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Monitoring Waterlogging and Soil Salinity in Jhang from 2005 to 2025

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Abstract

The comparison of vegetation and salinity indicators between 2005 and 2025 reveals notable environmental changes across the study area. The Modified Normalized Difference Vegetation Index (MNDVI) exhibited a wider range in 2025 (0.90 to -0.40) compared to 2005 (0.65 to -0.23), indicating greater spatial variability in vegetation conditions. The increase in the maximum MNDVI value from 0.65 to 0.90 suggests that certain areas experienced substantial improvement in vegetation density and health, likely due to enhanced agricultural practices, irrigation availability, or successful land management measures. Conversely, the decrease in the minimum value from -0.23 to -0.40 indicates that some locations remained devoid of vegetation or became more severely degraded, reflecting persistent barren land or waterlogged surfaces. Similarly, the Salinity Index (SI) showed a slight increase in the maximum value from 0.39 in 2005 to 0.42 in 2025, suggesting that localized zones of high soil salinity continued to persist or intensified over time. However, the minimum SI value declined significantly from 0.09 to 0.015, indicating a considerable reduction in salinity in less-affected areas. Overall, these changes suggest that while vegetation improved and salinity decreased across much of the study area, spatial disparities remain, with certain regions continuing to experience severe land degradation and salinity-related environmental stress.

Keywords: Waterlogging; Soil Salinity; Remote Sensing; GIS; MNDVI; Salinity Index; Jhang District

Introduction

The human induced changes in land use land cover (LULC) are globally putting into consideration the primary drivers of change in different areas such as agriculture, environment among others (Assede et al., 2023). Unwanted changes in land use and agricultural practices are also caused by many socio-economic elements (i.e. income, occupation, conveyance availability etc.), population increase, agro-technologies development and numerous other natural mechanisms (Ayeni et al., 2025). They are listed among the essential features of identifying the relation between the rise in population, the transformation of land use and other ecological and environmental issues (Zou et al., 2024). The salinity or salinization is a problem in the world that puts at risk the quality of the water and the utilization of the freshwater resources by the human; it is also a threat to both the agricultural production and the aquaculture (Khondoker et al., 2023; Musie & Gonfa, 2023). Pakistan is situated in arid and semi-arid continental region wherein the weather remains hot subtropical and the ongoing processes of salinization and sodification are undergoing (Arooj

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et al., 2025). The salinity has direct influence on the properties of soil such as the physical, the chemical and the biological (Wang et al., 2024). Agriculture forms the primary economy of Pakistan and the water logging and salinity is one of the primary agricultural issues in the country in addition to the rapid population growth, natural calamities, pest and viral attack among others (Masood et al.). It is approximated that over 6 million hectares agricultural lands in Pakistan were under water logging and salinity (Arooj et al., 2025). The Punjab province is leading in the manufacture of the numerous crops of the Pakistan (Rahman et al., 2023). The farmers encounter a number of difficulties when it comes to fulfilling their activities (Tahir et al., 2024). The farmers have numerous serious concerns to undertake the farming operations following the salinity and the water logging (Ahmed & Ambinakudige, 2023; Olana, 2025). The orchard fields and other crops can be seriously impacted by salinity and water logging (El Ramady et al., 2024). The causes of water logging include a high number of the causes such as excess of rainfall, extremely poor internal and external drainage system, runoff of the water and the inability of the soil to hold or absorb or absorb the superfluous water (Hasan & Eslamian, 2023; Rashid, 2023). The water logging can be attributed to man-made practices such as floods, excessive rainfall, and seepage of water in the canals as well as the unsustainable method of irrigation (Rani et al., 2023). When the water in the canal seeps in the adjacent regions and it enters at the highest level of water table through infiltration (Rajpriya & Rai, 2024). It leads to the increasing of the water table leading to the water logging and the salinity (Hagage et al., 2024). The water leaking down the canals causes accretion of the salt (Demo et al., 2025). The water logging may also affect the lands with the concave sloppy lands. Without the suitable water drainage installation the chances of the concave sloppy also increasing could also emerge (Sisodiya et al., 2025). The soils with thick top soil retain more water (He et al., 2025). The crops roots are drowned or submerged because the depositing of the flood water at the place significantly lacks good drainage system since no air is available in the soil (Ju et al., 2025). It is with the assistance of the appropriate irrigation methods that the water logging problem can be resolved to a large scale (Hagage et al., 2024). In the event the presence of the salt in water is in immense proportions such water body makes the water saline (Minhas & Qadir, 2024). The availability of the dissolvable salts in saturated soils increases the minimum pressure which essentially inhibits the movement of the water to plants in this manner it destroys the plants(Zhu et al., 2024). Deforestation is essentially the principal cause of the existence of the salinity in the water (Maurya & Vivek, 2025). The excessive application of the fertilizers could increase the salinity and growth of the heavy metals (Irin & Hasanuzzaman, 2024). Water logging raises the temperature of the soil (Y. Zhang et al., 2025). The accumulation of the salts in the waterlogged region inhibits the process of the cultivation in the soil (Y. Zhang et al., 2025). This led to the reduced crops production due to the low maturity period of different crops (Vadez et al., 2024). Water logging and salinity in Pakistan have a devastating socio-economic effect as it is associated with forced migration and health, diminished crop production and poverty, damage to infrastructure, transport breakdown, lower living standards and livelihood chances (Das & BHUTTA, 2025). Thus, immediate intervention is required to address those problems to safeguard the vulnerable communities and to achieve sustainable development within the impacted regions (Ugwu et al., 2025). In the same way, the salinity as well as the water logging in the Punjab affects the study area in a very significant way (Dhaloiya & Singh, 2024). The central theme of the study was to bring to the fore the effect of water logging and salinity on the generation of the chosen crops in Tehsil Shorkot, District Jhang in the period between 2009- 2019(Muneer et al.). The research would be of great assistance on

