Journal for Re Attach Therapy and Developmental Diversities
eISSN: 2589-7799
2023 November; 6 (1): 1215 -1226

"Water Resources Management In Nahargarh Wildlife Sanctuary And Eco-Sensitive Zone: A Geospatial Approach"

Ronak Parmar[1], Sanjay Choudhary[2], Nand Kumar[3*]

[1*,2,3]Department of Architecture and Planning, Malaviya National Institute of Technology, Jaipur, India
Email:- (nkumar.arch@mnit.ac.in) +91-9414062970 Malaviya National Institute of Technology (MNIT), Jawahar Lal Nehru Marg, Jhalana Gram, Malaviya Nagar, Jaipur, Rajasthan 302017

***Corresponding Author-** Nand Kumar
*Email:- (nkumar.arch@mnit.ac.in)

Abstract

Water is essential for preserving ecological balance, supporting human and animal life, as well as for all types of economic and development activities. It is a valuable and in-demand resource, especially in places like Nahargarh Eco-Sensitive Zone (ESZ), where the Nahargarh Wildlife Sanctuary is a prominent feature. Water resource management in Nahargarh wildlife sanctuary and ESZ is crucial for sustaining wildlife and plant species. Proper allocation, conservation, and monitoring of water resources ensure that habitats remain balanced and resilient. Adequate water availability supports diverse ecosystems, promotes plant growth, and ensures the survival of wildlife, fostering a harmonious coexistence between nature and humans. This paper included a background study about Nahargarh ESZ, and based on that, various parameters have been studied as a part of water resources management. This paper contains a study about the existing scenario of waterbodies around Nahargarh wildlife sanctuary and also outlines a study about drainage networks and watersheds especially for Nahargarh ESZ. The natural features of Nahargarh ESZ have been analyzed using GIS (Geographical Information System) techniques. Stream order and stream network, aquifer related data, the Digital Elevation Model (DEM), slope analysis, and identification of wet land areas surrounding major waterbodies-related data in Nahargarh ESZ provided further direction for water management initiatives. The study's role in preserving wildlife and their habitats is substantial, as it identifies optimal water allocation strategies. Moreover, its contribution extends to policy formulation, influencing decisions about water management in environmentally sensitive regions. The Geographic Information System (GIS) techniques employed in the study pave the way for future spatial analyses, collaborative efforts, and informed decision-making in comparable contexts, ultimately ensuring the harmonious coexistence of nature and human activities in the long term.

Keywords: Ecological Balance, Water Resources Management, Nahargarh Eco-Sensitive Zone, Wildlife, Geographical Information System.

1. INTRODUCTION

1.1. Wildlife Sanctuaries

Wildlife sanctuaries are crucial for preserving Earth's biodiversity and protecting endangered species. They provide safe habitats, maintain ecological balance, and serve as gene banks for genetic diversity. These protected areas support scientific research, eco-tourism, and environmental education, making them vital for conservation efforts and raising public awareness about wildlife protection. Ultimately, wildlife sanctuaries play a significant role in ensuring the survival of various species and safeguarding the natural wonders of our planet.

Wildlife sanctuaries are protected areas where wildlife and its natural habitats are conserved and preserved. The government established these sanctuaries to protect numerous animal, bird, and plant species from dangers like habitat destruction, poaching, and human encroachment. Wildlife preserves are essential for preserving the nation's natural balance and biodiversity.

In Indian context, the Wildlife Protection Act, 1972, is a crucial legislation focused on safeguarding the country's diverse wildlife and their habitats. It prohibits hunting, poaching, and trading of protected species listed under various schedules. The act empowers the government to establish wildlife sanctuaries and national parks for conservation purposes. It regulates the trade of wildlife and their products and imposes strict penalties for offenses. The act has contributed significantly to the preservation of India's biodiversity and ecological balance, ensuring the survival of endangered species and promoting sustainable management of natural resources.

1.2. Eco-Sensitive Zone

According to The National Wildlife Action Plan(NWAP) 2002-2016, to protect the fragments of biodiversity it is necessary to protect ecological corridor links as areas outside the protected area network. It also indicated that all such ecological corridors and areas around protected areas should be declared as ecologically fragile under the Environment (Protection) Act, 1986.

Declaration of Eco-Sensitive Zones around National Parks and Sanctuaries will act as Shock Absorber for protected areas as mentioned in guidelines for declaration of Eco- Sensitive Zone around National Parks and Wildlife Sanctuaries. Due to tremendous developments in vicinity to these protected areas, it is necessary to define their boundaries. Also some of the protected areas are lying into urban developments such as Guindy National Park (Tamilandu) and Sanjay Gandhi National Park (Maharashtra). So that defining specific extents for protected areas is to be considered as an essential stage. According to general principle as mentioned in Wildcare, the extent of Eco-Sensitive Zone can go upto 10 kms around protected areas and can also vary in all directions.

2. LITERATURE REVIEW

An Ecologically Sensitive Area (ESA) is defined as geographical region that meets certain predefined conditions, which are comprehensively outlined by Paul F. J. Eagles in 1981. ESAs encompass naturally occurring landscapes that contains attributes like the replenishment of underground water sources, the origin points of rivers, distinctive flora and fauna, unique geological formations, areas where animals breed or spend the winter, essential ecological processes, scarce or threatened species, as well as intricate blends of habitat types and terrain features (Eagles, 1981).

