OPEN ACCESS Freely available online

Journal of Geography & Natural Disasters

Research Article

Role of GIS in Study of Sustainable Development and Environmental Management

Arun Kumar Maurya[1*], Abhishek Kumar[2]

[1]Department of Geography, Cane Societies Nehru PG College, Uttar Pradesh, India; [2]Department of Geography, Jawaharlal Nehru University, New Delhi, India

ABSTRACT

Geographic Information Systems (GIS) are essential for environmental management and sustainable development as they facilitate the analysis of spatial data and enhance decision-making processes in domains such as disaster mitigation, urban planning, climate adaptation, and natural resource management. This chapter examines the primary functions of GIS in these fields, emphasizing its efficacy in integrating diverse information and promoting sustainable solutions in environmental management and sustainable development. Despite its potential, widespread adoption is hindered by challenges including cost, technological complexity, data availability, and ethical considerations. To effectively leverage GIS for global sustainability initiatives, these obstacles must be addressed through collaboration, funding, and capacity building.

This research article examines the many uses of GIS in sustainable development and environmental management, such as monitoring pollution and tracking sustainable development goals, managing natural resources, conserving biodiversity, responding to disasters, and mitigating the effects of climate change. It illustrates how GIS helps create a more resilient and sustainable environment using a mix of innovative methods and real-world examples. The research article also highlights the important role that geographic information systems play in accomplishing SDG goals by offering data-driven insights into infrastructure development, urban planning, and resource allocation.

Keywords: Geographical information system; Sustainable development; Environmental management; Disaster risk; Climate adaptation

INTRODUCTION

The integration of geography and technology through Geographic Information Systems (GIS) has transformed our approach to spatial data management. GIS offers robust solutions for gathering, examining, and displaying information about Earth's surface. This technology empowers users to identify patterns, connections, and developments across diverse disciplines by providing advanced tools to handle geographical data. Like Geography GIS is also hard to define however there are some definitions that are agreed by most of the scholars. According to the National Centre of Geographic Information and Analysis “A GIS is a system of hardware, software and procedures to facilitate the management, manipulation, analysis, modeling, representation and display of georeferenced data to solve complex problems regarding planning and management of resources”. Geographic Information Systems (GIS) are a sophisticated set of computer-based tools utilized for the collection, storage, manipulation, analysis, and display of spatially referenced information. These systems transform data into knowledge and present this information in various formats to facilitate decision-making processes. While GIS is often portrayed as an objective, knowledge-based technology, it is, in fact, a socially constructed technological framework [1]. The process of GIS production, encompassing data creation, analysis, visualization, and utilization of GIS output, is influenced by political, economic, and social factors that introduce inherent biases into their application.

Geographic Information Systems (GIS) have emerged as an essential tool for sustainable development, providing robust methodologies for the acquisition, management, and analysis of spatial data. As early as the 1970s, "sustainability" was employed to describe an economy "in equilibrium with basic ecological support systems.” Ecologists have pointed to The Limits to Growth, and presented the alternative of a “steady state economy” in order to address environmental concerns [2]. Sustainable development, as defined by the Brundtland Commission, refers to "development

Correspondence to: Arun Kumar Maurya, Department of Geography, Cane Societies Nehru PG College, Uttar Pradesh, India, E-mail: draruncsn@gmail.com

Received: 16-Nov-2024, Manuscript No. JGND-24-35237; **Editor assigned:** 19-Nov-2024, PreQC No. JGND-24-35237 (PQ); **Reviewed:** 04-Dec-2024, QC No. JGND-24-35237; **Revised:** 11-Dec-2024, Manuscript No. JGND-24-35237 (R); **Published:** 18-Dec-2024, DOI: 10.35841/2167-0587.24.14.326

Citation: Maurya AK, Kumar A (2024). Role of GIS in Study of Sustainable Development and Environmental Management. J Geogr Nat Disasters. 14:326.

that meets the needs of the present without compromising the ability of future generations to meet their own needs," and relies heavily on informed decision-making processes. The United Nations has established 17 sustainable development goals to direct international development initiatives through 2030. These are founded on three interrelated pillars: environmental sustainability, social sustainability, and economic sustainability. Their goal is to balance environmental preservation, social inclusion, and economic growth. In this sense, geographic information systems can be extremely helpful in understanding local disparities and inequalities, communicating SDG progress in relation to a specific region, promoting community involvement, and thwarting false information by providing reliable data and maps. GIS functions as a critical interface between environmental, social, and economic data, enabling policymakers and stakeholders to formulate solutions that effectively balance human requirements with environmental conservation.

