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Case Study

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Waterlogging Impact Assessment using Geospatial Approach: A Case Study of Bhiwani District, Haryana

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ABSTRACT

Waterlogging has emerged as a major environmental and agricultural problem in irrigated regions of north-western India, adversely affecting crop productivity, soil quality, and sustainable land use. The present study aims to map and assess the seasonal dynamics of waterlogged areas in Bhiwani district, Haryana, using Remote Sensing (RS) and Geographic Information System (GIS) techniques. Sentinel-2 multispectral satellite imagery acquired during the pre-monsoon and post-monsoon periods of 2025 was analyzed using the Normalized Difference Water Index (NDWI) and supervised classification in the QGIS environment to delineate waterlogged areas and evaluate Land Use/Land Cover (LULC) changes. The classification accuracy was assessed using a confusion matrix, yielding an Overall Accuracy of 91% and a Kappa Coefficient (κ) of 0.82, indicating high reliability of the classification results. The analysis revealed that the waterlogged area increased significantly from 5,511.8 ha (1.63%) during the pre-monsoon season to 41,786.0 ha (12.36%) during the post-monsoon season, representing an increase of 36,274.2 ha (10.73%). The LULC change analysis showed that the expansion of waterlogged areas occurred primarily at the expense of cropland, accompanied by increases in fallow land, salt-affected areas, and waterbodies. Spatial analysis indicated that waterlogging is predominantly concentrated in the eastern and north-eastern parts of the district, where flat topography, poor natural drainage, dense canal irrigation networks, canal seepage, excessive irrigation, and sediment deposition in drainage channels collectively contribute to prolonged surface water stagnation and groundwater rise. The expansion of waterlogged areas caused severe damage to Kharif crops, including cotton, pearl millet (bajra), guar, and moong, disrupted agricultural operations, delayed the sowing of Rabi crops, and resulted in considerable economic losses to farmers. The findings demonstrate that the integration of Sentinel-2 imagery, NDWI, and GIS provides an effective, rapid, and reliable approach for monitoring seasonal waterlogging and associated LULC changes. The study offers valuable spatial information for planners, irrigation engineers, agricultural departments, water resource managers, and policymakers to formulate appropriate drainage improvement, canal management, and salinity control strategies for sustainable land and water resource management in waterlogging-prone regions.

INTRODUCTION

Waterlogging is one of the major challenges in irrigated agriculture, posing serious threats to crop productivity and sustainable agricultural development. Excess soil moisture reduces oxygen availability in the root zone, inhibits plant growth, and ultimately leads to significant yield losses (Houk, et. Al., 2006). Waterlogging is a major environmental and agricultural issue caused by excessive accumulation of water in soil. Large portions of agricultural land are reduced due to seasonal or permanent waterlogging. Approximately 4.5 million hectares of agricultural land have already become barren due to prolonged waterlogging and associated salinity (Singh, 1992). Every year, additional areas are affected, with the extent of degradation depending on climatic conditions, topography, geohydrological characteristics, and groundwater regimes. Furthermore, India is estimated to have about 58.2 million hectares of wetlands, highlighting the importance of effective monitoring and management of water resources for sustainable agricultural and environmental development (Prasad et. Al., 2002). Remote sensing identifies and classifies land features based on their spectral signatures. These characteristic spectral response patterns enable the accurate delineation of water bodies on a pixel-by-pixel basis (Lillesand et al., 2015). Satellite remote sensing has the potential to monitor and identify waterlogging in agricultural fields. However, there is limited research available on waterlogging within the remote sensing community (Mondal et al., 2018). Surface water can be effectively detected using visible (VIS) and near-infrared (NIR) sensors because water exhibits distinct spectral reflectance characteristics in these wavelength regions compared with other land cover types, facilitating accurate identification and mapping of water bodies (Pekel et al., 2016). This situation calls for a systematic assessment using geospatial tools to map, analyze, and monitor waterlogged areas for effective planning and mitigation. This study derives the spatial and temporal patterns of waterlogging-prone areas using Sentinel-2 satellite data for the year of 2025 in Bhiwani district and identifies the causes and effects of waterlogging in the district.

