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Analysis of Environmental Footprints of Health Centers in Kangra District, Himachal Pradesh, India

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ABSTRACT

The experiment was conducted during December, 2020 to June, 2021 at Kangra district of Himachal Pradesh, India to evaluate the ecological footprint of 15 hospitals that were chosen at random. The purpose of this study was to assess the ecological impact of these medical facilities-which included both government and private hospitals—across five blocks of district. The ecological footprint framework was utilized to analyze factors such as food waste, solid waste, water consumption and energy consumption and material use, determining their impact on biocapacity. The average ecological footprints of the hospitals ranged from 116.5 to 271.4 global hectares (g ha). The ecological footprints varied across different blocks as follows Jawalamukhi (349.7 g ha), Dharamshala (535.6 g ha), Nurpur (698.3 g ha), Palampur (722.3 g ha), and Kangra (814.0 g ha). Notably, the hospitals in the Jawalamukhi block were the most sustainable, exhibiting the lowest ecological footprint. These results underscore the significant environmental impact of hospitals and the urgent need for initiatives to reduce their ecological footprint, particularly in the Kangra block. The results emphasize the importance of sustainable resource utilization in healthcare institutions to minimize their ecological footprint and promote environmental sustainability. To achieve a balance between providing healthcare services and protecting the environment, the research recommends extensive actions to enhance the effectiveness of resource utilization, waste management, and energy consumption in hospitals.

KEYWORDS: Biocapacity, consumption, ecological, footprint, hospitals, sustainability

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1. INTRODUCTION

Healthcare is a crucial aspect of social well-being as it offers essential services that enhance people's lives. However, there are significant environmental consequences linked to the operation of healthcare facilities, particularly hospitals. A useful approach for assessing these impacts is the concept of the ecological footprint, which measures the environmental impact of human activity in terms of natural resources used and waste generated. It is crucial to measure and reduce hospital ecological footprints to promote sustainable healthcare practices, as this need has become increasingly evident in recent years.

The ecological footprint assessment index measures the amount of energy and materials used to assess the environmental impact caused by population growth and industrial activities (Rees, 1992, Wackernagel and Rees, 1996).

Hospitals are intricate facilities that use a lot of resources, electricity, and water, and they also produce a lot of waste and pollutants. A hospital's environmental impact can be measured in several ways, including energy use, water use, trash generation, and greenhouse gas emissions. Hospitals utilize a lot of energy, as seen by the need for heating and electricity for lighting, medical equipment, and temperature control. According to studies (Herczeg et al., 2018; Eckelman and Sherman, 2016), the healthcare industry is one of the most energy-intensive and contributes considerably to carbon dioxide emissions. Furthermore, hospitals consume a lot of water since it's necessary for patient care, sanitization, and facility upkeep (Carpenter et al., 2020; Chiarelli et al., 2018).

Another crucial component of hospitals' ecological footprint is waste management. If medical waste is not appropriately managed, there are serious concerns to the environment and human health since it contains both hazardous and non-hazardous components. The incorrect handling of medical waste can result in air, soil, and water pollution, which can have an adverse effect on ecosystems and public health (Prüss-Ustün et al., 2019; Windfeld and Brooks, 2015). The problem of waste management is made worse by the growing usage of single-use medical supplies and the production of electronic waste from medical equipment (Lee et al., 2017; Voudrias, 2018). Due to incorrect medication disposal, hospitals also contribute to pharmaceutical pollution (Aus der Beek et al., 2016; Kümmerer et al., 2018). This results in the presence of pharmaceutical residues in the environment.

Several strategies have been put forth and put into practice in recent years to lessen the environmental impact of hospitals. According to studies (Caniato et al., 2016; Eckelman and Sherman, 2018), energy efficiency measures may dramatically lower energy consumption and greenhouse gas emissions. Examples of these strategies include the adoption of renewable energy sources and high-tech energy systems. A significant reduction in water use may be achieved with water conservation measures such as installing water-efficient fixtures and recycling wastewater (McGain and Naylor, 2014; Rutberg et al., 2015). To reduce the negative environmental effects of hospitals, it is important to implement sustainable waste management techniques, including the separation of medical waste, the recycling of non-hazardous materials, and the safe disposal of hazardous waste (Ellenbecker et al., 2015; McGain et al., 2018).

