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Impact Of Land Use Land Cover Change On The Godavari River Ecosystem In Nashik City: A Geospatial Analysis

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ABSTRACT
These changes were analyzed using geospatial methodology by employing Landsat Satellite data as well as GIS techniques such as remote sensing. The specific focus of the research covers the decades from 1980 to 2024, with prediction modeling for the year 2030. The QGIS and ARCGIS data processing show six classified LULC categories. Such categories are: vegetation, water bodies, barren land, and others. The region under study is the Nashik city which houses the Godavari River Ecosystem. The results indicate a notable urban expansion allied to the decline in the green cover and water bodies. The developed area is estimated to be 29.12% by 2030. Cropland stays steady at 43.13%, but rangelands are predicted to shrink to 23.44% and tree cover to 3.01% while water bodies further decrease to 1.30%. These patterns foreshadow increased environmental problems such as habitat destruction, poor water retention capacity, and a rise in susceptible floods. Thus, the investigation stresses the importance of sustainable planning to alleviate the negative effects, and promote environmental conservation as you focus on resource utilization. Employing geospatial tools allows for an efficient analysis of LULC change, and provides key information helps for policies and environmental decisions. This study aims to provide the necessary information that affects policy making regarding Godavari River basin and also facilitate integration of development with resource management overlooking the city of Nashik that is facing severe impacts of urbanization on natural resources and the river ecosystem.
Keywords: *- GIS Techniques, Remote Sensing, Godavari River, Land Use Land Cover (LULC), Satellite Data, Environmental Changes, Remote Data Processing*

1. INTRODUCTION

The quick growth of people's activities over the past few decades has dramatically changed the environmental conditions around the world, and much more so in sensitive areas. This has often been explained by unrestrained land use, deforestation, pollution, and rapid urbanization-the result of which is over-exploitation of resources as well as the changing face of natural systems to their detriment with biodiversity and public health suffering as a consequence [1]. One such case emerged with the deterioration of the Godavari river ecosystem in Nasik City, Maharashtra, India, due to spatiotemporal land use and land cover changes [2]. Therefore, it is essential that one analyzes these transformations, observes their impacts, and determines the necessary conservation measures. The use of such modern geospatial tools, such as GIS and Remote Sensing, is essential in the detection of environmental changes over time and serve as principal units in the process of creating and preserving nature. They enable a clearer analysis of how human activities affect the land cover and natural environment in terms of water bodies such as rivers [3]. Geospatial technologies of GIS and remote sensing have revolutionized the gathering, analysis, and interpretation of environmental data [4]. GIS is the seamless integration of spatial data from various sources and enables researchers to prepare highly detailed maps and models of a given area. Conversely, remote sensing employs satellite images and aerial sensors for data collection regarding the Earth surface [5]. Together, these technologies allow for the collection of accurate real-time data on environmental parameters such as vegetation cover, water bodies, and topography. In the classical methods of monitoring environment, manual mapping and field surveys are often time- and labor-intensive, less efficient for large scale changes. The integration of GIS and remote sensing allows for efficient processing of large datasets for land use land cover change detection over time. For instance, in Nashik, these instruments played a critical role in mapping the urban sprawl in and around the Godavari River and delineating areas of deforestation and urbanization that resulted in environmental degradation [6].

Great changes have been made in the Godavari River, which is located in Nashik City, thereby suffering a loss of integrity and character due to urban development, industrial development, and changing agricultural practices [7]. This influence from LULC changes directly impacts the river's hydrology, including flow conditions, sedimentation, and flood risks; for example, urbanization resulted in rough landscaping replacing the natural terrain with impervious surfaces like roads and buildings [6]. Urbanization has reduced the natural infiltration, thus increasing surface runoff, which in turn has the associated increased risk of flooding [8]. One of the major threats in the watershed is deforestation, which has led the soil toward more erosion and therefore increased rates of sediment entering the river at the cost of aquatic habitats [9]. Also, conversion of agricultural land to urban spans has created more rift in traditional water management practices that already exist in bad stock with the ecosystem of the river. The LULC analysis in a holistic way would be crucial in linking human actions and the health of the Godavari River [10]. Flooding is a recurring crisis in the area of the Godavari River that has far-reaching effects on the adjacent communities and ecosystems [11]. Disaster prediction and management greatly rely on the important role of GIS and remote sensing. GIS allows examining the river's catchment area and the identification of flood-prone areas based on environmental considerations, such as rainfall pattern, land cover, and topography [12]. In addition, the use of multi-temporal satellite data provides a system that enables one to monitor level and flow development in rivers in real time. Remote sensing gives very useful information about the spatial distribution of water and serves to visualize flood scenarios [13]. The potential applications include simulation of flood occurrences, predicting the effects on urban and rural areas during heavy rainfall, disaster preparedness, timely warning, and implementation of contingency measures [14]. The use of GIS and remote sensing is no less noticeable in Nashik, which aims to prepare flood-risk maps and evaluate areas prone to disasters along the Godavari River [15]. The integration of geospatial technology with sustainable environmental management is supposed to be the way forward. A detailed LULC analysis in the context of the Godavari River could assist policymakers and urban planners in striking a balance between development and conservation [16]. For instance, restoring vegetation cover over the river basin and implementing green infrastructure in urban regions will improve water absorption and reduce surface runoff. Sophisticated GIS software packages like ArcGIS allow for the amalgamation of different datasets for making an integrated model of river ecology [17]. These models can simulate the long-term effects of several land-use scenarios and assist the stakeholders in planning strategies for sustainable land use. Likewise, public awareness campaigns and community participation for conservation are of paramount importance [18]. Taking advantage of the potential of GIS and remote sensing in tandem with the right policy prescriptions can also minimize the impact of LULC changes and protect the Godavari River ecosystem for future generations. The Godavari River in Nashik City is a fine demonstration of the complex interaction between man's activities and the natural ecosystem [19]. The rapid change in land use and land cover is a big challenge threatening the health of the river, hydrologically and biologically [20]. However, the great advent of GIS and remote sensing technologies has delivered a powerful framework to examine such changes and provide sustainable solutions. Detailed mapping and modeling allow researchers and policymakers to identify the root of environmental degradation and design effective conservation strategies [21]. With the threat of growing urbanization and environmental afflictments, integrating geospatial analysis into environmental management will, therefore, be crucial in the preservation of the essential ecosystems like the Godavari River [22].

II. Material And Method

2.1 Study Area

Known to exist in Maharashtra, an important city on the banks of the river Godavari, Nashik is located in Latitude 19°33' N and Longitude 73°16' E, at an altitude of 565m above sea level [23]. It has become a fast-growing city due to its pleasant climate and natural surroundings. With urbanization spurred by an increase in population and industrialization, a number of environmental issues emerged within Nashik: air pollution, industrial dumping of wastes, and wastewater problems [24]. The city receives most of its rainfall during June to September, dotted by devastating showers, a phenomenon that adds to flooding risk, especially when extensive downpours come.