STUDY AREA

Bhiwani is located at the latitude 28.19° and 29.05° N, and longitude of 75.26° and 76.28° E. In Haryana. Bhiwani is influenced by the local steppe climate. The climate is classified as Bsh according to Koppen and Geiger. The average temperature in Bhiwani is 25.2°C (77.8°F) (fig 1)

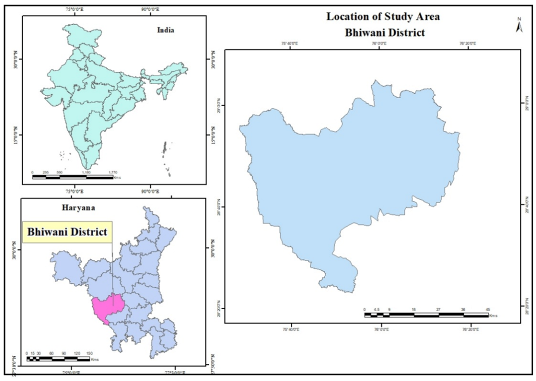

Figure 1. Location of the study area

Precipitation here is about 533mm/21.0 inch per year. Bhiwani is an area with alluvial plains in its northern sides and semi deserts on its south. Southern region of the district has Aravali mountain range making its soil sandy in nature. It has Predominantly agricultural land with canal irrigation systems. In the district a number of crops are grown but main crops are wheat, mustard, gram, cotton and bajra. Near about 79% geographical area of bhiwani district is under cultivation. Other major towns in the district are Siwani, Loharu, Tosham Bawani Khera, and Bhiwani.

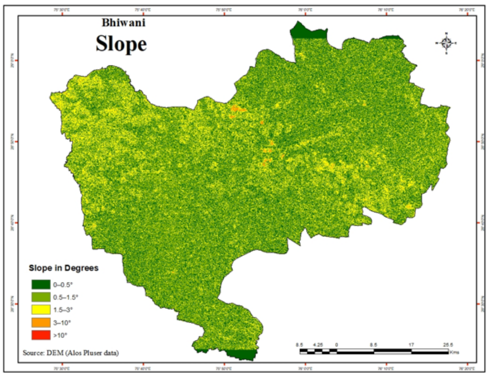

Figure 8. Slope of the Bhiwani District

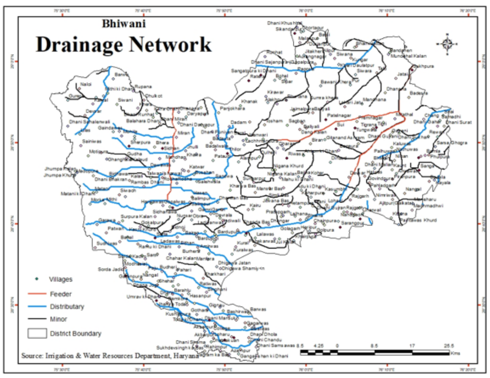

Figure 9. Drainage Network of the Bhiwani District

MATERIALS AND METHODS

Data Used

The present study utilized both satellite-derived and ancillary datasets to identify and analyze waterlogged areas in the study region. Multi-source geospatial datasets were integrated within a GIS environment to improve the accuracy of waterlogging assessment. The details of the datasets used are presented below.