Healthcare executives, politicians, and academics are increasingly recognizing the importance of comprehensively assessing and monitoring hospitals' ecological footprints. Sustainable practices and policies may be developed with the help of the ecological footprint assessment integrated into healthcare facilities' operations and planning. Hospitals may systematically assess and mitigate their ecological impacts by using sustainability reporting frameworks like the Global Reporting Initiative (GRI) and environmental management systems (EMS) (Anonymous, 2016; Anonymous, 2017.). Additionally, life cycle assessment (LCA) is a useful method for assessing how hospital operations affect the environment and pinpointing areas that might want improvement (Harris et al., 2017; Shinn et al., 2019).

The food footprint which has already exceeded all limits due to population growth, is a significant factor in the footprint calculation used in hospitals. This brought attention to the waste of personal protective material and other items, as the healthcare sector has a significant environmental impact. The health sector is largely to blame for the world's emission of greenhouse gases and air pollution; hence, the present study was conducted to estimate the hospital's ecological footprint.

2. MATERIALS AND METHODS

2.1. *Study area*

The experiment was carried out from December, 2020 to June, 2021 in district of Kangra, Himachal Pradesh, India. The Kangra district of Himachal Pradesh is located in the Western Himalayan region, between 31° 21' and 32° 59' N latitude and 75°47' 55'' to 77°45' E longitude. It spans 5,739 km^2 and has an altitude of 427 to 6,401 m. The area has subtropical to sub-humid climates. One of the reasons for selecting the Kangra district for the study was its large number of hospitals and due to sub-humid climate, the occurrence of disease was more frequent. During the course of investigation conducted in Kangra district 5 blocks were selected namely Kangra, Dharamshala, Palampur, Jawalamukhi and Nurpur. Further, one government and two private hospitals were selected from each block. The data obtained was statistically analyzed by Student's t- test with three replications.

2.2. Data collection

In the five blocks of Kangra district three hospitals from each block were chosen including both government and private were selected randomly (Table 1).

Table 1: Different hospitals selected from five blocks

Sl. No.	Name of block	Selected hospitals
1.	Kangra	Dr. Rajendra Prasad Govt. Medical College and Hospital, Fortis Hospital and Shree Balaji Hospital
2.	Dharamshala	Zonal Hospital, Delek Hospital and Sai Mahima Shukla Hospital
3.	Palampur	Civil Hospital, Vivekanand Medical Institute Hospital and Karan Hospital
4.	Jawalamukhi	Civil Hospital, Dhiman Hospital and Navjeevan Hospital
5.	Nurpur	Civil Hospital, Saxena Hospital and Sukhmani Hospital

To track the consumption of resources in various sectors, including electricity, water, material, solid waste, and food, a survey was conducted to collect data from the concerned doctors and other workers in these hospitals. The hospital land area was evaluated by measuring the ecological footprint of doctors, employees, and patients.

2.3. Data analysis

The data recorded was statistically subjected to Student's t-test with 5 blocks and 3 replications using Microsoft Excel and SPSS. The analyzed data was compared the Global Footprint Network's International Standards in Oakland were compared to the water, electricity, material, solid waste, and food footprints of a sample size of hospitals that were representative of the healthcare sector (Habibi et al., 2015) given in table 2.

2.4. Calculation of ecological footprint

Ecological footprint is calculated by using following formulae (Table 3) Habibi et al. (2015)

2.4.1. Estimation of biocapacity

The capacity of a biologically active land area to produce an ongoing supply of renewable resources and ecosystem services, as well as absorb spillover wastes, is referred to as biocapacity.