Environmental management constitutes a critical component in the global endeavor to ensure the long-term sustainability of natural resources and ecosystems. In an era characterized by unprecedented environmental challenges-ranging from deforestation and biodiversity loss to climate change and pollution-advanced tools are essential for monitoring, analyzing, and managing natural systems effectively. Geographic Information Systems (GIS) have emerged as one of the most powerful technologies for addressing these complex issues. GIS integrates spatial data with sophisticated analysis tools, enabling users to capture, visualize, and interpret environmental information in ways that enhance decision-making processes. From tracking deforestation to monitoring air and water quality, GIS provides a comprehensive perspective on the interactions among environmental factors, thereby empowering policymakers, environmentalists, and researchers to implement informed actions.

MATERIALS AND METHODS

Component of geographical information system

A Geographic Information System (GIS) is a framework for gathering, managing, and analyzing spatial and geographic data. The primary components of a GIS are [3]:

Hardware: The physical devices utilized for input, processing, and output of GIS data, including computers, servers, GPS devices, scanners, and printers.

Software: GIS software is employed to manage, analyze, and visualize spatial data. Prominent GIS software includes ArcGIS, QGIS, and MapInfo. These programs facilitate mapping, querying, and spatial analysis.

Data: The fundamental element of any GIS. It encompasses both spatial data (geographic locations, such as maps, satellite images, and aerial photographs) and attribute data (descriptive information about the spatial features, such as population, land use, or temperature).

People: GIS users, ranging from data collectors to analysts, who interact with the system to manage data, perform analysis, and make decisions based on spatial information.

Methods: These comprise the techniques, workflows, and procedures utilized to collect, process, and analyze spatial data in a consistent and standardized manner as shown in Figure 1.

In the context of sustainable development and environmental management, Geographical Information System (GIS) is an important tool to collect, analyze and visualize spatial data to make informed decisions. GIS component that assists to these areas given below:

- Data collection and management through remote sensing, data integration and geospatial data storage and access.
- Environmental analysis and modeling, which includes ecological modeling, climate change modeling and resource assessment.
- Decision support and policy-making through sustainable urban and regional planning, Multi-Criteria Decision Analysis (MCDA) and impact assessment.
- Monitoring and evaluation which involves environmental quality monitoring, land use and land cover change detection and SDG progress tracking.
- Mapping and visualization by thematic mapping, interactive dashboard and 3D and temporal visualisation.
- These GIS components are important for tackling the complex issues of environmental management and sustainable development, assisting people, scientists and policymakers in collaborating to save ecosystems and enhance quality of life.

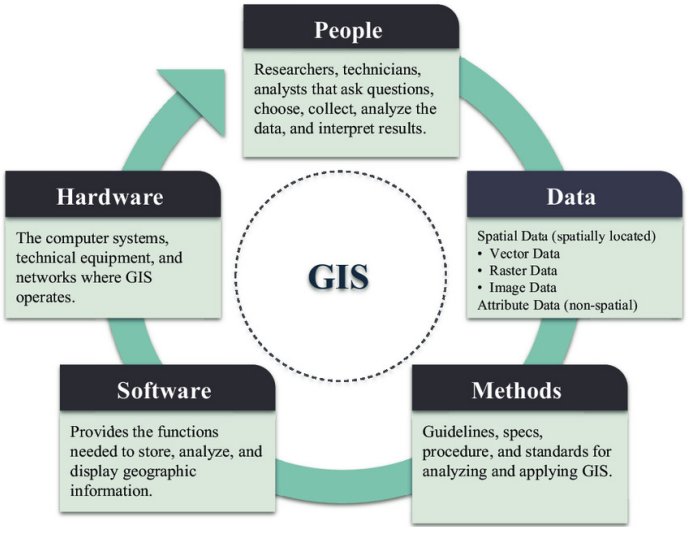

Figure 1: Components of geographical information system [3].