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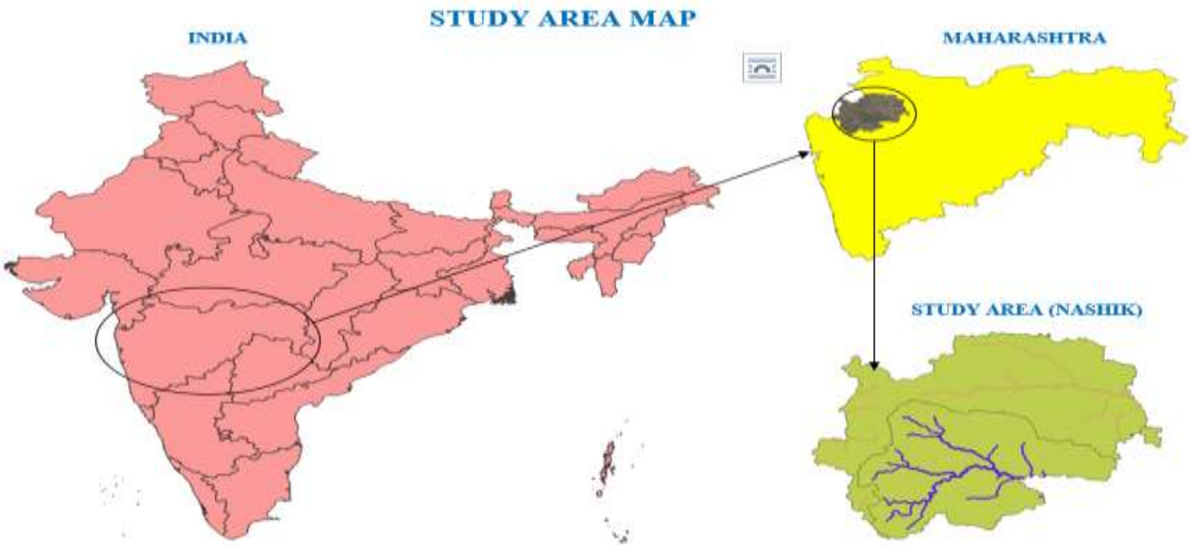


Fig 1. Study Area

The present research case study illustrates the application and uses of GIS approaches in flood analysis and prediction concerning the Godavari River [25]. Geographic Information Systems might help in delimiting the flood-prone areas, undertaking a topographic study, and estimating environmental impacts like urbanization within an area. For instance, through changes in land use and land cover, decision-makers can approach strategies to reduce the effects of flooding and pollution in Nashik through GIS. The study aims to bring forth better flood prediction models which would help in the environmental planning, as well as to act as a buffer against probably worsening industrialization and climate change. Insight into environmental dynamics through GIS could usher in an advent of better urban planning and disaster management strategies making Nashik more resilient to possible floods and environmental challenges.

2.2 Data Source and Method

In this study, multi-temporal satellite data will be fundamental in the detection of land use and land cover (LULC) changes along the Godavari from 2016-2021. The dataset for analysis was retrieved from the United States Geological Survey (USGS) Earth Explorer [26]. This platform provides users suitable satellite images from different time periods and locations free of charge for educational purposes. The first step in the analysis is downloading the data by visiting the Earth Explorer website (https://earthexplorer.usgs.gov), selecting the area of interest, and choosing the appropriate time zone. During data selection, one of the critical factors to check is cloud shadow: too much cloud cover will affect the quality of satellite images. For this study, the level of cloud cover was capped at 10% to ensure clarity of imagery.

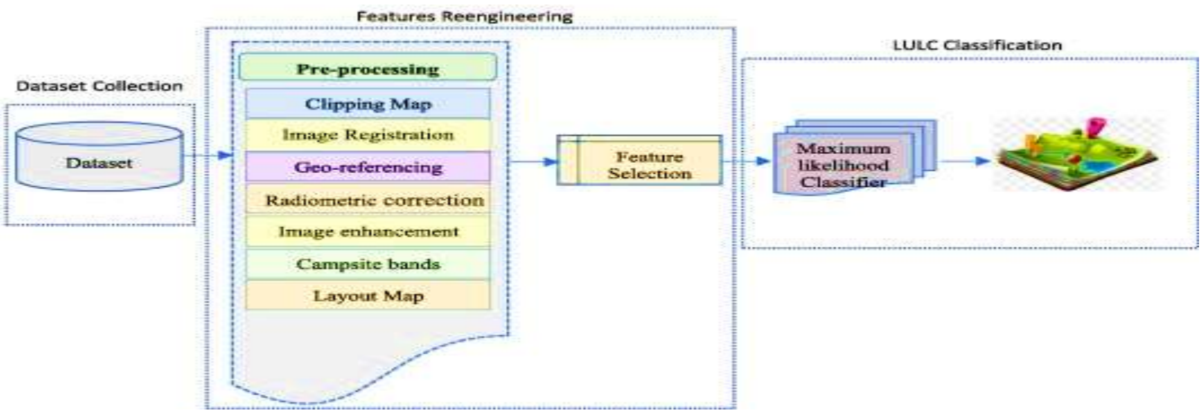


Fig 2. Method Flowchart

The process for analyzing the land use changes involves the use of GIS, remote sensing (RS), and Shannon's entropy techniques [27]. The Landsat images are first pre-processed using Erdas Imagine 2015 software, which includes layer stacking and mosaic processing to create multi-band composite images. These images undergo radiometric and geometric corrections for image enhancement. Approximately 125 ground control points (GCPs) were selected to ensure the accurate registration of the images to the Universal Transverse Mercator coordinate system. To minimize error, these GCPs were spread throughout the images, ensuring a root mean square (RMS) error of less than 0.5 pixels [28]. After resampling the images to 30-meter resolution using the nearest neighbor method and first-order polynomial fitting, the municipal boundaries of the study area were extracted using the 'Extract by Mask' function in the Spatial Analyst Tools module of QGIS 3.38.0 software [29]. This procedure facilitates precise analysis of LULC changes within the study area.

2.2.1 Loading and Processing

The first phase of flood analysis and prediction using GIS techniques is loading and processing raw data. In this case, the downloaded datasets are initially in .rar format; therefore, they must later be uncompressed for analysis. Upon extraction, the shape files are imported into the ArcGIS software, which is one of the most powerful GIS tools widely used for processing spatial data. ArcGIS must have a relevant folder for projects into which all files relating to the analysis can be imported. This ensures that all associated files, with their data and output results in a single working environment-also supporting easy access and better management of the project. Organized project files allow effective spatial analysis through maintaining links to related data.

