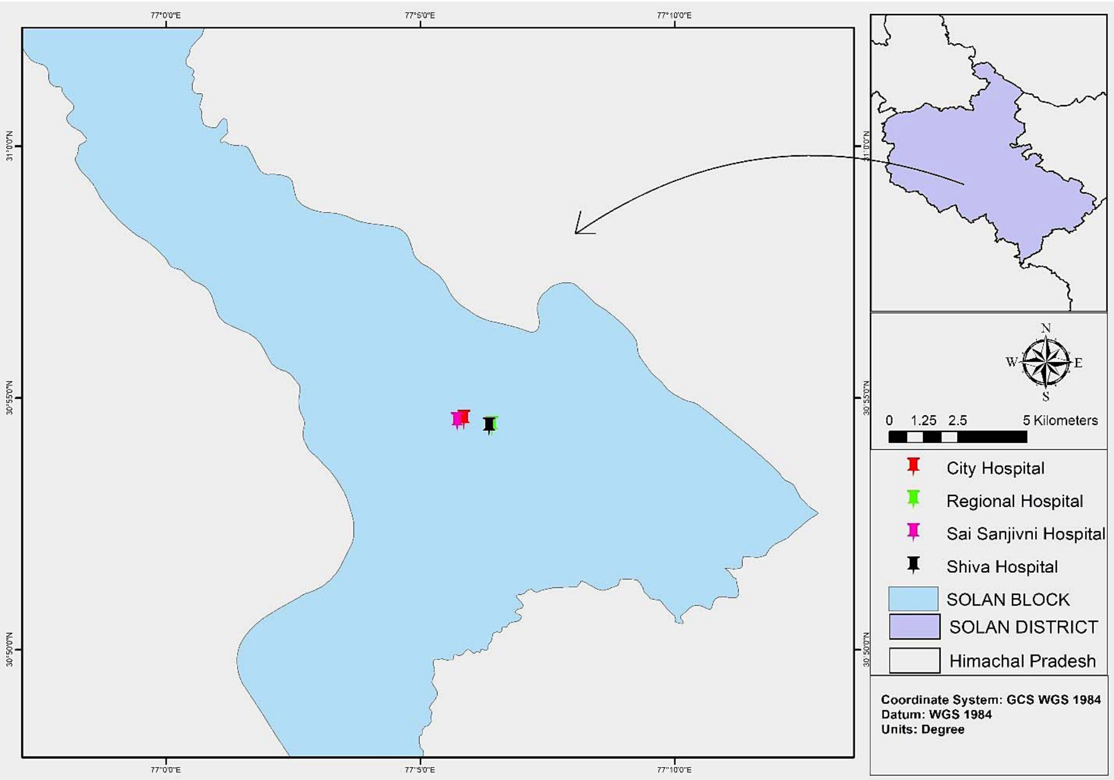

Fig. 1: Study area

90% of that received during the monsoon season. The wettest month is August with the highest rainfall of 333 mm. The driest month is November with the least rainfall of 14 mm.

Ecological Footprint Assessment

The use of electricity, water, transportation, and materials in various sectors was considered to assess the hospital's ecological footprint. The main goal of calculating an ecological footprint is to transform total consumption and waste patterns into the biologically productive land area needed to produce products and services for human consumption, as well as to assimilate waste produced by them. The amount of land that is ecologically beneficial is measured in global hectares (gha).

