Hindawi
Advances in Agriculture
Volume 2022, Article ID 6094160, 11 pages
https://doi.org/10.1155/2022/6094160

Research Article

To Study the Hydrological System and Watershed by Using Remote Sensing (RS) and Geographic Information System (GIS) in Kannad Taluka, Aurangabad District, MS, India

Eman Mohammed Garoon [1,2] **Sultan Abduh Al-Horaibi** [3] **and Mahadeo B. Mule** [1]

[1] *Department of Environmental Science, Dr. Babasaheb Ambedkar Marathawda University, Aurangabad 431001, India*
[2] *The General Authority for Agricultural Research and Extension in Dhamar, Dhamar, Yemen*
[3] *Department of Chemistry, Albaydha University, Al Baydha, Yemen*

Correspondence should be addressed to Eman Mohammed Garoon; emangaroon30@gmail.com

Received 4 March 2022; Accepted 20 May 2022; Published 14 June 2022

Academic Editor: Yunchao Tang

The current study in this research focuses on the importance of the digital elevation model (DEM) and satellite images to evaluate and interpret the relative parameters of watersheds in Kannad taluka, Aurangabad district, India. Watersheds in the area were identified and calculated using the SRTM DEM through ARCGIS 10.8 software. Kannad shows a first to fourth-order drainage network which is of dendritic type, which indicates a sign of the structural lack of control and homogeneity of the watersheds in Kannad taluka. The basin's mean bifurcation ratio is found to be 1.47 which indicates that the drainage network pattern is not much influenced by geological structures. Based on the hydrological assessment on the watershed scale, the present study reveals that the SRTM DEM is the most accurate application compared to other techniques. As visual or manual identification and evaluation are difficult and may not provide a holistic view of watersheds, modern tools of RS and GIS were used to study the watershed of Kannad taluka. There was lack of published reports on watersheds by using the RS and GIS and work undertaken.

1. Introduction

Natural and social processes in a watershed are complex, dynamic, and vary spatially, making them difficult to investigate and comprehend [1]. Expansion of activities in the watershed will inevitably intrude on natural resources. A watershed's land use shift is caused by a variety of reasons. The social and economic changes in society residing in an area have implications for the demographic changes [2]. Land use (LU) changes, in general, reduce natural open spaces and enhance impervious surfaces such as parking lots and roadways [3]. Increased impermeable surfaces make a watershed more hydrologically active, causing changes in streamflow and runoff volume, as well as an increase in peak discharge, all of which change the watershed's hydrology [4]. Increased quick runoff exacerbates a watershed's flooding problem (USDA, 2000).

Drought and flooding are becoming an issue in the watershed as communities and development activities grow. Storm water runoff should be reduced as much as possible, according to expert planners of natural resource [5]. As there is lack of holistic information about watershed from Kannad taluka from Aurangabad district, Maharashtra, India, it is very difficult to predict the nature of surface runoff and the presence of flood or drought in an area. Changes in land use affect hydrological factors such as interception, infiltration, evaporation, and transpiration, which have an impact on the local ecology [6]. The digital elevation model (DEM) is the dataset for various studies that include morphometric, neotectonic, and hydrologic studies [7–11]. Water resource system, design, planning, and management require systematic knowledge of the operations of watershed subsystems [12]; hence, the present work of detailed hydrological systems has been undertaken in Kannad taluka, which is supported by computer-based watershed models [13]. Hydrologic modelling, which deals with water flow and land surfaces, is seen to be a useful tool for dealing with the effects of an LULC change [14]. Using the GIS, a novel distributed hydrologic model has been built that can encompass the physical properties of a watershed as opposed to traditional lumped hydrologic models [15].

In a hydrologic model, defining physical characteristics for a watershed produces more exact and dependable results. Physical parameter derivation for distributed runoff modelling has recently improved, thanks to simple access to spatial geographical and meteorological data as well as GIS tools as an interface [16]. Recently, easy access to spatial geography and rainfall-runoff modelling has provided information on the varied nature of hydrological processes in the Kannad taluka watershed, which will aid in monitoring and predicting their effects on people and property. This would aid in the mitigation of a potential disaster in the vicinity of the watershed by disseminating information. It will also offer data on the pattern of land use/land cover (LULC) changes as well as their involvement in initiating the hydrological process. Overall, it would aid decision-makers in developing more sustainable watershed planning, as well as improving watershed management policies and their implementation in the Kannad taluka watershed. Watershed management approaches that are poor and unsustainable are often the result of lack of understanding of the subsystems that make up the watershed. This can result in a variety of environmental challenges that affect humans, ultimately influencing the watershed's socioeconomic aspects [17–19]. Watershed models can show major hydrologic parameters in many watershed systems despite the complexity and many uncertainties in hydrological processes [1]. Modelling is no longer limited to describing physical processes due to advancements in data gathering, remote sensing imagery, and computational capacity [9]. It also depicts a watershed's relationship with its socioeconomic and environmental context, which is critical for planning and management decision-making.

The usage of the SRTM DEM, satellite images, and GIS analysis was used to conduct a hydrological study of watersheds and their morphometric evaluation in Kannad watershed, Aurangabad district, Maharashtra, for water resource management. The primary goal of this research is to examine and identify numerous drainage factors in order to better understand the geometry of the watershed. This was carried out by using ARC GIS 10.8 version and by using the DEM. The input of the DEM followed by fill dam, flow direction-stream order, and delineation of the watershed from the stream network has been undertaken. The output in the form of the watershed is going to provide a good tool to conserve and manage the water resource by sustainable way. The findings of this study can serve as a scientific database for further detailed hydrological investigation and the identification of alternative water harvesting solutions in the study area through the construction of various suitable structures.

2. Study Area

Kannad is a taluka from the Aurangabad district of Maharashtra state, India, which was selected as a study area for the study of change in land use and land cover. It is a part of Marathwada region located 53 km^2 towards north from district headquarters, i.e., Aurangabad.

Kannad taluka is bounded by Khultabad and Phulambri talukas towards south, Chalisgaon taluka towards north, Sillod taluka towards east, and the part of Gangapur taluka towards west. Chalisgaon, Talode, Aurangabad, and Pachora cities are the nearby cities to Kannad. Kondbari is the smallest village, whereas Shafepur is the biggest village in taluka. It has 352 m elevation (altitude) from the mean sea level having some part hilly terrain region. The location map of the study area is shown in Figure 1. The soil type of Kannad taluka is shallow black soil cover followed by medium deep black soil and deep black soil. Most of the part of Kannad taluka is having hilly terrain; hence, it is very vulnerable soil due to the velocity of water runoff and which might result in high erosion of top soil during heavy rainfall. The soil erosion might affect the productivity of the agricultural system in the region. The present vegetation cover is a natural factor controlling the soil erosion. Hence, the Kannad taluka's soil erosion study is found to be very important along with the change in vegetation cover. The Kannad taluka consists of an area of 1523.23 km^2 having about 197 villages.