Wetlands need to be carefully assessed, just like any other resource that is sensitive to the environment. Although it is acknowledged that not all wetlands have the same value in terms of maintaining the world's life support systems, specific regions may be evaluated based on their irreplaceability or uniqueness of the resource. There are numerous methods for assessing the wetland resource (Turner & Brooke, 1988). A case study of Norfolk Broadland, England has been performed by R. Kerry Turner and Jan Brooke in 1988. In the battle between development and conservation critically evaluated. Indirect evaluation through the opportunity Cost-effective methods can produce useful data that have aided in reducing the intensity of such conflict situations.

Considering the prevailing concerns of dynamics, deterioration and conservation of forests, proper planning and management of forests are necessary. To protect the forests from the pressure of urban and industrial sprawl, it is necessary to define the extent of eco-sensitive zones, which acts as buffer around the forest areas. This process can also be performed by using geospatial techniques (Deb et al., 2013). Another GIS-based identification for ecologically sensitive area has been performed for promotion of tourism in Soon Valley, Pakistan. Soon Valley is rich in natural resources and also important location for tourist visitors. So that it is required to protect this valley area for developing tourism industry (Butt et al., 2019). Various ecological indicators have been identified for multi-criteria evaluation technique for promoting tourism in Soon Valley in the study by Muhammad Atif Butt in 2019.

2.1. Literature case studies

Gumti wildlife sanctuary, located in southern Tripura, spans 389.5km2 and is a biodiversity-rich semi-evergreen deciduous forest. It receives 2,625mm annual rainfall and has a high altitude of 319 meters. The sanctuary is bordered by the Khowai River, Dhumbur Reservoir, and Bangladesh. Sanctuary is having an Important Bird Area with vulnerable Lesser adjutant stork and winter migrants like Lesser Whistling Teal.

According to Eco-development strategy in Gumti Wildlife Sanctuary Management plan of Gumti wildlife sanctuary, it includes forest rights settlement, livelihood support, and wildlife conflict mitigation. This management plan also included project initiatives for defined objectives. Check dam, brushwood check dam, contour trench etc. have been considered as soil and moisture conservation measures.

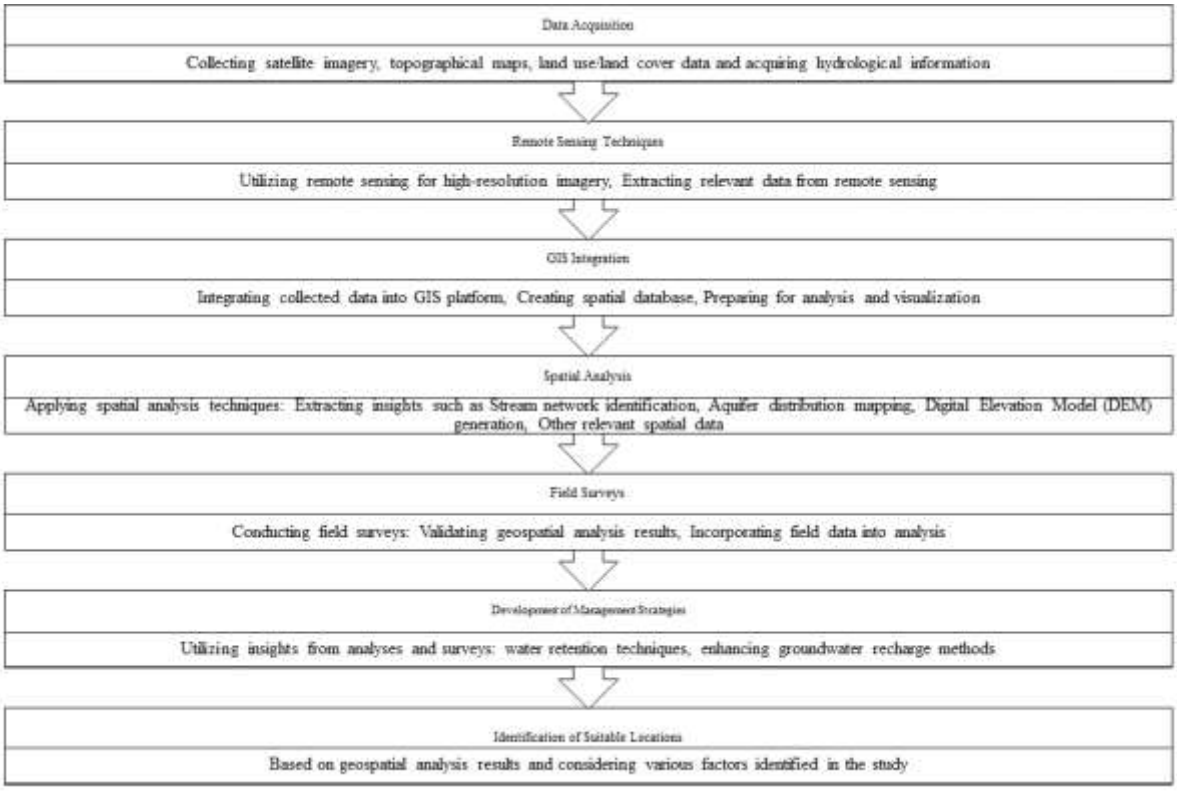
Other than that, Gebhard Schüler highlighted the importance of addressing flood disasters not only along major rivers but also in smaller tributaries. The European WaReLa project is focused on investigating water retention measures that can be beneficial for mitigating floods within small watersheds. The project involves the development of assessment tools and methodologies based on geographic information systems (GIS) and digital forest site classifications. These tools aim to assess the water retention functions influenced by landscape features and land use. The researchers have developed assessment keys using digital forest site classifications, which are essentially guidelines or criteria. These keys are used to evaluate how well different forested areas are able to retain water and prevent runoff. By applying these keys, digital maps are generated, highlighting forested sites and linear structures that are sensitive in terms of water retention. These maps offer a visual representation of different types and intensities of runoff across the landscape.

