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Ecological footprint of Solan district, Himachal Pradesh, India

Jyotsana Pandit[1,]*, S. K. Bhardwaj[1] and Anish Kumar Sharma[2]

[1]Department of Environmental Science, University of Horticulture and Forestry, Nauni, Solan 173 230, India
[2]School of Sciences, PP Savani University, Surat 394 125, India

Unsustainable resource use on earth must be addressed from a variety of perspectives and at multiple levels of governance. Understanding the environmental consequences of urban-dwellers will become increasingly important as the human population urbanizes. Having access to reliable, cross-cutting, quantitative city-level sustainability measures is crucial. By taking into account local facts, scientific analyses can assist in providing solutions. Emergence analysis, material flow analysis, data development analysis and ecological footprint analysis (EFA) are only some of the assessment methodologies that have been offered. EFA has been used to assess urban sustainability in a number of cities as a useful analytical and planning tool. The purpose of this study is to assess the sustainability of Solan district, Himachal Pradesh, India, using four EFA components: crop land, grazing land, forest land and infrastructure land footprints. According to the study, the total ecological footprint of Solan district is 6865.30 gha, and its components are in the following order: crop land footprint (3287.40 gha) > infrastructure land footprint (2088.21 gha) > grazing land footprint (978.03 gha) > forest land footprint (511.67 gha).

Keywords: Crop land, ecological footprint analysis, forest land, grazing land, infrastructure land, sustainability.

REES[1] introduced the ecological footprint (EF), which has been widely used as a comprehensive assessment of anthropogenic impact on the environment[2,3]. The examination of EF for smaller systems, such as provinces or cities, or even a single household or business structure, allows for the assessment of system sustainability and future development strategies[4]. Sustainable development management is ultimately concerned with earth's ability to support human societies[5]. Living within the means of the sole planet available to humanity is the first step toward building a future society in which everyone may thrive[6]. However, 'one planet' is a backdrop that forms our reality[7], not a goal. Sustainability is described as the process of achieving demonstrable long-term societal development through environmental, economic and social actions. Sustainability is a multidisciplinary issue, with no single statistic capable of addressing its entire complexity[8]. To address this, decision-makers must sift through a plethora of data, information and indicators[9]. In order to attain sustainability, the use of sustainability indicators is becoming increasingly important[10]. Sustainability indicators provide a solid foundation for regular and long-term monitoring of progress toward strategic development goals, as well as assessment of various types of sustainability[11]. Economic, social and environmental indicators are the three types of sustainability indicators. EF is sustainability indicator with an environmental focus. The aim of the present study is to determine the EF of Solan district, Himachal Pradesh (HP), India. EF is a measure of the environmental implications of modernization that outstrip those of the surrounding areas. Ecological footprint analysis (EFA) is defined as a synthetic method for tracking human impacts on an environmental system's regenerative capacity by identifying the amount of bioproductive land required to support average annual consumption and waste production of a given entity under current technologies[12]. Cropland, carbon land, grazing land, fishing grounds, forest land and infrastructure land are the six components of EF accounting. The sum of these elements yields an estimate of EF[4]. Cropland, grazing land, forest

*For correspondence. (e-mail: jyotsanapandit@gmail.com)

land and infrastructure land are the four components employed in this study to examine the footprints of five different Community Development (CD) blocks in Solan district (Kunihar, Nalagarh, Dharampur, Solan and Kandaghat) illustrated in Figure 1. Solan was chosen for the study because it is one of HP's fastest-growing districts, with a mix of commercial, industrial and transportation activities. It is a migrant-populated, state-owned industrial centre. In addition, the district is home to a slew of small and medium-sized businesses. Solan district has recently witnessed the highest amount of urbanization (18.26%) in HP, following Shimla, due to rural population migrating to cities in pursuit of jobs and better services such as education. The present study was conducted during 2019 in the CD blocks of Solan district that lie between 30°44′53″–31°22′01″N lat. and 76°36′10″–77°15′14″E long. (Figure 1). The district is a gateway of HP bordering the southern and western states of Haryana and the Punjab respectively. HP has a total geographical area of 1936 km^2, with a population of 580,320 (ref. 13), which is projected to increase to 665,671 by 2021.

Data on the population of various land types such as crop land, grazing land, forest land and infrastructure land from different CD blocks were obtained from official certified records maintained by the Census of India, while data on yield and equivalence factors were derived from national footprint accounts in order to assess the EF of Solan district. Crop production, grazing, forestry and infrastructure all place mutually exclusive demands on the biosphere, and the total EF is the sum of these demands. Following the technique provided by the Global Footprint Network, each of these categories represents an area (ha), which is then multiplied by its equivalence factor to obtain EF (gha). Crop land footprint represents the amount of land required to grow all the crops that humans and livestock consume as is calculated by follows: Crop land footprint (gha) = Crop land area (ha) * equivalence factor (gha/ha). Grazing land footprint assesses the demand for grazing land to feed livestock and the embodied demand for grazing land in traded goods. It is computed as follows: Grazing land footprint (gha) = Grazing land area (ha) * equivalence factor (gha/ha). Forest products footprint denotes the amount of forest land required to meet the demand of wood for fuel, construction and paper and is calculated by the following formula: Forest products footprint (gha) = Forest land area (ha) * equivalence factor (gha/ha). Infrastructure land footprint denotes bioproductive land that has been physically occupied by human activities and is computed as follows. Infrastructure land footprint (gha) = Infrastructure land area (ha) * equivalence factor (gha/ha). Equivalence factors reflect the relative productivity of world average areas (ha) of different land-use types. They are consistent across all countries and vary slightly each year. Crop land, pasture land, forest land and infrastructure land each has an equivalence factor of 2.51, 0.46, 1.28 and 2.51 gha ha^{-1} respectively in 2019. Most of the infrastructure is expected to be built on valuable agricultural land. As a result, infrastructure area and cropland have the same equivalence factor.