Electricity Footprint: The electricity footprint is calculated using the following formula given by Gottlieb.[21]

$$\text{Electricity Footprint}\left(\frac{gha}{year}\right) = \text{Energy land}\left(\frac{\frac{gha}{kwh}}{year}\right) \times kwh\ (year)$$

Water Footprint

The annual water intake was discovered using records from the hospitals. The information was then transformed into the necessary land area to meet the required water use using formula given below.[21]

$$\text{Water Footprint}\left(\frac{gha}{m^3}\right) = \text{Total Consumption}\left(\frac{\frac{gha}{m^3}}{year}\right) \times \text{Landarea}(ha) \times 1000000$$

Food Footprint

Food footprint captures the area (g ha) of energy land require to sequester the emitted carbon dioxide during growing and processing the food items and the total area of crop land required to produce 1 ton of the food. The food footprint is calculated by the formula and was expressed in g ha per year.[22]

$$\text{Food Footprint}\left(\frac{gha}{year}\right) = \text{Total Population of area} \times \text{Food Consumption per capita}$$

Material Footprint

It captures the total energy land area required to manufacture the product (paper) in terms of land area needed to sequester the carbon-dioxide emissions resulting in the manufacturing process. The annual paper consumption by the patients and staff was recorded. The material footprint was calculated with the following formula evaluated by[21]

$$Material\ Footprint\ \left(\frac{gha}{year}\right) = Items\ per\ year \times Ecological\ Footprint\ item\ \left(\frac{gha}{kg}\right)$$

Transport Footprint

It captures the carbon-dioxide emissions while commuting. The calculation included the distance traveled by each person from home to any other place, the number of days during the study period and the mode of transportation used recommended by Gottlieb[21] and Singh.[22]

$$Transport\ Footprint\ \left(\frac{\frac{gha}{km}}{year}\right) = Total\ Population\ of\ the\ area \times per\ capita\ emission\ of\ the\ city$$

Biomedical Waste Footprint

Any type of trash with infectious components is considered biomedical waste. Corporates with waste generated by biological waste that aesthetically resembles waste from a hospital or laboratory, as well as waste from research labs. The biomedical waste footprint may be calculated by using the following formula.[23]

$$Biomedical\ Waste\ Footprint\ (Waste\ produced\ per\ year) = No.\ of\ beds \times wt.\ of\ biomedical\ waste\ (kg)$$

Sustainability Scale

For assessing the sustainability of hospitals, a sustainability scale was used with the help of a survey-based questionnaire in which different scales were used like less than 60, 60-120, 120-180 and more than 180 (Table 1). With the help of the sustainability scale card provided by the EPA information centre, these scales were used to measure the impact of excessive use of resources or consumption of resources on future generations.[20]

Table 1: Sustainability scale

Scale	Measurements
<60	Very little land and resources are needed to support your lifestyle.
60-120	Your footprint has more of an impact on hospital resources. If everyone lived like you, we would need an entire extra campus to support us.
120-180	Your footprint uses a large share of hospital resources. If everybody lived like you, we would need more area to sustain us.
>180	If everyone lives like you, we would need more larger area just to support us.

Results and Discussion

Ecological Footprint of all selected Hospital in Solan City

The total EF of all selected hospitals comes out to be 2004.6 gha which is presented in (Table 2). The total EF of selected hospitals varied from 100.10 to 1,553.75 gha. The highest EF reported was in Regional Hospital, followed by Sai Sanjivni, likewise by City Hospital and the lowest was by Shiva Hospital. In the case of the electricity component, the highest total EF was found in Regional Hospital having a value of 1.59 gha, followed by Sai Sanjivni having a value of about 0.84 gha, followed by Shiva Hospital having an electricity EF of about 0.83 gha and minimum electricity EF was in City Hospital having a value of 0.61 gha. Water component reported the highest EF in Shiva Hospital having an EF of 5.18gha, followed by Regional Hospital with a water EF of 2.88gha, then Sai Sanjivni Hospital having EF of 0.864 gha and the least was reported by City Hospital having water EF of 0.004 gha. The material component reported highest EF was in Regional Hospital has a value of 374.13 gha, followed by City Hospital having a material EF of 89.10 gha, then in Sai Sanjivni Hospital reported a material EF of 72.18 gha and the least was reported in Shiva Hospital having material EF of 6.39 gha. For the Food component which was only reported in Regional Hospital had a food EF of 104.6 gha. Transportation EF was recorded highest in Regional Hospital having EF of 1068.98 gha, followed by Sai Sanjivni having EF of about 111.417 gha, likewise, City Hospital having transportation EF of 75.154 gha and minimum EF of transport component was reported by Shiva Hospital having EF value of 87.7 gha. Biomedical waste EF was reported highest in Regional Hospital having EF of 1.5768 gha, followed by Sai Sanjivni having a biomedical EF of 0.01095 g ha, Shiva Hospital reported an EF of 0.004328 gha and least was reported by City Hospital having biomedical waste EF of 0.000032 gha. Total EF was highest from transport followed by material, food, water, electricity, and biomedical waste with respected values of 134 3.251>541.8>104.6>8.932>3.87> 1.59211.