Role of GIS in sustainable development

Geographical Information System (GIS) plays an important role in sustainable development goals. It pertains to the utilization of geographic information and technologies, such as satellite imagery, Geographic Information Systems (GIS), and Global Navigation Satellite Systems (GNSS)/Global Positioning Systems (GPS), to acquire, analyze, and visualize data related to the Earth's surface for the purpose of examining and illustrating spatial patterns, trends, and relationships. One of the primary advantages of geospatial technology is its capacity to assist policymakers and planners in making informed decisions regarding land use, resource management, and infrastructure development. Geospatial technology can provide insights into the potential impacts of development projects on the environment, economy, and society through the mapping and analysis of data on parameters, such as population density, land cover, and natural resources [4]. Furthermore, geospatial technology has the potential to precise allocation of resources and enhance the efficiency of public services. A most important component of sustainable development is the judicious utilization of resources. For instance, through the analysis of traffic flow patterns and population density, urban planners can ascertain the most efficacious locations for public transportation routes and facilities.

Environmental, social, and economic phenomena are inherently spatial in nature. All given processes are the inherent component of sustainable development. It is challenging to fully comprehend these phenomena without considering their spatial dimensions. Given that the environment is characterized by the topographical relationships among physical entities (such as the soil or air composition in a specific spatiotemporal location, or the solar radiation on a given parcel of land), and because human activities exert spatial impacts on the environment, it is not feasible to accurately depict the relationship between humans and the environment without referencing a specific geographical context as shown in Figure 2 [5,6].

Urban planning and smart cities

As cities around the world evolve to become more intelligent, sustainable and efficient, Geographical Information Systems (GIS) are becoming an essential tool in the formulation of urban development. Smart cities rely on technology to optimize resources, improve infrastructure and improve the quality of citizens' lives [7]. It facilitates the gathering, processing, and display of enormous volumes of geospatial data, which in turn helps planners make well-informed choices on infrastructure, transit, land use, and environmental concerns, eventually promoting more sustainable and effective urban development as shown in Figure 3 [8].

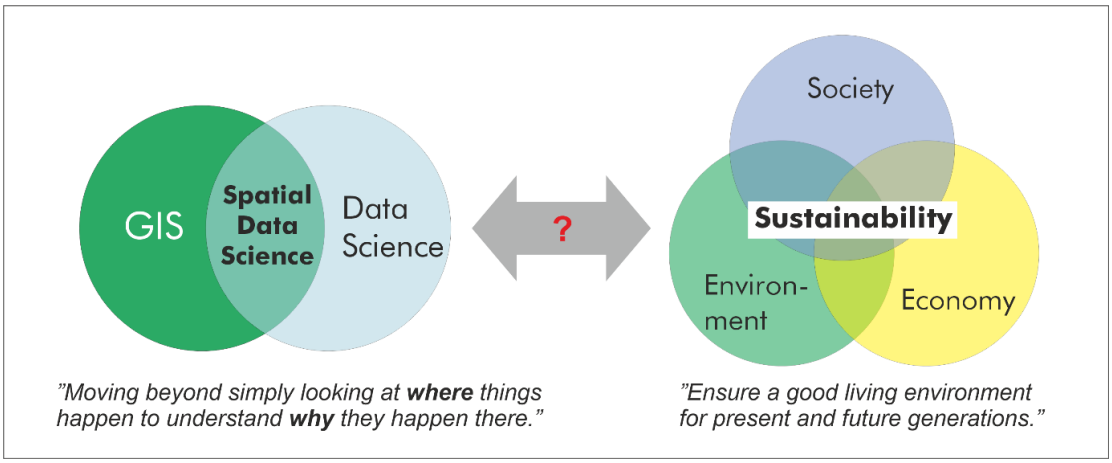

Figure 2: Two main components of the course: Spatial data and sustainable development [6].

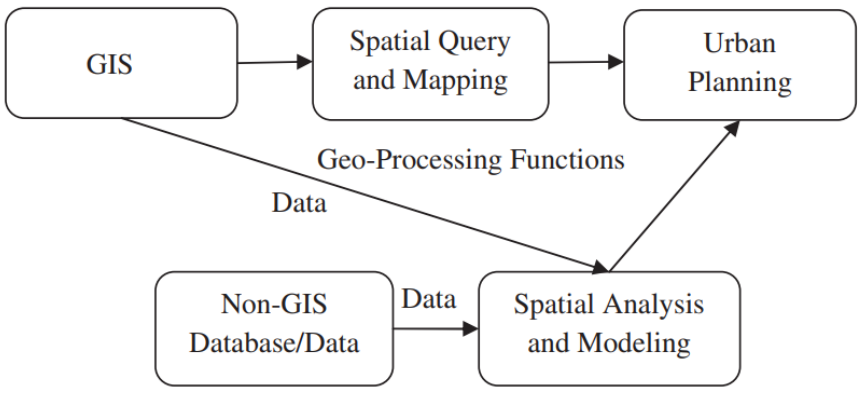

Figure 3: Integration of GIS, spatial analysis, and data for urban planning through geoprocessing functions [8].