Satellite Data: Sentinel-2 imagery for the year 2025, having a spatial resolution of 10 m, was obtained from the Copernicus Open Access Hub. The high spatial resolution and multispectral capability of Sentinel-2 data were used for mapping land cover and detecting surface waterlogged areas. (fig 2) (fig 3)

Figure 2. Sentinel-2 MSI (March-2025)

Figure 3. Sentinel-2 MSI (Sept. -2025)

Table 3.1: Sentinel satellite data Specifications

Seasons	Satellite image	Date of acquisition	Sensor	Bands	Spatial Resolution (m)	Wavelength Range (µm)
Pre-Monsoon 2025	Sentinel-2	09 March 2025	MSI	Blue (B2)	10	0.458 – 0.523
				Green (B3)	10	0.543 – 0.578
				Red (B4)	10	0.650 – 0.680
				NIR (Near-Infrared) B8	10	0.785 – 0.900
Post-Monsoon 2025	Sentinel-2	25 Sept. 2025	MSI	Blue (B2)	10	0.458 – 0.523
				Green (B3)	10	0.543 – 0.578
				Red (B4)	10	0.650 – 0.680
				NIR (Near-Infrared) B8	10	0.785 – 0.900

Digital Elevation Model (DEM): ALOS PALSAR Digital Elevation Model (DEM) with a spatial resolution of 12.5 m was used to generate the slope map of the study area. The slope information was incorporated to understand terrain characteristics and their influence on waterlogging.

Ancillary Data: To support the satellite-based analysis, several ancillary datasets were incorporated into the study:

Administrative Boundary: The district administrative boundary was obtained from the District Census Handbook and used for delineating the study area.

Drainage Network: Drainage data were collected from the Irrigation and Water Resources Department, Haryana, to examine the relationship between drainage characteristics and waterlogged zones.

Water Depth Data: Water depth information was acquired from the *Haryana Water Resources Atlas (2025)* and used to assess the severity and spatial distribution of waterlogged areas.

GPS Field Survey Data: Ground truth data collected through GPS-based field surveys were used for validation of the mapped waterlogged areas and accuracy assessment of the final outputs.

Methodology

The methodology adopted in the present study consists of a series of geospatial and remote sensing techniques for the identification and assessment of waterlogged areas during the pre-monsoon and post-monsoon seasons. The overall workflow is illustrated through the following sequential steps:

Data Collection and Pre-processing: Sentinel-2 multispectral satellite imagery (2025), ALOS PALSAR Digital Elevation Model (DEM), and ancillary datasets including administrative boundaries, drainage network, water depth data, and GPS field observations were collected from their respective sources. The satellite images were pre-processed by applying atmospheric correction, geometric correction, image mosaicking, and clipping to the study area boundary to ensure consistency and improve data quality for subsequent analysis.

Computation of Spectral Indices: The **Normalized Difference Water Index (NDWI)** was computed separately for the pre-monsoon and post-monsoon periods using Sentinel-2 imagery to enhance and delineate surface water bodies. The generated NDWI maps facilitated the identification of seasonal variations in surface water and potential waterlogged areas.

Land Use/Land Cover Classification: Supervised classification was performed on the Sentinel-2 imagery to generate Land Use/Land Cover (LULC) maps for both the pre-monsoon and post-monsoon seasons. Representative training samples for each land cover class were selected based on field observations and high-resolution reference imagery. The classified maps provided detailed information on the spatial distribution of different land use and land cover categories.

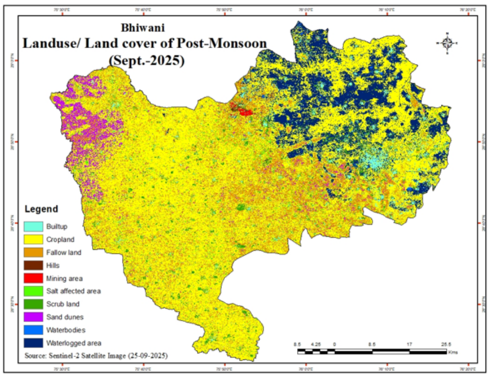

Figure 7. Land Use/ Land cover of Post- Monsoon period (2025)

LULC Change Detection Analysis: A comparative change detection analysis was carried out between the pre-monsoon and post-monsoon LULC maps to quantify seasonal land cover variations. The analysis enabled the identification of changes in waterlogged areas, agricultural land, built-up areas, vegetation, and other land cover classes influenced by monsoonal conditions.