Table 2: Ecological footprint (gha) in selected hospitals

Components Hospitals	ECOLOGICAL FOOTPRINT						
	Electricity	**Water**	**Material**	**Food**	**Transport**	**Biomedical Waste**	**Total**
Regional Hospital	1.59	2.88	374.13	104.6	1068.98	1.5768	1553.75
Shiva Hospital	0.83	5.184	6.39	*	87.7	0.004328	100.1
City Hospital	0.61	0.004	89.1	*	75.154	0.000032	165.44
Sai Sanjivni Hospital	0.84	0.864	72.18	*	111.417	0.01095	185.31
Total	3.87	8.932	541.8	104.6	1343.251	1.59211	**2004.6**
Mean	0.97	2.23	135.45		335.81	0.41	
S.E(Mean)	0.21	1.15	81.54		244.5	0.39	
C.V (%)	22.14	51.66	60.2		72.81	98.72	

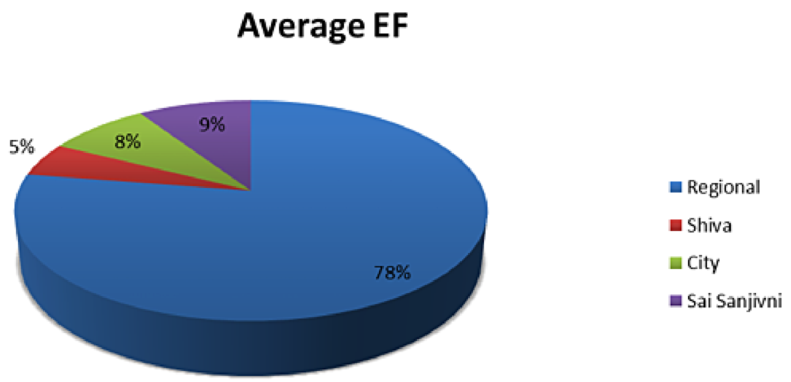

Fig. 2: Sustainability of selected Hospitals

The coefficient of variation (CV) was calculated for all the components of the ecological footprint and the maximum value of CV was found for biomedical waste EF (98.72%) whereas minimum CV was found for electricity EF (22.14%). This leads to the conclusion that biomedical waste EF accounts for the maximum variability among all the hospitals whereas there was the least variability for the electricity EF.