2.2.2 Georeferencing Images

Often, the imported images do not reference a specific coordinate system or lack any spatial reference data altogether. This is where georeferencing comes to the fore. Georeferencing is the process of aligning the imported images to a specific coordinate system, for example, WGS 84, which is a standard global coordinate system [30]. This is done so that the spatial data can properly correspond in accordance with real-world locations for accurate analysis and mapping. In this research, georeferencing is establishing that all the satellite images and raster data are aligned onto the Earth's surface and thus capable of proper consistency and reliability in subsequent GIS analysis.

2.2.3 Processing and Clipping

Basically, the dataset imported into the ArcGIS environment is relatively large and possibly, in some cases, divided into tiles based upon satellite scenes. For Landsat, there are 185 x 185 km scenes to facilitate data downloading and processing. The study area of this research was the Nashik district, and it needed the release of or "clipping" out the data from a larger dataset [6]. By clipping, the analysis remained limited to the area of interest without having to consider what may appear to be irrelevant data obtained from the regions around it. This, hence, becomes pertinent to flood prediction and analysis, as complete and accurate information regarding the region helps ascertain more localized and therefore more correct results.

2.2.4 Selecting Method of Classification

The classification of datasets is a crucial step in analyzing land use and land cover (LULC) changes, especially when assessing their impact on the Godavari River ecosystem in Nashik City. The research utilizes Landsat datasets with resolutions ranging from 15 to 90 meters, where pixel values represent different landscape features [31]. To classify these datasets, two primary methods are considered: supervised and unsupervised classification.

- **Supervised Classification:** Supervised classification relies on user-defined classes based on reference data, requiring extensive expertise and a deep understanding of the study area. Although this method provides high accuracy, it demands considerable time and effort. Conversely, unsupervised classification is more automated, clustering pixels with similar characteristics without predefined classes. While slightly less accurate than supervised methods, it is faster and provides satisfactory results for large-scale studies.
- **Unsupervised Classification:** In this research, the unsupervised classification method was selected for its balance between efficiency and accuracy. This approach ensures the effective interpretation of LULC changes while minimizing time and resource constraints. The classified data forms the basis for

analyzing the dynamics of LULC changes and their subsequent impacts on the Godavari River ecosystem, aiding in informed decision-making for sustainable urban planning and conservation.

2.2.5 Carrying Out Unsupervised Classification

For LULC analysis of the Godavari River ecosystem, an unsupervised classification was performed using ArcGIS. Thus, the pixels are detected using voxel analysis, which detects certain characteristics like color, reflectance, and texture. The raster tools will be used to cluster pixels into distinct classes of LULC, such as water bodies, vegetation, and urban areas. This type of classification categorizes the dataset into meaningful classes upon which a geospatial analysis should be implemented. The results show trends for urbanization, loss of vegetation, or shrinkage of water bodies that unveil the ecological impact on the Godavari River. The outcome would substantially underpin sustainable planning and conservation strategies in a rapidly changing urban landscape in Nashik.

2.2.6 Preparing LULC Map for 1980-2024

The land use and land cover (LULC) changes map from 1980 to 2024 for the Godavari River ecosystem indicating how LULC changes affect the ecosystem will be prepared [32]. The classification process involves describing different land uses and applying dedicated colors or patterns to improve and aid with the map pictorial interpretation. The map is designed specifically for the purpose of this study in accordance with the requirements so as to avoid ambiguity. Although an overview is provided for the last four decades (1980–2024), this map gives insight concerning the LULC changes in Nashik with particular reference to urban sprawl and ecosystem changes. This spatial representation will serve as an important platform for future comparative analysis in order to subsequently assess the health and resilience of the river ecosystem against these alterations.

2.3 LULC Classification

Land Use and Land Cover (LULC) classification is among fundamental methodologies to flood analysis and representation, especially where the study attempted to assimilate urbanization and flood-prone areas. They also help with surface mapping and meaningful extraction of data. Changes in land cover over time are critical to the water runoff and drainage processes in the forecasting of floods. In this current study on the Godavari river, LULC classification was performed using the supervised maximum likelihood algorithm that relies on training sets provided by the user. The training sets used were based on visual interpretation from satellite images such as Landsat MSS/TM/ETM+/OLI and were effective in identifying individual land cover classes [33]. The accomplished visual interpretation using the False Colour Composite (FCC) images indicated clearly the land cover diversity throughout the study period. The classification process divided the area into five distinct land classes so as to incorporate urban growth, agricultural practice, and other environmental factors that may affect the flood behaviors. This examination of trends allows prediction of potential flood-prone zones and the quantification of the influences of urbanization and land cover change along the Godavari River upon the risks of flooding.

III. RESULTS AND DISCUSSION

From 1890 to 2024, changes in Land Use/Land Cover (LULC) of the Godavari river basin in Nashik City indicate profound changes that have directly influenced the river ecosystem. Past analysis suggests that gradual change from predominance of natural vegetation and water bodies in 1890 represented then-led urbanization and agriculture over the years. Satellite data indicate that by 1990 all urban sprawl and hotter agricultural processes were to bring a heavy impact on vegetation cover, with a modification in the drainage pattern causing reduction in the waterable area; hence, more surface runoff exists. Although this trend sped up to 2000, with built-up area expansion, the effects on barren land would indicate a shift towards a more managed land use. The unwarranted side effect of this urban sprawl exerted on the basin's natural hydrology. The urban expansions took place during the years 2010-02 and aggravated the ability of the ecosystem to control water flow, thereby increasing the flood risk and the threat to biodiversity. The destruction of the vegetated areas, coupled with the unrelenting extension of urban areas, by 2024 raised tangible problems for the sustainability of flood management and ecological balance. These findings highlight the urgency to develop comprehensive geospatial planning and sustainable land management techniques, aimed at reducing the negative impacts of land-use-land-cover changes on the Godavari River ecosystem in Nashik City.

