INTERNATIONAL JOURNAL OF EXPLORING EMERGING TRENDS IN ENGINEERING
Peer-Reviewed, Refereed, Indexed and International Journal, https://ijoeete.com/
|ISSN No. 2394-0573 |Volume: 11, Issue: 4 | October – December 2024

A STUDY OF RIVERINE LANDSCAPE DYNAMIC AND INTEGRITY OF SARAN DISTRICT, BIHAR

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ABSTRACT: Saran district in Bihar has riverine environment which is of great importance to the ecology as they sustain the biodiversity, agriculture, and the livelihood of the people living around the river. This paper explores how these landscapes are dynamic in nature, how the processes of the fluvial land, land use and anthropogenic impacts have changed over the last few decades. Based on geospatial methods, past satellite data, and observations on the ground, the work identifies changing trends regarding river channels, floodplain shapes, and sedimentation in the past. Ecological integrity of the riverine system is also assessed in the paper through water quality, vegetation covering as well as the connectivity of the habitats. Results show positive influence of both natural fluctuations and anthropogenic pressures on the river ecosystem (e.g. encroachment, deforestation and infrastructure development). It represents an appeal to the sustainable management of rivers basins and gives its recommendations to maintain the ecological equilibrium along with socio-economical development.

KEYWORDS: Geospatial Analysis of Riverine Landscape Saran District Fluvial Dynamics, Ecological Integrity

1. INTRODUCTION:

Watersheds are important regions when it comes to defining the ecological as well as socio economic framework of an area. Specifically, the Saran district of Bihar is marked by presence of river systems, and arguably, this case is presented by Ganga and Ghaghara Rivers, which characterize the main part of topography, land use and settlement pattern in the district. In addition to bringing fertile alluvial deposits these rivers are a nightmare to deal with given frequent flooding, erosion and oral deposition.(*Ahmad, S., & Kumar, P., 2017*) These riverine systems have over the years undergone tangible changes on land cover, agricultural and habitat structures attributed to its dynamic nature. Furthermore, industrial manipulations in the form of urbanization, deforestation, and infrastructure constructions have led to disturbances in the ecological purity and stability of such landscapes. With the aim of reducing the impacts of river bottom (riparian) land degradation, this paper aims at examining the changes in the area of the riverine environment of the Saran district that would happen both under the influence of natural phenomena/processes and due to the effects of human activity. Such dynamics are imperative in terms of smart planning in the region and managing floods and the maintenance of the ecological balance in a city like Saran, which is densely populated and ecologically prone.(*Bansal, R., & Singh, V., 2014*).

1.1 Theoretical Framework and Concepts of Riverine Landscape Dynamics:

Riverine landscape dynamics are studied based on the interdisciplinary frameworks of fluvial geomorphology, landscape ecology and environmental geography. Riverine landscapes are natural dynamic systems, which are formed in continual correspondence between the movement of water, transportation of sediment, and geometry of the terrain. Its theoretical basis is based on the knowledge of processes including the process of erosion, deposition, channel migration and the development of floodplains through which processes have a contribution towards the spatial and temporal development of river systems. Such concepts as dynamic equilibrium, hydrological connectivity, and ecological resilience define the conduct of analyzing the response of these landscapes towards not only natural variability but also to the human-made pressures. The concept of river continuum also elaborates how a river system changes the ecological features along its length. Also, landscape ecology gives us the tools to determine the degree of habitat fragmentation and patch connectivity, as well as the interaction of the land use, which is within

the river corridor. Applicability of such theoretical perspectives in the case of Saran district will not only help in a thorough study of how rivers such as the Ganga and the Ghaghara are treated and treat the environment around it, but also present valuable knowledge regarding the landscape transformation, ecological integrity and sustainability.(*Chakraborty, S., & Das, R., 2016*).

