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Urban Sprawl and its Effect on Sustainable Urban Development: A Case Study of Shimla City

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***Abstract* - A fast-growing developing country like India is witnessing the phenomena of Urban Sprawl and land-use changes in almost all of its megacities which are the epicenters of economic growth, administration, and tourism prospects. The proximity to the growth center, availability of space, and increasing migration mainly lead to the gradual spreading of the urban landscape towards its adjacent regions, resulting in the loss of productive and agricultural lands, open green spaces, and surface water bodies. Considering the speed of urban sprawl growth rate, the city's scale and role have changed frequently. Thus, there is a need to study, surveil, and quantify the urban sprawl for sustainable development of the urban areas. The current study examines the importance of sustainable urban development, which seeks to create cities and towns to improve the long-term health of the planet's human beings and ecological systems. The main focus of this paper is to illustrate the analytical approach and challenges resulting from increasing population growth that has created a need for high-performing, cost-effective, resource-efficient, and environmentally friendly sustainable infrastructure. The task comprises steps delineation of urban area for consecutive years, comparison between urban areas, identification of the urban sprawl pattern, recognition of magnitude and direction of changing sprawl, and its effect on land use/land cover.**
***Keywords:* Urban Sprawl, LULC, Spatio-Temporal Changes, Sustainability, Resource-Efficient**

I. INTRODUCTION

The footprints of major metropolitan areas, suburbs, and small towns ultimately shape the environmental and social conditions within our communities. One development pattern that has received increasing attention from researchers and policymakers interested in fostering sustainable communities is sprawling. Sprawl is typically characterized by low population density and haphazard development that spirals away from urban centers, known as 'horizontal spreading' or 'dispersed urbanization' (Burchell *et al.,* 1998). It implies little control of the land sub-division, the conversion of plots for urban uses may create enclaves of agricultural land. Farmers in such areas may suffer negative externalities through the impact of neighbors on their land uses. The impact Urban Sprawl's has on communities is loss of farmland, vegetation degradation, health hazards, tree canopy decline, and an increase in brown fields. The haphazard growth in transitional areas between rural and urban areas, as well as densely populated dynamic urban center is a primary concern for city administrators and planners. If we continue to design and build as the planet can provide unlimited resources. In that case, nearly doubling the urban population will mean doubling the natural resources needed to develop and operate our cities, which is not sustainable. Sprawl results from a complex set of interrelated socio-economic and cultural forces. However, Land value is often considered the chief driver of expansion. Economists believe three factors contribute to how land values change in urban areas, i.e. population growth, infrastructure development, and market forces. Urban sprawl results from population growth, which leads to the outward expansion of urban areas. Second, as incomes rise, people can afford larger living spaces. They tend to locate themselves in suburban and ex-urban areas, generally on metropolitan areas' outskirts (Carruthers & Ulfarsson 2002).

The city's sustainability has become a significant challenge in the present context due to the rapid depletion of natural resources and the pressures of urbanization. A city can be defined as 'smart' when investments in human and social capital, traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic development and high quality of life, with a wise management of natural resources, through participatory governance." (Andrea Caragliu 2009). According to Bruckner (2000), urban sprawl can be attributed to three factors: increasing population, increasing incomes, and decreasing commuting costs. It is an urban regional development that features land-extensive, low density, leapfrogging development, separation of different land uses, low connectivity between land uses, extensive road construction and automobile dominance, economic and racial homogeneity, a shift of development and capital investment from the inner city to the periphery leads to the absence of regional planning (Anderson, 2002).

World Commission on Environment and development, in its report, Our Common Future, published in 1987, states, "Sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable development adheres to three interconnected areas: environment, social and economic. While sustainable urban advancement could be a profoundly created spatial frame of coordinates cities, urban sprawl mainly occurs in lower densities accompanied by an expansion of the urban periphery. It is acknowledged as the opposite force, with its character of scattered and leapfrogging development. Therefore, urban sprawl is the most impactful urban development pattern that occurred at an unprecedented rate that threatens sustainable development.

II. OBJECTIVES OF THE STUDY

1. To examine the urban sprawl and its impact on sustainable urban development.
2. To examine the factors leading to urban sprawl.
3. To explore the constantly changing nature of urban centers that calls for new and improved strategies to ensure sustainable and equitable development.