3. Database Sources

Input data and their types and their sources are shown in Table 1.

4. Methodology

To carry out the watershed delineation, the DEM was used with ArcGIS 10.8 software by using the flowchart as shown in Figure 2.

4.1. Preprocessing of the Terrain. Using a revised DEM produced with ArcGIS 10.8, Kannad taluka was demarcated. The DEM and the stream network are the input files, with the DEM being reconditioned to improve agreement between defined stream networks and watershed bins. Fill, flow direction, flow accumulation, stream definition, stream segmentation, catchment grid delineation, catchment polygon processing, drainage, contour line, hillshed, aspect, precipitation, and slope grid were all included in the preprocessing of the DEM in ArcGIS 10.8. All of these stages (Figure 2) were applied to the reconditioned DEM in order to improve the accuracy of Kannad watershed delineation using stream networks.

5. Results and Discussion

The most significant activity in agriculture, especially in dryland agriculture, is watershed management. It

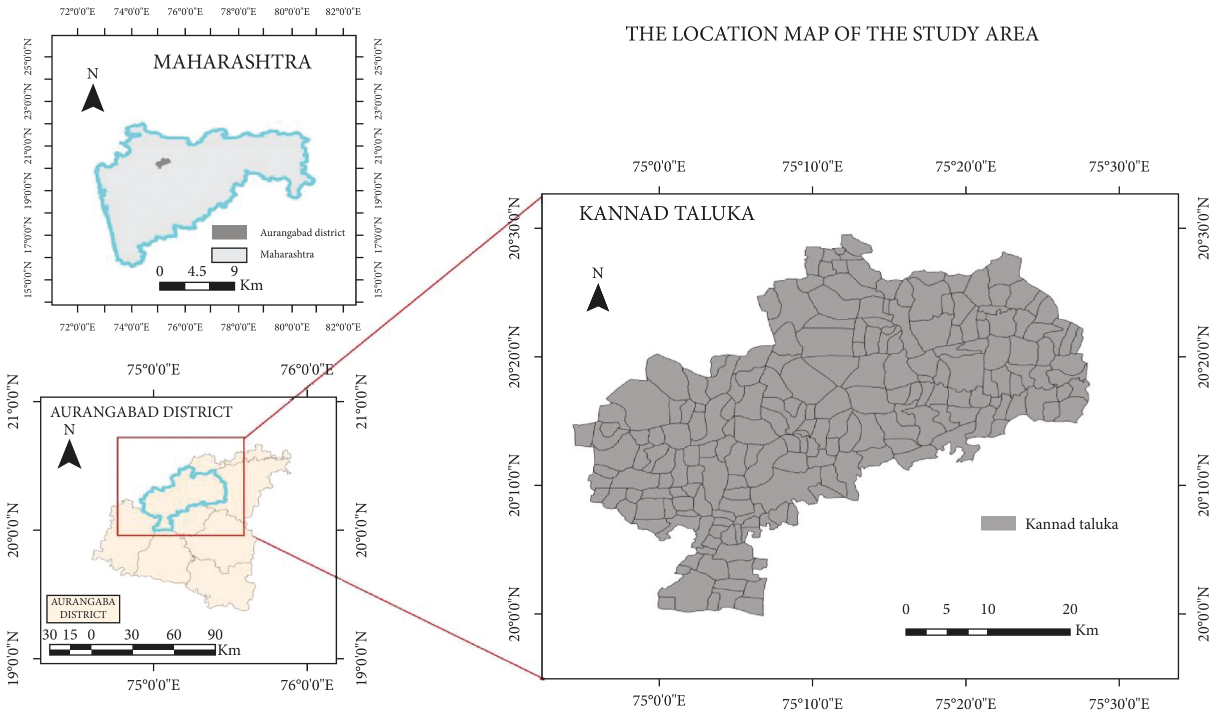

Figure 1: The location of the study area.

Table 1: Types of input data and their sources.

S. No.	Input data type	Sources
1	Digital elevation model (DEM), 30-meter spatial resolution	USGS, https://www.usgs.gov
2	Precipitation estimation from remotely sensed information using artificial neural networks (2013–2019)	CHRS, data portal https://chrsdata.eng.uci.edu/
3	Soil data and geological data	Geological Survey of India, https://www.gsi.gov.in

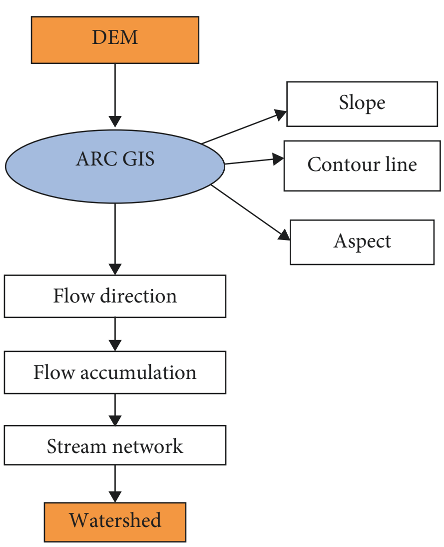

Figure 2: Flowchart for watershed delineation.

contributes more to the conservation of runoff water from various sources. The primary source of water in the watershed is rainwater harvesting. The gathered water is utilised to irrigate crops in dry areas that are under water stress. It is also used as supplemental irrigation or lifesaving irrigation for a variety of agricultural crops. Watershed management has become increasingly vital and necessary in order to protect crops from numerous pressures that occur during the growing season. The ecosystem is declining these days as a result of reduced forest area, increased soil erosion, decreased soil ground water table, increased drought intensity, and degradation of dryland soils.

