Journal of
Remote Sensing & GIS
https://journals.stmjournals.com/jorsg

ISSN: 2230-7990 (Online)
ISSN: 2321-421X (Print)
Volume 17, Issue 1, 2026
January–April
DOI (Journal): 10.37591/JoRSG

Research JoRSG

A Multi-Index Remote Sensing Analysis for Characterizing Water Stress and Environmental Indicators in Girnar Wildlife Sanctuary, Gujarat, India

Aditya Dharaiya[1,*], Girish Limaye[2], Ashwini Supekar[3], Nishith Dharaiya[4]

Abstract

Water scarcity is a critical concern in arid and semi-arid regions, with implications for ecological stability, public health, and sustainable resource management. The Girnar Wildlife Sanctuary, Gujarat, presents a case where ecological fragility intersects with cultural and religious pressures. This study employs satellite remote sensing and GIS-based approach to characterize water stress parameters within the sanctuary. Key spectral indices along with Land Use and Land Cover (LULC) were integrated through Weighted Overlay Analysis (WOA) to generate Water Scarcity Vulnerability Index (WSVI). Strong geographical variation within the sanctuary is revealed by the data, which show ecological resilience with lower vulnerability and higher vegetation cover and soil moisture. Conversely, peripheral zones dominated by barren lands and built-up areas emerge as hotspots of ecological stress and water scarcity, exacerbated by anthropogenic activities and limited perennial water sources. Seasonal dependence on streams and reservoirs further underscores vulnerability of both flora and fauna, potentially intensifying human–wildlife conflict during dry periods. This research highlights urgent need for integrated conservation strategies, including artificial waterhole creation, watershed restoration, and regulation of pilgrimage-related activities. By advancing geospatial framework, the study not only informs targeted water management and bio-conservation in Girnar but also offers methodological template for other protected areas.

Keywords: Conservation, ecological resilience, GIS, sustainable water management, water scarcity vulnerability

INTRODUCTION

Freshwater is a vital resource for all life forms, serving a fundamental role in human health, agricultural productivity, and the maintenance of the ecological balance. Despite the extensive coverage of water on the Earth's surface, approximately only 0.70% is accessible and suitable for direct human utilization, with groundwater constituting the bulk of this usable resource. The quality of the freshwater is characterized by its physical, chemical, and biological properties. However, the processes of rapid urbanization, industrial development, and inadequate waste management have increasingly contributed to the contamination of water sources with harmful chemicals and pathogens [1–5].

Water scarcity poses a significant challenge in Junagadh, India, a region characterized by arid and semi-arid conditions. To address this issue effectively, there is a pressing need for a comprehensive spatial

***Author for Correspondence**
Aditya Dharaiya
E-mail: adiradhu@gmail.com

[1]Research Scholar, Department of Geology, Savitribai Phule Pune University, Pune, Maharashtra, India.
[2]Ph.D. Scholar, Department of Environmental Science, Savitribai Phule Pune University, Pune, Maharashtra, India.
[3]Assistant Professor, Department of Geology, Savitribai Phule Pune University, Pune, maharashtra, India.
[4]Director, Center of Excellence for Wildlife and Conservation Studies (CWCS), Junagadh, Gujarat, India.

Received Date: December 04, 2025
Accepted Date: January 06, 2026
Published Date: February 06, 2026

Citation: Aditya Dharaiya, Girish Limaye, Ashwini Supekar, Nishith Dharaiya. A Multi-Index Remote Sensing Analysis for Characterizing Water Stress and Environmental Indicators in Girnar Wildlife Sanctuary, Gujarat, India. Journal of Remote Sensing & GIS. 2026; 17(1): 1–11p.

analysis of water scarcity vulnerability using advanced remote sensing and GIS techniques. Remote sensing provides up-to-date, large-scale data on parameters, like rainfall, vegetation, soil moisture, and surface water bodies, while GIS allows integration and spatial analysis of these factors to map vulnerable zones. Together, they help identify hotspots of water stress, understand underlying causes, and support effective planning and management strategies for sustainable water resource use in the arid and semi-arid conditions of Junagadh. The problem at hand entails integrating multi-temporal satellite data and GIS analysis to accurately assess the spatial distribution and drivers of water scarcity vulnerability in Junagadh. This research aims to develop a robust methodology for identifying vulnerable areas and informing targeted water resource management strategies [6–12].

In humid regions, like Junagadh, Gujarat, groundwater is often the primary source of drinking water, a challenge intensified during large gatherings, like the five-day Girnar Parikrama, which is a circumambulation around Girnar Mountain where people begin to walk in a chartered path, reflecting deep faith, endurance, and devotion. Therefore, thorough spatial monitoring and assessment of water sources before and after such events is essential for public health safety [13–17].

The Girnar Hills in Junagadh attract thousands of pilgrims during the Girnar Parikrama, creating significant demands on local water resources. Pilgrims depend on natural springs, wells, and temporary water stations, which may introduce microbial and chemical contaminants [18]. Previous studies indicate variable water quality parameters in Junagadh district, including high total dissolved solids (TDS), electrical conductivity (EC), microbial contamination, and salinity issues from seawater intrusion. Globally, numerous studies have assessed water scarcity using hydrological or socioeconomic indicators, but few have integrated multi-index remote sensing parameters with spatially explicit vulnerability modeling in culturally and ecologically sensitive semi-arid landscapes. This study, therefore, presents a novel geospatial framework that bridges ecological monitoring and water management, contributing to the growing international discourse on remote sensing – based environmental vulnerability assessment [19–21]. This study aims to investigate the composite metrics of environmental water stress parameters, providing a comprehensive spatial analysis of water scarcity vulnerability in Junagadh, facilitating evidence-based decision-making and sustainable water resource management practices. The results will enhance our understanding of anthropogenic impacts and support the development of effective water safety strategies during large-scale events [22–26].

