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Technical Note

Assessment of the Impact of Urbanization on Geoenvironmental Settings Using Geospatial Techniques: A Study of Panchkula District, Haryana

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Abstract: Urbanization is an unavoidable process of social and economic growth in modern times. However, the speed with which urbanization is taking place produces complex environmental changes. It has affected the surface albedo and roughness of the soil, thereby modulating hydrological and ecological systems, which in turn has affected regional and local climate systems. In developing countries of South Asia, rampant and unplanned urbanization has created a complex system of adverse environmental scenarios. Similar is the case in India. The state of the urban environment across India is degrading so quickly that the long-term sustainability of its cities is endangered. Many metropolitan cities in India are witnessing the harmful impacts of urbanization on their land ecology. In this context, remote sensing and geographic information system (GIS) based assessments provide a comprehensive and effective analysis of the rate and the impact of urbanization. The present study focuses on understanding the spatiotemporal characteristics of urban growth and its implications on the geomorphology of the Panchkula District, Haryana, one of the fastest-growing urban centers in India. The study links the changes in land use/land cover (LULC) with the changing geomorphology of the study area using satellite remote sensing and GIS. The results showed that between 1980 and 2020, agricultural (+73.71%), built-up (+84.66%), and forest (+4.07%) classes of land increased in contrast to that of the fallow land (−76.80%) and riverbed (−50.86%) classes that have decreased in spatial extents. It has been observed that the hill geomorphological class had decreased in the area owing to conversion to industrial and built-up activities. Assessment of the environmental quality of cities involves multiple disciplines that call for a significant amount of scientific evaluation and strong decision making, and the present study shall lay down the baseline analysis of the impact of changing LULC on the geomorphological setup of the selected urban center.

Keywords: land use and land cover; remote sensing and GIS; urbanization; geomorphology

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Citation: Kanga, S.; Singh, S.K.; Meraj, G.; Kumar, A.; Parveen, R.; Kranjčić, N.; Đurin, B. Assessment of the Impact of Urbanization on Geoenvironmental Settings Using Geospatial Techniques: A Study of Panchkula District, Haryana. *Geographies* **2022**, *2*, 1–10. https://doi.org/10.3390/geographies2010001

Academic Editor: Andreas Rienow

Received: 16 November 2021
Accepted: 4 January 2022
Published: 6 January 2022

1. Introduction

In recent years there has been mass migration to urban cities. There are different reasons for identifying settlement priorities in cities around the world [1]. There has been an increasing interest in the quality of life of metropolitan regions that attract people to these regions. Urban quality includes multidisciplinary characteristics and interrelated criteria, including jobs, recreation, better living conditions, and options for a wide range of livelihoods for human wellbeing [2,3]. Because of these factors, the United Nations Economic and Social Council reported that 54% of the population worldwide currently lives in cities [4].

The environmental problems of urbanization are critically damaging biological and ecological systems [5]. Unmanaged urban growth occurs worldwide, but urbanization is exceptionally rapid in emerging countries, notably in Asia [6]. In particular, India, which is at the forefront of economic growth, has one of the highest rates of urban sprawl in the world. Statistics reveal that India has the world's second-largest urban population after China [7,8].

Forests have been destroyed, meadows ramped, the wetlands drained, and croplands have been invaded due to the expansion of cities [9,10]. Each major Indian city faces the same growing urban expansion problems, such as limited housing, poor transport, poor drainage, unreliable electricity, and insufficient water supply [11]. More and more lorries, buses, vehicles, three-wheelers, and motorbikes spray uncontrolled fumes, all of them contending on urban roads with wandering pedestrians, rickshaws, and cattle [12]. The main causes of the fast urban economic growth and urbanization have, in addition to increasing living standards, been the growth of dense and unplanned residential areas, environmental pollution, the lack of services and amenities, the production of solid waste, and the growth of slums [13,14].

Contamination of air, water, and land have increased due to poor environmental management, which directly affects the quality of the urban environment, labor productivity, and overall socio-economic growth [15,16]. The urban air quality of India is among the worst in the World. Each urban center has various environmental challenges and dimensions that are impacted by elements like population size and density, climate, water supplies, and flora and fauna around the city center [9,17].

While urbanization has enormous consequences for demographic changes and changes in the physical landscape, it can profoundly impact several environmental components, particularly on land and water. Therefore, a complete understanding of the dynamics generated by urbanization changes is essential to cope with environmental changes and promote sustainability [18–20].