The importance of precautionary forestry management to minimize flood development has been also emphasized in study by Gebhard Schüler. It highlights the need for tailored water retention measures in forests, considering site conditions, weather events, and soil water balance. The effectiveness of retention strategies varies based on precipitation and site

attributes such as soil percolation capacity. In addition, multi-storied stands, rapid regeneration, and understory vegetation also affect soil health and retention capacity. Furthermore, wetlands play a crucial role in water retention, but their effectiveness is hindered by man-made drainage systems, which need to be deactivated for their natural functions to develop (Schüler, 2006).

Overall, this study by Schüler (2006) highlights the use of advanced techniques, such as GIS-based assessments and digital tools, to identify vulnerable areas and implement effective water retention strategies in smaller watersheds. The inclusion of economic and eco-efficiency evaluations in the Decision Support System underscores the comprehensive approach of the WaReLa project towards flood mitigation.

3. METHODOLOGY



The study utilizes a comprehensive methodology that utilizes geospatial techniques to analyze, manage, and promote sustainability in water resource management within the Nahargarh Eco-Sensitive Zone. Data acquisition involves collecting satellite imagery, topographical maps, land use/land cover data, and hydrological information. Remote sensing techniques are used to gather high-resolution imagery, which is then integrated into a Geographic Information System (GIS) platform for spatial analysis, visualization, and decision-making. Spatial analysis techniques are applied to extract valuable insights, such as stream networks, aquifer distribution, and Digital Elevation Models (DEMs). Field surveys validate and enhance the accuracy of the geospatial analyses, ensuring reliability and applicability. The insights gained from these analyses are used to develop effective water resource management strategies, including recommendations for optimizing water retention, enhancing groundwater recharge, and promoting sustainable usage practices. Geospatial analysis helps identify suitable locations for implementing these techniques, considering various factors identified in this study.

4. STUDY AREA

4.1.1. *Introduction*

Currently, the state of Rajasthan is divided into 33 districts, which are further categorized into 7 divisions, namely Ajmer, Bharatpur, Bikaner, Jaipur, Jodhpur, Kota, and Udaipur divisions. Each division encompasses 4 to 6 districts. The Nahargarh Wildlife Sanctuary and Nahargarh Eco-Sensitive Zone (ESZ) fall under the administration of the Jaipur district and Amer Tehsil (Figure 1). Furthermore, the Nahargarh Eco-Sensitive Zone comprises 26 revenue villages, with 13

villages falling under the jurisdiction of the Nahargarh Wildlife Sanctuary and the remaining 13 villages falling under the Nahargarh Eco-Sensitive Zone.

Figure 1 *Regional Setting of Nahargarh ESZ, 2022*

4.1.2. *Extent & Boundaries of Nahargarh Wildlife Sanctuary, and ESZ*

Nahargarh ESZ is named after the prominent sanctuary of Nahargarh. The ESZ has been demarcated up to an extent of 0 (zero) to 13 kilometers around the boundary of Nahargarh Wildlife Sanctuary and the area of the ESZ is 79.35 sq. km. Zero extents in the boundary are towards the sides with heavy urbanization. The extent of boundaries for the ESZ and Wildlife Sanctuary is presented in Figure 2 (see Gazette Notification of 8th March, 2019) which shows the Nahargarh Wildlife Sanctuary and ESZ as per Gazette Notification, 2019. Based on that from the respective Gazette Notification, Fig. 2 (Right) was prepared by the authors, which shows the boundaries of Nahargarh Wildlife Sanctuary, and Nahargarh ESZ.