5.1. Digital Elevation Model (DEM). DEM stands for digital elevation model, and it is a data file that depicts the elevation of the earth's surface in three dimensions. Readings can be taken from a specific spot on the earth's surface using the points that have been placed there [20]. The distance between each point is calculated using latitude-longitude or the Universal Transverse Mercator (UTM) coordinate system, in which case, the closer the points are to one other, the more information we can extract [21]. The production model depicts the difference in height of an area, the distance between points, or distance intervals for data collection that must be performed nearer or closer to avoid error and maintain data accuracy [21]. DEM files can be created in ASCII or the binary format [22]. As a result, the file's real

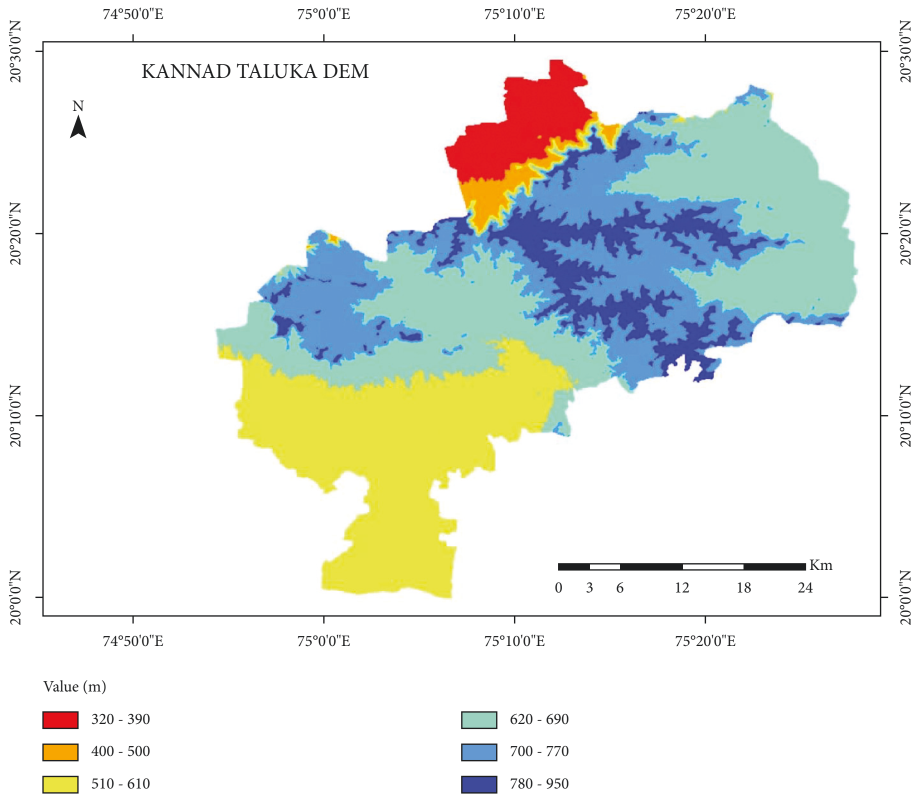

Figure 3: DEM map of Kannad taluka.

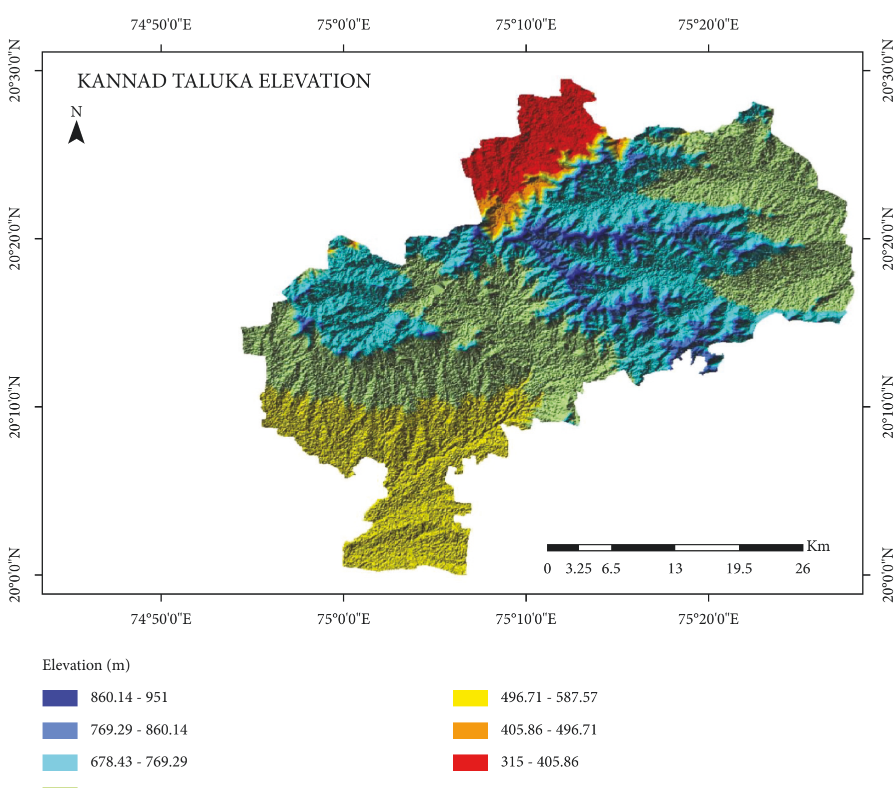

Figure 4: SRTM digital elevation model map of Kannad taluka.

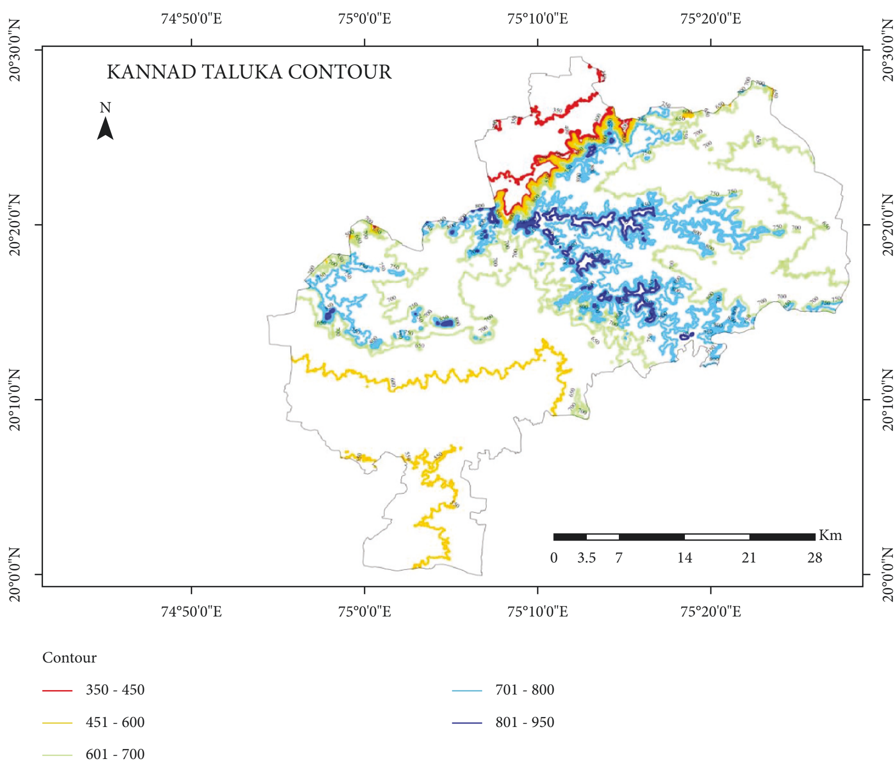

Figure 5: Contour line map of Kannad taluka.