Satellite remote sensing and the Geographical Information System (GIS) are integral to environmental assessment and strategizing efficient policing. Understanding urbanization and its effects on the physical and social environment is very well evaluated using integrated field-, remote sensing-, and GIS-based approaches [21]. Using spatial analytical tools, this method promotes decision making by integrating the specific geographical capabilities of this system [22,23].

The present study aims to understand the changing LULC and the associated changes in the geomorphological setup of the Panchkula urban center, Haryana, India, and focuses on the baseline data analysis for sustainable urban development policies and management frameworks for the region. The results shall also open the way for further research on how urbanization has affected geomorphological characteristics and its possible implications for the land system.

2. Study Area

Panchkula District, Haryana, is in the northern section of Haryana and is situated between 30° 26′–30° 55′ North and 76° 46′–77° 10′ East. Himachal Pradesh borders the north of the district, Uttar Pradesh borders the east, Ambala District to the west, Karnal District borders the south. The district's total geographical area is 882.92 sq. km (Figure 1). The district of Panchkula is divided into two tehsils and four development building blocks, namely Pinjore, Barwala, Raipur Rani, and Morni. Panchkula is a dense district with a population density of 522 persons per sq. km, higher than the state average of 478 persons per sq. km. The Ghaggar River and its affluents mainly drain the area. The Panchkula climate can be categorized as subtropical monsoons, mild and dry winters, and heated summers. The district's average annual rainfall is 1057 mm, with the Siwalik Hills occupying the north and northeast frontage of the district of Panchkula and reaching a height of up to 950 m AMSL. Concerning the nearby alluvial plains, the hills are around 500 m high. They are distinguished by the large plot of the topography carved into somewhat sharp slopes by the many ephemeral streams that descend to the outer slopes of the Siwalik Hills, spreading many gravel stones in the beds of these streams.