Biocapacity=Bioproductive Area (in hectares)×Productivity Factor (in global hectares hectare^{-1})

Table 2: International Standards for different components of Ecological footprint (Habibi et al., 2015)

Sl. No.	Components	International Standards (g ha)
1.	Electricity	0.004
2.	Water	0.003
3.	Material	1.50
4.	Solid waste	0.07
5.	Food stuff	7.34

Table 3: Component wise ecological footprint assessment methods

Sl. No.	Components	Formula used
1.	Electricity footprint	Energy land (g ha kWh^{-1} year^{-1})×kWh (year)
2.	Water footprint	Total consumption (g ha m^{-3} yr^{-1})×land area (ha)×1000000
3.	Solid waste footprint	Total Annual Solid Waste generated in the hospital×8 m2 landfill area required÷450 kg÷10000 m^2
4.	Food footprint	Items per year (kg)×Ecological Footprint item^{-1} (g ha kg^{-1})
5.	Material footprint	Items per year (kg)×ecological footprint item^{-1} (g ha kg^{-1})

2.4.2. Ecological deficit (EF_D)

It is measured by the difference of ecological footprint and biocapacity. If footprint surpasses biocapacity, the framework is considered unsustainable and if biocapacity surpasses footprint, it is considered sustainable.

EF_D=EF-BC

Where:

EF_D=Ecological deficit

EF=Ecological impact according to consumption types

BC=Bio-capacity

2.4.3. Relationship of lifestyle of hospital residents and sustainability

To evaluate the hospital's sustainability scale according to ecological footprint, specific data regarding resource utilization was collected through a questionnaire-based survey. The sustainability of the hospitals was determined in Table 4 with the use of the sustainability scale card that the EPA information center provided, as explained below.

3. RESULTS AND DISCUSSION

The ecological footprint analysis's findings provide important differences in resource usage across

Table 4: Sustainability scale according to EPA

Sustainability scale	Explanation
<60	It takes very little land and resources to sustain your way of life.
60–120	Hospital resources are more significantly impacted by your footprint. To sustain us, we would require a whole additional hospital if everyone lived like you.
120–180	Much of the hospital's resources are used by your footprint. We would require three hospitals to keep us alive if everyone lived like you do.
>180	In order to sustain us, four hospitals would be required if everyone lived as you do.

the hospitals in the Kangra district, illuminating their sustainability initiatives and effects on the environment.

3.1. The ecological impact of specific components

Here, the ecological footprint of various hospitals in the Kangra district is examined, revealing disparities in resource consumption and highlighting opportunities for sustainable practices.

3.1.1. Electricity resource

The highest electricity footprint (7.91 g ha) was observed in Sukhmani Hospital in Nurpur block as it was using a lot of energy to run different equipment like high-power lighting in operating rooms, air exchange, filtration, etc. It was followed by civil hospital Nurpur (5.14 g ha) and Shree Balaji Hospital Kangra (4.71 g ha) as they have less energy-consuming equipment compared to the Sukhmani hospital (Table 5). Similar results for energy consumption were obtained by Christiansen et al. (2015) in the University Medical Center of Hamburg, Germany, Morgenstem et al. (2016) in eight medium to large General Acute hospitals in England and Saidur et al. (2010) in Malaysian public hospital.

3.1.2. Water resources

The highest water footprint (0.75 g ha) was observed in Vivekanand Hospital in Palampur block because of central air conditioning and excessive use of water for sanitary purposes, pumping fixtures, landscaping, and medical process rinses. It was followed by Dr. Rajendra Prasad Govt. Medical College and Hospital (0.70 g ha) and Fortis Hospital (0.57 g ha) as they have fewer water-consuming facilities compared to the Vivekanand Hospital (Table 5). Similar results for water consumption were obtained by Collett et al. (2016) in hospitals of Eastern India.