STUDY AREA

The Girnar Hills, located in Junagadh district, Gujarat, form a distinctive ecological and cultural landscape at the edge of the Kathiawar Peninsula. The area encompasses Mount Girnar, an ancient volcanic massif rising to about 1,117 m above sea level, and is designated as the Girnar Wildlife Sanctuary (GWS) since 2008 to conserve its rich biodiversity, including the Asiatic lion (Panthera leo persica). The region experiences a semi-arid climate with an average annual rainfall of ~900 mm, characterized by short monsoons and prolonged dry periods. The sanctuary's terrain comprises hilly slopes, rocky plateaus, and seasonal streams, such as the Madhuvanti and Saraswati, with Deccan Trap and alluvial aquifers that are prone to depletion and contamination. Vegetation is mainly dry deciduous forest dominated by Tectona grandis, Anogeissus latifolia, Acacia catechu, and Boswellia serrata. Girnar also holds major religious significance, attracting thousands of pilgrims during the annual Girnar Parikrama a 36 km circumambulation around the hills (Figure 1) which exerts additional stress on local water resources. This intersection of ecological fragility and anthropogenic pressure makes the area ideal for studying spatial water scarcity vulnerability using remote sensing and GIS approaches [27–30].

MATERIALS & METHODOLOGY

Methodology for this study will employ an integrative and comparative approach to capture the environmental dynamics. Satellite remote sensing was used in deriving the water stress-related parameters, which ultimately yielded the Water Scarcity Vulnerability regions around the Girnar Parikrama regions.

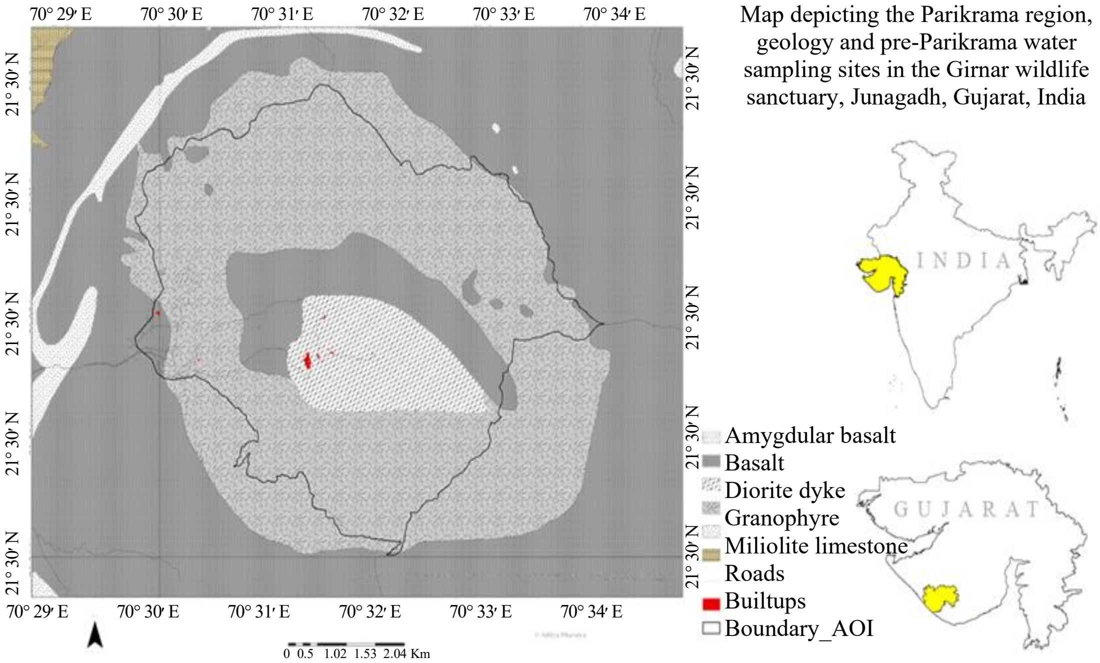

Figure 1. A geological map depicting the study area index along with Land use features and the lithological units.

The calculated physicochemical parameters were plotted as thematic layers to understand the spatial distribution of hydrochemistry, using ArcGIS Pro 3.4.3®. Correlations between multiple spectral indices and their correlative regression approach in GIS were explored through overlay analysis and Water Quality Index (WQI) modeling.

Indices for Water Scarcity Vulnerability Characterisation

Normalized Difference Vegetation Index (NDVI)

NDVI was used to assess vegetation health and density. Healthy vegetation typically indicates adequate water availability, while stressed vegetation may signal water scarcity. It is calculated using the reflectance values in the red (R) and near-infrared (NIR) portions of the electromagnetic spectrum, according to the formula:

$$NDVI = (NIR - R)/(NIR + R)$$

Modified Normalized Difference Water Index (MNDWI)

The Normalized Difference Water Index (MNDWI) is a remote sensing index designed to monitor changes in water content of vegetation and detect open water bodies. MNDWI is calculated using the reflectance values in the Visible-GREEN and shortwave infrared (SWIR) or green light portions of the electromagnetic spectrum:

$$MNDWI = (Green + NIR)\ /(Green - R)$$

Soil Moisture Index (SMI)

Studying soil moisture measurements across time offers valuable information about extended patterns in water availability. One of the methods to derive soil moisture involves using the relationship between NDVI and Land Surface Temperature (LST) as shown in the expression below.

$$SMI = (NDVI - NDVI\ Min) * (LST\ Max - LST) \\ /\ (NDVI\ Max - NDVI\ Min) * (LST\ Max - LST\ Min)$$

Analyzing soil moisture data over time provides insight into long-term trends in water availability. This temporal analysis helps to understand the impact of climate change on soil moisture levels and vulnerability to water deficits.