III. DATA BASE AND RESEARCH METHODOLOGY

The study is based upon the secondary data collected from the online sources earth explorer of the United States Geological Survey (USGS). The imageries were downloaded from Cloud Free Landsat satellite data of the multi-temporal image of four different periods, such as 1990, 2000, 2010, and 2020 were selected for analysis. Image processing and image interpretation for the development of land use/land cover maps are made in ArcGIS 10.4. Other relevant information had collected through various research articles; government reports published by multiple national and international institutions and government departments.

The obtained maps are studied and analyzed to detect the change in urban sprawl. The software had used for extracting the values, which were then used for correlating the values of the NDBI image and providing various levels of functionality for all interfaces. The data are preprocessed and projected to the Universal Transverse Mercator (UTM) projection system. The Kappa coefficient method had used to assess the mapping accuracy.

TABLE I META DATA OF DATASET

Data	Date of Acquisition	Spatial Resolution	Sources	Path and Row
Landsat TM	1990/06/06	30 m	Earth explorer	Path- 147, Row-038
Landsat ETM+	2000/10/15	28.5 m	Earth explorer	Path- 147, Row-038
Landsat TM	2010/10/03	30 m	Earth explorer	Path- 147, Row-038
Landsat 8 OLI	2020/10/14	30 m	Earth explorer	Path- 147, Row-038

Source: USGS Earth Explorer

The Arc-GIS software manipulated digital image processing. The landscapes were selected to be geometrically corrected, calibrated, and removed from their dropouts. The layer stack option in the image interpreter toolbox had used to convert the image into False Colour Composite (FCC) for the study area. The study area was clipped/extracted from the images by taking the geo-referenced boundary of the study area as AOI.