To assess the hospital's sustainability scale based on EF, detailed information on resource utilization was obtained from data collected by a questionnaire-based survey presented in Table 2. It is evident that the case of the Regional Hospital consisted of an area of about 0.87 hectares which was the largest among other selected hospitals and having a population of 2034 also reported the highest EF than other hospitals, only 10% of the population fell under the scale of less than 60 which means there was no usage of resources over there. The larger share of 55% of the population contribution comes under the sustainability scale of 60-120, which showed that there was a requirement to decrease the dependency on resources. 35% of the contribution by population fell under the scale of 120-180, which needs an immediate check on their ecological footprint. None of the population fell under the sustainability scale of more than 180, which represented that they utilize a much larger share of resources. In the case of Shiva Hospital having an area of about 0.068 hectares and a population on a daily basis was 167 indicated that only 10% of the population fell under the scale of less than 60, and 50% of the contribution comes under the category of 60-120. The larger share of about 35% fell under the sustainability scale of 120-180, which needs to control the consumption of resources. Only 5% of the population comes under a scale of more than 180. City Hospital has a population of about 143 and an area of 0.04 hectares, almost 5% of the population comes under the sustainability scale of less than 60, likewise larger share of 60% population comes under the scale of 60-120 which needs to lower their requirement of resources. 25% of the contribution by population comes under the scale of 120-180 and only 10% was on the scale of more than 180, which showed that their consumption of resources exceeded their limit. Sai Sanjivni Hospital has an area of about 0.07 hectares and a population of 212, none of the population comes under the sustainability scale of less than 60, likewise, 45% of the population fell under the category of 60-120 which needs to decrease their dependency on the consumption of resources. 35% of the population fell under the category of 120-180 and only 20% comes under the sustainability scale of more than 180 which indicated that they utilize a large share of resources available (Fig 2.). Thus, the result indicated the un-sustainability of selected hospitals as a higher percentage of the population was in the sustainability scale of 60-120 as reported.[22]

Table 3 evinced that the bio-capacity per capita of these hospitals varied from 0.0006 gha to 0.0013 gha, out of which Shiva Hospital reported the highest bio-capacity of about 0.0013 gha and minimum was by City Hospital 0.0006 gha and both Regional Hospital and Sai Sanjivni Hospital possesses the amount of bio-capacity per capita was 0.0011 gha and 0.0008 gha respectively. The average bio-capacity per capita of all selected hospitals was 0.00095 gha 24 which was less than India's bio-capacity per capita (0.45 gha per person)25. The winter per capita ecological footprint was 0.000742 gha, whereas the summer per capita total ecological footprint was 0.00147 gha. EF per capita was found to be 0.58 gha.

Table 3: Bio-capacity (gha) of selected hospitals for sustainability in Solan City

Hospitals	Population (workers / patients)	Area (ha)	Sustainability				Bio-capacity per capita
Regional	**2034**	**0.87**	**<60 (%)**	**60-120 (%)**	**120-180 (%)**	**>180 (%)**	**0.0011**
			10	55	35	*	
Shiva	167	0.068	10	50	35	5	0.0013
City	143	0.04	5	60	25	10	0.0006
Sai Sanjivni	212	0.07	*	45	35	20	0.0008
Total	2556	1.048	*	*	*	*	0.0038
Average	639	0.262	*	*	*	*	**0.00095**

Conclusions

The average environmental footprint of the selected hospitals was 2004.6 gha. The highest EF (1553.75 gha) was observed in the regional government hospital and the lowest (100.10 gha) in Shiva private hospital. The hospital's per capita EF ranged from

0.753 gha to 6.027 gha. Bio-capacity per capita of these hospitals varied from 0.0006 gha to 0.0013 gha and its average bio-capacity per capita was 0.00095 gha.

It is concluded that the EF of all selected hospitals exceeded bio-capacity, resulting in un-sustainability. The hospitals had extremely poor bio-capacity, making it hard for them to keep up with the expanding footprints. The percentage contribution of sustainability of all selected hospitals fell under the scale of 60-120 that leads towards un-sustainability that indicates, we should decrease the dependency on resources.

Our research demonstrates that the results obtained in our case study are relevant for small cities but will be higher in the case of bigger cities, but always understanding the differences in the social context and the social space across regions.[24]

Insights Open in Future Research

As a result, strategies for reducing the ecological footprint must be implemented in order to achieve resource sustainability. Staff and students should be encouraged to use

(i) Public transportation
(ii) Indigenous and local items
(iii) Energy-efficient gadgets
(iv) Waste recycling and reuse
(v) Water conservation to reduce EF in hospitals.
(vi) Renewable energy technologies

Furthermore, more awareness and comprehension of this idea is needed so that staff and students to understand the relationship between ecological footprint and bio-capacity and how their actions affect their ecological footprint.

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Conflict of Interest

The author(s) declares no conflict of interest.

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