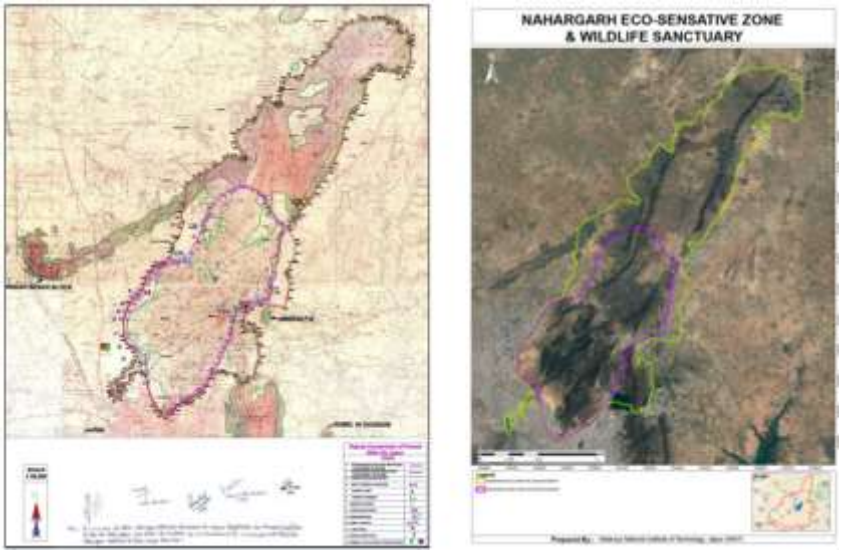


Figure 2 *Nahargarh Wildlife Sanctuary and ESZ as per Gazette Notification, 2019(Left), Prepared by authors based on Gazette Notification, 2019(Right)*

4.1.1. *Location and Natural Setting*

Nahargarh ESZ falls under the Biogeographic Zone-4 of India. Nahargarh Wildlife Sanctuary is the prominent identity of the Nahargarh ESZ. Nahargarh Wildlife Sanctuary is located in Tehsil Amber (Amer), which comes under Nahargarh ESZ, and it is situated in North-Eastern part of Aravalli Hills and Northern outskirt of Jaipur city (Rajasthan). The Sanctuary is at a distance of 3 km from Amer town on Delhi highway. Deciduous Forest covering hills is a home for wild life of this sanctuary. A part of this sanctuary was developed as a Biological Park in 1993, which known as Nahargarh Biological Park with the sole objectives of Wild Life Conservation, Wildlife Education and Research.

The ESZ is situated approximately 1,400 meters above from msl. The ESZ lies between 26° 55’56.655” N to 27° 8’20.771” N latitude, and 75° 46'48.630" E to 75° 57’39.966" E longitudes. Coming to the geographical location of the Sanctuary, it is confined between latitudes 26°56’15.08’’ N and 26°57’5.81’’ N and longitudes 75°48’55.70” E and 75°46’54.65’’ E.

4.1.2. *Linkages*

Nahargarh Sanctuary can be easily approached from earlier National Highway-08 i.e. road between Jaipur and Delhi. The bypass of NH-8 falls on the Eastern edge of the Sanctuary, which connects the Sanctuary to Delhi and Ajmer. The

Sanctuary is approachable from Jaipur-Amer road, which links Nahargarh fort from Kala Mahadeo area. It is also approachable from Amer fort, Akera, Nahri-Ka-Naka and a few outlets from Mungana area through low passes.

Figure 3 *Road Linkages*

Nahargarh Sanctuary is 254 km away from National Capital New Delhi on NH-48. Town, Sikar falls 108 km away on NH-52, and Ajmer is located at 148 km; connected through NH-48. Dausa, in the East direction, falls 63 km on NH-21(Figure 3).

5. WATERBODIES, DRAINAGE, AND WATERSHEDS

This section deals with the waterbodies in and around the Nahargarh ESZ and Amer sub-districts. Furthermore, the drainage and watersheds will also be discussed.

5.1.1. *Lakes of Amer and Surroundings*

The city's lakes further enhance Jaipur's beauty and make it the “paradise” of the desert region. Visiting lakes make the visitors re-energized. Lakes in and around the Amer with reference to Nahargarh ESZ are being discussed below:

a) Maota Lake

Positioned to the southern side of Amer town, in proximity to Amber Fort, Maota Lake features a central garden called Kesar Kyari Bagh, boasting star-shaped flowerbeds adorned with saffron blooms. The tranquil lake offers a serene vantage point to gaze upon the hillside-ensconced Amer Fort, beautifully mirrored on the lake's surface

b) Sagar Lake

A well-kept gem within Amer, Sagar Lake dates back to the 17th century and was the initial water source for Amer and Jaigarh forts, as well as the town itself. Hidden beyond Kheri Gate and the Anokhi Museum, the lake is accessible by car, followed by a leisurely walk along its border, divided into Upper Sagar and Lower Sagar sections. As the sun sets, the mud-plastered walls of Amer radiate a golden allure, beckoning exploration.

c) Man Sagar Lake

Functioning as a tourist attraction due to its proximity to Amer Fort and being the sole water body in Jaipur, the lake draws people from around the globe and across all age groups. Known as Jalmahal, Mansagar Lake spans 121.41 hectares, holding significance as a human-made reservoir. It originated from damming the Darbhawati River near Nahargarh Fort in 1610, serving irrigation and recreational purposes under Raja Man Singh I. A palace is situated within the lake, while a temple stands to its northwest.

Figure 4 Lakes in and around Amer Fort, Jaipur

This water body accommodates over 150 migratory and resident bird species. Downstream, the lake serves vegetable cultivation and irrigation purposes. Previously, sewage from Jaipur's walled city was directed into the lake, and deforestation in the adjacent hills has led to rapid sedimentation and decreased water storage capacity. However, after construction of STP the sewerage is not dumped in the lake but the lake gets the treated water from Sewerage Treatment Plant and the raw sewerage is diverted downstream. The lake also gets natural water from the catchment areas lying on Western as well as Northen side.