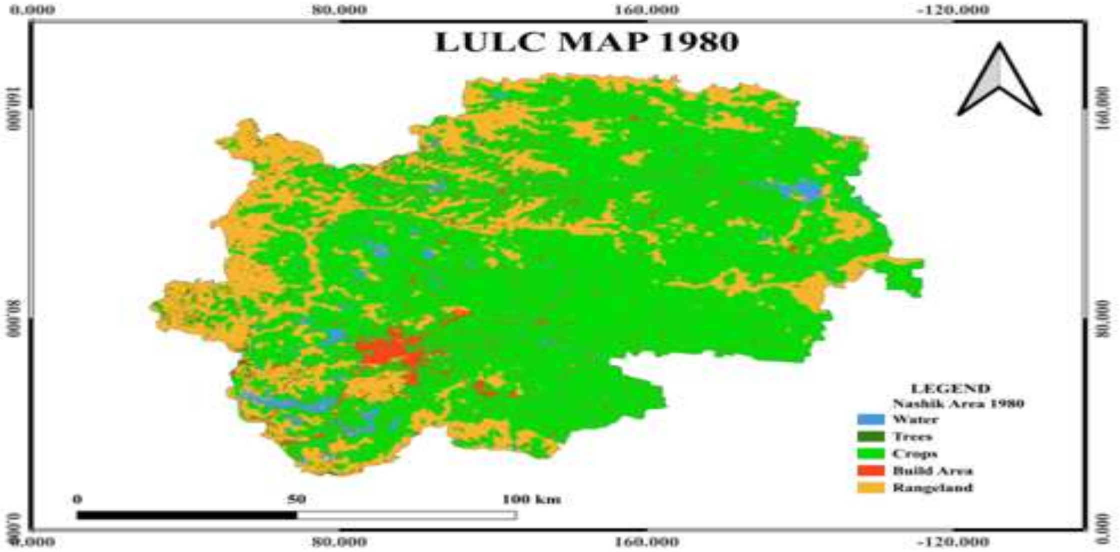


Fig 3. LULC Map 1980

The flood analysis and prediction of the Godavari River in 1980 highlight the significant impact of land use distribution on flood dynamics. During that period, 46.8% of the river basin was dedicated to agricultural crops, while rangelands made up 41.5%, indicating a landscape largely characterized by natural and semi-natural features. These land types played a crucial role in influencing water retention and runoff patterns, leading to a relatively stable hydrological system. Built-up areas were limited to just 3.80%, resulting in considerably less urban runoff compared to today's levels of urbanization. Trees, which covered 9.53% of the basin, were essential in reducing surface runoff and enhancing water absorption. Although water bodies were restricted to 3.37%, they affected local flood patterns by serving as temporary retention zones. In 1980, without the benefit of advanced GIS tools, traditional methods focused on analyzing natural factors like rainfall and river capacity. The existing land cover conditions had a strong influence on flood behavior, and employing modern geospatial techniques today could improve the accuracy of flood risk assessments, taking into account the changes in urbanization and ecosystem dynamics over the years.

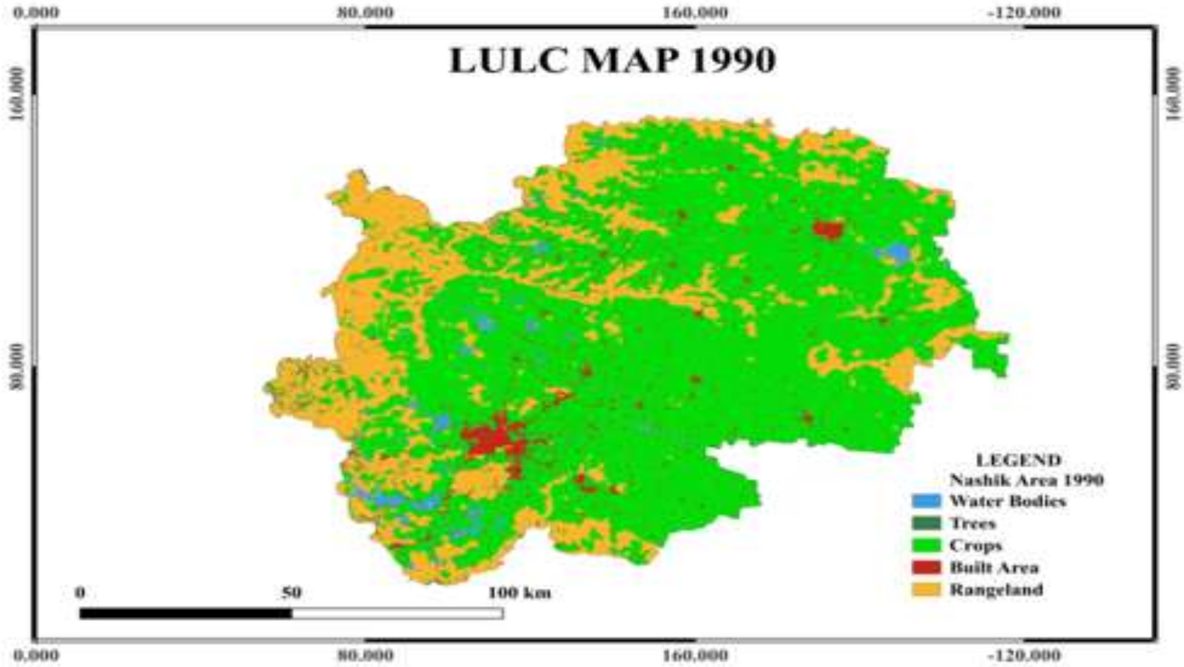


Fig 4. LULC Map 1990

The land use distribution and urban growth of Nashik City in 1990 significantly impacted the Godavari River ecosystem. Agricultural land, comprising 45.9% of the area, played a crucial role in water retention and reduced surface runoff. Rangelands, covering 33.95%, further supported this hydrological balance by influencing water absorption and runoff processes. Vegetation, accounting for 10.08%, mitigated surface runoff, enhancing groundwater recharge. Built-up areas, limited to 7.15%, resulted in lower urban runoff compared to present-day urbanization, thereby minimizing flood risks. Water bodies, occupying 3.93%, influenced local flooding patterns and water availability. This geospatial analysis provides critical insights into the interplay between land use changes and the river ecosystem, reflecting early urbanization's impact on Nashik's hydrology.