3.1.3. Material resources

The highest material footprint (263.9 g ha) was observed in

Table 5: Ecological footprint (g ha) of hospitals in Kangra district

Name of Hospital	Electricity		Water		Material (paper)		Solid waste		Food stuff	
	EF	Per capita EF	EF	Per capita EF	EF	Per capita EF	EF	Per capita EF	EF	Per capita EF
Dr. Rajendra Prasad Government Medical College, Tanda	0.63	6×10^{-6}	0.70	7×10^{-4}	263.9	27×10^{-3}	54.4	5×10^{-4}	112.8	11×10-3
Fortis	0.56	1×10^{-5}	0.57	1×10^{-5}	117.0	23×10^{-3}	41.6	8×10^{-4}	74.7	14×10^{-3}
Shree Balaji	4.71	12×10^{-4}	0.08	2×10^{-4}	72.0	18×10^{-3}	0.28	1×10^{-4}	70.0	18×10^{-3}
Zonal	3.10	27×10^{-4}	0.46	4.11	67.0	5×10^{-3}	4.43	3×10^{-4}	48.7	4×10^{-3}
Delek	2.94	1×10^{-4}	0.33	1.19	54.3	1×10^{-3}	3.79	13×10^{-4}	107.6	3×10^{-3}
Sai Mahima Shukla	1.89	15×10^{-4}	0.20	1.70	98.6	8×10^{-3}	1.96	16×10^{-4}	140.3	1×10^{-2}
Civil	1.60	6×10^{-4}	0.39	12×10^{-5}	55.0	17×10^{-3}	0.18	57×10^{-6}	216.1	6×10^{-3}
Vivekanand	4.02	1×10^{-4}	0.75	19×10^{-5}	60.8	15×10^{-3}	0.22	55×10^{-6}	206.2	5×10^{-3}
Karan	1.45	2×10^{-4}	0.38	7×10^{-5}	48.3	9×10^{-3}	0.16	3×10^{-5}	126.7	2×10^{-2}
Civil	1.33	5×10^{-4}	0.17	7×10^{-5}	57.1	2×10^{-2}	0.11	46×10^{-5}	76.0	32×10^{-2}
Dhiman	1.95	5×10^{-4}	0.14	4×10^{-5}	46.4	13×10^{-2}	0.10	28×10^{-5}	55.6	16×10^{-2}
Navjeevan	1.26	11×10^{-3}	0.16	14×10^{-4}	34.4	3×10^{-2}	0.09	8×10^{-5}	73.8	67×10^{-2}
Civil	5.14	6×10^{-4}	0.19	2×10^{-5}	90.1	12×10^{-2}	0.14	19×10^{-5}	96.5	13×10^{-2}
Saxena	3.71	17×10^{-3}	0.25	1×10^{-5}	98.3	4×10^{-2}	0.26	11×10^{-4}	129.8	5×10^{-2}
Sukhmani	7.91	6×10^{-3}	0.29	2×10^{-4}	129.4	1×10^{-1}	0.47	4×10^{-4}	135.7	1×10^{-1}

Dr. Rajendra Prasad Govt. Medical College and Hospital of Kangra block due to a large population, a large number of patients barging in daily, and a large amount of paper was used. This could be attributed to the non-adoption of paperless office work, which results in the consumption of paper, the production of which requires a large amount of forestland. Furthermore, the hospital's non-recycling of paper contributed to wasteful consumption (Table 5). It was followed by Sukhmani hospital (129.4 g ha) and Fortis hospital (117.0 g ha). Similar results for material consumption were obtained by Almaden et al. (2014) at Xavier University of Ateneo de Cagayan in Alexandria, Egypt (Kandil et al. (2019)).

3.1.4. Solid waste resources

The highest solid waste footprint (54.4 g ha) was observed in Dr. Rajendra Prasad Govt. Medical College and Hospital of Kangra block because of improper disposal of waste items in designated receptacles and a lack of awareness among healthcare staff (Table 5). It was followed by Fortis hospital (41.6 g ha) and Zonal hospital Dharamshala (4.4 g ha). Similar results for solid waste were obtained by Ngwuluka et al. (2009) who investigated the solid waste footprint in Nigeria, revealing significant environmental impacts due to inadequate waste management practices. and Salequzzaman et al. (2006 examined the solid waste footprint in Khulna, Bangladesh, highlighting the challenges of urban waste management and the need for sustainable solutions.

3.1.5. Food footprint resources

The highest food footprint (216.1 g ha) was observed in the Civil Hospital of the Palampur block due to food wastage, higher consumption of food, and packing waste in the hospital's canteen by hospital visitors, and this may have resulted in an increased food footprint (Table 5). It was followed by Vivekanand hospital (206.2 g ha) and Sai Mahima Shukla hospital (140.3 g ha). Singh (2019) in Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan.