Water temperature of Man Sagar lake varies from 14.0 C to 31.10° which is highest in the region (Srivastava et al., 2009) following are the key concerns of these lakes based on sample study from respective lakes.

Figure 5 *Google View of Lakes in and Around Amer Fort, Jaipur*

Drawing from the 2006 study by Srivastava et al. (2009), the subsequent examination of these lakes reveals their physio-chemical attributes. In various studies concerning aquatic ecosystems, pH levels are commonly documented within the range of 6 to 9. However, the current investigation observes pH values spanning 7.0 to 9.2, with a pH range of 7 to 8 being considered conducive for fish culture (Jhingran, 1997). Dissolved Oxygen (DO) concentrations vary from 8.64 mg l-1 to 3.51 mg l-1, exhibiting a gradual decline from winter to summer across all four lakes. Hardness values span 91.33 mg l-1 to 416.7 mg l-1. Notably, the order of decreasing hardness values is observed as Jalmahal > Amer > Nevta > Ramgarh. Among these, Jalmahal Lake stands out as the most polluted, characterized by elevated alkalinity, free CO2, hardness, and pH, juxtaposed with low DO levels. Moreover, Jalmahal Lake records high levels of Endosulfan and Zinc, rendering it unsuitable for aquatic life and fish habitat.

5.1.2 Drainage and Watersheds

The arrangement of land features in a region determines its drainage system and watershed characteristics. When the city of Jaipur was designed and built, ensuring water availability was a significant consideration. The urban plan harnessed the natural topography, enabling efficient stormwater runoff through permeable soils. This is evident from the city's division marked by Suraj Pole Gate to the East and Chand Pole Gate to the West. The northern part of this division directs water flow northward, while the southern portion guides it southward.

Jaipur is enveloped by the Nahargarh hills to the north and the Jhalana hills to the east, which are a segment of the Aravalli range. The higher elevations in the city's northern region comprise low, flat-topped hills, including Nahargarh, Jaigarh, Amber, and Amargarh. These hills are currently heavily eroded and fragmented. The Aravalli range extends farther northward toward Alwar and Kotputli, vanishing near Delhi. The southern and western flanks of Jaipur are marked by scattered hills that lack continuous connections. The southern expanse of the city opens into plains, featuring gentle slopes.

Figure 6 *Drainage Map*

The encircling hills are not uniform but rather intersected by passes and gaps. Three main passes exist: one in the east, another in the north, and a third in the west. The Eastern hills include the Jhalana hill from the south to the Purana ghat pass, followed by the Gulta hill. At Surajpol Gate, a pathway leads to the Galta holy tank, and the Gulta hill extends northward. Further north, a depression blocked by Maharaja Man Singh I forms the Man Sagar Lake. The Jaipur-Jamwa Ramgarh road traverses this pass. At the confluence of the Eastern and Western hills in the north, the former Govind Ghati area serves as a passage for the Jaipur-Delhi road. The Western hill is punctuated by a single pass between Nahargarh hill and Ganeshgarh, known as Gaitor. The southern segment of this hill is Nahargarh, while the northern part is Amber hills. A small colonial mount called Moti Doongari is located in the southern section of the triangular plain.

5.2. Analysis of Natural Features

For management of protected areas, Geographic Information Systems plays and essential role as information support tools. Spatial information system data of protected areas and associated factors can facilitate the required outcomes defined earlier.

5.2.1. *Watersheds and Drainage of Nahargarh ESZ*

For understanding of drainage network, topographic maps of the Nahargarh ESZ area were generated, was used in this regard. Based on the SRTM-DEM, 1 Arc Second Global data were used and following topographic map were generated:

i) Contour lines are shown in Base Map
ii) Watershed and Stream Network Map
iii) Stream Order Map
iv) Aquifer Map
v) Digital Elevation Model (DEM) and slope analysis Map
vi) Wet Land Buffer Surrounding Major Waterbodies
vii)