There are numerous applications of GIS in urban planning and smart cities development but some of the important application given below:

- Mapping the Infrastructure and Utilities- Cities can use GIS to produce intricate maps of their communication networks, water pipes, electrical grids, and roadways. By highlighting locations in need of upkeep or improvements, this aids in effective infrastructure management. Cities can also guarantee improved departmental collaboration and avoid conflicts during development by superimposing various infrastructure networks [7]. For example Singapore`s Smart Nation Initiative extensively uses GIS in urban mapping.
- Integration of GIS with Internet of Things (IoT): The creation of smart cities has been transformed by the combination of GIS and the Internet of Things (IoT). IoT sensors placed across cities gather data on public safety, energy use, traffic, and weather in real time. GIS is then used to evaluate this data and produce useful insights that can enhance city operations.
- Smart traffic signals, for instance, can modify timings in response to real-time traffic data, which eases congestion and enhances vehicle flow. In a similar vein, cities may optimize power consumption and lower their carbon footprint by using GIS and IoT devices to monitor building energy use [7].
- Improving mobility with real-time traffic and transportation management: Controlling traffic and making sure that transportation is efficient are two of the biggest problems facing modern cities. City officials can spot bottlenecks, manage public transit lines, and track traffic trends in real time with the aid of GIS. Cities may create intelligent transportation systems that cut down on emissions, shorten commutes, and encourage the use of electric or bicycle-powered cars by evaluating spatial data [7]. For instance, Amsterdam utilizes GIS in real-time traffic management.

RESULTS AND DISCUSSION

Land use and resource management

GIS plays a significant role in land use and resource management by providing tools for mapping, analyzing and planning optimal use of land and natural resources. Geographical information system integrates the spatial and geographic data. By this integration, the decision-making process for sustainable development, environmental conservation and resource management have made. Natural resources management is indispensable in ensuring environmental sustainability and reducing the risk associated with climate change and increasing demand for ecological goods and services [9]. There are countless applications of GIS in land use and resource management, however some of them given below:

- Watershed management: Watershed management is one of the main areas where GIS is used in land use and resource management. A watershed's state, including elements like topography, land use patterns, and water quality, can be evaluated using GIS. These evaluations are essential for creating management plans that work. This is especially important in areas where human activities like urbanization, agriculture, and industrial expansion are putting strain on water resources.
- In order to help policymakers and resource managers make well-informed decisions on the distribution and utilization of land and resources, GIS may also be used to model and simulate the environmental effects of various land use scenarios. Additionally, GIS-based technologies can be used to track and identify changes in resource condition and land use over time, allowing for the early detection of possible problems and the application of suitable mitigation strategies.
- Mining and natural resources extraction: GIS is used to map mineral deposits, analyze geological data and impact of the mining process. GIS enables efficient resource extraction planning, minimizing the adverse impact on the surrounding ecosystem, and assists the rehabilitation process in the post mining phase. GIS-based research on mine planning is generally classified into four topics: ore reserve estimation, open pit optimization, mine infrastructure design, and potential conflict region analysis [10].

Sustainable agriculture

By offering instruments for spatial analysis, monitoring, and decision-making, Geographic Information Systems (GIS) are essential for advancing sustainable agriculture and guaranteeing food security. There are various uses of GIS in sustainable agriculture some of them are:

- Monitor water quality parameters like plankton, turbidity and suspended matter.
- GIS can assess the precipitation, ground water levels and monitor drought like conditions.
- It supports precision agriculture by enabling farmers to manage crops at fine scale.
- High erosion zone areas based on various geographical factors.
- GIS can look out on crop health, assess high stress areas which are caused by any crop disease and nutrient difficiencies.