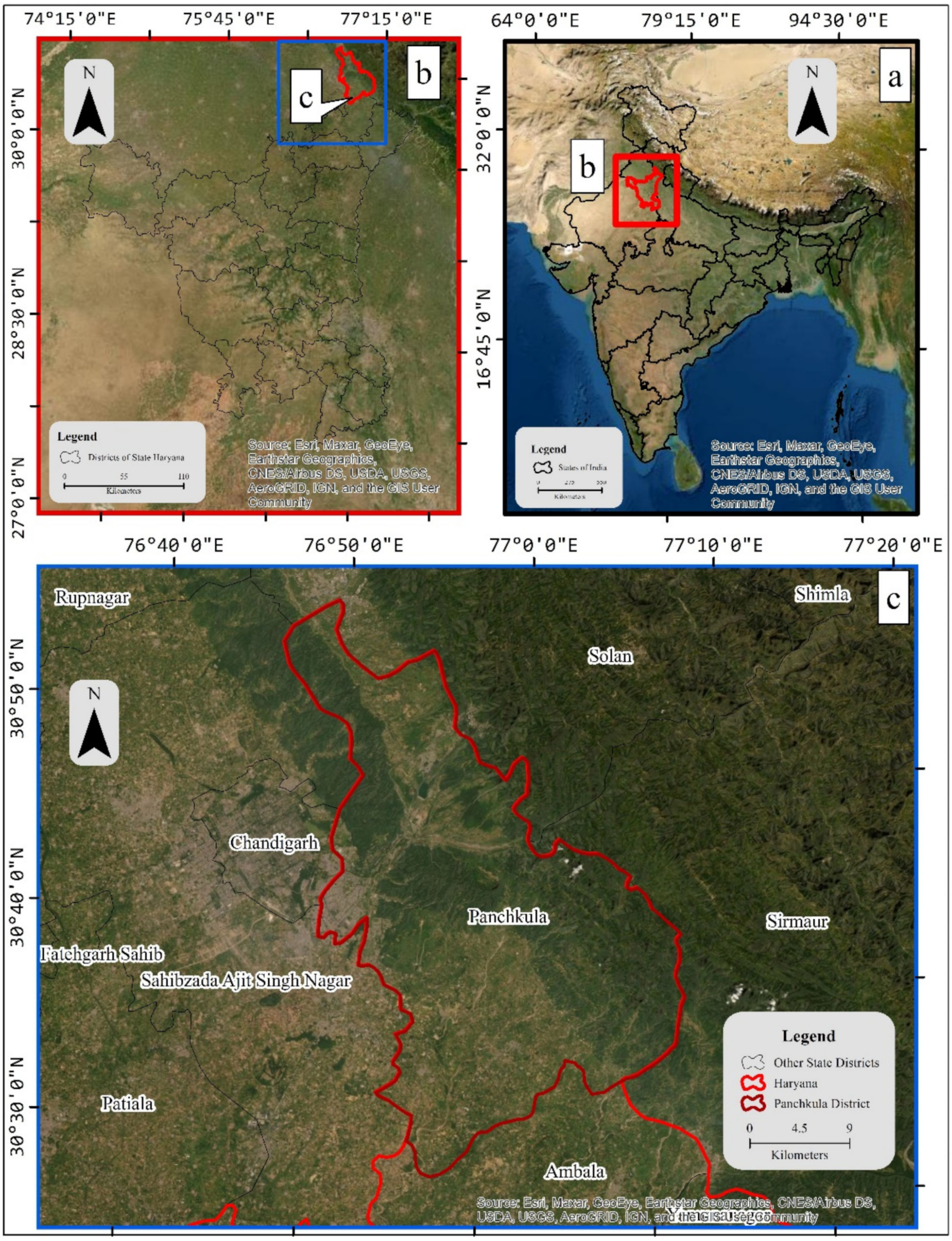

Figure 1. Location map: (**a**) the location of the state of Haryana in relation to India (red square); (**b**) the location of Panchkula District with respect to the state of Haryana (blue square); (**c**) the location of Panchkula District along with neighboring districts of other states. The map coordinates are in the UTM 43 (North) World Geodetic System (WGS-1984) reference system.

3. Materials and Methods

Landsat Multispectral Scanner (MSS) (22 October 1980) and Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS) sensors (20 September 2020), with 60 m and 30 m spatial resolutions, respectively, were used in the study (Figure 2a,b). The topographical maps on a scale of 1:50,000 from the India Survey (SOI) were used as auxiliary data for georeferencing satellite images. All maps were georeferenced to a similar projection system, UTM WGS 43 North, officially used in India for mapping purposes. We used ERDAS image

10 for co-registration (georeferencing) of different dates Landsat images with the already georeferenced topo sheets from SOI [24]. Pixel-level registration accuracy was established between the two Landsat images for accurate change-detection analysis [25].