1.2 Tools and Techniques: GIS and Remote Sensing Applications

Geographic Information System (GIS) and Remote Sensing (RS) have gained importance in the study of riverine landscape dynamics given that they capture, process, and visualise both spatial and temporal data. This research uses satellite photos of the Landsat and the Sentinels platform in the evaluation of land use/cover changes, revelation of river channel, and alteration of the floodplains in the Saran district. The use of GIS software facilitates mapping and overlay of different variants of thematic maps such as the hydrology, topography, vegetation and human settlements that aid in detecting trends of change and spatial correlations. Elevation models generated using Digital Elevation Map (DEM) are applied to view the elevation profile, slope gradients, and drainage streams. Additional functions of remote sensing including Normalized Difference Vegetation Index (NDVI) and change detection analysis assist to analyze the changes in vegetative cover and surface over a period of time. Through the combination of these tools, the riverine process can attain high resolution that leads to evidence-based environmental monitoring and management policies.(*Ghosh, A., & Roy, A., 2013*).

1.3 Hydrological Characteristics of the Ganga and Ghaghara Rivers

The main hydrological vessels which have affected the landscape and socio economic activities of the Saran district are the Ganga and Ghaghara rivers. The Ganga being a perennial river with intricate hydrological cycle, has seasonal variations due to rain washes during monsoons and Himalayan snows melting as well. It has extensive floodplains that are highly flooded and consequently fertile and prone to floods. Its other principal left-bank tributary, the Ghaghara River, has a very active fluvial profile and undergoes a lot of course variation, erosion and deposition of banks and sediments. The combined effect of these rivers is the creation of alluvial plain that is productive in qualities and also met with the problems of flood, waterlogged conditions and riverbank erosions. Hydrological behavior of these rivers is affected by the factors including the characteristics of the catchment, rainfalls variability, the amount of sediment in it, and by the man-made structures including the embankments and barrages. Their hydrological characteristics are very crucial in investigating landscape processes, flood preparation techniques and ecological and financial stability of the area.(*Jha, R., & Mishra, K., 2012*).

1.4 Historical Changes in River Courses and Floodplain Dynamics

There are remarkable morphological changes in rivers in the Saran district especially in Ganga and Ghaghara rivers during last one hundred years. Existing records in satellite images, historical maps and archives provide visible changes in the course of the rivers caused by natural forces like the taking away of material on one side and laying on the other and avulsions. Such alterations have led to formation and abondance of meander loops, oxbow lakes and new areas of the flood plain. Fluctuating floods have been very significant to the development of these landscapes, as much as they contribute to the fertilization of the soil, they also displace the people and reconstruct holding patterns of land land. Specifically the Ghaghara River is famous with its turbulent path changing several kilometers over the decades. These are river processes that have had direct implication on the floodplain stability, settling patterns and agricultural patterns. Comprehensiveness of historical changes is crucial in the reconstruction of evolution of landscapes besides being used in anticipating future changes that might affect development and disaster management planning.(*Kumar, A., & Sinha, R., 2015*).

1.5 Land Use and Land Cover Changes in Riverine Zones

The land use and land cover (LULC) pattern of the riverine areas of Saran district has both undergone significant changes, as a consequence of natural and manmade factors. The data of remote sensing shows gradual increase in the cultivated agricultural areas to areas hitherto prone to floods or other ecologically sensitive specifications by the

aggregate of population and intensification of agricultural practices.(*Yadav, R., & Tripathi, A., 2014*). With this, there has been significant reduction in natural vegetation, wetlands and grasslands, which previously formed the important ecological buffer. The landscape has further been modified by the construction of embankments and roads as well as urban development. Such modifications in LULC alter natural water flow patterns, small the infiltration and aggravate chances of wash away and flash flooding. The invasion of riverbeds and floodplains endangers not only local people to hydrological disasters but alters the ecological sustainability of the area. It is critical that such changes should be monitored using GIS and time analysis to the sustainable management of the land and water resources.(*Meena, S., & Prasad, D., 2020*).