Evapotranspiration

Remote sensing-based ET maps offer valuable spatial and temporal data on water loss from evapotranspiration, which is important for evaluating vulnerability to water scarcity. The surface energy balance method is widely used in remote sensing-based ET estimation. The Surface Energy Balance Algorithm for Land (SEBAL) is one such model. SEBAL uses LANDSAT 8 satellite imagery to estimate ET by solving the surface energy balance equation:

$$\lambda E = Rn - G - H$$

where:

- λE is the latent heat flux (ET).
- Rn is the net radiation at the surface.
- G is the soil heat flux.
- H is the sensible heat flux.

Monitoring water balance in various regions heavily relies on ET maps, as they provide valuable insights into the amount of water lost to the atmosphere.

Land Use and Land Cover (LULC)

At first, the false color composite from the Sentinel 2 image was created, and the LULC classes were identified by visual interpretation, followed by the creation of a training sample signature file to be used in Supervized image classification. The Supervized Classification technique with an ML-aided Support Vector Machine (SVM) classifier was used to classify the satellite image into appropriate land use and land cover classes with respect to the study area.

Weighted Overlay Analysis (WOA)

Utilizing the outcomes of all the above five spectral indices, these were then subjected to the Analytical Hierarchy Algorithm (AHP), where, by statistical calculations, specific weights for the five parameters were assigned, which will be taken as input for the WOA process. Using the Raster calculator, the sum of the product of the assigned weight for respective parameters was calculated, and a new index named Water Scarcity Vulnerable Index (WSVI) was derived.

The Water Scarcity Vulnerability Index (WSVI) combines multiple remote sensing indices and environmental data to deliver a thorough assessment of water scarcity vulnerability. By merging data from NDVI, MNDWI, LULC, Evapotranspiration, and Soil Moisture maps, WSVI provides a comprehensive understanding of water availability, demand, and distribution across various regions.

RESULTS

The integration of LULC, vegetation indices, water indices, soil moisture, and evapotranspiration analysis provides a multi-dimensional understanding of ecological dynamics in the Girnar Wildlife Sanctuary. These results, when synthesized into the WSVI, reveal critical insights into spatial heterogeneity, ecological resilience, and areas of vulnerability to water scarcity.

The LULC analysis demonstrates that the Girnar wildlife sanctuary is dominated by vegetation cover, reflecting its designation as a protected forest ecosystem (Figure 2). Out of 31.03 km2 area, 0.053% is covered by Water body, 42.56% is covered by Moderate Vegetation, 2.70% is covered by Dense Vegetation, 1.47% is covered by Builtups, and rest of the area, i.e., 53.21% is covered by Barren lands Dense to moderate forest patches are concentrated within the core hilly region of Girnar, whereas barren lands and built-up areas are more prominent along the peripheries, particularly near Junagadh city and pilgrimage corridors.

Journal of Remote Sensing & GIS
Volume 17, Issue 1
ISSN: 2230-7990 (Online), ISSN: 2321-421X (Print)

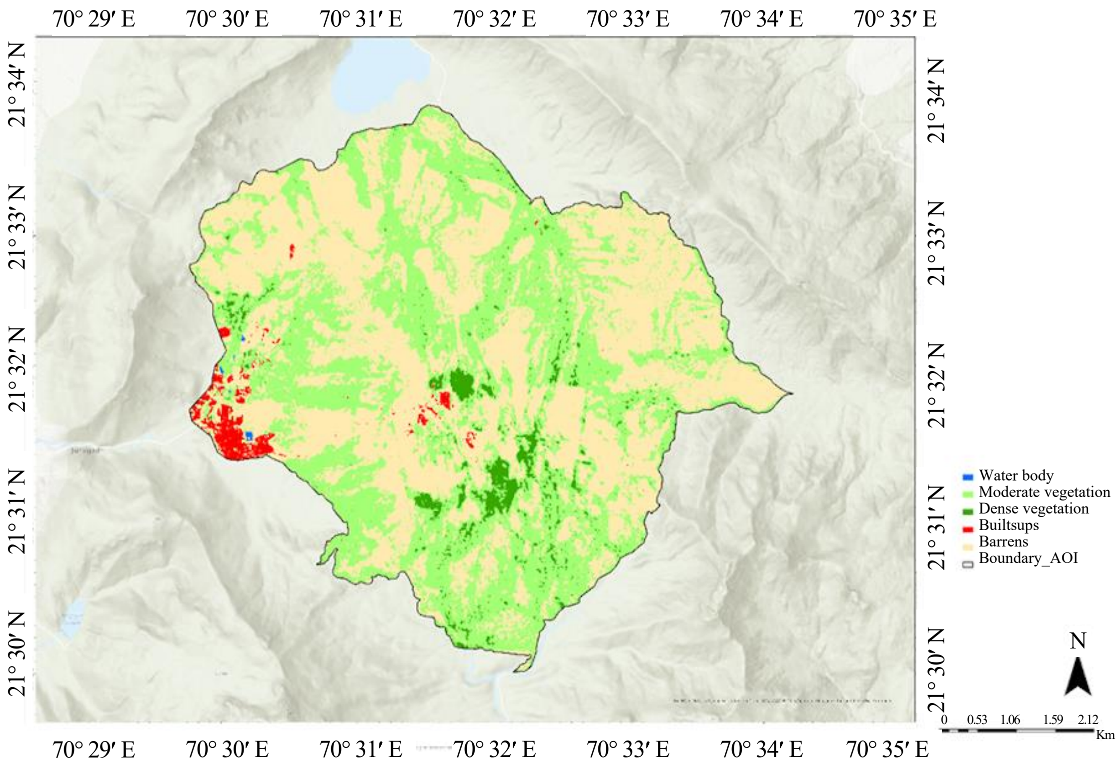

Figure 2. Map depicting the Land Use and Land Cover of the sanctuary, generated using the SVM Classifier of Supervized Classification algorithm

NDVI values indicate healthy vegetation in the dense forested areas, confirming the ecological vitality of core zones. However, lower NDVI values are prominent in peripheral regions, where vegetation stress is attributed to human encroachment, grazing, and infrastructural expansions (Figure 3).