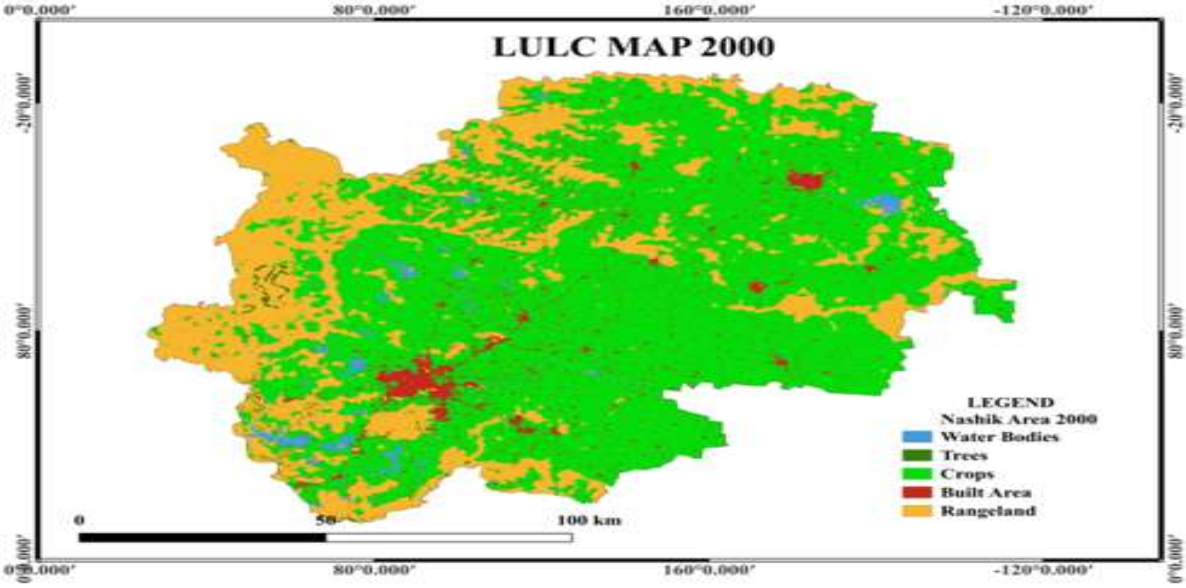


Fig 5. LULC Map 2000

In the year 2000, the land use and land cover of Nashik City were primarily agricultural, comprised of 40.19% of total area: secondly, 28.48% rangeland, which served for grazing and as open land; thirdly, trees occupied 6.50%, providing some vegetative cover that possibly reduced surface runoff and promoted water absorption. Built-up areas comprised 22.60%, indicating the early beginnings of urban expansion, with water bodies occupying only 2.23% of the space. This distribution marks the transitional period of Nashik from when urbanization took shape, but much of the landscape was still categorized as rural and agricultural. The historical LULC trends provide insight into the growth of urban development and their ecological consequences for the Godavari River ecosystem. The incidence of built-up areas has likely aggravated runoff levels, thereby reducing the rate of groundwater recharge, with the simultaneous reduction of agricultural and vegetative land claimed to interfere with the biological health of the river. Such changes can now be assessed accurately with modern geospatial techniques, and resultant outputs are of great assistance to city planners and sustainable river ecosystem management. Generally speaking, this analysis could help in strategies to alleviate the adverse impacts of urbanization on water retention, biodiversity, and flood management while permitting Nashik City to grow in a balanced manner in tandem with the Godavari River ecosystem.

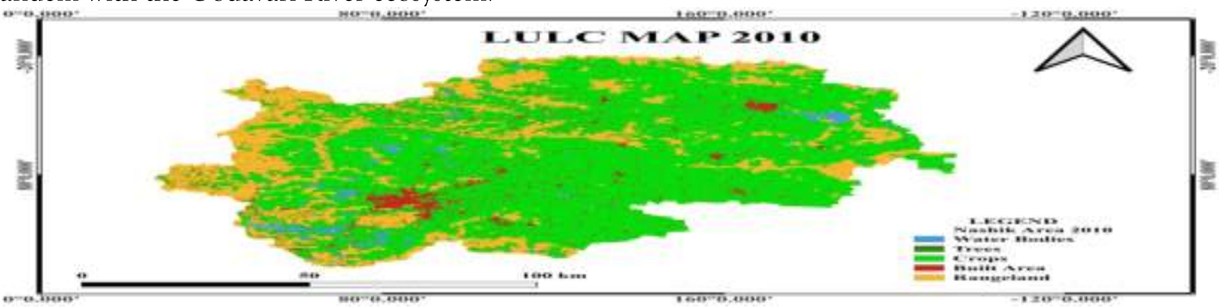


Fig 6. LULC Map 2010

Changes in land use and land cover (LULC) in the Godavari River ecosystem within Nashik City underscore the necessity for geospatial analysis to comprehend changing urban and environmental settings. The LULC of Nashik in 2010 shows the geographical trend with agricultural lands giving 36.22% of the area, although dominant, in terms of declining role. Rangelands constituted 32.13%, which denotes grazing and open spaces. Tree cover made up 5.45%, contributing to water retention and reduced runoff, vital for ecological balance. Built-up areas, making 24.11%, showed signs of urban expansion and infrastructure development in the city. Water bodies, with a total share of 2.09%, played an important role in the hydrological cycle, influencing flooding behavior and water storage capacity. This changeover from traditional land use to urbanized land has far-reaching effects in many ways, such as change in ways of flowing water, increase in flood risk, and further ecological degradation. Geospatial techniques provide an excellent tool for observing these changes for sustainable urban planning and environmental conservation measures.

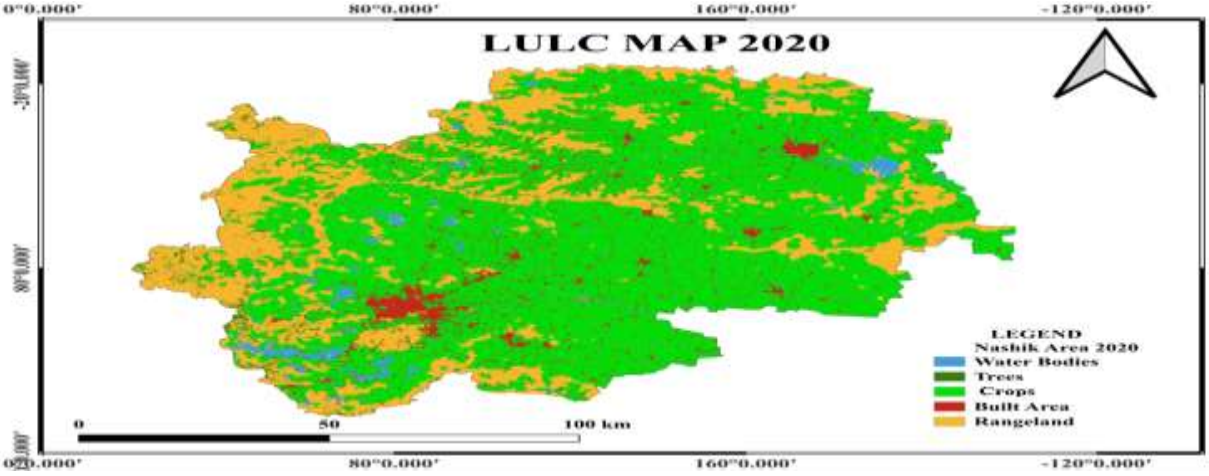


Fig 7. LULC Map 2020

Land use and land cover change (LULCC) dynamics within Nashik City had not drastically changed in certain terms until around the 2020 events influential on the Godavari River ecosystem and urban growth. Agriculture constituted 39.13% of the total land area and contributed to water retention and runoff behavior patterns. Rangeland comprised 30.73%, affecting the hydrology of the region. Vegetation played a great role in surface runoff regulation and enhancement of water absorption, thus aiding in flood mitigation, occupying land area only 3.92%. On the contrary, built-up area expanded from the 2020 area to 24.38%, thus posing patterns of rapid urbanization which led to increases in impervious surfaces, altered drainage patterns and increased runoff. Water, although occupying only 1.84%, is very important in the local hydrology and flood processes. The decline in vegetative cover and rise in space for urban settlements would have entailed a similar alteration in the Godavari River ecosystem, thus increasing the challenges in foretelling and managing floods. Nowadays, adequate geospatial tools, more advanced than in 1980, allow for proper evaluating the urbanization effects on hydrology and flood risks. Such advances suggest urgent considerations for sustainable land use planning and ecosystem conservation benefiting the river and urban land management. Such geospatial analysis provides key insights to mitigate adverse effects and enhance resiliency for Nashik City.