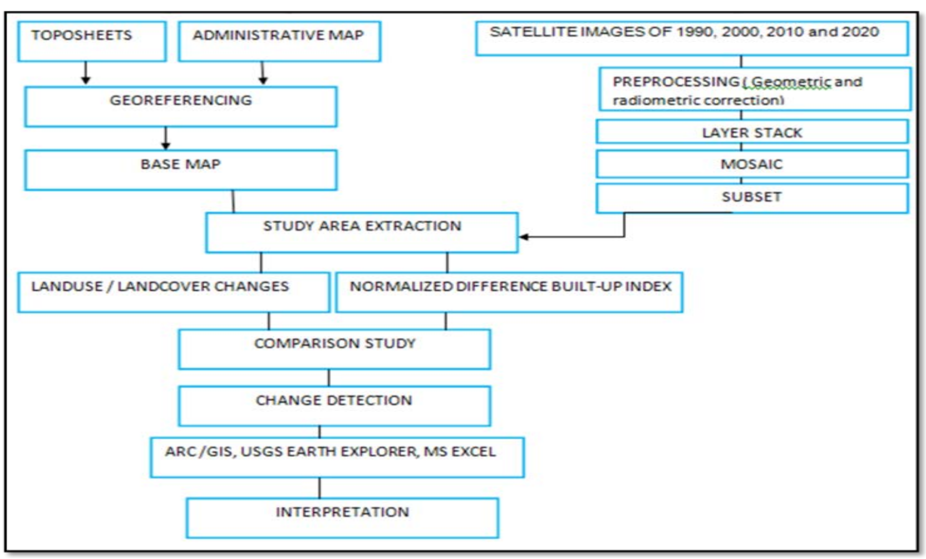

Fig. 1 Methodological flow chart

A. Study Area

Shimla is a capital city and one of the famous tourist destinations in North India. It has a massive influx of local, national, and international tourists. Shimla city is located between 31°3_ and 31°8_ N latitudes and between 77°7_ and 77°13_ E longitudes. It has an average altitude of 2195 m above mean sea level and extends along a ridge with seven spurs. The city is spread over an area of 30 km^2. The population of Shimla city is 1,69,578, of which 93,152 are males while 76,426 are females, as per a report released by Census India 2011. In Shimla Municipal Corporation, the Female Sex Ratio is 820 against the state average of 972. Moreover, the Child Sex Ratio in Shimla is around 890 compared to the Himachal Pradesh state average of 909. The literacy rate of Shimla city is 93.63 % higher than the state average of 82.80 %. In Shimla, Male literacy is around 94.79 %, while the female literacy rate is 92.19 %. Shimla Municipal Corporation has total administration of over 46,306 houses to which it supplies basic amenities like water and sewerage. The climate in Shimla is mostly cool during the winter months and moderately warm during the summer months. Shimla has an average temperature of 19°C - 28°C from March to June (in summer), and average temperatures in the winter season (November-February) range from 03°C-09°C. As a result of the northwest monsoon, the city receives an annual rainfall of 1577 mm between July-October.

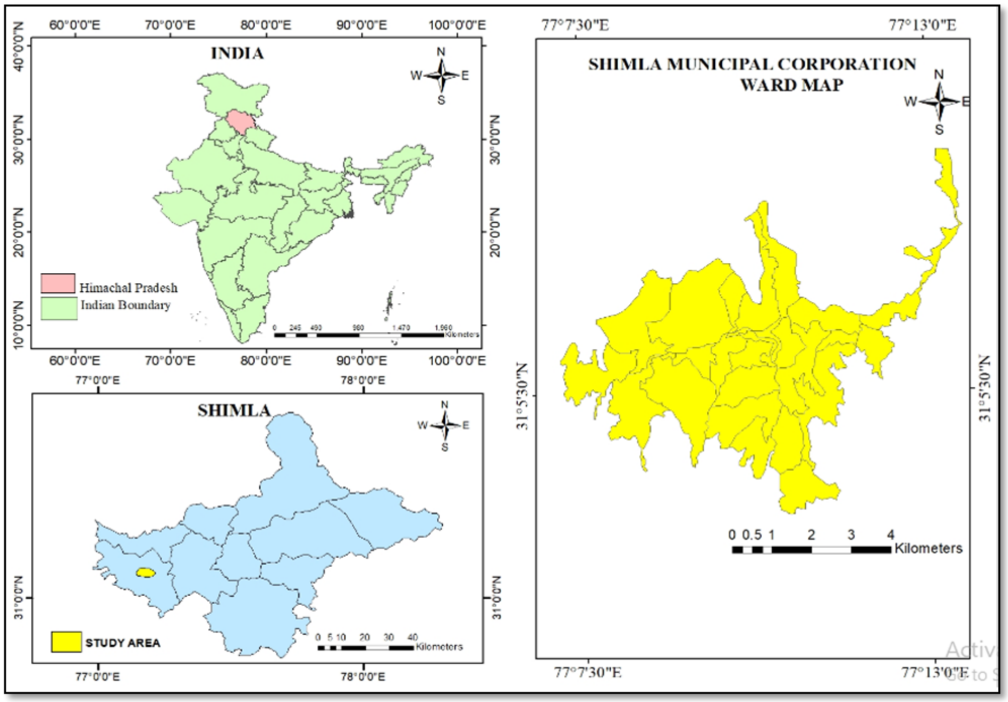

Fig. 2 Study Area

B. Land Use/Land Cover Changes from 1990 to 2020

The constantly changing nature of urban centers calls for new and improved strategies to ensure sustainable and equitable development. While the population growth and consequently more pressure on resources, there has been an increased focus on intelligent and innovative mechanisms that encourage the optimum utilization of resources. Earth observations from space platforms play a crucial role in generating and disseminating information on LULC patterns in a timely and reliable manner, providing vital inputs required for optimal land use planning.

The spatial analysis has been performed beyond the Shimla Municipal Council's administrative boundary. The classified images for land use/land cover in 1990 and 2020 are shown below. The extent of land use/land cover between 1990 and 2020 comprised a built-up area of 274 hectares and 892.9, respectively. Similarly, the non-built-up area comprising dense forest area, agriculture, and fallow land had 2610 hectares, 93.13 ha, and 117 ha in 1990 and 2011.09 ha, 186.53 ha, 4.39 ha, ha in 2020. The LULC change analysis had based on spatial scale and temporal variation differences in land use/land cover.