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the aspects of agro-ecological and future studies on the water logging and salinity and agro-ecological dilemmas, as far as agricultural planning is concerned (Mohanty et al., 2025).

Material and Methods

To comprehensively complete the aim of the current study, both primary and secondary data was collected regarding the yield of the sampled crops, salinity, and water logging information in the research site. Its effects on the chosen crops i.e. the wheat, sugarcane and rice during the specified years 2015 to 2025 had been tracked and pointed out in the present study.

Study Area District Jhang

The study area District Jhang. It is located on the border of the central and southern Punjab (Khan & Hassan, 2025). The region contains the confluence of two rivers, Chenab and Jhelum. It also borders the Head Trimmu therefore a number of irrigation canals and some link canals flow through it (Jaiswal & Kumar, 2025). Jhang is a key area of Pakistan-Punjab and it has a population of over 3 million people (Amin et al., 2025). It is located at the centre of Punjab region. Jhang is bounded to the north by Sargodha, on the north east by Chiniot, on the east by Faisalabad and Toba Tek Singh Districts, on the south by Khanewal and Muzaffargarh, and by Layyah and Bhakkar on the North West (Figure 1). The capital city of the region that is surrounded by two waterways Jhelum and Chenab is Jhang city. Surge and Monsoon downpours are so damaging in Jhang locale always due to the Trimuu stream flood and convergence point area of both streams at the point zone (Khan et al., 2025). During summer and winter, the climate is sweltering and dry and cold and dry. May, June and July are the hottest months. Most severe mean temperature during summer is 44 C (Hassan et al., 2025).

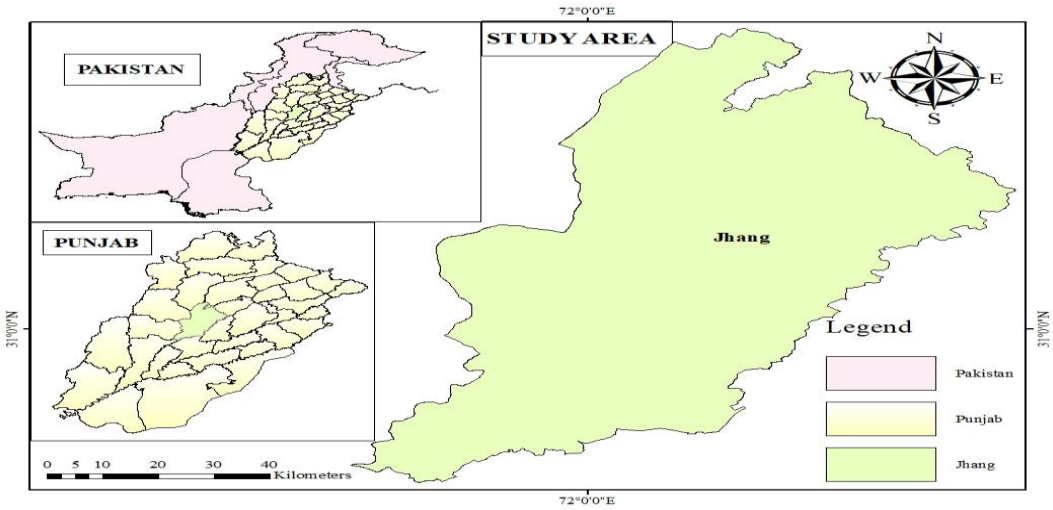


Figure: 1 showing study Area

Data Collection

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In the evaluation of how water logging and salinity affect crops growing, the remotely sensed data have been used. Change in time period of cropped area analyzed 19 years. It required the selected chronological satellite images of the various times. The satellite images were obtained on the site of United States Geological Survey (USGS) to gather secondary data of the years 2015 and 2025.