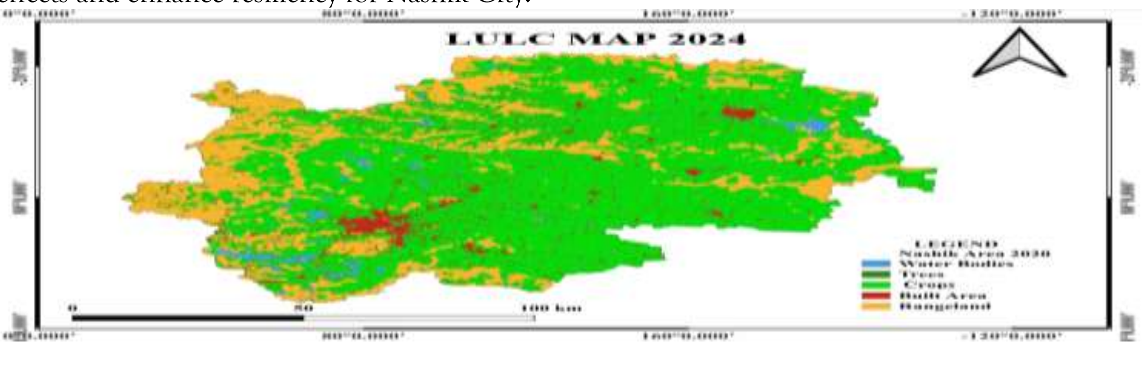


Fig 8. LULC Map 2024

The Land Use and Land Cover (LULC) data for Nashik city in 2024 reveals significant transformations in land patterns, with profound implications for the Godavari River ecosystem. Agriculture remains a dominant land use, covering 41.97% of the area, highlighting its importance to the region's economy and food security. Rangelands, encompassing 27.02%, indicate the presence of natural vegetation and grazing areas, which contribute to ecological balance. However, urbanization has surged, with built-up areas now constituting 26.03% of the land, leading to increased surface runoff and alterations in the local hydrology. The decline in tree cover, which now accounts for only 3.19%, reflects the growing pressures of urban encroachment, adversely affecting biodiversity and carbon sequestration. Water bodies, making up 1.79%, continue to play a critical role in regulating water flow and mitigating flood risks but are at risk of shrinkage due to land transformation. These LULC changes disrupt the natural processes supporting the Godavari River, leading to increased sedimentation, reduced water retention, and heightened flood risks. Effective management of urban expansion and conservation of natural resources is essential to preserve the ecological integrity of the river. Geospatial techniques offer invaluable tools for monitoring, analyzing, and predicting these changes, enabling proactive measures to mitigate their impact on the Godavari River ecosystem.

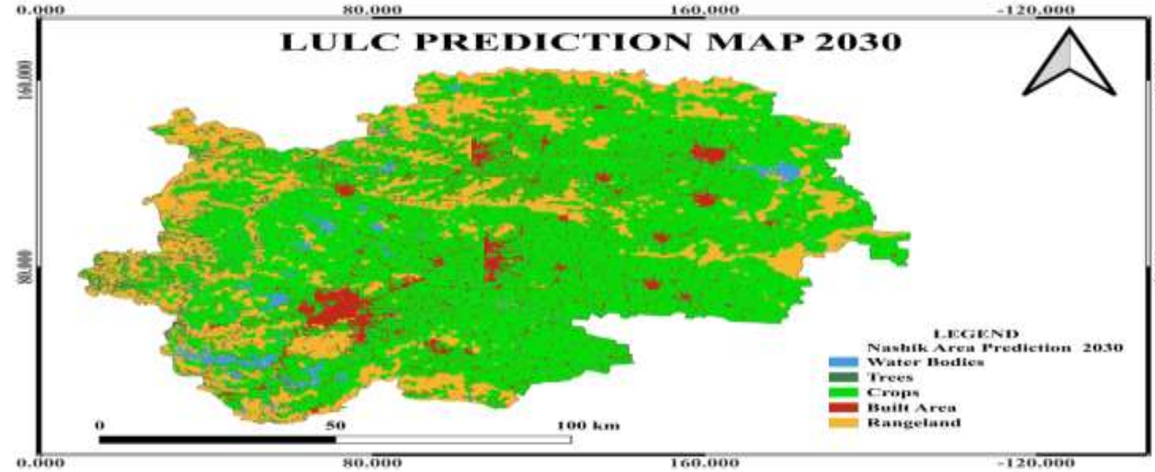
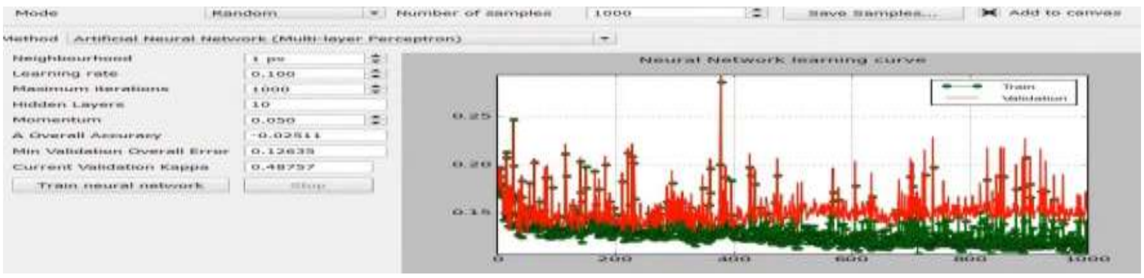


Fig 9. Predictive LULC Map 2030

The outlook for land-use and land cover (LULC) change in Nashik City by the year 2030 suggests a dramatic increase in urban areas and the relevant impacts such urban growth may have on the Godavari River ecosystem. Agriculture and crop land is expected to cover 43.13% of land, followed by rangeland at 23.44%, tree cover at 3.01%, and water bodies at 1.30%. The most striking change is a build-up by 29.12% representing an accelerated pace of urbanization. Such alteration has far-reaching consequences for the River ecosystem. The increase in impervious surfaces that accompany urban growth will likely result in increased water runoff and decreased groundwater recharge, further intensifying urban flooding. A decline in agricultural and rangeland areas naturally drains off water from the sinking landscapes. In spite of their small coverage, trees and water bodies have a contributing role in flood mitigation through water absorption and lessening the effects of extreme climate events. These dynamics of LULC suggest that adequate planning and construction of the future flood forecasting models are thus essential to guide lawful urban growth and maintain the river ecosystem. Geospatial analysis of these changes has thus gained a great deal of importance in guiding policy decisions for an acceptable balance between urban growth and environmental sustainability in Nashik City.