Disaster risk reduction

GIS helps to identify and mitigate adverse impacts of hazard risk. Geographic Information Systems (GIS) is a tool in Disaster Risk Reduction (DRP) that supports officials and leaders, in planning for and responding to disasters while aiding in the recovery process as well. GIS assists in disaster risk reduction in the following ways:

- Early warning and system by integrating real time data from sensors, satellites and weather stations. Example: By utilizing GIS technology, in tsunami alert systems. It can monitor movements. Forecast potential effects, on coastal areas. This provides time for residents to evacuate safely. For instance, Bihar Flood Management Information System (BFMIS).
- Geographic Information Systems (GIS) play a role, in pinpoint. This technology is important for recognizing and mapping regions at risk of disasters such as floods, earthquakes, landslides and hurricanes, and visualizing zones vulnerable to various natural calamities, such as floods, tremors, mudslides and hurricanes. For example landslides risk mapping in Himachal Pradesh.
- Using Geographic Information Systems (GIS) helps in predicting disaster situations due, to the increasing occurrence and intensity of calamities caused by climate change. For instance, Cyclone risk management in Odisha.

Role of GIS in environmental management

The management and planning of the environment that involves controlling processes related to the achieving, changing, moving, and ensuring resources are in such a way as to be productive and healthy for human life without excessive interference with physical, ecological, and social processes is referred to as Environmental Planning and Management (EPM) [11]. GIS integration with environmental management enhances the process of precise decision-making. Its role is not only limited to decision-making itself, but it can also utilize habitat and biodiversity conservation through identifying critical habitat and mapping ecosystem and biodiversity hot spots, then focused conservation required in that highlighted areas. While this involvement of GIS assists in stakeholder engagement and communication, other ways to support these are presenting through its visual representations of complex spatial data for explaining the issues that agents cannot easily comprehend. It is especially of significance in community-based environmental management, where the local knowledge and active participation of local stakeholders are inherently required for successful outcomes. In general, GIS plays a variety of roles in environmental management, including monitoring, data analysis, stakeholder interaction, and scenario modeling. GIS is a vital tool for tackling difficult environmental issues and advancing sustainable resource management because of its capacity to combine various data sources and offer geographical insights.

Water resource management: Since technology has advanced there is now more. The distribution of surface and subsurface water resources is convenient. As efficiently as possible using remote sensing and GIS technologies. Various objectives. The use of these technologies is widespread. To put the information in a scientific order. It's beneficial to have. Data over a wide area regularly by remote sensing and the desired. Data processing with the aid of can yield results [12]. Conventional methods usually struggle to solve complex spatial and temporal variables of water resources. It is GIS which offers useful solutions to combine and analyze large scale spatial datasets and provide a more comprehensive approach for water resource management.

There are various roles of GIS in water resource management, like runoff modeling from a snow covered area, flood mapping, erosion and accretion along the banks and coastal areas mapping and identification of ground water zones etc. Some of them are given below in detailed explaination:

- Ground water management: By offering resources for the following GIS, it helps ensure that groundwater resources are managed sustainably. Finding regions with the best groundwater replenishment is known as groundwater recharge mapping which helps with groundwater conservation and sustainable extraction. GIS supports water conservation policy-making by tracking the rate of groundwater extraction and identifying areas where aquifers are overused. For instance, GIS based groundwater management in Rajasthan by mapping ground water levels, recharge zones, and utilization patterns.
- In order to develop thorough water management plans, GIS integrates data from multiple sources, including hydrological, meteorological, and socioeconomic data. This helps IWRM. It makes it possible for stakeholders to take into account the economic, social, and environmental aspects of managing water resources.
- GIS can be used in the analysis and adaptation of climate change. The issues to be considered are snow/glacier monitoring, land cover monitoring, carbon trace/accounting, atmospheric dynamics, terrestrial temperature monitoring, biodiversity conservation, ocean and coast monitoring, erosion monitoring and control, agriculture, flood monitoring, health and disease. The ordinary processes of nature such as erosion, leaching of minerals from the soil by water, natural corrosion, shifting of sand dunes, animal activities and various climatic conditions have accelerated the problems [13].

Biodiversity conservation: According to the IUCN, "The main purpose of wildlife conservation is to maintain maximum plant and animal diversity through genetic traits, ecological functions and bio geo-chemical cycles, as well as uphold aesthetic values." Wildlife and Biodiversity Management has emphasized the need of having updated spatial information for (a) Decision making; (b) Implementation of plans [14].

RS and GIS are highly effective tools for managing our natural resources. The data collected from various satellites offers a robust geographic database that can aid in the future planning of these resources. A resource information system is essential for effective management planning and its successful implementation.

