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Assessment of Waterlogging and Mitigation Strategies for Alanda Micro Watershed Using Remote Sensing in Akola District of Vidarbha Region, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The socio-economic progress of Vidarbha, where 89% of the land is used for rainfed farming, is significantly influenced by water resources. Unfortunately, waterlogging, driven by insufficient drainage and erratic weather conditions, poses serious challenges to agricultural productivity and soil health. The Alanda micro watershed in Barshitakli tehsil, Akola district, Vidarbha region of Maharashtra, features hard basaltic terrain and clay soils primarily used for agriculture. Poorly drained soils have caused waterlogging and salinization, highlighting the need for assessment of mitigation measures for the waterlogging to improve agricultural productivity and address climate change impacts. Waterlogging can be effectively identified through remote sensing techniques like NDWI, NDMI and NDVI, using high-resolution Landsat 8 imagery processed in ArcGIS 10.8. These methods facilitate the analysis and management of waterlogged areas, which is critical for improving agricultural output. The NDVI, NDWI and NDMI maps of the Alanda micro watershed highlight vegetation health, moisture levels and waterlogging potential, with the northern regions showing higher moisture and increased waterlogging risk. Mitigating waterlogging in the area requires the implementation of efficient drainage systems, soil improvement through organic matter and deep tillage and precise water management practices, including levelling fields to prevent water accumulation and using drought-resistant crops.

Keywords: NDMI; NDVI; NDWI; GIS; remote sensing; waterlogging.

1. INTRODUCTION

Water is a perilous resource for socio-economic progress and requires careful management and assessment. Proper evaluation of groundwater levels is essential for effective integrated watershed development and management strategies across various regions of the country (Patode, et al., 2017, Shakak, 2015). Waterlogging is a natural occurrence in lowlands and a key factor in studying human-environment interactions. It is a global issue affecting various countries, including China, Pakistan, Bangladesh and India (Bowonder, et al., 1986, Bastawesy and Ali, 2012). In the Vidarbha region, approximately 89% of the land is used for rainfed farming, with major crops impacted by waterlogging in poorly drained areas (Dongardive, et al., 2018). Soil conservation is essential for protecting productive lands and mitigating waterlogging, as rainfed farming plays a significant role in the region's agricultural economy. Both drought and waterlogging frequently occur during the crop growth period, leading to partial crop failure. These issues, driven by irregular weather patterns, erratic rainfall and inadequate drainage, are recurring challenges in dryland agriculture in Vidarbha. Remote sensing and GIS technology are highly effective for analysing waterlogged areas, as satellite images provide a comprehensive view of large areas (Moharir, et al., 2021). These tools, along with GPS, offer efficient solutions to mitigating waterlogged plans, surpassing traditional methods (Sener, et al., 2005, Jha, et al., 2007, Sharma, et al. 2011). The major portion of the study area comes under agricultural land. The disturbance of the hydrological balance, particularly due to irrigation of poorly drained soils, has caused elevated perched water tables, which in turn has led to issues of waterlogging and salinization. So, Waterlogged assessment of the study area is important for enhancing agricultural productivity, maintaining soil health and ensuring effective water resource management. It helps preserve ecosystems, plan infrastructure and create adaptive strategies to address climate change and socio-economic impacts.

1.1 Study Area

Alanda micro watershed is in Barshitakli tehsil of Akola district in Vidarbha region, Maharashtra, India. It is situated 3km away from Barshitakli and 17 km away from Akola city. The average height of the study area is 290 – 337m from the mean sea level. The area is formed by hard basaltic rocky terrain, also known as Decan traps. It’s covered and occupies a total part of the study area. The maximum area is covered with clay soil and clay loam soil. Geology and soil texture have low permeable capacity, which produces water stagnation in the research areas. The location map of the study area is shown in Fig. 1. Climatic conditions of the micro watershed are generally semi-arid throughout the year. Annual rainfall is between 750 to 1250mm. Rains are mostly received from southwest monsoon from June to September and winter rains from October to January which are uncertain. The minimum average temperature is 13 ºC and the maximum average temperature in the study area is 42 ºC.