format must be known in order to read it directly. A reference location is usually provided in the file name at some point in the map file. This file only provides the actual value of z (height) and does not include the real geographical location of that point. Using software that can read DEM file headers, the real location linked with elevation data can be discovered. DEM files also include information such as roads and buildings, but they do not include elevation contours; instead, they merely include the elevation value at a given area on a single grid point [23]. Digital elevation model (DEM) data from the Shuttle Radar Topography Mission (SRTM) with a horizontal grid spacing of 1 arc-second (resolution of 30 m) were downloaded from the URL: https://srtm.csi.cgiar.org/. It has a geographic projection with WGS84 (World Geodetic System, 1984). The data were utilised to extract the basin's topological characteristics. In ArcGIS 10.8, the SRTM DEM of the Kannad taluka basin was mosaicked and clipped to the basin boundary.

The DEM was classified into six classes, whereas the result showed that the lowest value (red color) was 320–390 m and the highest value (blue color) was 780–950 m as shown in Figure 3. The map of the SRTM digital elevation model for Kannad taluka has been classified into seven classes, whereas the result showed that the lowest value (red color) was 315–405.86 m and the highest value (blue color) was 860.14–951 m as shown in Figure 4.

5.2. Contour Lines. Contour lines are the most common way to describe the surface of a landscape. Contour lines implicitly preserve the topology of the earth's surface in addition to representing its geometry. To illustrate their height, elevation values are frequently provided as text descriptions on topographic maps. Furthermore, spot altitudes, which appear as a dot or a cross at a given horizontal place, are available. They are employed in this context to indicate notable natural features on a dominant region, such as hilltops, knolls, isolated summits, mountaintops, mountain passes, saddles, and other high points. Figure 5 shows a contour map of the watershed. Because the watershed is tiny but mountainous, the contours flowing across it range from 350 to 950 metres. The watershed's water divisions are primarily mountainous.

5.3. Aspects. The aspect map shows a mountain slope's general orientation. An elevation map is an important tool for understanding the effect of the Sun on the microclimate of a specific place. The aspect map has a considerable impact on the distribution of vegetation types in a given area. The display map derived from the SRTM DEM represents the side's compass direction. East-facing slopes in Kannad taluka watershed have more moisture content and more vegetation than west-facing slopes (Figure 6).

5.4. Soil. Heavy clay soils with a significant concentration of swelling clays are churned by vertisols. When these soils dry out, which happens most years, deep wide fractures form from the surface downward. Vertisols (from the Latin word "vertere," which means "to turn") refer to the ongoing internal rotation of soil particles. The soil map created by the FAO (Food and Agriculture Organization) categorization

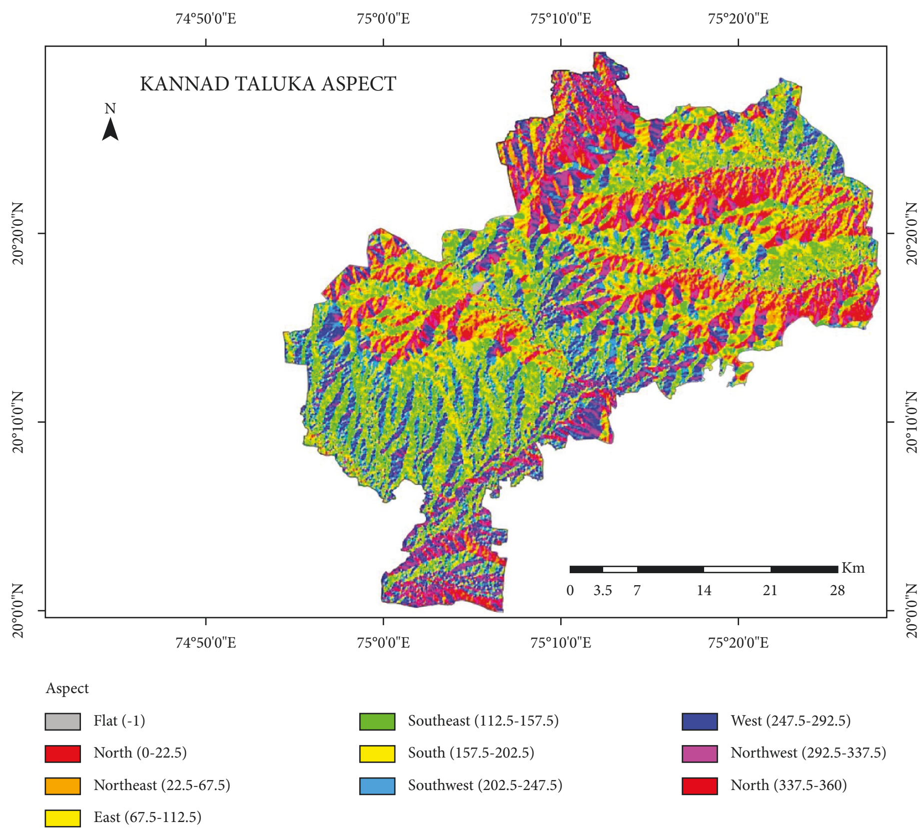

Figure 6: Aspect map of Kannad taluka.