Geographic Information Systems (GIS) can offer spatial insights alongside traditional statistics when data is converted into a computer-readable format. This technology can transform wildlife management by focusing more on up-to-date information and location-based strategies. There are various ways through which Geographical Information System can contribute for wildlife and biodiversity conservation. Some of them are given below-

- GIS plays an important role in creating species distribution models that help predict where different species are likely to be found based on various environmental factors. This information is essential for conservation efforts, as it allows conservationists to pinpoint areas vital for the survival of specific species. By integrating remote sensing data with field observations of species presence and environmental conditions, conservationists can craft precise species distribution models that inform conservation strategies aimed at protecting critical habitats for these species [15].
- GIS helps local stakeholders by giving them access to maps and spatial data for community-driven conservation projects. In managing local biodiversity resources, it enables improved community and conservation agency participation and collaboration.
- Habitat mapping and monitoring, monitoring of invasive species, assessment of forest cover change, monitoring of wetland ecosystems, Environmental Impact Assessment (EIA), detection of forest fires are several other roles of GIS in biodiversity conservation. For instance, Brazil constantly monitors deforestation rate, illegal logging in Amazon forest through GIS.

Climate change impact assessment and adaptation: GIS is essential in climate change research, equipping scientists, policymakers, and communities with the necessary tools and data to grasp the intricate dynamics of our evolving environment. By integrating spatial data, GIS helps us visualize and analyze vast amounts of information, allowing us to spot patterns, trends, and possible impacts. GIS gives researchers a thorough understanding of how climate change is affecting different regions and ecosystems

by enabling them to superimpose data like temperature records, precipitation totals, and vegetation cover onto geographic maps [16]. There are several important roles of geographical information system in climate change impact assessment and adaptation:

- Coastal erosion rates, storm surge patterns, and sea level rise forecasts may all be examined using GIS. Researchers can determine which locations are most susceptible to floods and create mitigation and adaptation plans by merging these statistics [16].
- Additionally, it enables lawmakers to make well-informed choices about resource allocation, infrastructure development, and land management.
- GIS can also make it easier to track and monitor indications of climate change. Scientists can identify changes and evaluate the success of climate change policies and interventions by gathering data on temperature, precipitation, and other environmental parameters across time.
- Increasing forest areas and stopping deforestation are effective and straightforward ways to decrease CO_2 levels in the atmosphere and combat global warming. To track carbon content, GIS techniques are essential. GIS technology can effectively map the carbon stored in forests [17].
- The capacity of GIS to graphically convey complicated data is one of its most potent features in climate change study. GIS makes it possible to effectively distribute information to a large audience through interactive maps and infographics.
- Maps assist us in recognizing problem regions, comprehending the geographical patterns of climate change, and creating focused solutions. They facilitate cooperation and well-informed decision-making by giving communities, scientists, and policymakers a shared language [16].
- Software-based GIS mapping and assessment play an important role in geographic planning, helping to identify environmental changes and develop action plans. By leveraging GIS data, we can create climate maps and make estimates regarding anticipated future climate changes. Additionally, GIS simulations of climate change can be employed to assess the potential impacts on specific areas [17].

The incorporation of Geographic Information Systems (GIS) into climate change research has markedly enhanced our comprehension of this global issue. GIS technologies offer researchers important instruments for examining and tackling the complexities associated with a changing climate, ranging from the visualization of climate change effects to the simulation of prospective scenarios. The application of GIS methodologies facilitates efforts towards establishing a sustainable and adaptable future for both contemporary and forthcoming generations.

In addition to the above described uses, GIS may be a useful tool for sewage treatment, oil spill cleanup, and wastewater management. In practically every business, spatial information produces better results, and GIS offers priceless location data that enhances and greatly increases the productivity of decision-making. The potential of GIS is only constrained by human ingenuity and resourcefulness.

Challenges

But even with all of its benefits, there are still major obstacles that prevent it from reaching its full potential. To optimize the use of GIS for environmental management and sustainable development, these complex issues must be resolved on a technical, financial, institutional, and social level.

There are some intricate problems in implementation of GIS in sustainable development and environmental management [18]. The problems posed with the global scenario are:

Lack of standardization: It can be challenging to exchange or integrate GIS data across platforms when different companies, regions, or nations employ disparate standards for data gathering and storage.

High initial investment: The setup of GIS systems necessitates a large outlay of funds for data collecting, software, hardware, and qualified staff. This may be a significant obstacle for NGOs, local governments, and smaller businesses with lower finances.