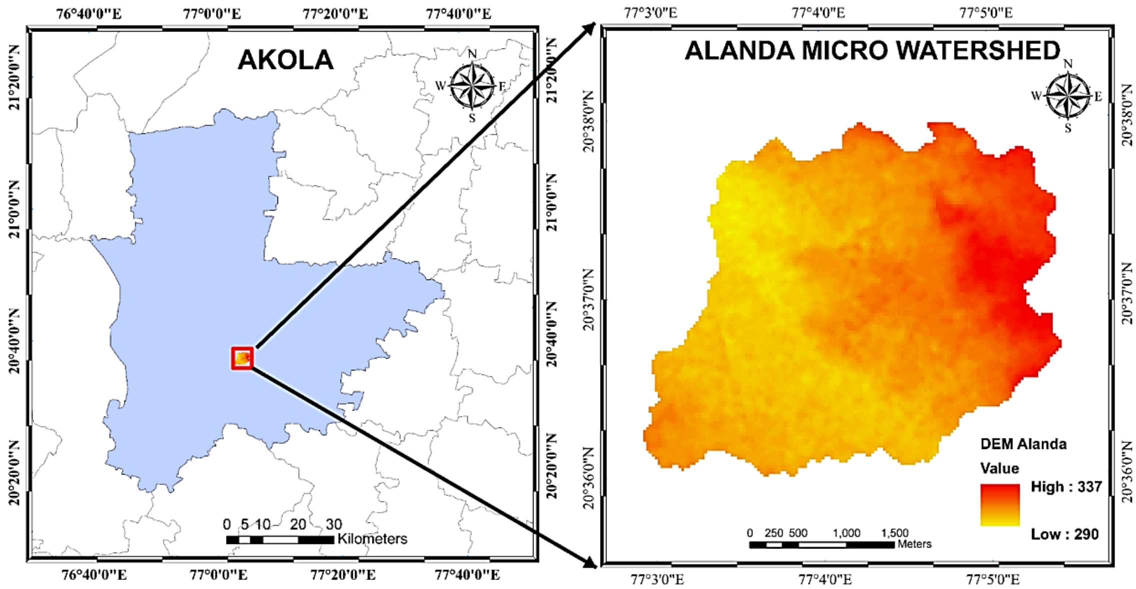

Fig. 1. Location map of the study area

2. MATERIALS AND METHODS

Waterlogging can be identified using remote sensing and digital analysis techniques, primarily through high-resolution satellite imagery and visual interpretation. The Normalized Difference Water Index (NDWI) and Normalized Difference Moisture Index (NDMI) are effective for detecting water bodies and assessing soil moisture, respectively. Change detection techniques allow for tracking moisture changes over time, while vegetation indices, like the Normalized Difference Vegetation Index (NDVI), indicate plant water stress. Additionally, Digital Elevation Models (DEMs) help predict waterlogging by analysing topography and drainage patterns. These methods offer efficient and cost-effective solutions for monitoring waterlogging and improving water resource management. NDVI, NDMI and NDWI all maps of the study area were prepared by satellite Landsat 8 image. Cloud-free LANDSAT 8 imagery was downloaded from (https://earthexplorer.usgs.gov/) Website. All the maps are generated in ArcGIS 10.8 software. Table 1 describes the wavelength range and the characteristics of different features of the Landsat 8 satellite provided by USGS.

The Normalized Difference Vegetation Index (NDVI) was developed by Tucker (1979). To calculate NDVI using ArcGIS 8 software, this formula is applied to the TM (Thematic Mapper) bands, producing a map that visually represents vegetation density and health based on the varying NDVI values. To create an NDVI (Normalized Difference Vegetation Index) map, two satellite image bands are required. The Red band captures visible red light and the Near Infrared (NIR) band detects infrared light reflected by vegetation and utilizes these red and near-infrared bands to assess vegetation health and is calculated using Eq.1:

$$\boldsymbol{NDVI} = \frac{(\boldsymbol{NIR}-\boldsymbol{Red})}{(\boldsymbol{NIR}+\boldsymbol{Red})} \quad \dots (1)$$

This index provides values between -1 and +1, where higher values indicate denser, healthier vegetation and -1 denotes the presence of water bodies

Developed by McFeeters, (1996), the Normalized Difference Water Index (NDWI) is a key tool in remote sensing for tracking variations in water content within vegetation, monitoring drought conditions and evaluating waterlogging. It plays an essential role in mapping water bodies and is utilized in water resource management, land use planning and environmental studies. The Normalized Difference Water Index (NDWI) is primarily used to detect and monitor water bodies, as well as to distinguish water from vegetation and soil in satellite imagery. The NDWI is computed using two spectral bands: the Green band and the Near Infrared (NIR) band, following a specific Eq.2:

$$\boldsymbol{NDWI} = \frac{(\boldsymbol{Green}-\boldsymbol{NIR})}{(\boldsymbol{Green}+\boldsymbol{NIR})} \quad \dots (2)$$