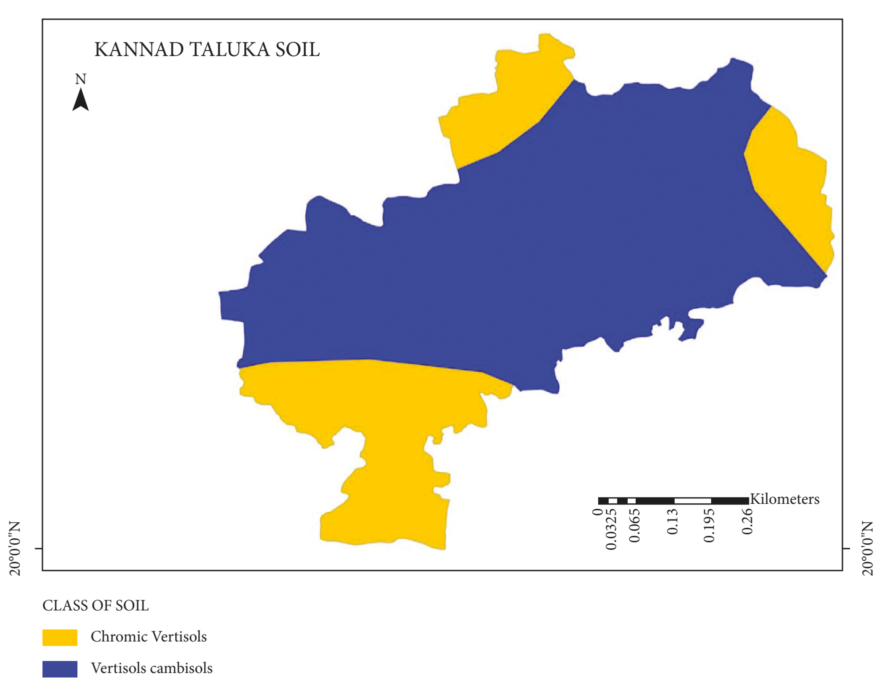

Figure 7: Soil map of Kannad taluka.

system was utilised in this study. Clay is the most common soil type in the Kannad, but clay-loam soil is also found in some areas [24]. Figure 7 depicts a soil categorization map for Kannad taluka. Table 2 shows soil classifications and their percentage in the study area.

5.5. Flow Direction. The corrected DEM (also known as the hydro-DEM) created in the preceding phase was utilised to determine the sharpest downward flow direction from each cell. This function generates flow direction codes for each cell using the D8 model, which specifies that, for each

Table 2: Soil type for Kannad taluka.

Sr. No.	Category	Soil class	Percentage (%)
1	Clay (chromic vertisols)	Vc 43-3ab	96.17
2	Clay loam (vertisols and cambisols)	Bv12-3b	3.83

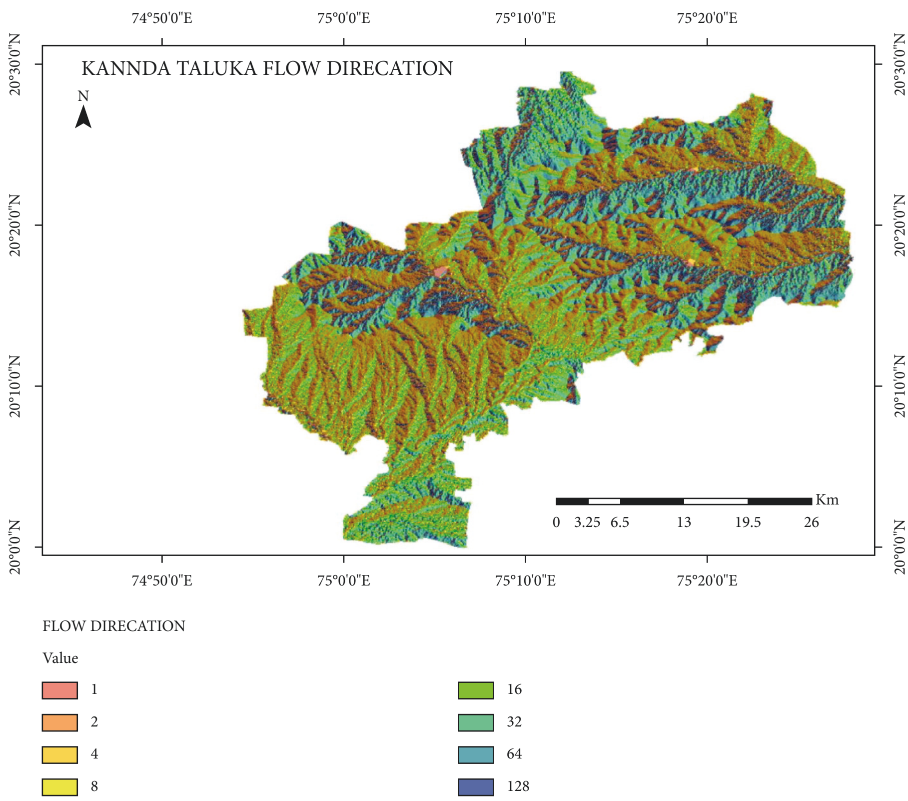

Figure 8: Flow direction map of Kannad taluka.

possible direction, seven values (1, 2, 4, 8, 16, 32, 64, and 128) were allocated (Figure 8).

5.6. Flow Accumulation. The accumulated flow is calculated using the weight of all cells flowing into each downslope cell in the output raster using the flow accumulation tool. If no weight raster is specified, each cell is given a weight of 1, and the number of cells that flow into each cell equals the value of cells in the output raster. From the flow direction grid, this function generates the flow accumulation grid. This function can be used to determine the upstream drainage area of a cell (Figure 9).

5.7. Stream Network. The stream within the study area forms the watershed and assembles a network of interconnected streams that lead to the outlet. The drainage system for the watershed is made up of streams. Drainage density, defined as the ratio of the total length of streams to the total area of watersheds, is used to evaluate drainage systems. A watershed with a high drainage density is well drained, and the opposite is true. Furthermore, the degree of watershed drainage is determined by the stream frequency, which is defined as the ratio of the total number of streams to the watershed area. Dendritic drainage is present in the watershed (Figure 10). A stream of the first order is 84.09 kilometer long, whereas streams of the second, third, and fourth orders are 44.75, 19.35, and 16.27 kilometer long, respectively (Table 3). The high bifurcation ratio, ranging from 1.734 to 2.017, indicates that the area is highly fragmented. The basin's mean bifurcation ratio is found to be 1.47. This suggests that structural disturbances have not had effect on the basin's drainage pattern. Table 1 displays the total length (L_t), mean length (L_m), and length ratio (R_l) of the Kannad basin's various stream orders. The form factor (F_f) of the Kannad taluka basin is 0.054, indicating that the length of the main stream and the combined lengths of streams of lower orders are significantly different. The watershed's low drainage density (D_d) in Kannad taluka (0.11) indicates that it is made up of permeable subsurface material, good vegetative cover, and low relief, resulting in greater infiltration capacity in the watershed. The frequency (F_s) value reveals a positive relationship between the drainage density in the basin and the number of streams,