TABLE II LANDUSE AND LANDCOVER CATEGORIES AFTER NRSC

Categories	Description
Built-up	The urban and rural settlement, mining, residential, commercial, transportation, services, industries, roads, educational institutes, and recreational areas.
Agriculture	Cropland, Plantation, orchards
Dense Vegetation	Forest, evergreen and semi-evergreen forest, scattered trees, dense
Fallow Land	wasteland, landfills sites, scrubs, stony wastes, barren

Source: Modified based on Ninefold LULC classification of ICAR (1951)
http://mospi.nic.in/45:nine-fold-classification-land-use

During 1990-2020, it has been observed that the extent of built-up area has increased by 20%. It reveals positive trends in urban expansion, and most of the growth is close to the national highway. The analysis revealed that the urban development in Shimla city follows a regular radial pattern. A ribbon pattern of sprawl is observed along the roads and a leapfrog pattern towards the southern direction due to employment opportunities, cultural and educational facilities, and the geographical feasibility of the study area. The increase was observed in Agricultural areas, but dense forest decreased tremendously from 1990 to 2020 respectively. This picturesque hill town has been experiencing tremendous pressure for development for the last few decades, which has changed the developmental and visual character. Moreover, it is not feasible to construct new buildings in all areas or sites due to topography, slope morphology, and other geo-environmental factors. The land divisions or plots available for development are irregular in shape, reducing the land public for urbanization in the town and intensifying the pressure of development on suitable sites or areas. Forest area is decreasing due to the city's increasing population, which requires more land for new settlers. Three primary purposes, i.e., residential, industrial, and commercial, have crept mainly on open ground and other natural land use.

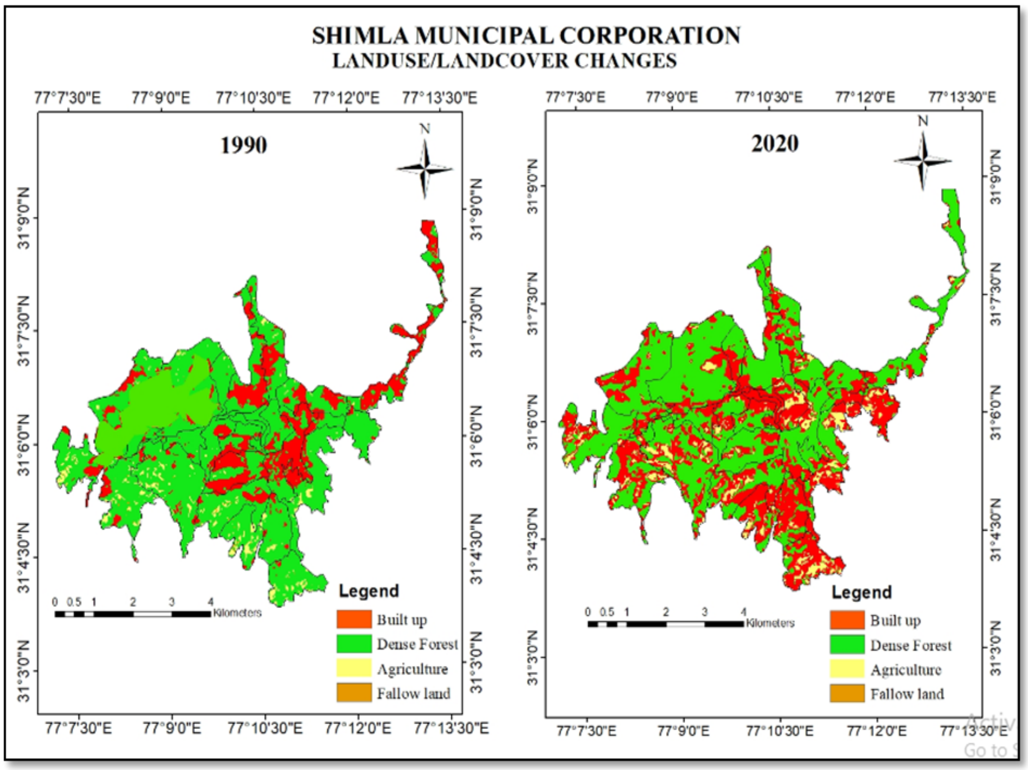

Fig. 3 Land use/Land cover map (1990 and 2020)