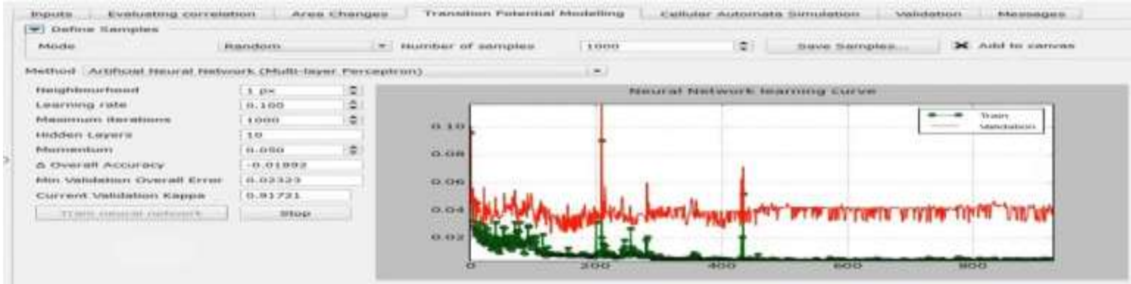


Fig 10. Learning Curves of a Neural Network Model

The Neural Network Model used in carried out predictive analysis in evaluation of the impact of land use and land cover (LULC) changes on the ecosystem of Godavari River in Nashik City is depicted in fig.10 above. These curves are used to depict the trends of training versus validation error throughout any number of iterations. A stabilizing trend starts exhibiting up to the point of reversal, indicating an improvement in model performance with the reduction of overfitting. The second chart showcases the training (green) and validation (red) errors that initially showed large fluctuations, probably indicating initial overfitting in training stage, where the network had weaknesses in its generalization of predictions. As iterations proceeded, the validation error seemed to stabilize, indicating improved model performance with reduced overfitting. This predictive analysis expresses their admiration for the use of machine learning in geospatial investigations. The spatial model has allowed the simulation of probable future alterations in LULC and their impacts on the runoff from urbanization and dampness retention due to the shrinking of agricultural land. Such useful predictions will inform future sustainable urban planning and flood mitigations for Nashik City. Lending urgency to all of this are the resolutions that do properly highlight the importance of digital modeling to understand and mediate the environmental consequences of LULC change in the Godavari River ecosystem.

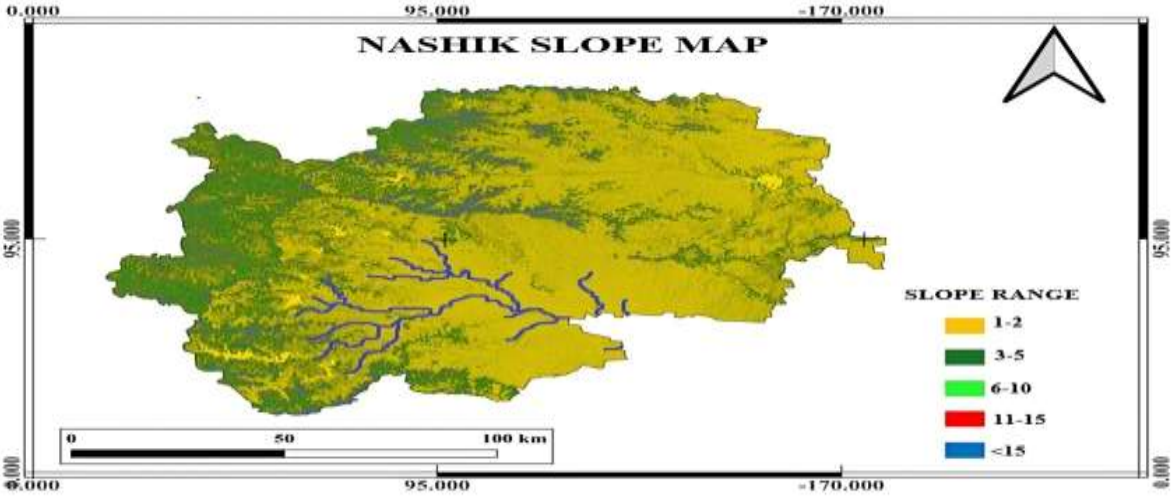


Fig 11. Nashik Slope Map

The Nashik slope map indicates variations in terrain elevation across the region, which significantly influences land use, land cover (LULC) patterns, and the Godavari River ecosystem. Areas with gentle slopes (1-2%) dominate the map, particularly in the central and eastern parts, suggesting suitability for agriculture and urban expansion. Moderately sloped regions (3-5%) are present in scattered patches, supporting mixed vegetation and infrastructure. Steeper slopes (6-10% and above) appear concentrated in the western and southern areas, limiting construction and promoting forest preservation. Changes in LULC, such as deforestation or urban sprawl on critical slopes, can accelerate soil erosion and alter natural drainage, impacting the Godavari River's flow, sediment load, and water quality. Sustainable land management practices are essential to mitigate these effects and protect the river ecosystem's health in Nashik City. Geospatial tools provide vital insights into how topography influences these environmental changes.

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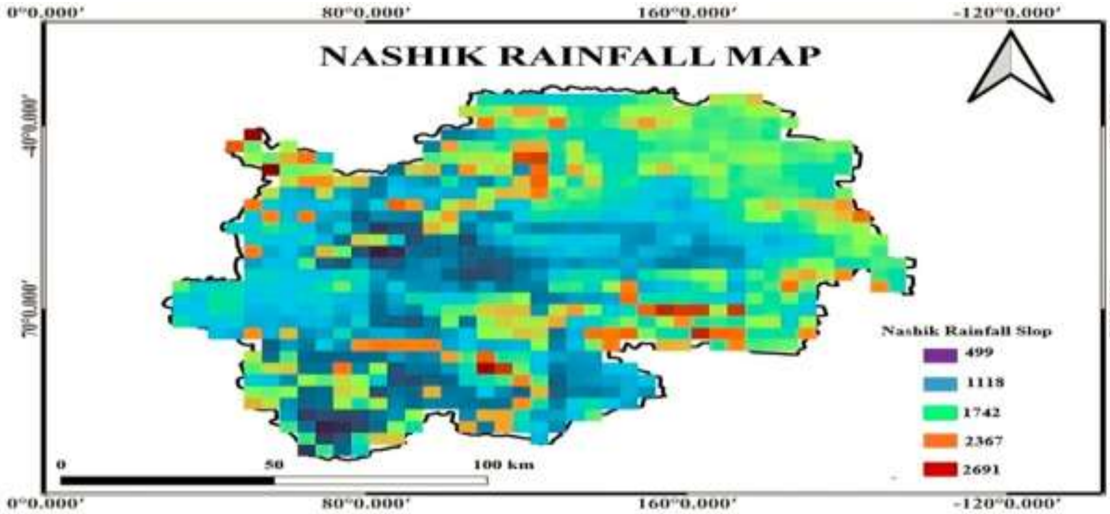