The low values of MNDWI highlight the extreme scarcity of perennial surface water bodies in the sanctuary (Figure 4). Seasonal rivers, small reservoirs, and ephemeral streams are the only sources of surface water within the sanctuary. These are highly dependent on monsoon recharge, making the sanctuary ecologically vulnerable during prolonged dry seasons.

Soil moisture distribution is highly heterogeneous, with valleys and lower elevations showing relatively higher SMI values, while the steep central hills exhibit low values due to rapid runoff and reduced infiltration (Figure 5). Such micro-topographic control on soil moisture not only governs vegetation productivity but also impacts faunal habitat suitability.

Evapotranspiration values are highest in dense forest patches, signifying active vegetation transpiration (Figure 6). While this reflects healthy vegetation functioning, it simultaneously points to substantial water loss from the system. In contrast, barren, and built-up areas record very low ET, indicating negligible ecological productivity.

The synthesized WSVI map (Figure 7) synthesizes the above indicators and reveals clear spatial differentiation in vulnerability. Core forested and valley regions exhibit low to very low vulnerability, owing to better vegetation cover, higher soil moisture, and ecological resilience.

In contrast, the peripheral barren lands and built-up areas exhibit high to very high vulnerability, strongly linked to anthropogenic disturbance and water scarcity.

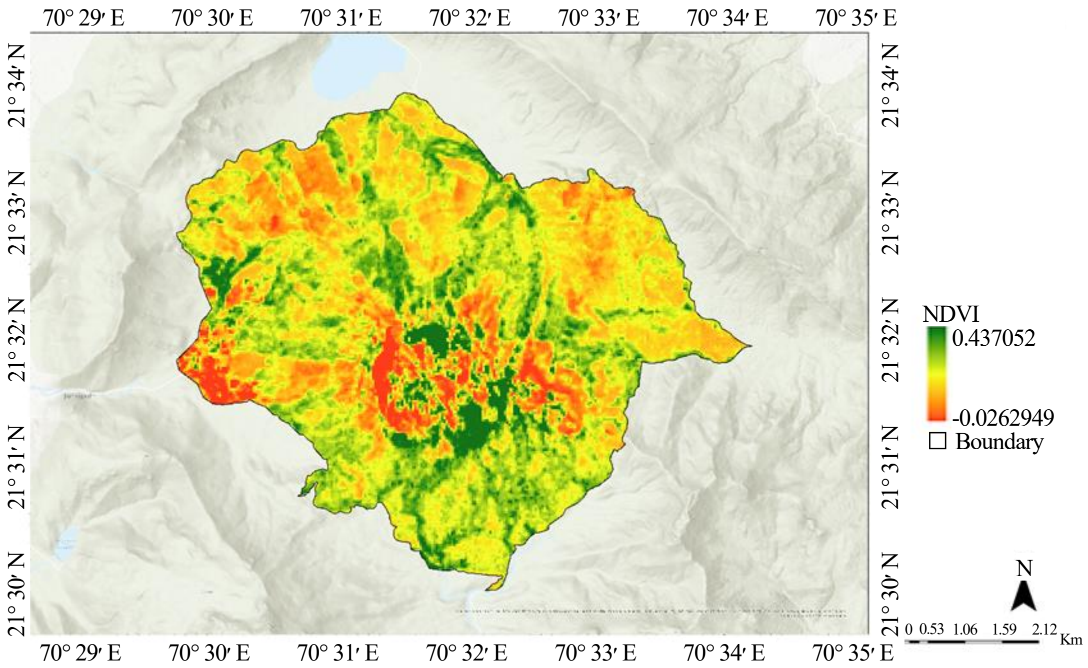

Figure 3. Spectral index, i.e., NDVI, generated using NIR and VIS-Red band ratios depicting the vegetation health over the sanctuary.