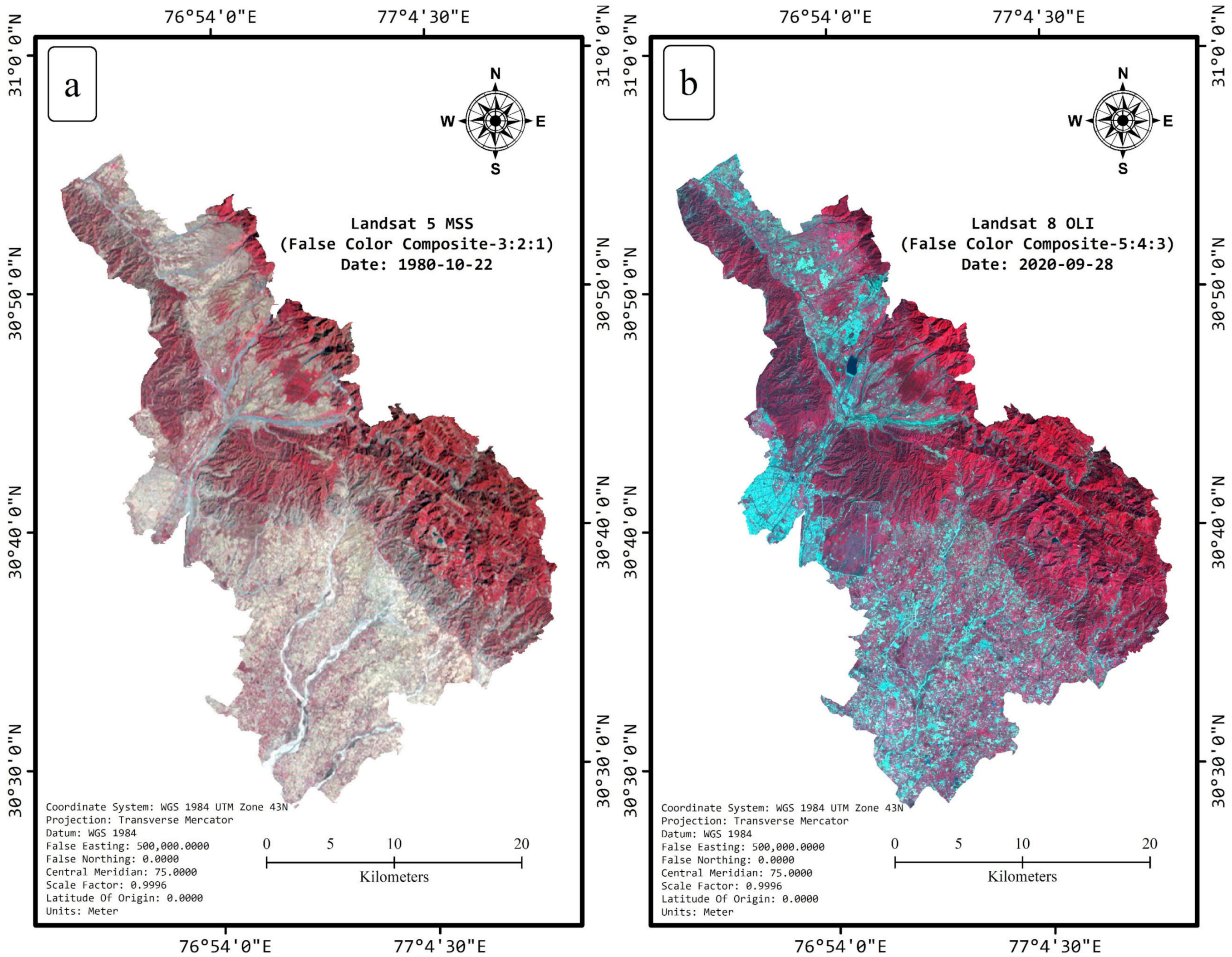

Figure 2. Satellite view of Panchkula District: (**a**) Landsat MSS 1980; (**b**) Landsat OLI 2020.

Visual image interpretation was used for land use/land cover and geomorphological classification. Initially, a false color composite (FCC) of infrared:red:green (IR:R:G) as RGB was used to understand different land use/land cover and geomorphological classes [26]. It must be noted the vegetation class has maximum spectral reflectance in the infrared band (IR), and as such, it has been used as a standard spectral band for mapping vegetation classes. The visual image interpretation classification technique is based on various elements of interpretation such as location, tone, texture, pattern, association, shape, and size. These are the basis for image interpreters for classifying the image into different classes of various information layers, such as in the present case for land use/land cover and geomorphology [27]. The overall methodology shown in Figure 3.

Moreover, since the Landsat images used were of different resolutions, accordingly the minimum mappable unit (MMU) was governed by the Landsat MSS 1980 image. This led to the constant scale of digitization being kept constant at a scale of 1:25,000 to avoid errors in change-detection analysis [28].