Infrastructure challenges: The usage and implementation of GIS are restricted in many developing countries by inadequate technological infrastructure, low power supplies, and a lack of internet access.

Confidentiality issues: Certain GIS data, especially when it involves land ownership, personal information, or sensitive environmental data, may raise privacy issues. Protecting data from unauthorized access or misuse is becoming a growing challenge.

Ethical issues: When using GIS for environmental management or land-use planning clashes with traditional land ownership systems, local customs, or indigenous rights, ethical issues may arise.

The use of GIS in environmental applications has a bright future. GIS applications in environmental science and urban planning, when combined with the most recent developments in artificial intelligence, machine learning, and remote sensing technologies, are becoming important for robust and efficient urban ecosystems. A more complete approach to resource management is also made possible by the integration of GIS with these cutting-edge technologies, which guides a thorough data-driven decision-making process and promotes harmony between environmental preservation and human requirements [19].

CONCLUSION

Geographic Information Systems (GIS) are becoming essential resources for researching environmental management and sustainable development. GIS enables a more comprehensive understanding of the complex interactions between human activity and the natural environment by integrating geographical data with robust analytical and visualization capabilities. It facilitates informed decision-making across various domains, including disaster risk reduction, biodiversity conservation, resource management, and urban planning. Notwithstanding its potential, GIS presents several challenges, such as economic constraints, technological complexity, and data availability issues. To ensure responsible and inclusive utilization of the technology, it is also necessary to adequately address concerns related to data standards, institutional resistance, and ethical considerations. Governments, organizations, and local communities must collaborate to address these challenges by developing the requisite infrastructure, acquiring the necessary skills, and fostering cross-sector cooperation. In conclusion, while GIS is not a panacea for all environmental and developmental challenges, it remains an important tool that, when applied judiciously, can significantly advance sustainable development objectives. By maximizing the potential of geographical data and ensuring equitable access to

GIS technology, we can strive toward a more resilient, sustainable, and equitable future for all.

REFERENCES

1. Warren S. Teaching GIS as a socially constructed technology. Cartog Geograph Inform Sys. 1995;22(1):70-77.
2. Băneş A, Orboi MD, Monea A, Monea M. Sustainable development by GIS. Res J Agricul Sci. 2010;42(3):405-407.
3. Costantini RA, Thompson CM. Leveraging geographic information in organization studies: Beginning the conversation. Management. 2023;26(1):35-51.
4. Joshi PK. Geospatial technology for sustainable development. GW Prime. 2023.
5. Campagna M. GIS for Sustainable Development. Taylor Franc. 2005.
6. Spatial data science for sustainable development. Sustainab GIS. 2024.
7. Nimisha. Mapping smart cities: How GIS shapes urban development. AGSRT. 2024.
8. Banerjee S, Chakraborty C, Das D. An approach towards GIS application in smart city urban planning. Taylor Franc. 2020:71-110.
9. Nyeko M. GIS and multi-criteria decision analysis for land use resource planning. J Geograp Inform Sys. 2012;(4)4:1-8.
10. Choi Y, Baek J, Park S. Review of GIS-based applications for mining: Planning, operation, and environmental management. Appl Sci. 2020;10(7):2266.
11. Omusotsi OG. Role of GIS as a tool for environmental planning and management. Int J Res Environ Sci. 2019;(5)1:6-10.
12. Kumar H, Singh K. Water resources: Role of GIS and remote sensing. Int J Eng Res Technol. 2018.
13. Eniolorunda N. Climate change analysis and adaptation: The role of Remote sensing (Rs) and Geographical information system (Gis). Int J Computat Engin Res. 2014;4(1):41-51.
14. Shanila, Faizan D. Relevance of RS and GIS in wildlife and biodiversity management. Int J Comp Applicat. 2014.
15. Kour A, Singh D, Kiran. Role of GIS and remote sensing in wildlife conservation. Just Agricul. 2023.
16. GIS in climate change analysis. GIS People. 2023.
17. Global climate change assessment using GIS. Satpalda. 2023.
18. Pujar CN. The Role of Geographic Information Systems (GIS) in environmental conservation and sustainable development: A geographical study. J Emerg Technol Innovat Res. 2020;(7)3:779-786.
19. Akther R. Exploring the wonders of GIS in environmental applications. Terra Nexus. 2023.