The data in (Figure 1) revealed that Dr. Rajendra Prasad Government Medical College, Tanda (Kangra) had the highest ecological footprint (432.5 g ha) of any of the components. Because Tanda operates as both a college and a hospital, a large population gathered there due to patients visiting and students residing there. As a result, the annual consumption was higher than in other Kangra district government hospitals. The findings revealed that the Dr. Rajendra Prasad Government Medical College, Tanda (Kangra) had exceeded its environmental carrying capacity (overshoot). The findings are consistent with those of Budihardjo et al. (2013).

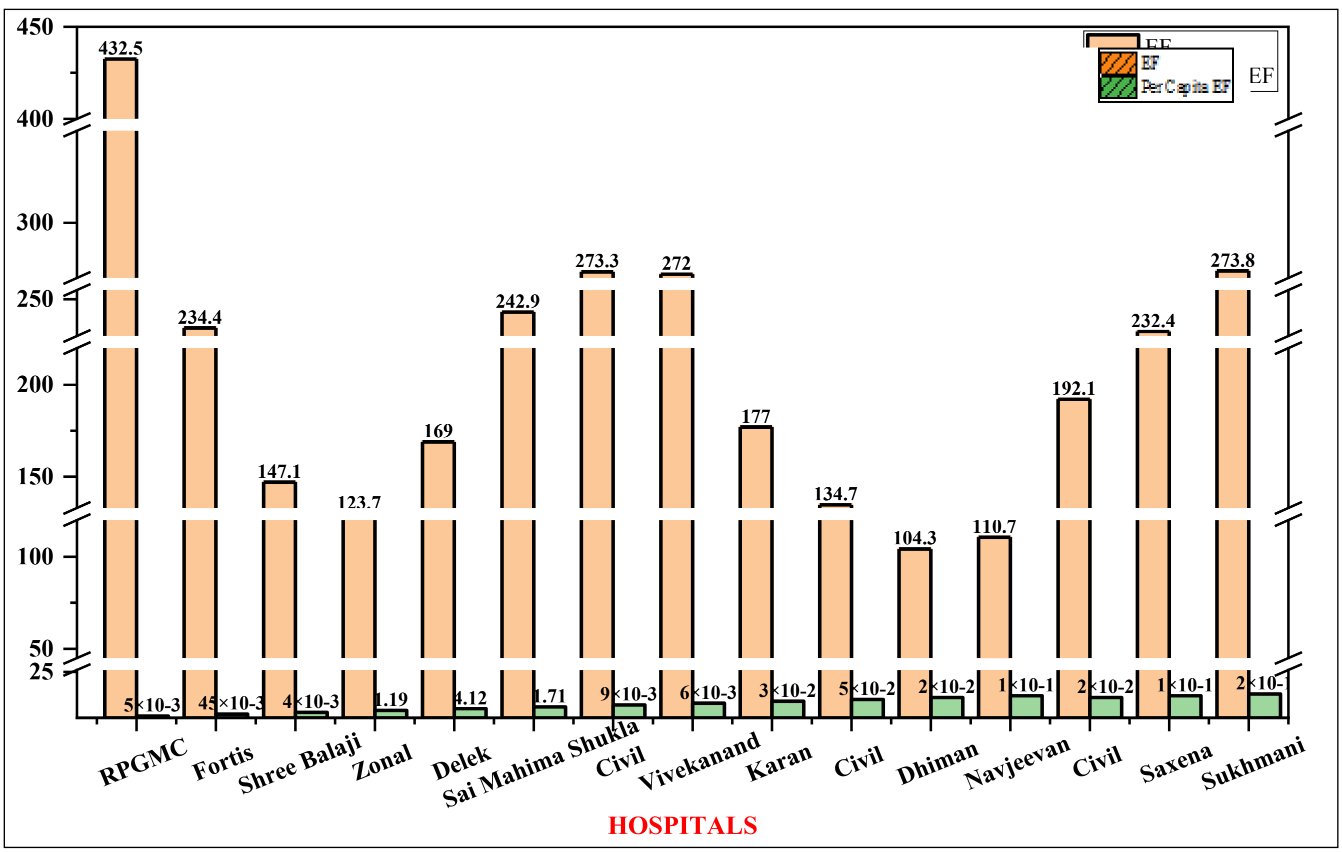

Figure 2: Ecological Footprint and per capita EF of hospitals

Dhiman Hospital, on the other hand, ranked the most sustainable because it had the smallest ecological footprint (104.3 g ha) for all components, including electricity, water, material (paper), solid waste, and foodstuff (Figure 1). This entailed implementing more energy-efficient infrastructure and healthcare facility management practices in the Dhiman Hospital, as well as raising awareness about water conservation and food waste. This means that hospital staff were more aware of the negative effects of overshoot (Ruzevicius and Juozas, 2010).

As we can see from Table 5 the food components that contributed the highest ecological footprint among all components were Civil Hospital, Palampur (216.1 g ha)>Vivekanand Hospital (206.2 g ha)>Sai Mahima Shukla Hospital (140. 3 g ha)>Saxena hospital (129.8 g ha)>Karan hospital (126.7 g ha)>Dr. Rajendra Prasad Govt. Medical College and Hospital (112.8 g ha)>Delek hospital (107.6 g ha)>Civil hospital, Nurpur (96.5 g ha)>Civil hospital, Jawalamukhi (76.0 g ha)>Fortis hospital (74.7 g ha)>Navjeevan hospital (73.8 g ha)>Shree Balaji hospital (70.0 g ha)>Dhiman hospital (55.6 g ha)>Zonal hospital (48.7 g ha).

In figure 1 highest per capita EF was observed in Sukhmani hospital (2×10^{-1} g ha) and lowest was observed in Dr. Rajendra Prasad Government Medical College, Tanda (5×10^{-3} g ha).

3.2. Biocapacity