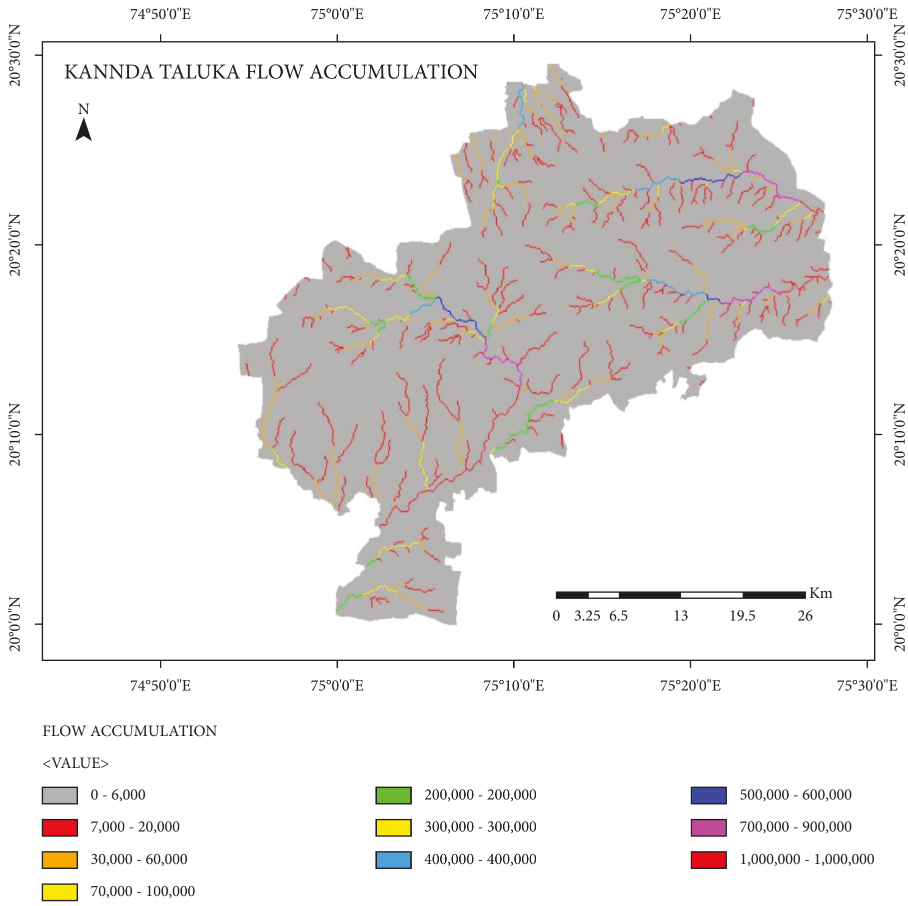

Figure 9: Flow accumulation map of Kannad taluka.

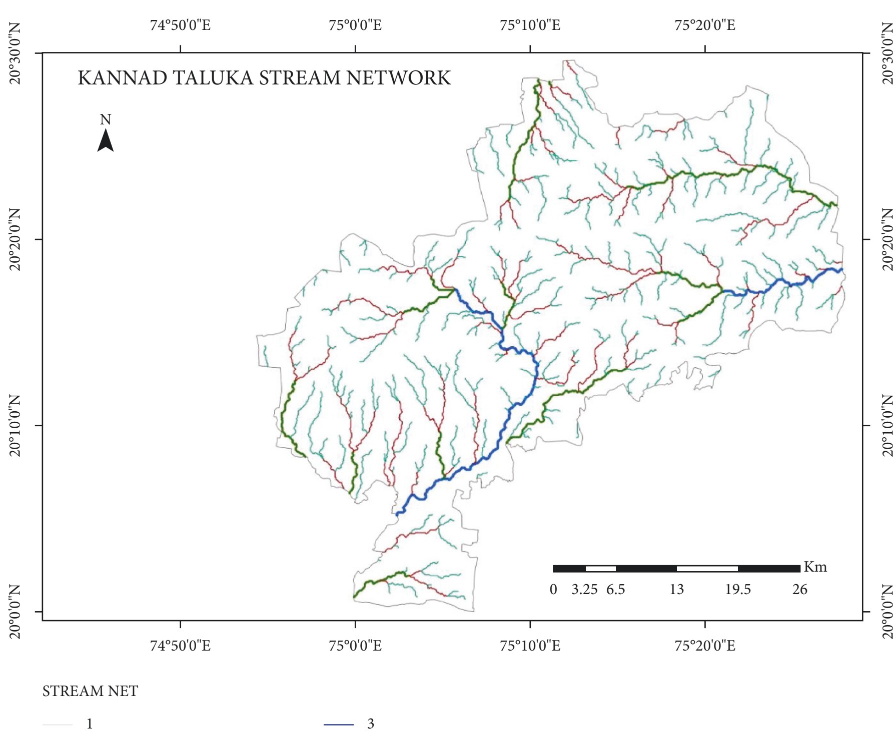

Figure 10: Stream network map of Kannad taluka.

Table 3: Aspects of Kannad taluka's watershed that are linear.

Stream order (w)	No. of streams (N_u)	Bifurcation ratio (R_b)	Mean bifurcation ratio (R_{bm})	Total length of streams (km)	Mean length of streams (km)	Length ratio (R_L)	Form factor (F_f)	Drainage density (D_d)	Stream density (D_s)	Frequency (F_s)
1	2919	2.017	1.47	84.09	0.03	1.0	0.054	0.11	0.664	0.004
2	1447	2.134		44.75						
3	678	1.734		19.35						
4	391	—		16.27						
Total	5435	5.885		164.45						

Mean length of streams (Lsm) = Lu/Nu, (R_b) = $Nu/Nu\ +1$, $D_d = Lu/A$, $R_L = Lu/(Lu{-}1)$, and $Fs = Nu/A$ [18].

Table 4: Slope classes of the study area.