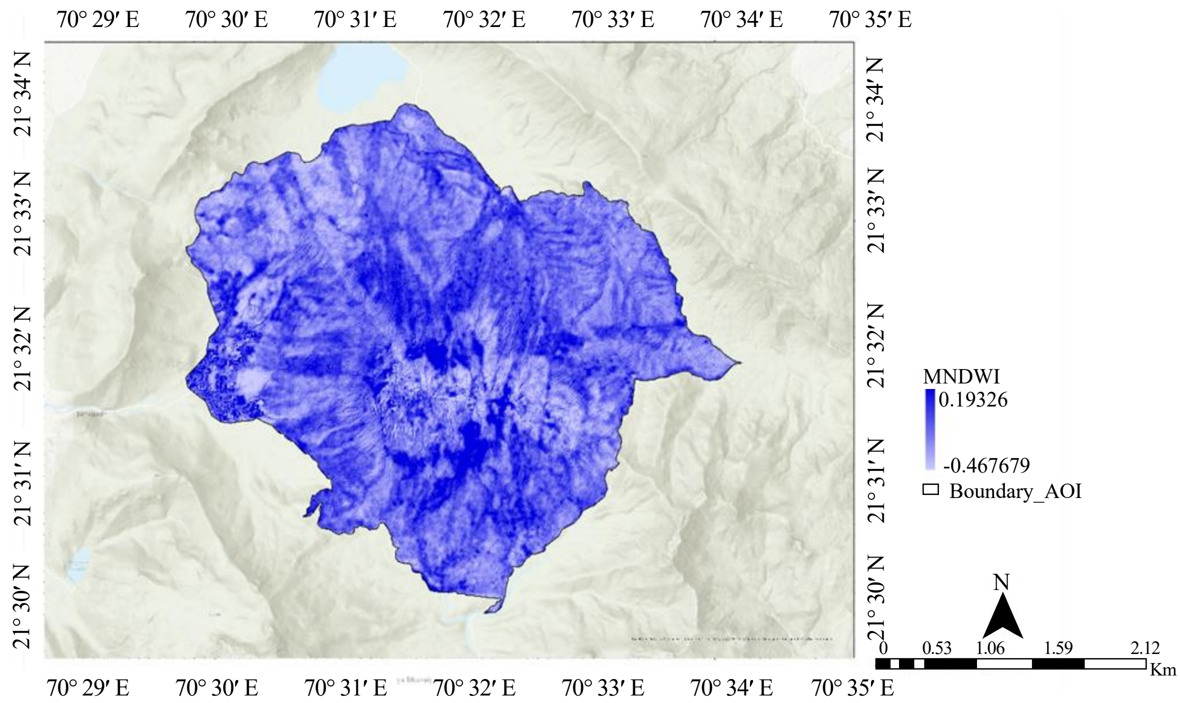

Figure 4. Spectral index, i.e., MNDWI, depicting the plant moisture and water abundance within the sanctuary, generated using SWIR & VIS-Green band ratios.

DISCUSSIONS

The spatial patterns observed in vegetation health, soil moisture, and evapotranspiration collectively underline the fragile ecological equilibrium of the Girnar Wildlife Sanctuary. While the core zones maintain ecological resilience through dense vegetation and better water retention, peripheral regions are under significant stress due to expanding urbanization, pilgrimage activities, and agricultural encroachment.

Journal of Remote Sensing & GIS
Volume 17, Issue 1
ISSN: 2230-7990 (Online), ISSN: 2321-421X (Print)

The high NDVI zones provide crucial habitats for herbivores, thereby indirectly supporting predator populations, such as the Asiatic lion (Panthera leo persica), which has been recorded within the Girnar landscape.

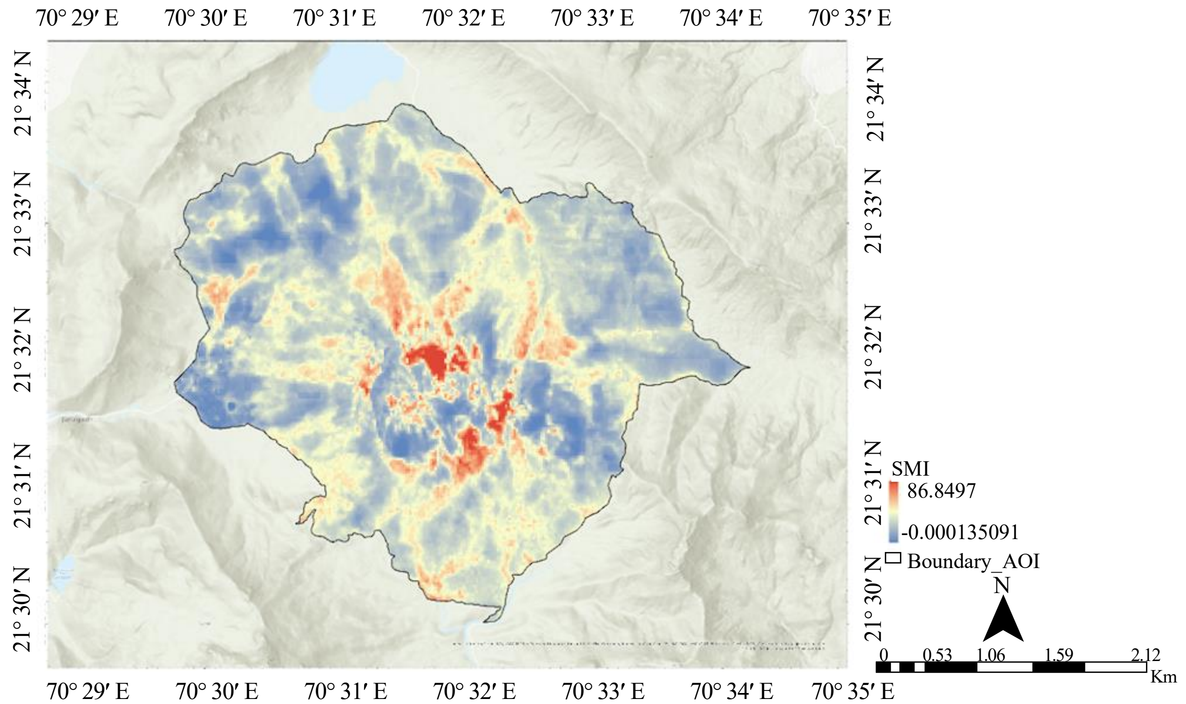

Figure 5. Map depicting the moisture content in the soil calculated using the band ratio method provided NDVI and LST as functions.