The biocapacity of the selected hospital in the Kangra district ranged from 0.2 to 20.2 g ha, while the ecological footprint ranged from 104.3 to 432.5 g ha (Table 6). Block-wise biocapacity was in the order of Navjeevan hospital (0.25 g ha)<Dhiman hospital (0.56 g ha)<Fortis hospital (0.6 g ha)<Shree Balaji hospital (0.7 g ha)=Civil hospital, Jawalamukhi (0.7 g ha)<Zonal hospital (1.1 g ha)<Sai Mahima Shukla hospital (1.1 g ha)<Delek hospital (1.8 g ha)<Karan hospital (2.5 g ha)<Saxena hospital (3.1 g ha)<Civil hospital, Palampur (3.7 g ha)<Sukhmani hospital (4.1 g ha)<Civil hospital, Nurpur (7.3 g ha)<Dr. Rajendra Prasad Government Medical College and hospital, Tanda (19.0 g ha)<Vivekanand hospital (20.2 g ha). The average population of government hospitals was (29962.4), biocapacity (6.3 g ha), ecological footprints (231.3 g ha), and ecological deficit (83.5 g ha). Similarly, the average population of private hospitals was (18097.7), biocapacity (3.5 g ha), ecological footprints (196.4 g ha), and ecological deficit was (172.8 g ha). All of the hospitals situated in different blocks have insufficient land space to support their current populations and require more and more land area to support the current population's lifestyle and future trends. The findings are consistent with those of Moore et al. (2013), who observed that the nation's total footprint exceeded biocapacity.

Table 6: Status of biocapacity and ecological footprint of hospitals

Blocks	Hospital	Population	Biocapacity	EF	Ecological deficit (g ha)
Kangra	Dr. Rajendra Prasad Government Medical College and Hospital, Tanda	97697	19.0	432.5	22.7
	Fortis	50002	0.6	234.4	360.7
	Balaji	38646	0.7	147.1	201.6
Dharamshala	Zonal	11189	1.1	123.7	111.5
	Delek	27640	1.8	169.0	93.9
	Sai Mahima	12196	1.1	242.9	216.9
Palampur	Civil	31214	3.7	273.3	72.8
	Vivekanand	39456	20.2	272.0	13.4
	Karan	5150	2.5	177.0	70.5
Jawalamukhi	Civil	2356	0.7	134.7	184.5
	Dhiman	3465	0.5	104.3	186.2
	Navjeevan	1098	0.2	110.7	443.1
Nurpur	Civil	7356	7.3	192.1	26.3
	Saxena	2169	3.1	232.4	74.9
	Sukhmani	1155	4.1	273.8	66.7
Kangra district	Government	29962.4	6.3	231.3	83.5
	Private	18097.7	3.5	196.4	172.8