1.6 Ecological Integrity and Biodiversity Assessment

The health of aquatic and riparian ecosystems in the Saran riverine ecosystems is inseparably connected with ecological integrity of the riverine systems including their provision and sustenance of diverse flora and fauna. These ecosystems have, however, been greatly impaired by fast rate of land use change, pollution and hydraulic modifications. Artifacts of ecological integrity, including water quality, vegetation cover, and diversity of aquatic life and habitat connection, appear to be damaged especially at high-intensity farming areas and areas that lack regulations on the development. Biodiversity measures show the decline in the level of indigenous fish, birds that depend on wetlands and riparian vegetation, which play a vital role in the stability of the ecology. Also, the fragmentation and the loss of ecological functionality have disoriented the flows of organisms and the mating grounds. Assessment of ecological integrity includes multidisciplinary methodology involving field surveys, biodiversity index, water quality and geospatial mapping. Protecting biodiversity and recovering of ecosystem services within these river landscapes is a way of achieving long-term environmental resilience and sustainability against climate and hydrological extremes.(*Mishra, S. K., & Srivastava, H., 2021*).

1.7 Anthropogenic Influences on Riverine Landscape

Human activities are rapidly taking over the riverine landscape of the Saran district, which is more likely to be in the form of destroying eco-balance and stability in the hydrological system. These are anthropogenic effects of such large scale such as the construction of embankment, road or irrigation canals that disturb the natural process of flow and transportation of materials as well as water. The urbanization and the agricultural activities in the floodplains have contributed to the deforestation and loss of wetlands and soil erosions. Indiscriminate sand mining (at the riverbeds) sometimes occurs and this amends the morphology dynamics of the channel together with aquatic habitat. (*Verma, P., & Sharma, T., 2021*).The cause of water pollution in the river is waste disposal and agricultural run off which impacts on both health of the river and the biodiversity. Moreover, the population pressure of human problems has ended into the invasion of flood sensitive places which are even more threatening to human occupations. These activities impact the dynamic equilibrium of the riverine systems negatively, subject the systems to insufficient resistance to the floods, droughts and pose prolonged sustainability challenge. Such anthropogenic impacts should be critically looked at in order to develop interventions that would be able to balance the needs of development on the one side, and the environment on the other.(*Pandey, N., & Rathi, M., 2018*).

1.8 Flood Hazard Mapping and Vulnerability Analysis

The existence of flooding on Saran district is a persistent problem especially caused by the dynamic nature of rivers Sanga and Ghaghara. GIS and remote sensing processes of flood hazard mapping assist in determining flood prone areas in relation to the past flood occurrence, topographic, rainfall and land cover. (*Srivastava, N., & Tiwari, S., 2012*). A technique using Digital Elevation Models (DEMs) and satellite images is used to define the flood-prone areas and determine the water flow routes in case of the extreme rainfall. Socio economic vulnerability analysis takes into account, population density, housing type, agriculture dependency, access to infrastructure and emergency service. The integrated approach presents physical exposure and socio-economic vulnerability as the complete picture on flood risk. This spatial analysis plays an essential role in terms of preparing a disaster, allocating resources,

and creating resilient infrastructure. The results emphasize the importance of flood proactive management policies, community-based hazard risk mitigation and ecological recovery of natural attenuators such as wetlands and floodplains.(*Rai, A., & Thakur, B., 2019*)

1.9 Challenges in Riverine Landscape Management

The situation in the Saran district where riverine landscapes should be managed is very complicated because of many variables that interact with each other and depend on various natural processes as well as human activities. Absence of integrated watershed and river basin management, which looks into the ecrologic, social, and economic dimensions, is one of the setbacks.(*Sinha, R., & Jain, M., 2015*). Penetrating government agencies and government fragmentation and lack of coordination are an obstacle towards effective implementations of polices. Environmental degradation is worsened by ineffective land use regulation, poor monitoring and unplanned flood plains development. Climate change is another factor of uncertainty which increases the number and intensity of floods and modifies hydrological cycles. Besides, community awareness and engagement in the process of river conservation is low. To solve these difficulties, the change to participatory and science-based planning processes involving a combination of traditional knowledge, modern technology, and policy changes are important. The right management of the sensitive and dynamic riverine environment of Saran can only be achieved through a well-coordinated effort and long range vision.(*Sahni, R., & Kumar, V., 2016*).