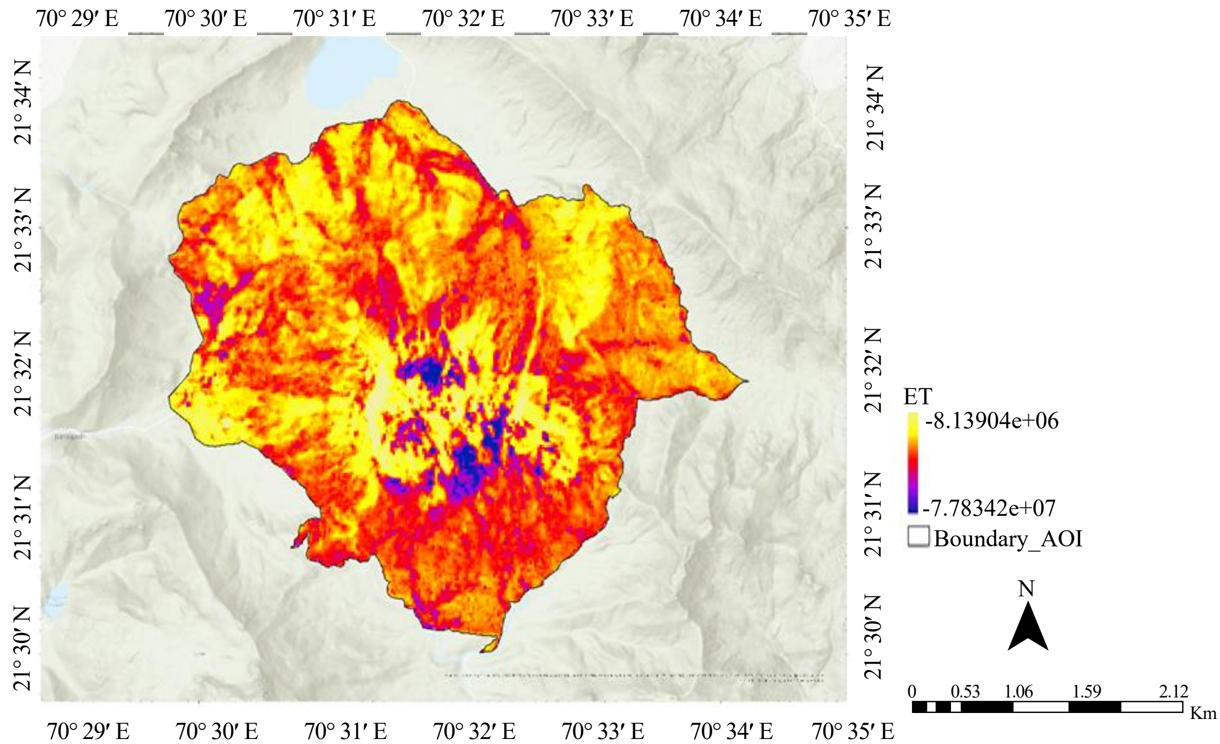

Figure 6. Map showing the amount of Evapotranspiration within the sanctuary estimated using the SEBAL model.

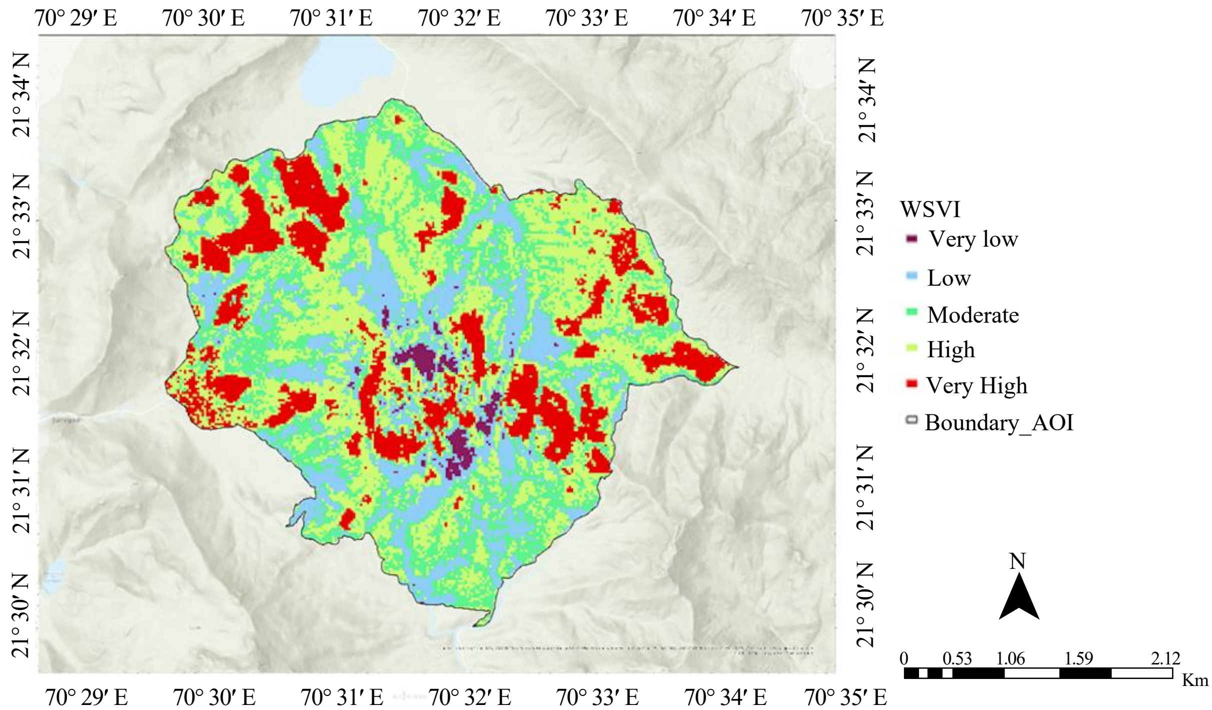

Figure 7. The resultant map of Water Scarcity Vulnerability Index derived through Weighted Overlay method using the above five parameters.