Sr. No.	Slope category	Slope (%)
1	Level to nearly level	0–3
2	Very gentle sloping	3.1–7.8
4	Moderate sloping	7.9–14
5	Moderate steep sloping	15–22
6	Steep sloping	23–44

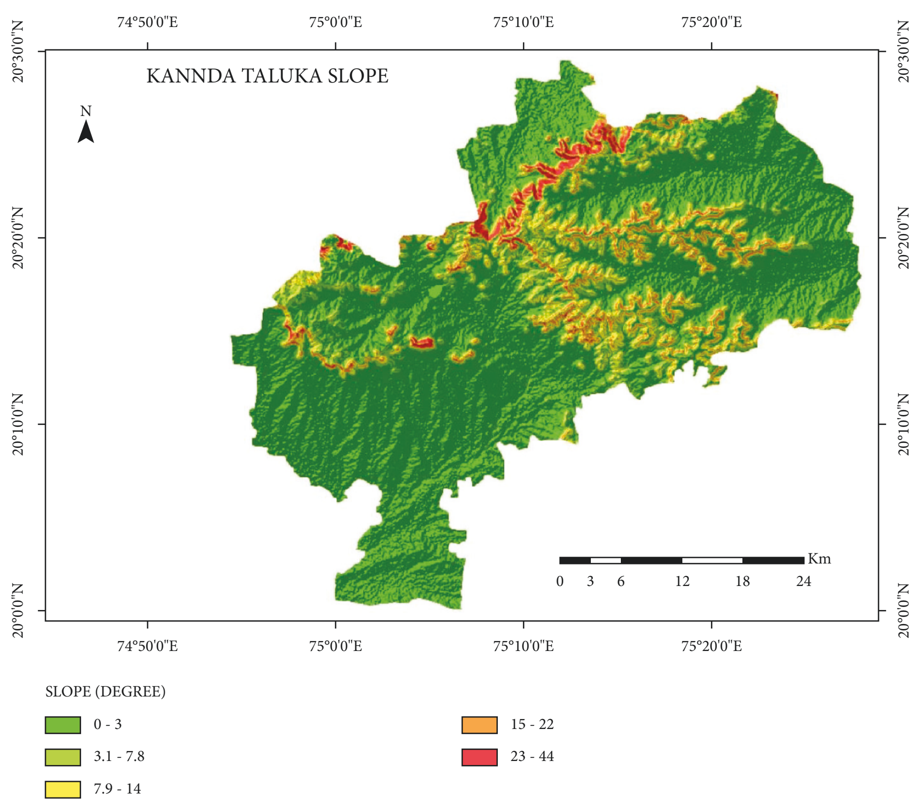

Figure 11: Map slope of Kannad taluka.

showing that, as the drainage density rises, so does the number of streams. The basin's measured F_s of 0.004 shows a positive relationship with the area drainage density value, indicating that increased drainage density leads to an increase in stream population (Table 3).

5.8. Slope. The term "slope" refers to a surface with one end or side that is higher than the other. It is a critical factor in determining the rate at which water mixes with soil and contributes to soil erosion. The vulnerability of soil erosion has been assessed using the slope of the surface in this model.

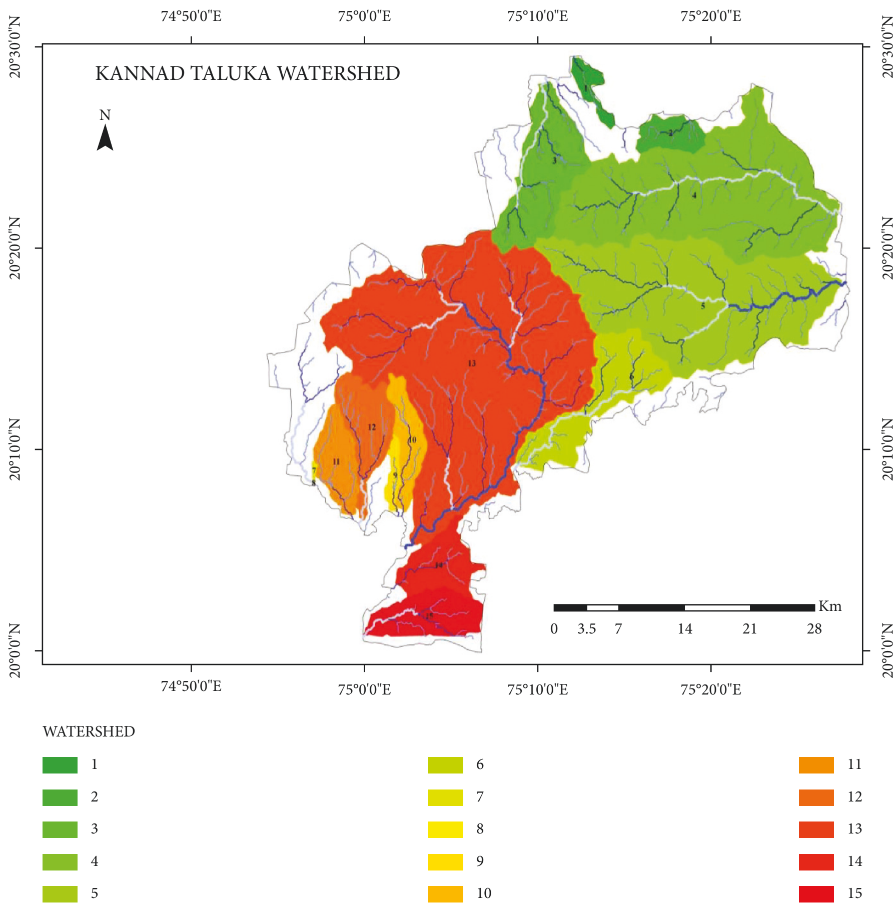

Figure 12: Map of the watershed of Kannad taluka.

The SRTM DEM was used to generate the data. Soil erosion is less common on very soft slopes, while soil erosion is more common on steep slopes. Slope is a crucial consideration for determining the terrain's nature. The degree of slope affects the command area's drainage characteristics and soil erosion. As shown in Table 4, the slope map has been further divided into several slope classes (Figure 11).

5.9. Watershed. A watershed is a small area with a well-defined borderline that drains rainwater into a single outlet. A watershed encompasses a variety of natural resources such as soil, water, and natural vegetation within its boundaries. There is also a stream system in place to drain the rainwater. The drainage system of a watershed is often known as the stream network. A gauged watershed is one that has hydrological parameters such as rainfall, runoff, and others that have been measured. Hydrological input data are critical for watershed hydrological studies. Shape, size, morphology, and other characteristics differ from one watershed to the next. Figure 12 depicts a view of the watershed.