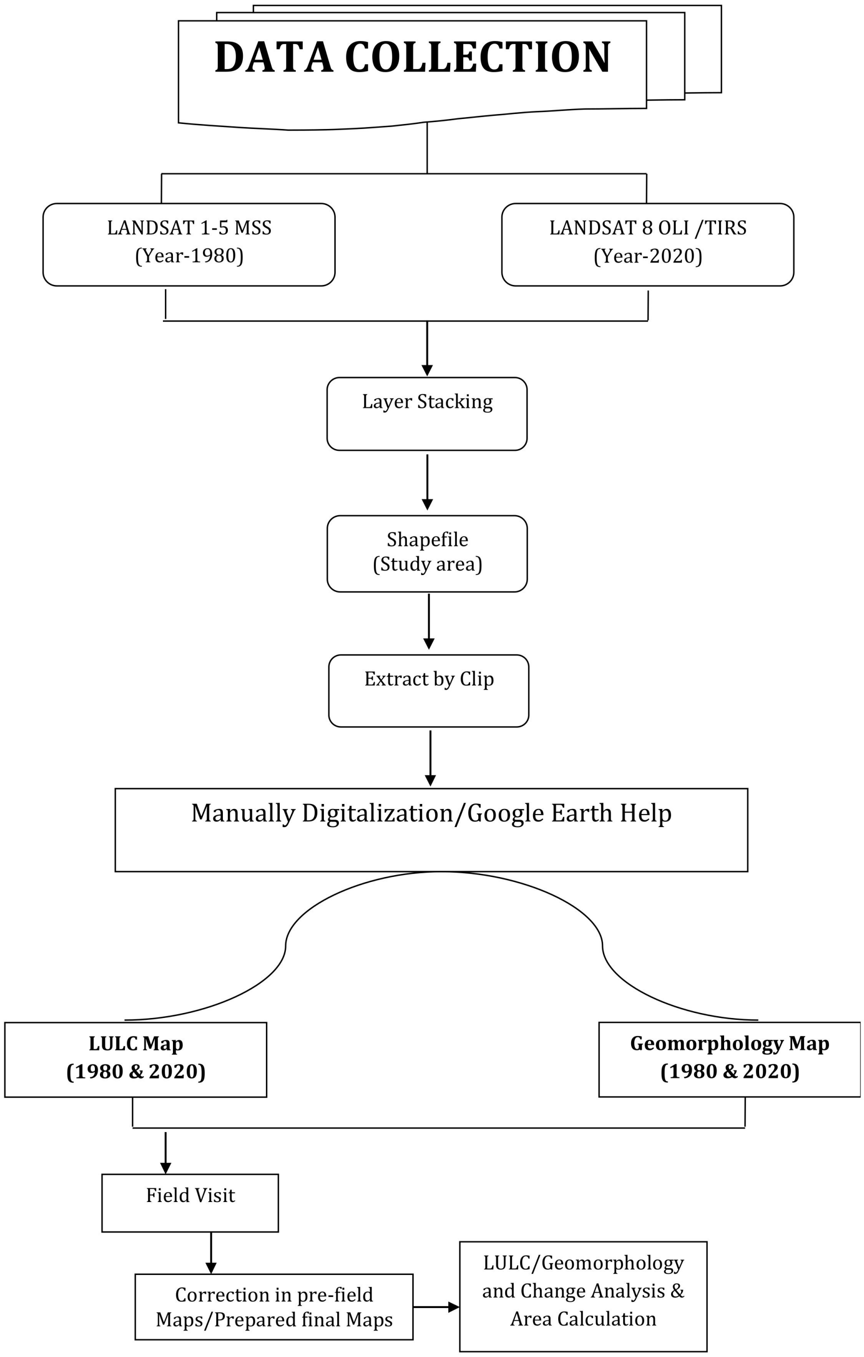

Figure 3. Methodology flowchart used in the present study.

4. Results and Discussion

Land use/land cover assessment is critical for planners, managers, government and non-governmental organizations, and the scientific community to implement policies for natural resource conservation and sustainable development while reducing environmental damage. The purpose of this study is to examine the changes in land use/land cover (LULC) between 1980 and 2020 in Panchkula District, India, and the associated changes in the geomorphological setup of the area. The results depicted a sharp increase in the built-up area from 38.93 sq km to 71.89 sq km between 1980 and 2020. The district has been sprawling outward, and peripheral nuclear patches of the settlement are observed. It has been observed that agriculture has increased from 181.37 sq km in 1980 to 315.06 sq km in 2020, suggesting an increase in agricultural practices to fulfill the needs of the increasing population (Table 1). Agriculture practices are directly correlated with the water resources, as they have a direct relationship with rainfall and finally the recharged groundwater and surface water for drinking, irrigation, and domestic purposes. The water body area has not changed too much, showing only a small insignificant change (2.22 sq km to 2.73 sq km from 1980 to 2020). In contrast, a sharp decrease in riverbed area (drainage) from 55.76 sq km in 1980 to 27.40 sq km in 2020 has been observed, indicating an intensification of urbanization and industrialization in the study area. The land under the fallow land category has declined from 200.18 sq km to 46.45 sq km between 1980 urban centers. The forest land has increased slightly from 402.95 sq km in 1980 to 419.33 sq km in 2020 due to various government initiatives undertaken during the observation period (Figure 4a,b).

Table 1. Land use and land cover change analysis.