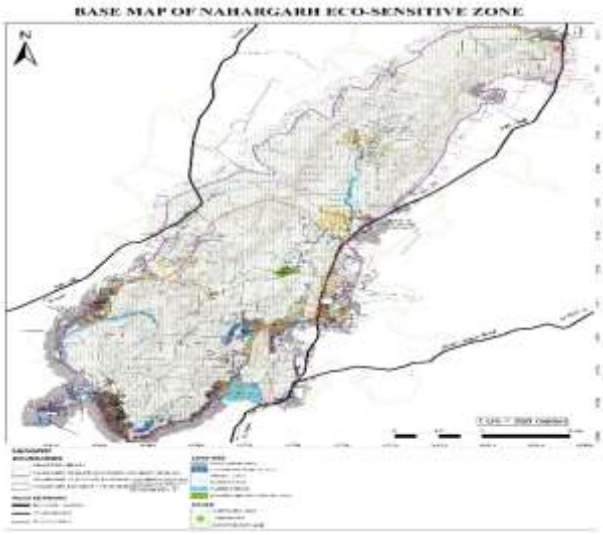


Figure 7 *Base map of Nahargarh ESZ*

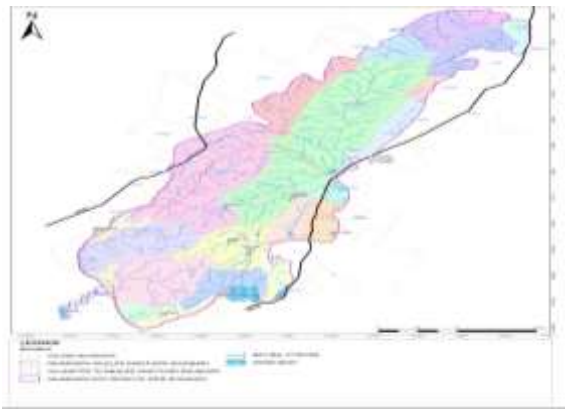


Figure 8 *Watersheds and Stream Network in Nahargarh ESZ*

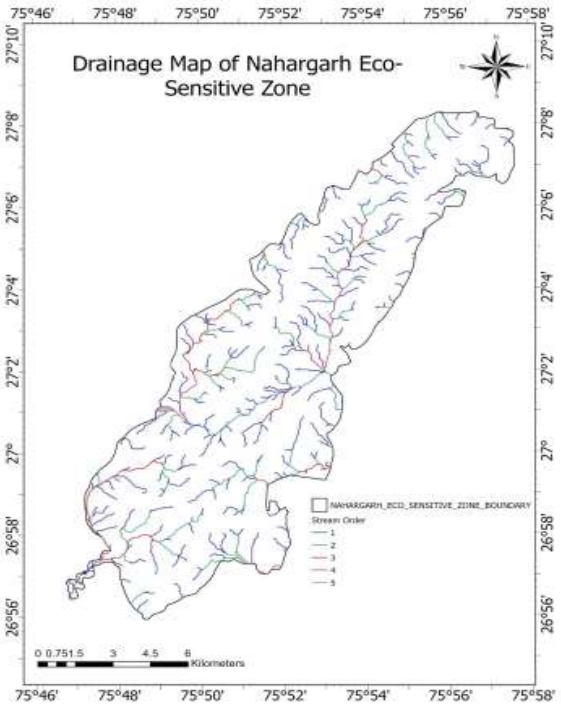


Figure 9 *Stream Order Map*

Based on analysis of Figure 8 and Figure 9, natural flow of the Nahargarh ESZ was identified, which is synchronous to the drainage of the ESZ area. Stream order has been analysed as shown in Figure 9, such as higher number shows higher order stream and lower number values show lower order stream, i.e. from 1 to 5, the stream order increases from lower order to higher. Central Ground Water Board (CGWB) periodically monitors the National Hydrograph Network Stations (NHNS) four times in a year in the Jaipur district i.e. in January, May (Pre-monsoon), August and November (Post-monsoon). The Nahargarh ESZ aquifer has a significant negative influence on the groundwater. There are two kinds of aquifers i.e. Quartzite and Younger Alluvium type, are noted based on the Atlas Map of Jaipur.

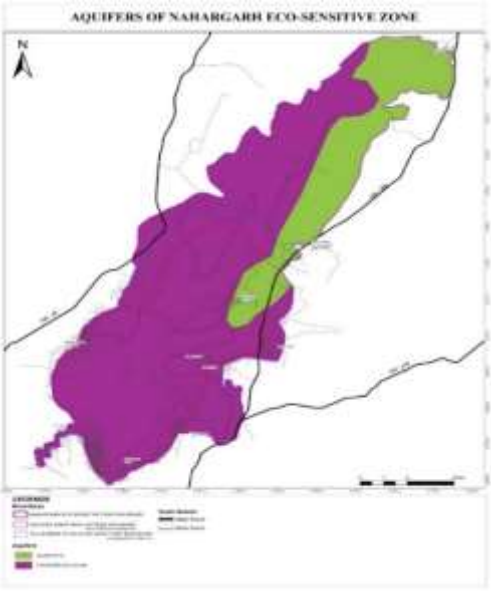


Figure 10 *Aquifer in Nahargarh ESZ Source: Prepared based on Atlas of Jaipur (2022)*

Viewing the above aquifer map (Figure 10) of the ESZ, it is noticed that the younger alluvium type aquifer is dominating comparative to quartzite aquifer.

5.2.2. *Slope Suitability*

Slope suitability is one of the integral components of the land suitability analysis. Preparing land suitability analysis, three factors are taken into consideration i.e. soil, forest and slope. The slope of the ESZ has been prepared using Digital Elevation Model (DEM) on GIS platform. The DEM model counts typical contours in analyzing the topography and relief. The relief elevation varies between 329 to 608 meters.

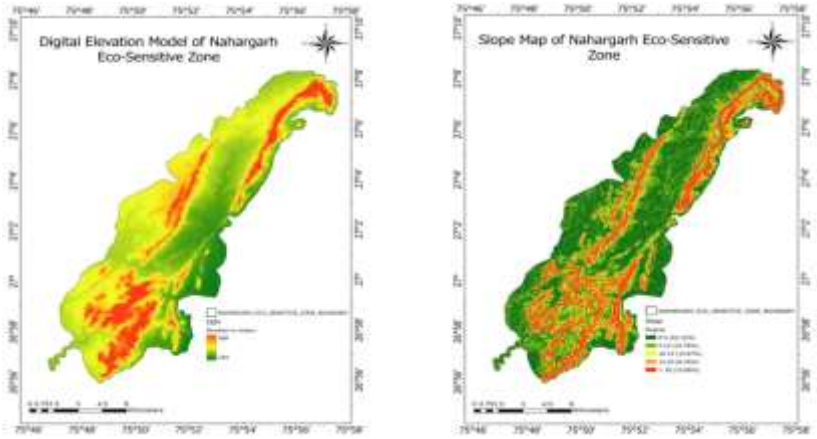


Figure 11 *Digital Elevation Model (DEM) and slope of Nahargarh ESZ, 2022*

Viewing, the slope suitability, the slope of ESZ is divided into five following categories based on steepness topography i.e:

1) Very Low Slope: 0-5 Degree
2) Low Slope: 5-10 Degree
3) Gentle Slope: 10-15 Degree
4) Moderate Gentle Slope: 15-20 Degree
5) Steep Slope: >20 Degree

Hilly areas are the most fragile sub-zones of the Nahargarh ESZ. In hill areas of Nahargarh ESZ, no construction more than slope (gradient), having 20-degree inclination should be allowed. On the other hand, slope below than 20-degree may be considered for the development. The specific emphasis should be given to the afforestation ventures in the hilly areas

where the soil, and slope suitability meets the favorable. The development promotions and control regulations will be admirable applicable in the ESZ.

5.2.3. *Buffers Zones along Wetlands*

There is a total area of 202.12 ha under waterbodies in the Nahargarh ESZ, which is 1.42 percent of the total geographical area of ESZ. It is important to conserve the waterbody and surrounding wetland, hence a buffer of it is proposed around the major waterbodies of the ESZ to enhance the wetland ecosystem around these waterbodies. A major issue arises from the existing development which lies within the buffer zone of water bodies. It is hence clarified that existing development need not be demolished and can be retained as such but no new construction in this buffer zone shall be allowed to take place.

As per MOEF&CC there is no wetland in Nahargarh ESZ Area. However important water bodies of Nahargarh ESZ are important as they support in biodiversity & helping ground water recharge. These identified water bodies are shown in the Figure 12.

Figure 12 *Wet Land Buffer Surrounding Major Waterbodies*

5.3. Major Water Management Initiative Needed for ESZ

5.3.1. *Land Suitable for Water Retention*

The important drainage channels have been identified for construction of anicuts/check dams. The ideal locations for construction of check dams would be where the gradient of water channel is less, and large capacity of water can be stored due to availability of water storage area. The topographical suitability of such sites has also been checked with the help of contour map. These water retention structures would help in percolation of water in soil as well as meet the needs of wildlife animals and birds round the year. Location of available water retention points are as show in the images below:

Ram Sagar Lake

Artificial water point Jaigarh Fort

Water Body in the old

Water Bodies in the vicinity of

5.3.2. *Water Retention and Recharge*

To mainatian soil moisture and ground water recharge, earthern embarkement of 1 meter height may be proposed in the various parts of ESZ. These embarkements will also act as surface water sources for animals. Location of these proposed embarkments can be seen in Figure 13. This suggestion needs to be examined by forest department and monitioring committee. The availability of water during off monsoon season is a serious concern for the wildlife animals and birds. Such check dams will have maximum height of 1m only.