The low MNDWI and high ET in forested areas indicate the dual challenge of ecological productivity and water loss. High evapotranspiration increases ecosystem water demand, which, under semi-arid conditions and climate variability, could lead to unsustainable water stress. Similarly, the observed low soil moisture in steep slopes highlights vulnerability to erosion and vegetation degradation, which may further diminish ecosystem resilience.

These findings align with previous research in semi-arid protected areas emphasizing that anthropogenic pressure combined with natural scarcity intensifies ecological vulnerability. Moreover, the reliance of wildlife on seasonal water bodies increases the potential for human–wildlife conflict, particularly during dry periods when animals move toward human settlements in search of water. These high-vulnerability zones are ecologically critical, as they represent potential hotspots for habitat degradation and wildlife stress. The alignment of WSVI hotspots with anthropogenic pressure zones underscores the compounded impact of human activity and natural scarcity, echoing findings from vulnerability assessments in other protected areas of India.

The results highlight the urgent need for integrated management interventions. Strategies – such as artificial waterhole creation, watershed restoration, and rainwater harvesting – can mitigate seasonal scarcity. The sanctuary's high ET values in forested areas indicate robust ecological productivity, but in the absence of water management interventions, this could lead to unsustainable ecosystem water demand. Similarly, the observed low soil moisture in hilly slopes reveals vulnerability to erosion and vegetation degradation, further weakening ecosystem resilience. Regulating pilgrimage-related expansion and monitoring water quality before and after large gatherings – like the Girnar Parikrama – are also critical for sustainable coexistence between human and ecological systems.

In a broader context, the geospatially derived WSVI framework presented in this study demonstrates the potential of multi-index remote sensing approaches to identify vulnerability hotspots and guide conservation policy. By combining ecological, hydrological, and anthropogenic dimensions, the approach offers a replicable model for other semi-arid protected and pilgrimage landscapes globally.

CONCLUSIONS

This research carries significant implications for ecological integrity, societal welfare, and environmental policy. By integrating multi-criteria remote sensing indices, the study addresses a critical gap in understanding water scarcity vulnerability within ecologically sensitive landscapes such as the Girnar Wildlife Sanctuary. The results highlight spatial heterogeneity in vegetation health, soil moisture, evapotranspiration, and water availability, with the core forested zones displaying resilience while peripheral built-up and barren areas emerge as hotspots of ecological stress. These findings hold direct relevance for local governance entities, such as the Junagadh Nagar Palika, the Gujarat Pollution Control Board, and regional forest and water management authorities, enabling more strategic resource allocation for habitat conservation and conflict mitigation.

From a societal perspective, the study underscores the importance of ensuring water security in and around the sanctuary, especially during peak pilgrimage periods, such as the Girnar Parikrama, when human pressure intensifies. The vulnerability of peripheral zones necessitates proactive interventions, such as artificial waterhole creation, watershed restoration, and regulation of ad hoc water supply systems, to safeguard both wildlife and public health.

The insights also provide a strong basis for NGOs and public health agencies to develop targeted awareness campaigns and sanitation strategies that account for temporary and often stressed water sources during such events.

At the policy level, the findings advocate for embedding hydrological and ecological monitoring within protected area management frameworks, thereby linking conservation planning with sustainable religious tourism practices. Scientifically, this research advances interdisciplinary discourse by demonstrating the utility of geospatial indices (NDVI, MNDWI, SMI, ET, and WSVI) in diagnosing landscape-level vulnerabilities.

Moreover, it establishes a scalable methodological framework applicable to other semi-arid protected areas and pilgrimage landscapes across India. Ultimately, the study aspires to inform evidence-based, community-centric action plans that secure both biodiversity conservation and sustainable resource use in the Girnar region.

Acknowledgments

A sincere acknowledgment to Gujarat Wildlife division for granting the permissions to carry out a research work in the sanctuary and providing necessary data. An extended gratitude to Center of Excellence for Wildlife and Conservation studies for providing us with the logistics support. USGS and BHOONIDHI is thankfully acknowledged for providing us the free and open-source datasets for the smooth conduct of software analysis.

REFERENCES

1. Aditya D, Nishith D. Assessment of wildlife habitats using geo-spatial techniques; implications for long-term habitat management of Girnar Wildlife Sanctuary, Gujarat, India. J Environ Stud. 2021;7(1):8.
2. Iyiola AO, Asiedu B, Kolawole AS, Failler P. Assessment of water quality and bacteriological levels in Nile tilapia (Oreochromis niloticus) of Aiba Reservoir, Nigeria, West Africa. Tropicultura. 2019;37(3):1367. doi: 10.25518/2295-8010.1367.
3. Amanatidou E, Adamidou K, Trikoilidou E, Katsiouli F, Patrikaki O, Tsikritzis L. Physicochemical and microbiological characteristics of the potable water supply sources in the area of Kozani, Western Macedonia. Desalination. 2007 Jul 15;213(1–3):1–8.
4. Anand A, Keesara VR, Sridhar V. Studying the relationship between satellite-derived evapotranspiration and crop yield: A case study of the Cauvery River Basin. AgriEngineering. 2024 Aug 5;6(3):2640–55.