Land Use/Land Cover	Area in 1980 (sq. km)	Area in 2020 (sq. km)	% Change in LULC (1980–2020)
Built-up land	38.93	71.89	+84.66
Agriculture	181.37	315.06	+73.71
Fallow land	200.18	46.45	−76.80
Forest	402.95	419.33	+4.07
Water body	2.22	2.73	+22.97
Riverbed	55.76	27.40	−50.86
Total	882.92	882.92	

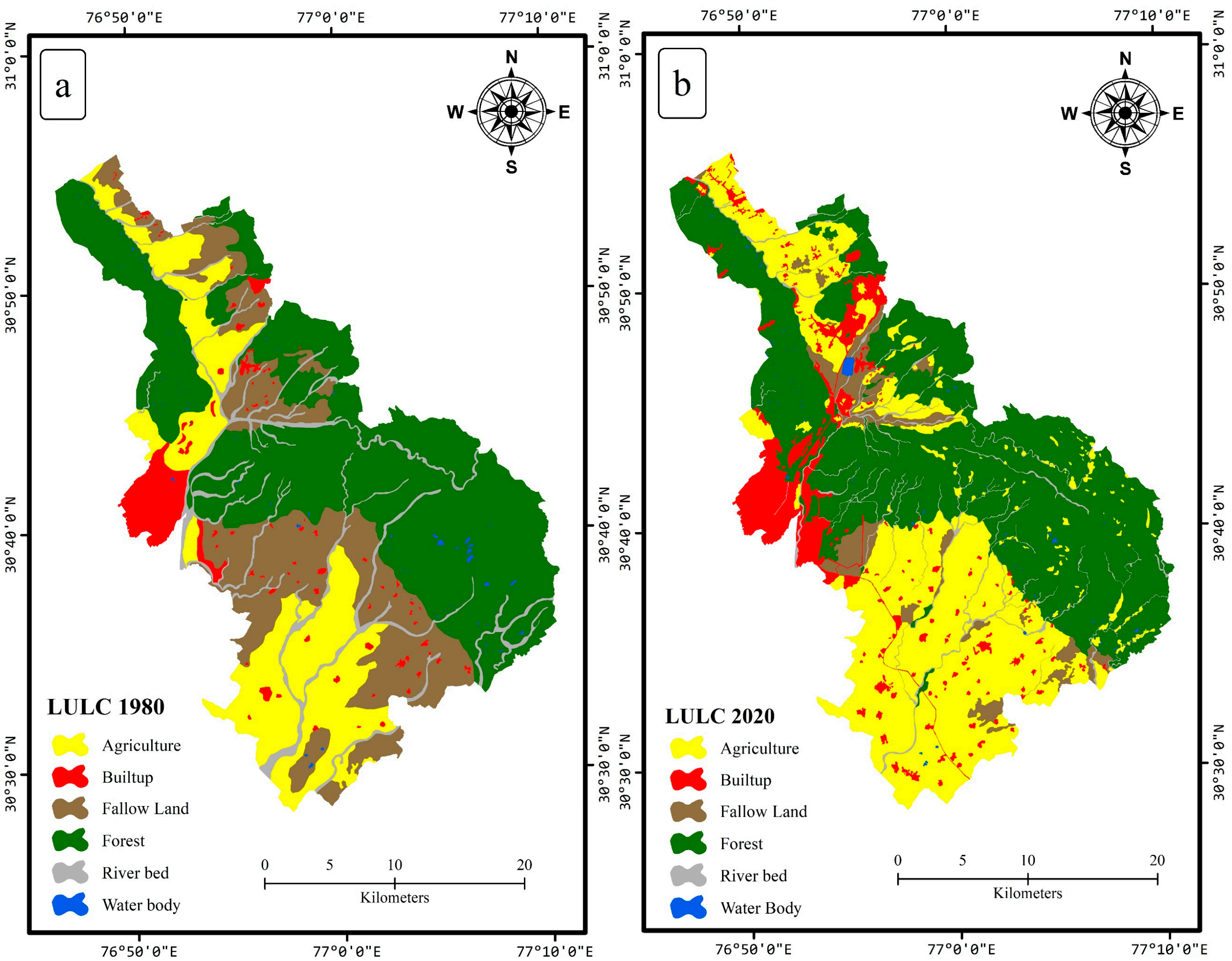

Figure 4. Land use and land cover (LULC) map: (**a**) 1980; (**b**) 2020.

Geomorphology is the study of landscapes and is primarily concerned with the lithology, geomorphic processes, hydrological conditions, and topological features of a given location. These features are affected due to urbanization [29]. In this district, it has been observed that the riverbed has been transformed into a built-up area, and hills have been cut for road construction and mined for construction materials. In the current study, anthropogenic activities have been observed to alter the natural landscape, which has badly affected the ecology and environment, as has been observed in other areas of the region [30].