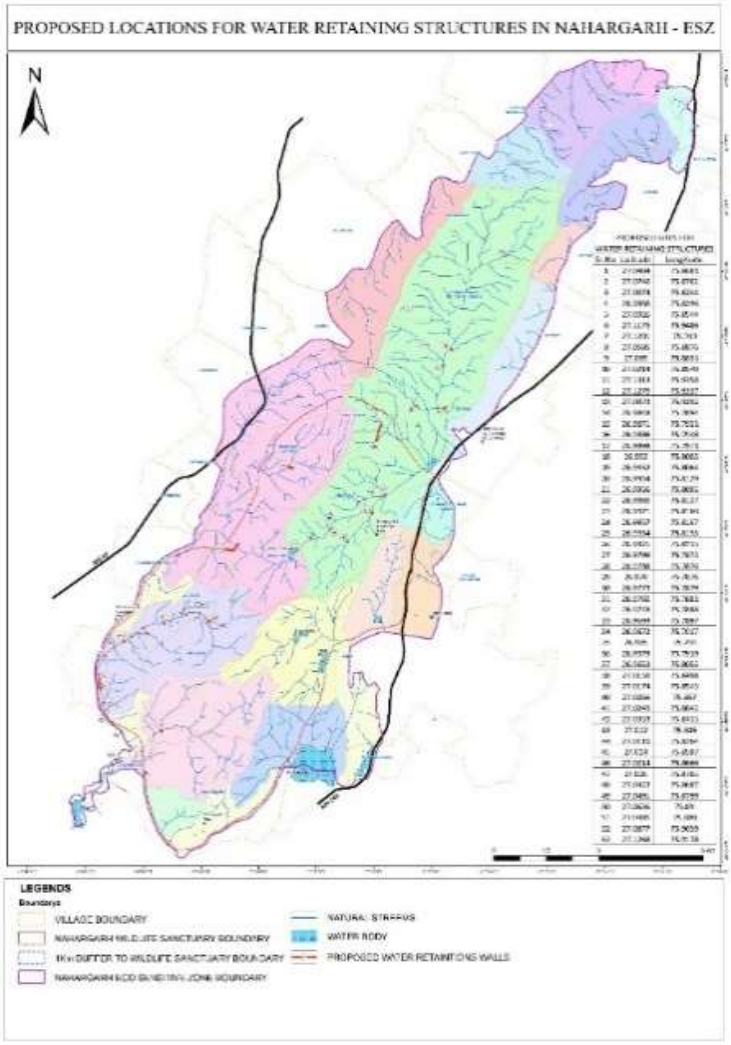


Figure 13 Major Water Management Initiatives Needed for ESZ

6. CONCLUSION AND FUTURE SCOPE

In conclusion, this study underscores the essential role of a comprehensive and integrated geospatial approach in water resources management and sustainability within the Nahargarh Eco-Sensitive Zone. By meticulously employing geospatial techniques, data integration, and field surveys, a profound understanding of the intricate water dynamics in the region has been achieved.

Commencing with meticulous geospatial data acquisition, encompassing satellite imagery, topographical maps etc., and the study ensures a solid foundation for analysis. The application of remote sensing techniques guarantees the acquisition of high-quality, distortion-free imagery, subsequently refined through preprocessing.

Integration of the collected data into a Geographic Information System (GIS) facilitates not only spatial analysis but also visualization. By georeferencing and layer integration, relationships between diverse elements like stream networks, aquifer distribution, and Digital Elevation Models (DEMs) are unveiled. These insights contribute to a comprehensive understanding of water resource dynamics.

Field surveys play a crucial role in reinforcing the credibility of geospatial findings and augmenting accuracy. Ground truthing validates data, enhancing the reliability of remote sensing and GIS analysis.

The culmination of geospatial analysis and field surveys guides the formulation of effective water resource management strategies. Based on identified patterns, recommendations are proposed to optimize water retention, boost groundwater recharge, and foster sustainable usage practices. Crucially, specific proposals for water retention techniques are conceived, addressing soil moisture preservation and groundwater replenishment, taking into account the findings of the geospatial analysis.

The future scope of research lies in the extension of this methodology to encompass advanced hydrological modeling for predictive analysis, integrating socio-economic dimensions, establishing long-term monitoring mechanisms, conducting multi-zone comparisons, and embedding research outcomes within policy frameworks for practical implementation.

In essence, the geospatial approach demonstrated herein empowers stakeholders with a robust foundation for effective water resource management, aligning with ecological preservation and societal welfare.

7. REFERENCES

1. (n.d.). *Guideline for Eco Development and Microplanning in Gumti Wildlife Sanctuary*. GOVERNMENT OF TRIPURA.
2. Butt, M. A., Nisar, K., Mahmood, S. A., Sami, J., Qureshi, J., & Jaffer, G. (2019, May 14). Toward GIS-Based Approach for Identification of Ecological Sensitivity Areas: Multi-Criteria Evaluation Technique for Promotion of Tourism in Soon Valley, Pakistan. *Journal of the Indian Society of Remote Sensing*, *47*(9), 1527–1536. https://doi.org/10.1007/s12524-019-00971-1
3. Deb, S., Ahmed, A., & Datta, D. (2013, December 14). An alternative approach for delineating eco-sensitive zones around a wildlife sanctuary applying geospatial techniques. *Environmental Monitoring and Assessment*, *186*(4), 2641–2651. https://doi.org/10.1007/s10661-013-3567-7
4. Dovers, S., Feary, S., Martin, A., McMillan, L., Morgan, D., & Tollefson, M. (2015). ENGAGEMENT AND PARTICIPATION IN PROTECTED AREA MANAGEMENT: WHO, WHY, HOW AND WHEN? In S. Feary, G. L. Worboys, M. Lockwood, A. Kothari, & I. Pulsford (Eds.), *Protected Area Governance and n Management* (pp. 413–440). ANU Press. http://www.jstor.org/stable/j.ctt1657v5d.21
5. Eagles, P. F. J. (1981, July). Environmentally Sensitive Area Planning in Ontario, Canada. *Journal of the American Planning Association*, *47*(3), 313–323. https://doi.org/10.1080/01944368108976513
6. Schüler. (2006). Identification of flood-generating forest areas and forestry measures for water retention. *For. Snow Landsc. Res.*, *80*(1), 99–114.
7. Srivastava, Harit, & Srivastava. (2009). A study of physico-chemical characteristics of lakes around Jaipur, India. *Journal of Environmental Biology*, *30*(5), 889–894.
8. The Environment (Protection) Act, 1986 Ministry of Environment and Forests, Department of Environment Forests and Wildlife, Government of India, New Delhi.
9. Turner, R., & Brooke. (1988). Management and Valuation of an Environmentally Sensitive Area: Norfolk Broadland, England, Case Study. *Environmental Management*, *12*, 193–207.
10. Wildlife Protection Act, 1972, No. 53 of 1972, India. (1972).
11. Worboys, G. L., & Trzyna, T. (2015). MANAGING PROTECTED AREAS. In G. L. Worboys, M. Lockwood, A. Kothari, S. Feary, & I. Pulsford (Eds.), *Protected Area Governance and Management* (pp. 207–250). ANU Press. http://www.jstor.org/stable/j.ctt1657v5d.15