The analysis of 1990 imagery shows that high built-up is towards the Bharari, Ruldu Bhatta, Lower Bazar, Malyani Panthaghati, Totu, and Engine ghar. The type of settlement in the Shimla Municipal Corporation was sparsely distributed during 1990. The transformation of the earth's surface from non-urban land to urban land becomes irreversible, thereby generating severe problems, such as farmland loss, heat island effect, flood hazard, and habitat fragmentation. Up to 2020, urban areas' expansion started to increase, especially in Sanjauli Chowk, Lower Dhali, Shanti Vihar, Bhatakufar, Phagali, Krishna Nagar, Rambazar, Kaithu, some portion of Majath, and Summer Hill. This speedy increase in a built-up area is due to migrated population problem, the rapid growth of the local population, tourism development, the continuous establishment of national/multinational companies, and development of major and minor roads, etc. During the study period, it has been observed that the fringe area, forest area, and open space have changed to the built-up area from 1990-2020; a decrease in the dense forest area and fallow land is due to the increase in the built-up area.

Transportation influences the urban spatial structure and is marked by the evolution of the built-up areas and the changes in land use. Urban expansion processes in the Shimla Municipal Corporation during the period of 30 years (1990-2020) has further evaluated by analyzing a distance decay concept from major roads. For this purpose, National Highway No.-NH 22, National Highway No.-NH 88, Summer hill road, Bharari Road, Mall Road, Ridge, etc., have been analyzed. Urban expansion and a buffer zone of 20 meters have been created along these roads. The result of the present analysis indicated that the area and density under urban land were decreasing while going away from major highways. The border area growth has resulted in increased residential areas and other facilities such as transportation nodes. The continually growing population pressure has led to the development of the adjoining regions, and the city has extended outwards, filling in spaces between it and the suburbs. It has been found that urban sprawl is faster in the outer area of (ward number 20-23) and the inner area of (ward number 9-13) along the city's major roads. As against the recommended density of 450 persons per hectare in hill settlements, the town's localities have a density ranging from 2,500 to 3,500 persons per hectare for the same area.

C. Change Detection Analysis

Change detection for GIS is a process that measures how the attributes of a particular area have changed between two or more periods. The classified images of the two years have been used to calculate the area of different categories of land use land covers and observe the changes that are taking place in the span of data.

TABLE III LULC CHANGE DETECTION (1990-2020)

Categories	1990	2020	Change from 1990 to 2020	1990	2020	Change from 1990 to 2020
	Area (in Hectares)	Area (in Hectares)		Percentage	Percentage	
Built-Up	274	892.90	-618.9	8.85	28.85	-20
Dense Forest	2610	2011.09	598.91	84.35	64.98	19.37
Agriculture	93.13	186.53	-93.4	3.199	6.02	-2.821
Fallow Land	117	4.39	112.61	4.019	0.14	3.879