Table 1. Landsat 8 satellite and their uses

Band	Name of the band	Wavelength	Characteristics and usage
1	Coastal Aerosol	0.43 - 0.45	Coastal and aerosol studies
2	Blue	0.45 – 0.51	Bathymetric mapping, distinguishing soil from vegetation and deciduous from coniferous vegetation
3	Green	0.53 -0.59	Vegetation health analysis, distinguishing plants from soil
4	Red	0.64 – 0.67	Vegetation and plant discrimination, plant species analysis
5	Near Infrared (NIR)	0.85 -0.88	Biomass, vegetation Vigor, land/water interfaces, delineation of water bodies
6	Short-wave Infrared (SWIR) 1	1.57 – 1.65	Soil moisture, vegetation health, wildfire risk assessment, geology and mineral mapping
7	Short-wave Infrared (SWIR) 2	2.11 – 2.29	Detection of mineral and rock types, moisture stress in plants and burned area detection
8	Panchromatic	0.50 – 0.68	High-resolution imagery, urban area mapping, road and building feature extraction
9	Cirrus	1.36 -1.38	Cirrus cloud detection and masking
10	Thermal Infrared Sensor (TIRS) 1	10.60 – 11.19	Surface temperature mapping, urban heat island analysis, thermal energy studies
11	Thermal Infrared Sensor (TIRS) 1	11.50 – 12.51	Surface temperature mapping, heat studies, thermal pollution monitoring

NDWI shows the opposite result of NDVI. Water bodies have higher reflectance in the green band and lower reflectance in the NIR band, which helps highlight the presence of water. The index produces values between -1 and +1, where positive values typically indicate water bodies and negative or near-zero values correspond to non-water surfaces like soil or vegetation.

The Normalized Difference Moisture Index (NDMI) was developed by Wilson and Sader (2002), The Normalized Difference Moisture Index (NDMI) is primarily used to assess and monitor vegetation moisture content, which is crucial for understanding plant health, drought conditions and land cover dynamics, including waterlogging. NDMI is calculated using the Near Infrared (NIR) and Shortwave Infrared (SWIR) bands, with the Eq. 3:

$$\boldsymbol{NDMI} = \frac{(\boldsymbol{NIR-SWIR})}{(\boldsymbol{NIR+SWIR})} \qquad \ldots (3)$$

The index leverages the fact that healthy, well-watered vegetation reflects more NIR light and less SWIR light compared to stressed or dry vegetation. Areas with high NDMI values indicate greater moisture content, which means these areas have more water and may be prone to waterlogging, while low values denote lower soil moisture levels.

Therefore, by applying supervised classification techniques to the image and maps utilizing NDVI, NDWI and NDMI methods, it is possible to automatically assess waterlogged areas.

3. RESULTS AND DISCUSSION

3.1 Assessment of Waterlogging

3.1.1 NDVI map of the micro watershed

The NDVI map for the Alanda micro watershed highlights vegetation health, with values ranging from -0.0610568 to 0.3888 shown in Fig. 2. Green areas indicate healthy, dense vegetation, while yellow to red areas suggest sparse vegetation, degraded land, waterlogged regions or built-up areas. This map is useful for watershed management, agricultural monitoring and land use analysis, providing insights into vegetation density. The relatively low maximum NDVI value points to agricultural lands or waterlogged zones. The lowest value which is the waterlogged area marked in the figure with a circle.

3.1.2 NDWI map of the micro watershed

The NDWI map (Fig. 3) for the Alanda micro watershed highlights varying water content and potential waterlogging across the region, with green areas representing higher NDWI values (up to +0.0567854), indicating higher moisture, potential water bodies and waterlogging, while yellow to orange areas indicate lower values (down to -0.362193), suggesting drier conditions. The northern part of the watershed shows more moisture and potential waterlogging zones, while the southern and western regions are drier. The Highest value was marked in a circle which was a waterlogged area.