5. Beck PS, Juday GP, Alix C, Barber VA, Winslow SE, Sousa EE, et al. Changes in forest productivity across Alaska consistent with biome shift. Ecol Lett. 2011 Apr;14(4):373–9.
6. Beyer C, Altfelder S, Duijnisveld WH, Streck T. Modelling spatial variability and uncertainty of cadmium leaching to groundwater in an urban region. J Hydrol. 2009 May 15;369(3–4):274–83.
7. Desai JS. Studies on some physico-chemical and microbiological characteristic of potable water used in some different area of Ahmedabad in Gujarat. Res J Pharm Biol Chem Sci. 2012;3(2):1006–1014. ISSN: 0975-8585.
8. Descheemaeker K, Amede T, Haileslassie A. Livestock and water interactions in mixed crop-livestock farming systems of sub-Saharan Africa: interventions for improved productivity. IWMI. 2009 Jun 25. Colombo, Sri Lanka.
9. El Bably W, Meguid MA, Mostafa H, Bakery MF. Investigating shoreline development along of Marsa Matrouh coastal zone area. J Egypt Acad Soc Environ Develop. 2014;15(2):121–34.
10. Jain J, Choudhary S, Munoz-Arriola F, Khare D. Remote sensing and machine learning applications for the assessment of urban water stress: A review. In: Balaji E, Veeraswamy G, Mannala P, Madhav S, editors. Emerging technologies for water supply, conservation and management. Cham: Springer; 2023. p. 49–64. doi: 10.1007/978-3-031-35279-9_3.
11. Jhala YV, Qureshi Q, Yadav SP. Status of leopards in India, 2018. National Tiger Conservation Authority, Government of India, New Delhi, and Wildlife Institute of India, Dehradun. Technical Report TR/2020/16; 2020.
12. Rawat M, Pandey A, Gupta PK, Yadav B, Patel JG. A novel framework for wetland health assessment using hydro-ecological indicators and landscape metrics. Model Earth Syst Environ. 2025;11:167. doi: 10.1007/s40808-025-02371-6.
13. Karami S, Madani H, Katibeh H, Fatehi Marj A. Assessment and modeling of the groundwater hydrogeochemical quality parameters via geostatistical approaches. Appl Water Sci. 2018 Mar;8(1):23.
14. Karasali H, Pavlidis G. Environmental contamination by organochlorine persistent organic pollutants: A globally alarming detriment from the past. In: The Old and New Persistent Organic Pollutants. 2025 Aug 1:122–162. CRC Press.
15. Meena V, Macdonald DW. Balancing conservation planning and mitigation: Perspectives from a case study of the Asiatic lions. Front Ecol Evol. 2023 Aug 8;11:1196421.
16. Mehta A, Rakholia S, Yosef R, Bhatt A, Shukla S. Regional sustainability through dispersal and corridor use of Asiatic lion Panthera leo persica in the Eastern Greater Gir Landscape. Sustainability. 2024 Mar 20;16(6):2554.
17. Mishra A, Bhatt V. Physico-chemical and microbiological analysis of under ground water in VV Nagar and near by places of Anand District, Gujarat, India. J Chem. 2008;5(3):487–92.
18. Mishra A, Bhatt VD, Sevak N, Shah P, Patel K, Patel C. Comparative study of physico-chemical and microbial parameters on lotic and ground-waters in selected outlying areas of central Gujarat. J Chem Pharm Res. 2010;2(4):174–177. ISSN: 0975-7384.
19. Manonmani R, Suganya G. Remote sensing and GIS application in change detection study in urban zone using multi temporal satellite. Int J Geomat Geosci. 2010;1(1):60–5.
20. Nakar RN, Jadeja BA. Flowering and fruiting phenology of some herbs, shrubs and undershrubs from Girnar Reserve Forest, Gujarat, India. Curr Sci. 2015 Jan 10:111–8.
21. Nura AD, Hamzaraj E. Assessment of microbiological and physico-chemical parameters in Gjakova watershed. Int J Ecosyst Ecol Sci. 2016 Jun 1;6(3):455–60.
22. Li Z, Li X, Wang Y, Ma A, Wang J. Land-use change analysis in Yulin prefecture, northwestern China using remote sensing and GIS. Int J Remote Sensing. 2004 Dec 1;25(24):5691–703.
23. Raja P, Amarnath AM, Elangovan R, Palanivel M. Evaluation of physical and chemical parameters of river Kaveri, Tiruchirappalli, Tamil Nadu, India. J Environ Biol. 2008 Sep 1;29(5):765–8.
24. Sharma A, Patel SK, Barla A, Singh GS. Evaluating variability in soil attributes and forest vegetation in a degraded dry tropical region: An ecological restoration perspective. Environ Develop Sustain. 2024 Dec 14:1–31.
25. Shrivastava N, Mishra DD, Mishra PK, Bajpai A. Water quality deterioration of Machna River due to sewage disposal, Betul, Madhya Pradesh, India. J Environ Earth Sci. 2013;3(6):1–5.

26. Tian G, Boken VK. Monitoring agricultural drought in China. In: Monitoring and Predicting Agricultural Drought. Oxford Univ Press, Oxford; 2005:354–68.
27. Tucker CJ. Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing Environ. 1979 May 1;8(2):127–50.
28. Vyas VG, Hassan MM, Vindhani SI, Parmar HJ, Bhalani VM. Physicochemical and microbiological assessment of drinking water from different sources in Junagadh City, India. Am J Microbiol Res. 2015;3(4):148–54.
29. Xu H. Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery. Int J Remote Sensing. 2006 Jul 20;27(14):3025–33.
30. Yadav SS, Kumar R. Monitoring water quality of Kosi river in Rampur district, Uttar Pradesh, India. Adv Appl Sci Res. 2011 Nov 2;2(2):197–201.