Fig 12. Rainfall Map Nashik

The Nashik rainfall map fig.12 illustrates spatial variability in annual precipitation across the region, which directly impacts land use and the Godavari River ecosystem. The map shows lower rainfall areas (around 499 mm) in the central and southeastern zones, which are more prone to drought and reduced vegetation cover. In contrast, higher rainfall regions (up to 2691 mm) are concentrated in the northern and western parts, fostering dense vegetation and natural recharge of water bodies. Variability in rainfall distribution affects surface runoff, soil moisture, and groundwater recharge, influencing agricultural practices and urban water management. Excessive rainfall in some areas may lead to erosion and increased sediment transport into the Godavari River, altering its ecosystem balance. Conversely, insufficient rainfall can result in reduced river flow, affecting aquatic habitats. Understanding these rainfall patterns is essential for planning sustainable land use practices and conserving the river ecosystem in Nashik City.

4.1 Year Wise LULC Comparison

Table 1. Year Wise LULC Comparison

Classes	Year 1980 (%)	Year 1990 (%)	Year 2000 (%)	Year 2010 (%)	Year 2020 (%)	Year 2024 (%)	Year 2030 (%)
Crops	46.8	45.9	40.19	36.22	39.13	41.97	43.13
Rangeland	36.5	33.95	28.48	32.13	30.73	27.02	23.44
Trees	9.53	10.08	6.50	5.45	3.92	3.19	3.01
Built Area	3.80	7.15	22.60	24.11	24.38	26.03	29.12
Water Bodies	3.37	3.93	2.23	2.09	1.84	1.79	1.30
Total	100%	100%	100%	100%	100%	100%	100%

The land use and land cover (LULC) dynamics of Nashik city from 1980 to 2024 have been evaluated to understand the urban growth trends, using geospatial techniques. This evaluation includes year-wise comparisons of various land cover classes such as Crops, Rangeland, Trees, Built Area, and Water Bodies, providing a comprehensive picture of the transformation of the landscape over time. The data, as presented in Table 1, reveals significant trends in LULC changes that can be utilized to predict future urban growth.

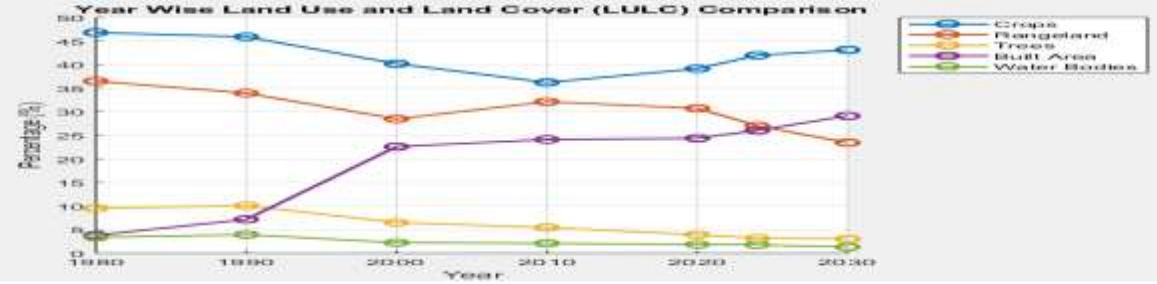

Fig 11. Year Wise LULC Comparison

The Godavari River ecosystem in Nashik city has undergone considerable change owing to land use and land cover changes over these four decades. The landscape was mainly characterized by cropland (46.8%), rangeland (36.5%), trees (9.53%), built-up area (3.8%), and water bodies (3.37%). In 2020 cropland reduced to 39.13% while built- up area enjoyed a growth of 26.03%, thus denoting a rapid rise in the rate of urbanization of the city. The urban infrastructure and population increase resulted in a drastic decline of rangeland (27.02% by 2024), denoting an ongoing encroachment of natural landscape for urban development. Despite slight recoveries in cropland, which accounted for 41.97% in 2024, the ongoing urban expansion faced challenges against the river ecosystem by affecting its hydrological balance and biodiversity. Future projections for 2030 indicate an increase of 29.2%, premised on the guidelines of continuous urban growth. Further, cropland could improve slightly to 43.13% whereas rangeland and tree cover may go down to 23.44% and 3.01%, respectively. The water bodies, though relatively stable, could decrease slightly due to land reclamation. These trends indicate the compelling need for urban sustainability planning to avert negative impacts on the Godavari River ecosystem. It would involve strategies such as the preservation of green spaces, restoration of water bodies, and the promotion of eco-friendly urban designs, which would ensure a sustainable balance of the development and thrust environmental protection in Nashik city, putting the river's ecologic status on an even keel for many generations to come.

CONCLUSION

The Godavari River ecosystem in Nashik City is a scenario that has seen substantial change in land use and land cover (LULC) between 1980 and 2024. Urbanization has greatly influenced the changes over the last 40 years. The built-up area rose dramatically from a mere 3.8% in 1980 to 26.03% in 2024, indicating rapid population growth and infrastructure development. In contrast, agricultural land has seen a decrease, from 46.8% in 1980 to 39.13% in 2020; slight signs of recovery are observable by 2024. It is paralleled with a gradual loss of rangelands, which fell from 36.5% to 27.02%, as well as an alarming degradation of tree cover corresponding to a drop from 9.53% to only 3.19%. Water bodies have remained relatively stable though still have decreased from 3.37% in 1980 to 1.79% in 2024, raising alarmingly worried heads over water resource management. The changes are having a serious toll on the Godavari River ecosystem-a rise in flood hazards, reduced groundwater recharge, and threaten to biodiversity. The urban area is projected to expand further till 2030 with built-up areas projected to be 29.12%. At the same time, cropland is likely to remain at 43.13% and further reductions in rangelands and tree cover at 23.44% and 3.01%. The expected health of the water bodies, crucial for the river, is at an anticipated low of 1.30%. These developments make it evident that sustainable practices of urban planning should be instituted to avert environmental degradation. Geospatial tools like GIS and remote sensing are key to such changes, and hence may provide crucial inputs for informing better decisions. This will balance the development and the preservation of the Godavari River ecosystem for the future by making the use of these technologies in the urban planning process in Nashik City.

Statements and Declarations

Ethical Approval

"The submitted work is original and not have been published elsewhere in any form or language (partially or in full), unless the new work concerns an expansion of previous work."

Consent to Participate

"Informed consent was obtained from all individual participants included in the study."

Consent to Publish

"The authors affirm that human research participants provided informed consent for publication of the research study to the journal."

Author Contributions

"All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Megha Kokate] and [Dr. Ravi Kant Pareek]. The first draft of the manuscript was written by [Megha Kokate] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript."

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