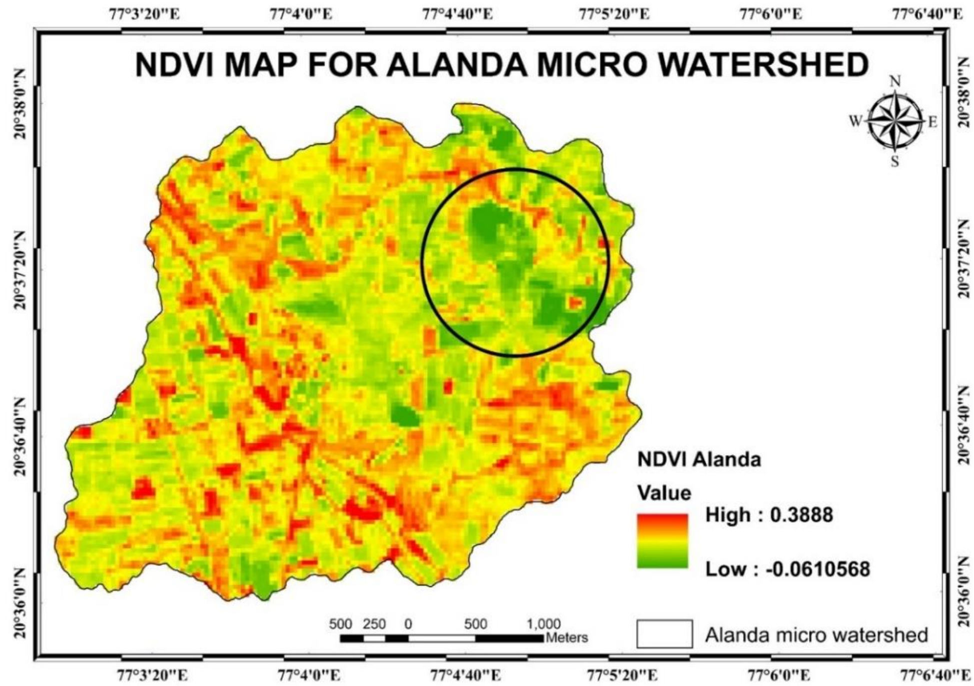

Fig. 2. NDVI map of Alanda micro watershed

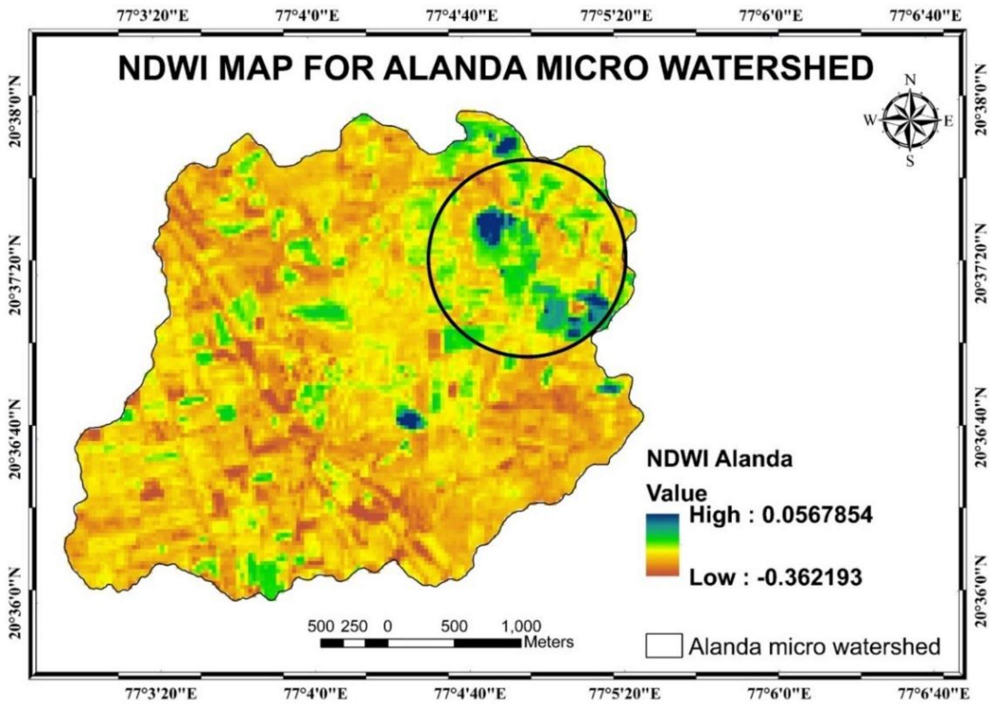

Fig. 3. NDWI map of Alanda micro watershed

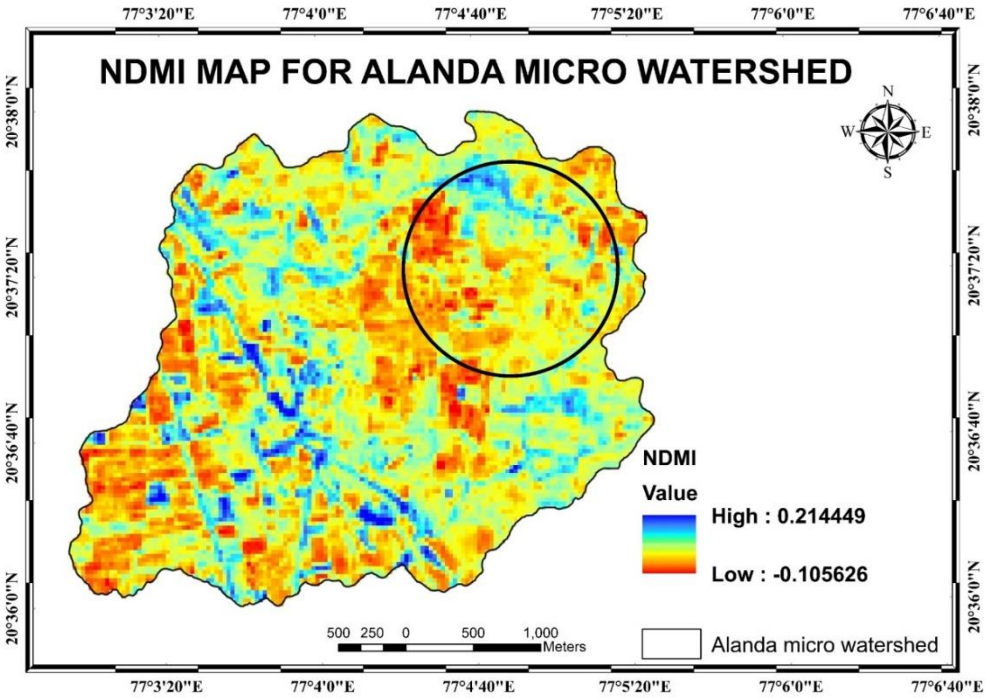

Fig. 4. NDMI map of Alanda micro watershed

3.1.3 NDMI map of the micro watershed

Waterlogging The NDMI map for the Alanda micro watershed highlights varying moisture levels and potential waterlogging across the region, with blue areas representing higher NDMI values (up to +0.214449), indicating higher moisture content in the soil or vegetation and waterlogging, while yellow to red areas show lower NDMI values (down to -0.105626), suggesting drier conditions. The northeastern regions display higher moisture levels and potential waterlogging, while the southern and western parts are drier. The areas of the highest values are marked in Fig. 4 within a circle.

The northeastern regions of the study area show potential for waterlogging, which degrades soil, reduces crop yields, damages infrastructure and disrupts ecosystems. Mitigation measures are essential to prevent these impacts, including soil and water management strategies and mitigation processes are suggested below.

3.2 Mitigation of Waterlogging

In the study area, mitigating waterlogging involves ensuring efficient water drainage while conserving moisture. Installing surface and subsurface drainage systems is key to removing excess water from occasional heavy rains. Improving soil structure by incorporating organic matter and deep tillage helps enhance water infiltration without excessive retention. Effective water