GIS Overlay Analysis and Ground Truth Validation: The derived NDWI maps, LULC maps, slope map, drainage network, and water depth data were integrated using GIS-based overlay analysis to identify and evaluate waterlogged zones. The accuracy of the mapped waterlogged areas was validated using GPS-based ground truth observations collected during field surveys.

Mapping and Visualization: The final waterlogging maps, thematic layers, and spatial distribution patterns were prepared using Geographic Information System (GIS) techniques. Appropriate cartographic layouts, legends, and map elements were incorporated to effectively visualize the spatial extent and severity of waterlogging in the study area.

RESULT AND DISCUSSION

This study maps and analyses waterlogged areas in Bhiwani district, Haryana using Sentinel-2 (High-resolution) remote sensing data in 2025. Bhiwani experienced excess rainfall during the 2025 monsoon season, particularly from July through August. In Bhiwani district, it is due to over-irrigation, poor drainage, and canal seepage. The district faces severe waterlogging affecting 15-20% of agricultural land during 2025 monsoon season, causing significant crop losses. Kharif crops including cotton and bajra severely affected by prolonged water inaction

Normalized Difference Water Index (NDWI)

Monsoon changes the surface water availability significantly. Comparing NDWI maps for pre-monsoon (dry season) and post-monsoon (wet season) reveals water dynamics. NDWI is an index used to highlight water bodies in satellite imagery. It helps distinguish water from land, vegetation, and built-up areas. From the figure 4.1 it is evident that water bodies expand after monsoon. Seasonal lakes and floodplains are visible in post-monsoon NDWI. By comparing pre- and post-monsoon NDWI maps, you can easily quantify seasonal water changes, identify flood-prone zones in the Bhiwani district. Mostly waterbodies found in the north-east part of the district.

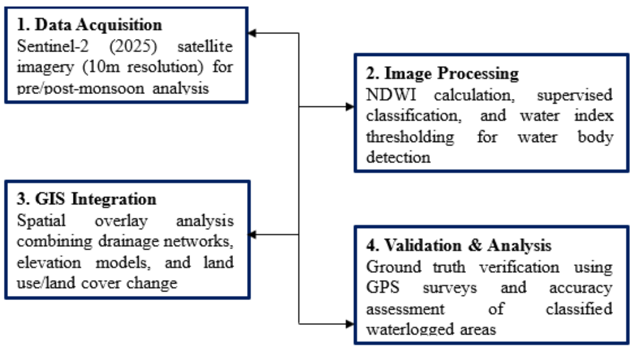

Figure 4. Geospatial Methodology Workflow

Land Use/ Land cover change of Bhiwani District (2025)

The land use land cover has been prepared with the help of Sentinel-2 satellite data for the year of 2025 for analysis the waterlogging impact on the various land use categories of the study area (Fig. 4.2 & Fig. 4.3). The pre and post-monsoon land use change analysis given below.

Table 4.1: Land Use/ Land cover Change Matrix of Pre and Post Monsoon period (2025)

LULC Classes	Area in Ha. (Pre-Monsoon-2025)	Area in %	Area in Ha (Post-Monsoon-2025)	Area in %	Area (Ha.) change from Pre -Post -2025	% change from Pre -Post
Built-up	9540.1	2.8	9584.5	2.8	44.5	0
Cropland	252026.2	74.5	194263	57.4	-57763.2	-17.1
Fallow land	34963.3	10.3	51224.8	15.1	16261.5	4.8
Hills	1750.7	0.5	1748	0.5	-2.6	0
Scrub land	13261.8	3.9	12331.2	3.6	-930.6	-0.3
Salt affected area	2631.3	0.8	8932.7	2.6	6301.4	1.9
Sand dunes	14791.9	4.4	13414.6	4	-1377.3	-0.4
Mining area	3379.1	1	3449	1	69.9	0
Waterbodies	343.9	0.1	1466.2	0.4	1122.3	0.3
Waterlogged area	5511.8	1.6	41786	12.4	36274.2	10.7
Total	338200	100	338200	100	0	0

Table 4.1 presents the spatial distribution of Land Use/Land Cover (LULC) classes in the study area during the pre-monsoon and post-monsoon seasons of 2025, along with the corresponding changes in area and percentage.