Figure 1. Map showing the study area of Solan district, Himachal Pradesh, India.

Table 1 shows that crop land footprint was the highest in Kunihar (1007.00 gha) and lowest in Solan (136.91 gha). According to the verified statistics of the Census of India, this can be attributed to the highest cropland area in Kunihar and the lowest in Solan. In terms of various CD blocks, the grazing field footprint follows the pattern: Nalagarh (344.99 gha) > Kandaghat (268.46 gha) > Dharampur (212.56 gha) > Kunihar (94.79 gha) > Solan (57.23 gha). Maximum forest land footprint of Kunihar may be attributed to its highest forest land area. No forest land footprint was observed for Solan and Kandaghat due to the absence of forest area in both the CD blocks, according to the information obtained from official certified records maintained by Census of India. Infrastructure land footprint of different blocks followed the trend: Nalagarh (1210.19 gha) > Kandaghat (306.07 gha) > Dharampur (263.59 gha) > Kunihar (195.00 gha) > Solan (113.37 gha). Table 1 also shows that the maximum percentage contribution to total EF was made by crop land footprint in Kunihar (65.66), Dharampur (37.55), Solan (44.52), Kandaghat (57.55) and by infrastructure land in case of Nalagarh (45.21). Component-wise ecological footprint of different CD blocks in Solan district (Figure 2) follows the pattern: crop land footprint > infrastructure footprint > grazing land footprint > forest land footprint.

The per capita EF of different locations ranged from 0.004 to 0.033 gha $capita^{-1}$ and followed the order: Kandaghat (0.033 gha $capita^{-1}$) > Kunihar (0.017 gha $capita^{-1}$) > Nalagarh (0.015 gha $capita^{-1}$) > Dharampur (0.010 gha $capita^{-1}$) > Solan (0.004 gha $capita^{-1}$). The per capita EF did not exhibit any particular trend, because different cities have distinct geographical areas and do not accommodate people equal to their area. The present study reveals that the Nalagarh CD block in Solan district has a large total

Table 1. Ecological footprint (EF) of Kunihar, Nalagarh and Dharampur community development blocks of Solan district, Himachal Pradesh, India

CD block	Kunihar		Nalagarh		Dharampur		Solan		Kandaghat	
Land type	EF (gha)	Percentage of total EF	EF (gha)	Percentage of total EF	EF (gha)	Percentage of total EF	EF (gha)	Percentage of total EF	EF (gha)	Percentage of total EF
Crop land footprint	1007.00	65.66	991.39	37.03	373.11	37.55	136.91	44.52	778.98	57.55
Grazing land footprint	94.79	6.18	344.99	12.89	212.56	21.39	57.23	18.61	268.46	19.83
Forest land footprint	236.85	15.44	130.33	4.87	144.49	14.54	–	–	–	–
Infrastructure footprint	195.00	12.71	1210.19	45.21	263.59	26.52	113.37	36.87	306.07	22.61
Total EF	1533.64		2676.90		993.75		307.51		1353.51	

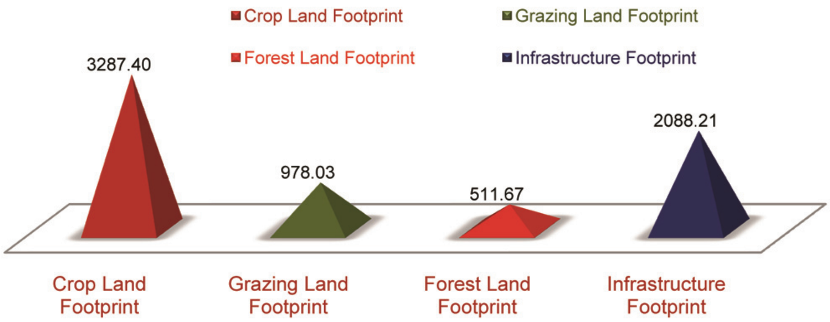

Figure 2. Component-wise ecological footprint of different CD blocks in Solan district.

EF, indicating increased anthropogenic pressure in the area. This can be ascribed to the large number of industries in this region. Similar studies must be conducted on a regular basis so that we can learn how the region is growing sustainably. As a result, the process of urban redevelopment and adoption of environment-friendly measures should be prioritized in order to promote sustainable growth in the district. Furthermore, a unified sustainability strategy must be designed for Solan district, that recognizes its particular qualities and connections to global processes, while encouraging periodic monitoring.

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