Source: Computed and Compose by authors using classified LULC map

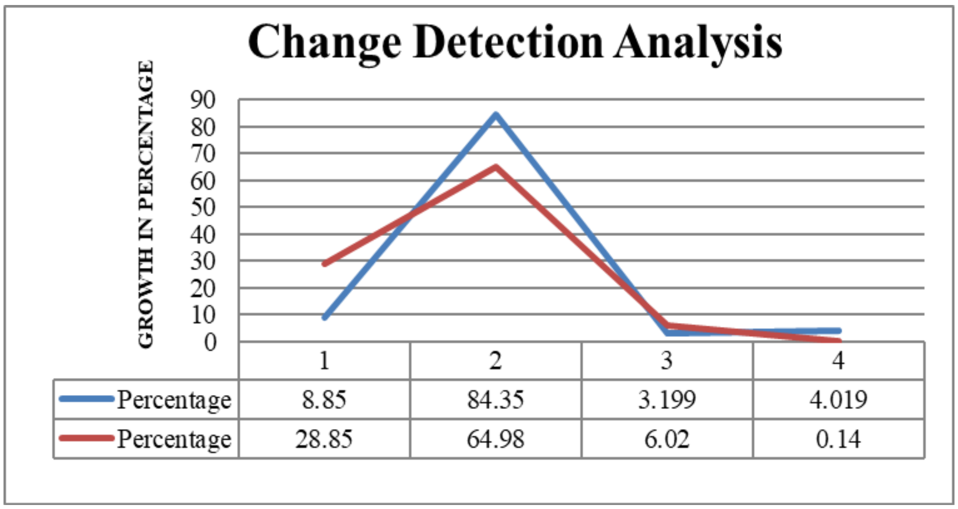

Fig. 4 Change Detection of LULC classes

Satellite Remote Sensing, with repetitive and synoptic viewing and multi-spectral capabilities, is a powerful tool to map and continuously monitor the emerging changes in the urban core and any peripheral areas of any urban entity. Change detection analysis has recorded a phenomenal rise in the built-up area, which has grown by 20 percent. Today, these consequential impacts of human activities by increasing population, rapid urbanization, high private motor vehicle dependency, deregulated industrialization, and mass livestock production is growing exponentially and causing many global, social, and economic challenges on a global and local scale. In such a situation, establishing sustainable cities through sustainable urban development practices is seen as a potential panacea to combat these challenges responsibly, effectively, and efficiently.

D. Classification Accuracy Assessment

Supervised classification assesses the accuracy between NDBI images and Landsat images. Classification is done by defining four classes by varying the training pixels. Initially, fewer training pixels have been defined for Landsat data and overall accuracy assessment, and kappa statistics are carried out. Similarly, the image is classified by increasing training pixels for various classes, and comprehensive accuracy assessment and kappa statistics are carried out.

TABLE IV ACCURACY ASSESSMENT FOR LULC

Land Use/Land Cover	Overall Accuracy	Kappa Coefficient
1990	86.67%	0.744
2020	84%	0.921

Source: Computed and Compose by authors using classified LULC map

E. Indices

To enhance the applicability of the remote sensing data and image analysis Normalised Difference Built-up Index (NDBI) indices were used to classify the satellite images. The temporal data for 1990, 2000, 2010, and 2020 had acquired to measure the 30 years' transformation in the built-up area. These factors increase the quality of the Land Use Land Cover (LULC) mapping.

The NDBI was developed initially for Lands at 8 with bands 5 and 6, respectively. The accuracy derived from the image classification technique depends on the image analyst & method followed by the analyst. Although, NDBI calculation is simple and easy to derive. It is ratio-based to mitigate the effects of terrain illumination differences and atmospheric effects. Also, the Normalize Difference Build-up Index value lies between -1 to +1. A negative value of NDBI represents water bodies, whereas a higher value represents build-up areas. NDBI value for vegetation is low.

NDBI = (SWIR – NIR) / (SWIR + NIR)

For Landsat 7 data, NDBI = (Band 5 – Band 4) / (Band 5 + Band 4)
For Landsat 8 data, NDBI = (Band 6 – Band 5) / (Band 6 + Band 5)

NDBI (Source: Landsat TM, ETM+, OLI satellite data of 1990, 2000, 2010, 2020)

New construction/building built according to existing building regulations do not contribute to sustainability and leads to environmental degradation. The development in Shimla Municipal Corporation is because of Tourist agglomeration and cultural pilgrimage. These processes have led to overexploitation, overuse, and over-extraction of natural resources, mainly water and forest, resulting in the conversion of pasture lands to non- pasture lands, decreased freshwater availability, decreased soil quality, and several other interlinked impacts.