The built-up area remained almost unchanged, increasing marginally from 9,540.1 ha (2.8%) to 9,584.5 ha (2.8%), a gain of only 44.5 ha, indicating minimal urban expansion during the study period. Likewise, the mining area showed only a negligible increase of 69.9 ha, while the hill area remained virtually constant with a minor decrease of 2.6 ha, reflecting the stability of permanent landscape features.

Cropland was the dominant land use class during the pre-monsoon period, occupying 252,026.2 ha (74.5%) of the total geographical area. However, after the monsoon, its extent declined significantly to 194,263.0 ha (57.4%), representing a loss of 57,763.2 ha (-17.1%). This substantial reduction indicates that a large portion of cultivated land became inundated and was reclassified as waterlogged following heavy monsoon rainfall.

The waterlogged area exhibited the most remarkable increase among all LULC categories. It expanded from 5,511.8 ha (1.6%) during the pre-monsoon season to 41,786.0 ha (12.4%) in the post-monsoon period, recording an increase of 36,274.2 ha (10.7%). This dramatic expansion clearly demonstrates the severe impact of monsoon rainfall on low-lying agricultural lands and confirms the widespread occurrence of seasonal waterlogging in the study area.

The extent of fallow land increased from 34,963.3 ha (10.3%) to 51,224.8 ha (15.1%), registering a gain of 16,261.5 ha (4.8%). This increase may be attributed to temporary abandonment of agricultural fields due to prolonged inundation or unsuitable conditions for cultivation after the monsoon.

Similarly, salt-affected areas increased considerably from 2,631.3 ha (0.8%) to 8,932.7 ha (2.6%), representing an increase of 6,301.4 ha (1.9%). The expansion of saline land is likely associated with prolonged water stagnation, poor drainage, and evaporation processes that concentrate salts on the soil surface.

The area under waterbodies also increased substantially from 343.9 ha (0.1%) to 1,466.2 ha (0.4%), with a net gain of 1,122.3 ha (0.3%), reflecting the filling of ponds, reservoirs, canals, and natural depressions during the monsoon season.

In contrast, scrub land declined slightly from 13,261.8 ha (3.9%) to 12,331.2 ha (3.6%), showing a decrease of 930.6 ha (-0.3%), while sand dunes decreased from 14,791.9 ha (4.4%) to 13,414.6 ha (4.0%), a reduction of 1,377.3 ha (-0.4%). These reductions may be due to increased vegetation cover, soil moisture, or temporary inundation that altered their spectral characteristics.

Overall, the results reveal that the monsoon season caused significant transformations in land cover, primarily through the expansion of waterlogged areas, waterbodies, fallow land, and salt-affected land at the expense of cropland. These findings highlight the profound influence of seasonal rainfall and inadequate drainage on agricultural landscapes and demonstrate the usefulness of remote sensing and GIS techniques for monitoring waterlogging dynamics and associated LULC changes.

Accuracy Assessment of LULC Classes

The accuracy assessment of the Land Use/Land Cover (LULC) classification was performed to evaluate the reliability of the supervised classification results. The classified LULC map was validated using reference data collected through field surveys (GPS points) and high-resolution satellite imagery. A confusion (error) matrix was prepared by comparing the classified pixels with the corresponding ground truth data.