Geomorphology is impacted by one of the most complex human settlement structures in the form of cities and its relationship with natural and environmental variables [31]. The ultimate drawback of urbanization is the loss of natural resources and the conversion of land use/land cover in the built-up area. Urbanization also degrades natural resources like water quality and quantity, land, and air [32]. In the Panchkula District, geomorphological features are being rapidly altered as many changes are noticed due to the rapid increase in urbanization (Figure 5a,b). An increasing population leads to vanishing natural drainage, with many roads and highways under construction, and as well as the construction of industries, commercial areas have led to the destruction of hills and other geomorphological features, thus severely degrading the ecosystem services in the study area [33] (Table 2).

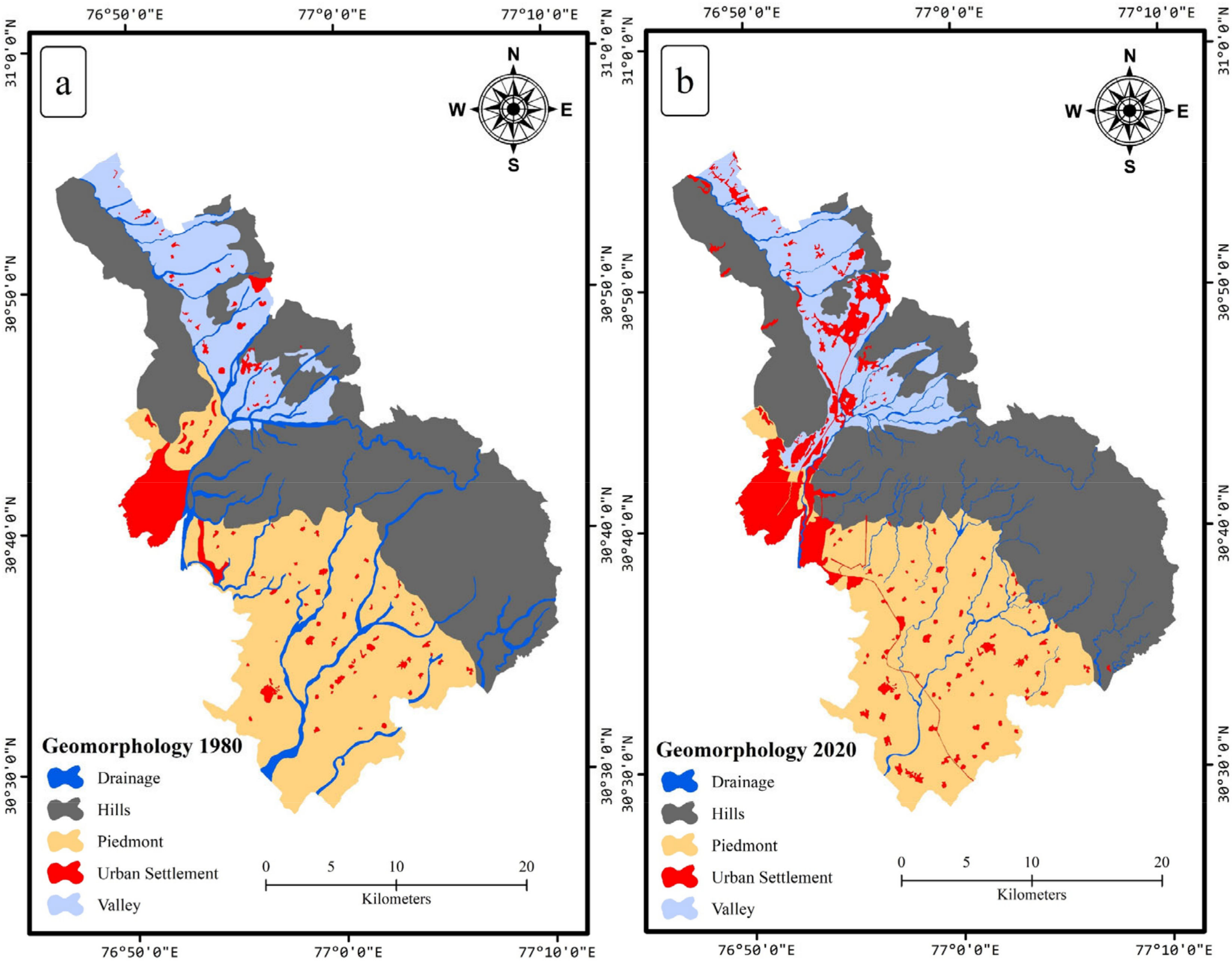

Figure 5. Geomorphological map: (**a**) 1980; (**b**) 2020.