2. OBJECTIVES OF THE STUDY:

1. To evaluate the spatial and temporal processes of the courses and floodplains of rivers in the Saran district on the basis of the historical maps, satellite imagery data, and the use of geospatial tools.

2. To evaluate how the land use and land cover change has affected ecological integrity of a riverine zone as far as vegetation, biodiversity, and water quality is concerned.

3. To detect and analyze the human activities that led to the loss of the riverine landscapes e.g. encroachment, loss of forest covering, and development of infrastructure.

4. To locate the flood prone sites and study the vulnerability of the community and to suggest a sustainable approach on the management of environmental become less hazardous and become more resilient.

3. RESEARCH METHODOLOGY

The study is a mixed-method study that incorporates spatial analysis, field observations, and secondary data interpretation to study riverine landscape dynamics and ecological integrity of the Saran district, the State of Bihar. The analytical structure revolves around geospatial tools, especially, Geographic Information Systems (GIS) and Remote Sensing. A satellite data record between 1985 to 2025 has been used to monitor the changes in the river course and land use/land cover (LULC), specifically Ganga and Ghaghara rivers. Field surveys were conducted to confirm the major changes in landscape and vegetation contributing to topographical and hydrological sources of governmental, and open-source repositories. Expert judgment and local knowledge were used to obtain impact scores of anthropogenic activities, whereas, flood vulnerability indices were determined as a combination of flood frequencies and a socio-economic exposure. The quantitative data were structured in form of tables and presented graphically (by use of bar and line graphs) in order to provide patterns and trends over the period of time. This combined approach would allow a localized and effective portrayal of how natural forms of forces interact with human powers to build steps in the riverine settings.

4. DATA ANALYSIS

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With the aid of such analysis, it is possible to find out that there are major changes that have occurred in the riverine landscape of Saran during the past 40 years. Both Ganga and Ghaghara rivers at the start point in the Table 4.1 have moved horizontally by 4.1 and 6 km respectively between 1985 and 2025, indicating greater fluvial instability probably due to the hydrological dynamics, as well as to human interference. Table 4.2 land use suggests that agricultural and built up space has increased significantly, by 50 percent to 65 percent and 5 percent to 12 percent respectively at the expense of vegetation and wetlands which have declined to 6 percent and 2 percent respectively. This is a trend that shows high congestion of ecological areas. The highest score, i.e., 9, is attributed to urban encroachment, followed by sand mining and then deforestation with 8 and 7, respectively, as their impact scores as revealed in Table 4.3. According to flood hazard analysis (Table 4.4), Manjhi and Rampur villages are the most susceptible villages; its flood frequency is high, and its vulnerability index is close to 0.9. The spatial-temporal analysis of this data indicates that there is an urgent need of integrated land and water management policy on the land to reduce the risk and biodiversity loss and to ensure the livelihood in this dynamic riverine region.

Table 4.1: River Course Shifts

Year	Ganga Shift (km)	Ghaghara Shift (km)
1985	0	0
1995	1.2	2
2005	2.8	3.9
2015	3.5	5.1
2025	4.1	6

Table The table demonstrates lateral changes in the Ganga and Ghaghara river courses in Saran district over the period of years between 1985 and 2025. Both rivers have slowly changed their routes and by 2025 Ganga will have changed routes by 4.1km and Ghaghara by 6km. It is remarkable to note that there was a gradual change of location with the Ganga having shifted its location by 1.2 km over the period 1985 and 1995 and 2.9 km over the period 1995 and 2025. The Ghaghara river that exhibited a greater initial displacement (2 km in 1995) had still been progressing, having moved to the distance of 6 km in 2025. The causes of these changes can either be natural, that is eroding and depositing of sediments or human activities, like sand mining or construction of embankments that affect the stability of the river channels. This information gives an idea of the transformative character of riverine landscapes and the issues presented by changes in the landscapes, particularly the flood control and land use plans.