Table 4.2: Land Use/ Land cover Error Matrix table of 2025

LULC Classes	Built-up	Cropland	Scrub land	Waterbodies	Mining area	Sand dunes	Waterlogged	Hills	Fallow land	Salt affected area	Row Total
Built-up	15385	602	177	2	3477	1076	0	129	122	0	20848
Cropland	183	71768	11	0	122	2495	0	3	131	0	74582
Scrub land	844	138	10300	1	131	3318	10	1400	1	2	16144
Waterbodies	0	4	6	572	1	0	52	48	294	0	683
Mining area	2475	52	25	0	16783	3146	0	37	978	7	22525
Sand dunes	120	370	166	0	336	294171	0	27	45	16	295206
Waterlogged area	101	50	294	1	9	0	1332	447	456	0	2234
Hills	408	0	978	0	79	334	134	10259	45	0	12192
Fallow land	2475	52	25	1	131	27	0	35	3146	8	5900
Salt affected area	263	25	119	0	339	16878	0	0	56	432	18056
Column Total	19779	73009	12076	576	21277	321418	1528	12350	5229	457	462470

Table 4.3: Land Use/ Land cover Accuracy Assessments

LU/LC	Producer Accuracy	User Accuracy	Overall Accuracy
Built-up	77.8	73.8	91%
Cropland	98.3	96.2	
Scrub land	85.3	63.8	
Waterbodies	99.3	83.7	
Mining area	78.9	74.5	
Sand dunes	91.5	99.6	
Waterlogged area	87.2	59.6	
Hills	83.1	84.1	
Fallow land	77.0	72.8	
Salt affected area	94.5	2.4	

The results indicate that the LULC classification achieved an Overall Accuracy (OA) of 91%, suggesting that the majority of the classified pixels correspond well with the reference data. Furthermore, the Kappa coefficient (ϰ) was calculated as 0.82, indicating almost perfect agreement between the classified map and the ground truth data according to the classification proposed by Landis and Koch (1977). These statistics confirm that the classification is highly reliable and suitable for subsequent analyses of land use change and waterlogging.

The class-wise accuracy assessment revealed varying levels of classification performance among the LULC categories (Table X). Waterbodies achieved the highest Producer's Accuracy (99.3%), indicating that nearly all reference waterbody pixels were correctly identified in the classified image. Cropland also exhibited excellent classification performance, with a Producer's Accuracy of 98.3% and a User's Accuracy of 96.2%, reflecting both low omission and commission errors. Similarly, sand dunes recorded a Producer's Accuracy of 91.5% and the highest User's Accuracy (99.6%), indicating excellent class discrimination.

Causes of Waterlogging

Flat topography and low natural slope- The slope of study area has classify based on the waterlogging susceptibility using ALOS PALSAR DEM data. The table has shown the description of the slope categories. The slope which is range from 0°–1.5° indicating the high waterlogging susceptibility in the study area which cover 45% area under the flat topography and low natural slop of the district.

Table 4.4:Slope susceptibility for waterlogging

Slope in Degrees	Slope Description	Area (Ha)	Area (%)
0–0.5°	Very Low Slope (Very high waterlogging susceptibility)	46530	13.8
0.5–1.5°	Low Slope (High susceptibility)	107440	31.8
1.5–3°	Moderate Slope (Moderate susceptibility)	145276	43
3–10°	Steep Slope (Low susceptibility)	38340	11.3
>10°	Very Steep Slope (Very low susceptibility)	614	0.2
	Total Area	338200	100

Source: ALOS PALSAR DEM

Poor surface and subsurface drainage- Bhiwani lies mostly in a low-relief plain with slopes <1% and its Runoff velocity is extremely low in the North-East part of the district. The natural drainage network of the district is limited and consists mainly of seasonal streams (nallahs) and distributaries, including the Bawani Khera Distributary and Nigana Distributary, which carry water primarily during the monsoon season. During the remaining part of the year, these channels remain dry and therefore contribute little to effective drainage. Furthermore, inadequate connectivity between natural drainage channels and the man-made canal drainage system restricts the efficient removal of excess surface water, thereby aggravating waterlogging conditions. In addition, sediment deposition within natural and artificial drainage channels has considerably reduced their flow capacity. As a result, runoff accumulates in depressions and low-lying areas, leading to widespread seasonal waterlogging across the district.