As the population grows, so does the need for more housing, schools, transit solutions, and other municipal facilities. The measurement of these qualities and other variables is used to create standardized indices of sprawl development [34]. The fast development of urban areas due to rising populations and economic growth puts additional pressure on natural resources, resulting in land-use changes, particularly in mega-cities [35]. As a result, serious problems associated with rapid development, such as illegal settlements, environmental pollution, destruction of the ecological structure, and a scarcity of natural resources, have been thoroughly studied for the rapidly growing Panchkula District, using remote sensing and GIS technologies [36]. Pollution loads have started to affect air, water, and land in Panchkula District due to their dramatic increase, and the so-called 'heat pollution' average night-time temperature has increased tremendously [37]. The management of enormous volumes of trash and solid waste, especially medical waste, is exceedingly complicated and has led to increased health costs for the environment. Increasing surface temperatures and noise pollution also have health consequences [38].

Table 2. Geomorphology change analysis.

Geomorphology Classes	Area in 1980 (sq. km)	Area in 2020 (sq. km)	% Change in LULC (1980–2020)
Hills	403.35	393.33	−2.48
Piedmont	277.98	286.36	+3.01
Valley	107.17	107.17	0.00
Drainage	55.49	24.30	−56.21
Urban Settlement	38.93	71.89	+84.66
Total	882.92	882.92	

The use of remote sensing and GIS have helped to understand the changes in the LULC and the geomorphology of the study area. The temporal analysis and synoptic capabilities of satellite remote sensing have made it possible to understand the human influence on natural systems [39]. Moreover, the spatial analysis of the GIS has been pivotal in formulating various policy-backed sustainable management agendas for the conservation of ecosystems and the environment [40–42].

The current study assesses changes in land use/land cover (LULC) and urban development, highlighting the significant effects of fast urbanization and population increase [43]. The findings show that the city is spreading towards its periphery, with rural areas being converted into urban expansions. In the research period from 1980 to 2020, the built-up area of Panchkula increased. The findings emphasize the need to use urban-planning principles to protect and manage land-use classes to improve human wellbeing in urban settings.

5. Conclusions

The main issues linked with city centers in India are unplanned growth, changing land utilization/land cover, and the loss of valuable agricultural areas. The analysis presented in this research reveals that rapid population growth in the Panchkula District, Haryana, has led to an unregulated urban expansion from 1980 to 2020. Fallow land has been reduced because of urban development in the periphery zones. The study further showed that the transformation of geomorphological units of the study area into urban units between 1980 and 2020 has affected the region's geoenvironmental setting. The use of remote sensing and GIS through their temporal and synoptic vision capabilities have proved to be efficient tools for mapping, assessing, and monitoring changes in the urban environments of the Panchkula District. The methodology used in this study is of crucial relevance in order to combat environmental degradation problems and effectively implement sustainable development goals. The study shows that the geospatial analysis helps to evaluate urban environmental quality in the metropolitan cities of developing nations. Such a strategy helps promote the United Nation's Sustainable Development Goals at micro-planning levels in developing countries.

Author Contributions: Conceptualization, S.K. and A.K.; methodology, S.K.S.; software, R.P.; validation, A.K., S.K. and S.K.S.; formal analysis, N.K.; investigation, R.P.; resources, B.Đ.; data curation, S.K.; writing—original draft preparation, S.K.S. and G.M.; writing—review and editing, B.Đ. and G.M.; visualization, N.K.; supervision, S.K., S.K.S. and G.M.; project administration, A.K.; funding acquisition, N.K. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments: The authors are grateful to Suresh Gyan Vihar University, Jaipur, for providing financial support for this study. Additionally, the authors appreciate Haryana Space Application Centre (HARSAC), Department of Science and Technology, Haryana, for their guidance and assistance in designing the templates. The author, G.M. is thankful to Department of Science and Technology, Government of India for providing the Young Scientist Fellowship under Scheme for Young Scientists and Technology (SYST-SEED) [Grant no. SP/YO/2019/1362(G) & (C)]. We thank the three anonymous reviewers for critically analyzing our manuscript and suggesting invaluable suggestions that have greatly improved its content and structure.

Conflicts of Interest: The authors declare no conflict of interest.

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