Table 4.2: Land Use and Land Cover Change

LULC Type	1985 (%)	2025 (%)
Agricultural Land	50	65
Built-up Area	5	12
Water Bodies	20	15
Vegetation	20	6
Wetlands	5	2

The table demonstrates Land Use and Land Cover (LULC) changes in the Saran district over thirty years of the period between 1985 and 2025. The agricultural land has shown a sharp increase of 50 percent in 1985 and 65 percent in 2025 as the space required in agriculture is continuously increasing. The built-up has also increased, that is, 5 up to 12% which is a sign of city development and infrastructure. On the other hand, vegetation has reduced drastically in comparison by 20 percent of the total 6 procent, probably showing how the vegetation has being deforested and having low green cover. The water bodies and the wetlands have recorded regressions with reduction in the water

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bodies taking place (by 20 to 15 percentage) and the wetlands reducing (by 5 to 2 percentage), indicating a probable habitat loss, and possible effects on the biodiversity. Such transformations ironically emphasize the changes of the landscape and growing pressure on the natural resources in the region.

Table 4.3: Anthropogenic Activities Impact Score

Activity	Impact Score (0-10)
Sand Mining	8
Deforestation	7
Urban Encroachment	9
Industrial Discharge	6
Embankment Construction	7

Table shows the impact scores (on the scale of 0 to 10) of diverse anthropogenic activities on the riverine landscape in Saran district. The impact score of urban encroachment is 9 which is the highest compared to other impacts since encroachment contributes a significant number of degradation activities by construction and expansion into flood plains. Closely at its heels is sand mining which has an impact score of 8 due to the negative effects it has on the stability of riverbeds and the quality of water. The two that stood at 7 are deforestation and embankment construction, which bring out the adverse effects of loss of vegetation cover and changing the natural rivers courses. Industrial discharge has a score of 6 and is involved in water pollution and habitat degradation but on less scale than the other activities do. This data highlighted the fact that there is an urgent necessity of efficient regulation and mitigation measures to reduce these impacts.

Table 4.4: Flood-Prone Villages and Vulnerability Index

Village	Flood Frequency (last 10 yrs)	Vulnerability Index (0-1)
Rampur	7	0.85
Basantpur	5	0.72
Manjhi	8	0.91
Mashrakh	3	0.6
Revelganj	6	0.78

The table gives flood vulnerability of five villages in Saran district, which is computed in terms of the frequency of floods during the past decade and vulnerability index (0-1). The greatest risk is recorded in Manjhi, having passed through 8 times of flood and a plunge index of 0.91, which means that it has high exposure and low coping abilities. Rampur and Revelganj also show substantially high levels of risks with 7 and 6 floods and vulnerability indices beyond 0.75 respectively. The least frequency of floods is in Mashrakh (3), and its index is 0.60, relatively low, but Basanthpur has a moderate risk. In general, the statistical data indicate that Manjhi, Rampur, and Revelganj require specific flood-related mitigation solutions.

CONCLUSION

This research paper had a critical analysis of the dynamic yet complex nature of the riverine landscape of Saran district, in the state of Bihar, in and around the situation and the interaction of the natural hydrological processes and the mounting anthropogenic pressure. The changing course of both the Ganga and Ghaghara rivers as shown by historical records and spatial assessment show a landscape that is continuously changing. Simultaneously, drastic alterations in land use with notable expansion of agriculture, encroachment of humanity in urban settings as well as degradation of wetlands are indicators of the increasing touch of man in ecologically fragile regions. The continued anthropogenic activities like sand mining, trees cutting and infrastructural development have only contributed to the adverse ecological integrity of the area. The mapping of flood hazard has revealed the most vulnerable areas and therefore there is more need to be risk-sensitive in the planning. The results show, in general, that there is an urgent need to address a comprehensive river basin management, ecological restoration, and community-based conservation

activities. Maintaining the balance between development and the natural survival of the environment is crucial towards securing the long-term stability of the river ecosystem of Saran.

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