6. Conclusion

The hydrological analysis demonstrates that the drainage network of the Kannad watershed is of the dendritic type, indicating homogeneity and reduction in the structural control, which aids in understanding topographical characteristics such as runoff and infiltration amplitude. It is possible to identify and understand terrain parameters such as infiltration capacity, bedrock, and surface runoff using a digital elevation model (DEM), a geographic information system, and remote sensing data, which aid in understanding the nature of the land for drainage management and the development of groundwater capabilities in order to plan watershed management in the region. The high bifurcation ratio, ranging from 1.734 to 2.017, indicates that the area is highly fragmented. The basin's mean bifurcation ratio is found to be 1.47. This suggests that structural disturbances have had no effect on the basin's drainage pattern. The form factor (F_f) of the Kannad taluka basin is 0.054, indicating that the length of the main stream and the combined lengths of streams of lower orders are significantly different. The watershed's low drainage density (D_d) in Kannad (0.11) indicates that it is made up of permeable subsurface material, good vegetative cover, and low relief, resulting in greater infiltration capacity in the watershed. Though the most part of Kannad taluka is hilly region predicting high surface runoff from the study area, because of vegetation cover, it displays a moderate flow rate, and at barren land, it shows comparatively high surface runoff. This study is useful for the development of natural water resource management in the protected forest area and useful for inhibiting wildlife in an area.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] A. Mirchi, D. J. Watkins, and K. Madani, "Modeling for watershed planning, management, and decision making," *Watersheds: Management, Restoration and Environmental*, Nova Science Publishers, Inc, New York, NY, USA, 2009.

[2] S. Elfert and H. Bormann, "Simulated impact of past and possible future land use changes on the hydrological response of the Northern German lowland "Hunte" catchment," *Journal of Hydrology*, vol. 383, no. 3-4, pp. 245–255, 2010.

[3] L. B. Leopold, *Hydrology for Urban Land Planning-A Guidebook on the Hydrologic Effects of Urban Land Use*, United States Department of the Interior, Reston, VA, USA, 1968.

[4] W. G. Coutu and C. Vega, "Impacts of land use changes on runoff generation in the East branch of the brandywine creek watershed using a GIS-based hydrologic model," *Middle States Geographer*, vol. 40, pp. 142–149, 2007.

[5] C. McColl and G. Aggett, "Land-use forecasting and hydrologic model integration for improved land-use decision support," *Journal of Environmental Management*, vol. 84, no. 4, pp. 494–512, 2007.

[6] M. Ali, S. J. Khan, I. Aslam, and Z. Khan, "Simulation of the impacts of land-use change on surface runoff of lai nullah basin in Islamabad, Pakistan," *Landscape and Urban Planning*, vol. 102, no. 4, pp. 271–279, 2011.

[7] S. Singh, K. Prakash, and U. K. Shukla, "Spatiotemporal migration of the river ganga in middle ganga plane: application of remote sensing and GIS technique," *Journal of the Indian Society of Remote Sensing*, vol. 48, no. 11, pp. 1495–1507, 2020.

[8] S. Kanhaiya, B. P. Singh, S. Singh, P. Mittal, and V. K. Srivastava, "Morphometric analysis, bed-load sediments, and weathering intensity in the Khurar river basin, central India," *Geological Journal*, vol. 54, no. 1, pp. 466–481, 2019.

[9] S. Singh, A. K. Singh, P. Kumar, and M. K. Jaiswal, "Morphotectonic analysis of the Bihar river, Madhya Pradesh, India," *Proceedings of the Indian National Science Academy*, vol. 87, no. 1, pp. 163–174, 2021.

[10] K. Prakash, D. Rawat, S. Singh, K. Chaubey, S. Kanhaiya, and T. Mohanty, "Morphometric analysis using SRTM and GIS in synergy with depiction: a case study of the Karmanasa river basin, North central India," *Applied Water Science*, vol. 9, pp. 13–10, 2019.

[11] S. Singh, K. Prakash, and U. K. Shukla, "Decadal scale geomorphic changes and tributary confluences within the ganga river valley in Varanasi region, ganga plain, India," *Quaternary International*, vol. 507, pp. 124–133, 2019.

[12] T. Everest, "Prioritization of Karamenderes basin's groundwater potential with morphometric analyses (in semi-arid climatic conditions Çanakkale, Turkey)," *Fresenius Environmental Bulletin*, vol. 27, 2018.

[13] M. Öztürk, N. K. Copty, and A. K. Saysel, "Modeling the impact of land use change on the hydrology of a rural watershed," *Journal of Hydrology*, vol. 497, pp. 97–109, 2013.

[14] H. W. Dotson and J. Handmer, "Watershed modeling with HEC-HMS (hydrologic engineering centers- hydrologic modeling system) using spatially distributed rainfall," *Coping with Flash Floods*, vol. 77, pp. 219–230, 2001.

[15] M. H. Alipour, A. Shamsai, and N. Ahmady, "A new fuzzy multicriteria decision making method and its application in diversion of water," *Expert Systems with Applications*, vol. 37, no. 12, pp. 8809–8813, 2010.

[16] D. R. Easterling, J. L. Evans, P. Y. Groisman, T. R. Karl, K. E. Kunkel, and P. Ambenje, "Observed variability and trends in extreme climate events: a brief review∗," *Bulletin of the American Meteorological Society*, vol. 81, no. 3, pp. 417–425, 2000.

[17] Y. Zeng, Y. Cai, P. Jia, and H. Jee, "Development of a web-based decision support system for supporting integrated water resources management in Daegu city, South Korea," *Expert Systems with Applications*, vol. 39, no. 11, pp. 10091–10102, 2012.

[18] E. F. Lambin, H. J. Geist, and E. Lepers, "Dynamics of land-use and land-cover change in tropical regions," *Annual Review of Environment and Resources*, vol. 28, no. 1, pp. 205–241, 2003.

[19] D. Ramsbottom and J. Wicks, *Catchment Flood Management Plans: Guidance on Selection of Appropriate Hydraulic Modelling Methods*, pp. 466–473, Environment Agency, Bristol, UK, 2003.

[20] M. E. Toriman, J. Othman, M. A. Khairul et al., "Modelling flood inundation in river catchment using hydraulic and geographical information system (GIS) simulation approach," *Journal of Engineering and Applied Sciences*, vol. 6, p. 428, 2011.

[21] S. Suganthi and K. Srinivasan, "Accuracy assessment digital elevation model generation and its application in landslide studies using cartosat-I," *International Journal of Geomatics and Geosciences*, vol. 1, p. 41, 2010.

[22] S. Li, G. Hu, X. Cheng, L. Xiong, G. Tang, and J. Strobl, "Integrating topographic knowledge into deep learning for the void-filling of digital elevation models," *Remote Sensing of Environment*, vol. 269, Article ID 112818, 2022.

[23] P. Singh, A. Gupta, and M. Singh, "Hydrological inferences from watershed analysis for water resource management using remote sensing and GIS techniques," *The Egyptian Journal of Remote Sensing and Space Science*, vol. 17, no. 2, pp. 111–121, 2014.

[24] H. Özcan, S. Aydemir, M. A. Çullu et al., "Vertisols," *In the Soils of Turkey*, Springer, Berlin, Germany, pp. 169–206, 2018.