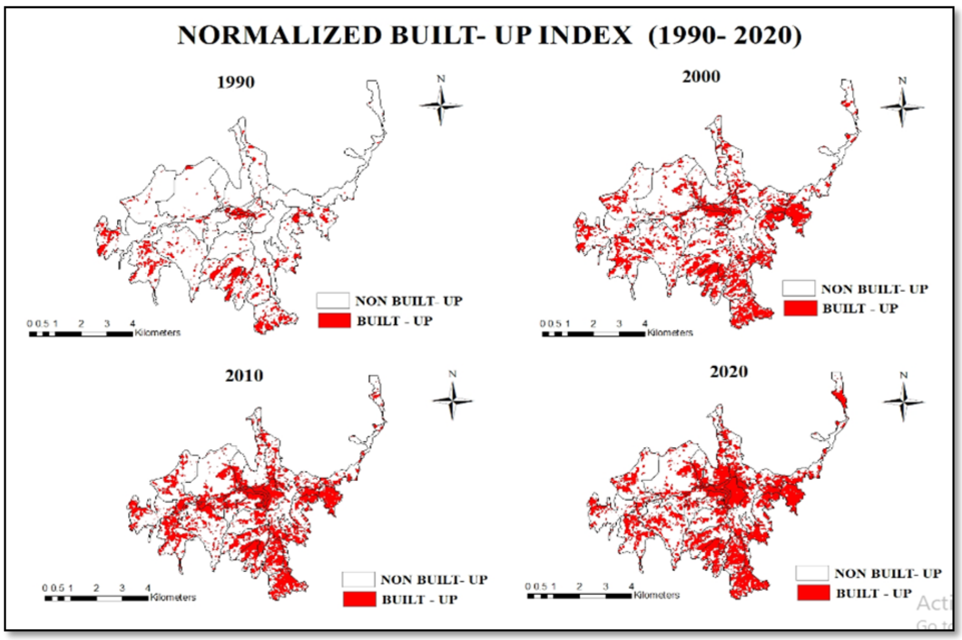

Fig. 5 Normalized Built-up Index

The prevailing building regulations of Shimla are inspired mainly by National Building Code and Delhi Master Plan(s), and the geo-environmental and socio-developmental context of Delhi is different to a great extent from that of Shimla. As a result, the existing building regulations of Shimla are not appropriate to the geo-environmental context and lead to inappropriate development. Smart cities have emerged as a possible solution at the present time to sustainability problems deriving from rapid urbanization. From intelligent grids and district energy solutions, or real-time traffic management, to waste management and water systems, innovative technologies will enable our future cities to operate more effectively. Therefore, urbanization is the primary type of human-induced land degradation in the investigated areas.

IV. CONCLUSION

Sustainable urban planning means explicitly achieving a balance between social equity and environmental quality while improving the standard of living. To achieve this, we need to have a sustainable city plan and provision with proper management of the essential services like water supply, sanitation, solid waste, and transportation. This paper has presented a detailed analysis of 30 years of the spatial urban growth pattern of Shimla Municipal Corporation. Rapid and unplanned urbanization leads to urban sprawl, making the study area highly vulnerable to climate change-induced urban flooding, global warming, and heat waves. Urban sprawl further results in inadequate transportation infrastructure, leading to air pollution and affecting health and well-being. The city lies in Seismic Zone IV (high-damage risk zone). Due to construction on hilly terrain and steep slopes, Shimla is highly vulnerable to natural hazards such as landslides, the sinking of land, and earthquakes. However, different building regulations are enforced in Shimla to regulate and guide development. Still, the condition worsens, thus highlighting the need to have contextually appropriate building regulations for Shimla. The smart city is an umbrella concept that contains several sub-themes such as smart urbanism, smart economy, sustainable environment, innovative technology, smart energy, smart mobility, and wise health. The Ministry of Housing and Urban Affairs has chosen Shimla beneath the Smart Cities Mission to be developed as a smart city in June 2017. The Shimla Municipal Corporation prepared a detailed smart city proposal describing aspects that require immediate attention for the sustainable development of Shimla. The proposal contains plans and initiatives to accomplish the much-needed improvements in service levels through optimal resource utilization. There is significant emphasis on using modern technologies to improve various aspects of city life, including mobility and liveability. Despite this, few claim that the Rs 2905 Crore project Shimla smart city is still on the drawing board and improbable to meet its 2022 due date. It is essential to formulate new building regulations following the geo-environmental (geotechnical, ecological concerns, and climatic factors), developmental (uses, locational context, existing development pattern and character, available infrastructure, performance, and appearance), and technological context of hill towns. Before implementing planning and building regulations for hilly areas, the criteria that need to be considered are topography, slope stability, drainage and erosion, infrastructure, access, aesthetics, natural qualities, fire hazard, recreational values, and open space. The target of the sustainable urban planning process is to achieve the status of sustainability in urban communities and create or strengthen sustainability's characteristics of economic, social, cultural, and environmental aspects.

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