Canal Seepage- It is one of the major anthropogenic factors contributing to the development of waterlogging in Bhiwani district. the canal network has declined due to silt deposition and the excessive growth of aquatic weeds and unwanted vegetation within the canals. These obstructions reduce the carrying capacity of irrigation channels, resulting in increased water depth, higher hydraulic head, and greater seepage pressure along canal banks. Consequently, larger volumes of water infiltrate into the adjoining lands, intensifying waterlogging conditions.

Water Depth - In a study for the period 2005–2024, the annual average depth to groundwater ranged roughly 2.00 m to 29 m below ground level (bgl) across different observation wells in Bhiwani district (CGWB). The More specifically in the northern, north-eastern and eastern blocks (e.g., Tosham, Bhiwani Khera) depths were about 3–10 m bgl, while in the southern and north-western parts (for example Kairu and Bhiwani block) depths were about 10–20 m bgl, and in the western and some central parts (e.g., Loharu & Siwani blocks) depths were more than 20 m bgl. The North-eastern and Eastern areas of the district with very shallow depth to water table (e.g., <2 m or <5 m) are highly prone to waterlogging because the groundwater is close to the surface and capillary rise and surface ponding become more likely.

Waterlogging and Its Impact

The analysis of pre-monsoon and post-monsoon Land Use/Land Cover (LULC) maps reveals a substantial seasonal expansion of waterlogged areas in Bhiwani district. During the pre-monsoon period, the waterlogged area covered 5,511.78 ha, accounting for 1.63% of the total geographical area of the district. Following the monsoon, the extent of waterlogging increased dramatically to 41,786.00 ha, representing 12.36% of the total area. Thus, the waterlogged area expanded by 36,274.22 ha, corresponding to an increase of 10.73 percentage points between the pre- and post-monsoon periods. This remarkable increase highlights the significant influence of monsoonal rainfall, low topographic relief, poor drainage conditions, and canal seepage on the development of seasonal waterlogging.

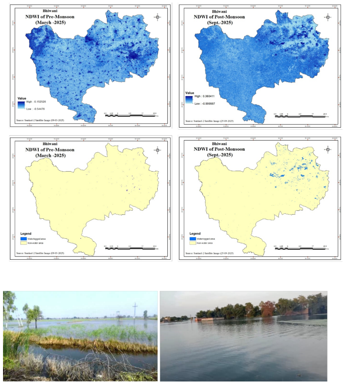

Figure 5. Pre-Monsoon and Post-Monsoon Waterlogging status in the District (2025)

The agricultural sector was particularly affected during the Kharif season, with major crops such as cotton, pearl millet (bajra), guar, and moong experiencing severe damage due to prolonged inundation. Many cultivated fields remained submerged for extended periods, resulting in crop failure and substantial reductions in farm productivity. Consequently, a large proportion of agricultural land was transformed into waterlogged, fallow, and salt-affected land, as reflected in the LULC change analysis. This conversion represents the most significant land use transition observed between the pre- and post-monsoon periods.

Persistent waterlogging also disrupted the agricultural calendar by delaying land preparation and sowing operations for the subsequent Rabi (winter) season. The delayed recession of floodwater prevented farmers from carrying out timely field operations, thereby affecting crop establishment and reducing the potential productivity of winter crops. In several locations, farmers were compelled to plough standing Kharif crops back into the soil to minimize further economic losses, reflecting the severe financial burden imposed by seasonal flooding.