management, such as precise irrigation when needed and levelling fields to prevent water accumulation in low areas is important. Also, drought-resistant crops and vegetative solutions like buffer zones and cover crops can manage runoff and improve soil health and thereby groundwater quality (Patode, et al., 2017, Ramamohan, et al., 2013). Agronomic practices like crop selection, mulching, fertilization, crop density and using raised beds further aid in preventing waterlogging by enhancing drainage. Soil science amendments, including the application of gypsum to improve clay soil structure and adding biochar to enhance aeration are beneficial (Lamptey, 2022, Chandel, et al., 2017). Furthermore, land reshaping and geospatial tools help monitor vulnerable areas, ensuring proper drainage and water conservation. Groundwater is a vital natural resource, especially in areas lacking surface water bodies. About one-third of the global population relies on it for drinking, irrigation and industrial purposes. However, excessive and unregulated exploitation has led to a rapid decline in water tables, emphasizing the need for sustainable groundwater management (Mondal, et al. 2024). Regular maintenance of drainage systems and soil moisture monitoring are crucial for balancing water retention and drainage in the study area. Mitigating waterlogging in micro watersheds benefits enhance local livelihoods and support long-term economic growth.

This study can serve as a foundational framework for future research in complex terrains worldwide, adaptable to the region's specific climate and hydrogeological conditions.