3.3. Ecological footprint of hospitals situated in different blocks

The block-wise average electricity footprint was in the order of Nurpur (5.58 g ha) >Dharamshala (2.64 g ha)>Palampur (2.35 g ha)>Kangra (1.96 g ha)>Jawalamukhi (1.51 g ha). Then, the average water footprint was in the order of Palampur (0.50 g ha)>Kangra (0.45 g ha)>Dharamshala (0.33 g ha)>Nurpur (0.24 g ha)>Jawalamukhi (0.15 g ha). Then, the material footprint was in the order of Kangra (151.02 g ha)>Nurpur (105.97 g ha)>Dharamshala (73.33 g ha)>Palampur (54.74 g ha)>Jawalamukhi (46.01 g ha). Then, the solid waste footprint was in the order of Kangra (32.09 g ha)>Dharamshala (3.39 g ha)>Nurpur (0.29 g ha)>Palampur (0.18 g ha)>Jawalamukhi (0.10 g ha). And lastly, foodstuff footprint was in the order of Palampur (183.04 g ha)>Nurpur (120.72 g ha)>Dharamshala (98.90 g ha)>Kangra (85.88 g ha)>Jawalamukhi (68.48 g ha) (Table 7).

3.4. Distribution of sustainability scale for different hospitals:

On average 20% of hospitals fall under the 60–120 sustainability scale, followed by 35% in the 120–180 range and 46% in the more than 180% range (Table 8) demonstrating that (20%) of hospitals are using resources inefficiently and have a detrimental impact on the long-term viability of hospitals. 35% of the hospitals fall in the 120–180 range, which the EPA considers unsustainable. The highest percentages of hospitals (46%) are on a scale of more than 180, meaning that a significant portion of hospital resources are being used by their consumption pattern. Not a single hospital falls into the category of less than 60 sustainability scale, which has been determined to not affect resources.

Table 7: Ecological footprint of hospitals situated in different blocks

Block	Electricity	Water	Material	Solid waste	Food stuff	Total
Kangra	1.96	0.45	151.02	32.09	85.88	271.4
Dharam-shala	2.64	0.33	73.33	3.39	98.90	178.59
Palampur	2.35	0.50	54.74	0.18	183.04	240.81
Jawala-mukhi	1.51	0.15	46.01	0.10	68.48	116.25
Nurpur	5.58	0.24	105.97	0.29	120.72	232.8
Kangra district	14.04	1.67	431.07	36.05	557.02	1039.85

Table 8: Percentage of hospital falling under different sustainability scale

Hospitals	Population	<60 (%)	60–120(%)	120–180 (%)	>180 (%)
Dr. Rajendra Prasad Government Medical College, Tanda	97697	-	10	25	65
Fortis	50002	-	15	33	52
Shree Balaji	38646	-	20	35	45
Zonal	11189	-	10	40	50
Delek	27640	-	35	25	40
Sai Mahima Shukla	12196	-	15	30	55
Civil, Palampur	31214	-	10	35	55
Vivekanand	41201	-	60	25	15
Karan	5150	-	15	40	45
Civil, Jawalamukhi	2356	-	20	45	35
Dhiman	3465	-	10	40	50
Navjeevan	1098	-	15	30	55
Civil, Nurpur	7356	-	20	45	35
Saxena	2169	-	10	35	55
Sukhmani	1155	-	40	50	-
Average	22168.9	-	20	35	46

4. CONCLUSION

Evaluating the environmental footprints of hospitals in Kangra, Himachal Pradesh, underscored the need for sustainable healthcare practices. Resource consumption variations highlighted the importance of targeted measures for effective environmental impact mitigation. By implement ing customized strategies, hospitals supported sustainability and provided high-quality healthcare.

6. ACKNOWLEDGEMENT

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