In addition to crop damage, prolonged waterlogging contributed to the expansion of salt-affected areas, indicating that inadequate drainage and a rising groundwater table have accelerated secondary soil salinization in several parts of the district. Such conditions gradually reduce soil fertility, deteriorate land quality, and threaten the long-term sustainability of agricultural production.

Overall, the results demonstrate that seasonal waterlogging has become a major environmental and agricultural challenge in Bhiwani district. The substantial increase in waterlogged area after the monsoon emphasizes the urgent need for integrated waterlogging management strategies, including the development of efficient surface and subsurface drainage systems, regular maintenance and desiltation of drainage channels, canal lining to reduce seepage losses, scientific irrigation scheduling, and effective salinity management practices. Implementing these measures would help minimize water stagnation, reclaim affected agricultural lands, improve crop productivity, and enhance the long-term sustainability of irrigated agriculture in the district.

CONCLUSIONS

The present study demonstrates the effectiveness of Remote Sensing (RS) and Geographic Information System (GIS) techniques for mapping and assessing seasonal waterlogged areas in Bhiwani district, Haryana. Sentinel-2 multispectral imagery, integrated with the Normalized Difference Water Index (NDWI) and supervised classification in the QGIS environment, successfully identified the spatial distribution and seasonal variation of waterlogged areas with a high level of classification accuracy (Overall Accuracy = 91% and Kappa Coefficient = 0.82), confirming the reliability of the adopted methodology. The results revealed a significant seasonal increase in waterlogged areas between the pre-monsoon and post-monsoon periods of 2025. Waterlogged land expanded from 5,511.8 ha (1.63%) during the pre-monsoon season to 41,786.0 ha (12.36%) in the post-monsoon season, representing an increase of 36,274.2 ha (10.73%). The Land Use/Land Cover (LULC) change analysis further indicated that this expansion occurred primarily at the expense of cropland, accompanied by increases in fallow land, salt-affected areas, and waterbodies. These changes demonstrate the considerable influence of monsoon rainfall on the land surface and agricultural landscape of the district. The spatial analysis indicates that waterlogging is concentrated mainly in the eastern and north-eastern parts of Bhiwani district, where the terrain is characterized by very gentle slopes (<1%), poor natural drainage, and a dense canal irrigation network. Seepage from unlined canals and distributaries, excessive irrigation, inadequate drainage connectivity, and sediment deposition within drainage channels have collectively contributed to groundwater rise and prolonged surface water stagnation. These factors have accelerated the development of seasonal waterlogging and secondary soil salinity in canal command areas. Seasonal waterlogging has adversely affected agricultural productivity, particularly during the Kharif season, causing severe damage to crops such as cotton, pearl millet (bajra), guar, and moong. The conversion of cropland into waterlogged, fallow, and salt-affected land has disrupted the agricultural cycle, delayed the sowing of Rabi crops, and imposed substantial economic losses on farming communities. These findings emphasize the need for effective drainage management and sustainable irrigation practices to minimize crop losses and improve agricultural resilience. The outcomes of this research provide important scientific information for planners, irrigation engineers, agricultural departments, water resource managers, and policymakers in developing effective strategies for waterlogging mitigation.

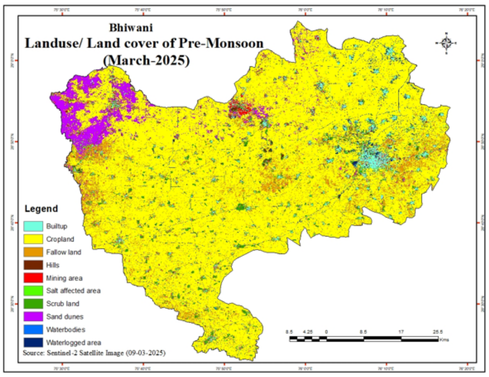

Figure 6. Land Use/ Land cover of Pre - Monsoon period (2025)

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NDWI methodology

(McFeeters, 1996)

Accuracy assessment (Congalton

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