4. CONCLUSION

The NDVI, NDWI and NDMI maps for the study area provide insights into vegetation health, moisture levels and potential waterlogging. The NDVI map shows values ranging from -0.0610568 to +0.3888. The lowest NDVI value scripts a waterlogged area. The NDWI map highlights water content, with values ranging from -0.362193 to +0.0567854. The highest NDWI value, noticeable in the northern region, signifies waterlogging. Similarly, the NDMI map, with values between -0.105626 and +0.214449, shows higher moisture in the northeastern part and drier conditions in the southern and western areas, with the highest value staining potential waterlogging. Mitigating waterlogging in the study area recovered effective drainage, improved soil structure and precise water management, including drought-resistant crops and vegetative solutions. These measures enhance local livelihoods, improve agricultural productivity and support long-term economic growth in micro watersheds.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

Bastawesy, M. E., & Ali, R. R. (2012). The use of GIS and remote sensing for the assessment of waterlogging in the dryland irrigated catchments of Farafra Oasis, Egypt. *Hydrological Processes*.

Bowonder, B., Ramana, K. V., & Rajagopal, R. (1986). Waterlogging in irrigation projects. *Sadhana*, 9(3), 177–190.

Chandel, A., Gabhane, V. V., Nagdeve, M. B., Turkhede, A. B., & Patode, R. S. (2017). Effect of INM on soil fertility, productivity and economics of cotton-green gram intercropping system in vertisols. *International Journal of Current Microbiology and Applied Sciences*, 6(11), 3738-3743.

Dongardive, M. B., Patode, R. S., Nagdeve, M. B., Gabhane, V. V., & Pande, C. B. (2018). Water resources planning for the micro watersheds using geospatial techniques. *International Journal of Chemical Studies*, 6(5), 2950-2955.

Jha, M. K., Chowdary, V. M., & Chowdhury, A. (2007). Groundwater assessment in a hard rock terrain using remote sensing and GIS techniques. *Journal of Hydrology*, 349(1-2), 142-154.

Lamptey, S. (2022). Agronomic practices in soil water management for sustainable crop production under rain-fed agriculture of drylands in Sub-Sahara Africa. *African Journal of Agricultural Research*, 18(1), 18-26.

McFeeters, S. K. (1996). The use of Normalized Difference Water Index (NDWI) in the delineation of open water features. *International Journal of Remote Sensing*, 17, 1425–1432.

Moharir, K. N., Pande, C. B., Patode, R. S., Nagdeve, M. B., & Varade, A. M. (2021). Prioritization of sub-watersheds based on morphometric analysis using geospatial technology. In *Water Management and Water Governance: Hydrological Modeling* (pp. 19-33). Springer International Publishing.

Mondal, S., Patode, R. S., Mhaske, A. R., Gabhane, V. V., Tupe, A. R., & Chorey, A. (2024). Sustainable water resource planning for Alanda micro watershed using geospatial techniques. *Asian Research Journal of Agriculture*, 17(4), 260-267.

Patode, R. S., Nagdeve, M. B., Ganvir, M. M., & Gabhane, V. V. (2017). Evaluation of insitu moisture conservation practices for sustainable productivity of major crops in Vidarbha region. *International Journal of Current Microbiology and Applied Sciences*, 6(10), 261-268.

Patode, R. S., Nagdeve, M. B., Pande, C. B., & Moharir, K. N. (2017). Land use and land cover changes in Devdari watershed. *Trends in Biosciences*, 10(8), 1622-1625.

Ramamohan Reddy, K., & Patode, R. S. (2013). Assessment of groundwater quality: A case study of Kondapur mandal, Medak district, Andhra Pradesh. *Current World Environment*, 8(2), 267-273.

Sener, E., Sener, S., & Luter, L. (2005). The use of remote sensing and GIS in determining the groundwater potential of Burdur, Turkey. *Journal of Environmental Management*, 89(1), 55-62.

Shakak, N. (2015). Integration of remote sensing and geographic information system in ground water quality assessment and management. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 40(7), 1483–1490.

Sharma, A., Tiwari, K. N., & Bhadoria, P. B. S. (2011). Effect of land use land cover change on soil erosion potential in an agricultural watershed. *Environmental Monitoring and Assessment*, 173(1-4), 789-801.

Tucker, C. J. (1979). Red and photographic infrared linear combinations for monitoring vegetation. *Remote Sensing of Environment*, 8, 127–150.

Wilson, E. H., & Sader, S. A. (2002). Detection of forest harvest type using multiple dates of Landsat TM imagery. *Remote Sensing of Environment*, 80, 385–396.

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