Results

Synthesis of the Multi-Temporal Indicator Evidence (2005–2025)

The twenty-year (2005–2025) multi-indicator record generated for the Jhang study area provides the empirical basis on which the following management strategies are anchored. Summarizes the range of MNDWI, and Salinity Index (SI) values recorded for the three reference years.

Table: 1 results of MNDWI and SI

Indicator	2005	2025
MNDVI (High : Low)	0.65 : -0.23	0.90 : -0.40
SI (High : Low)	0.39 : 0.09	0.42 : 0.015

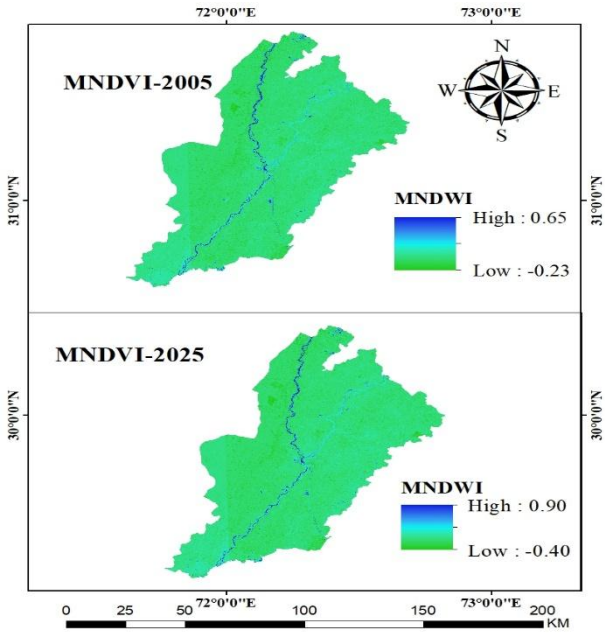


Figure: 2 showing MNDWI

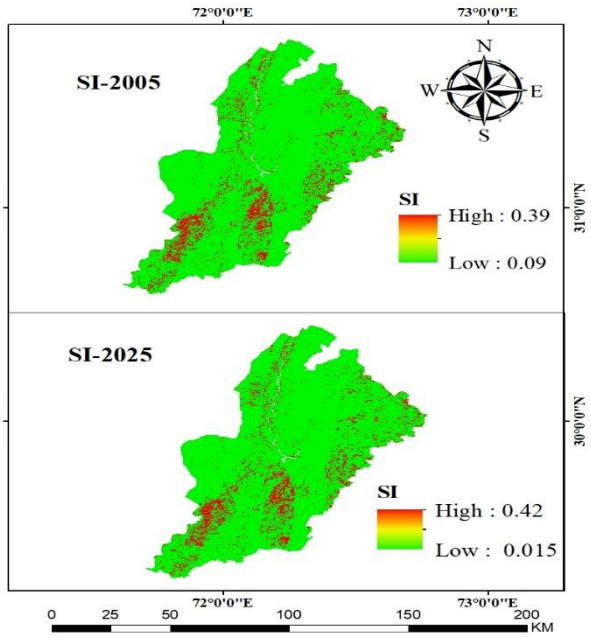


Figure: 3 showing SI

Read together, three trends stand out. First, vegetation vigor has genuinely improved: SI maps show a persistent, spatially stable high-salinity belt along the western margin of the district (broadly the area lying between roughly 71°40′E and 72°00′E) in all three epochs, with the peak SI value actually increasing slightly from 0.39 in 2005 to 0.42 in 2025. Third, the MNDWI

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record shows a widening spread rather than a simple wetting or drying trend: the maximum MNDWI has increased (0.65 → 0.90), indicating that the driest, most moisture-stressed patches largely coincident with the high-SI western zone and the expanding built-up core — have simultaneously become more extreme. This co-location of chronic high salinity, low MNDWI, and comparatively depressed vegetation vigor in the western sub-catchment, alongside a growing built-up cluster in the central agricultural belt is the spatial signature that the strategies below are designed to address.

Engineered Sub-Surface and Surface Drainage

The persistence of a high-SI zone over two decades, despite general vegetation improvement elsewhere, indicates that natural drainage and evapotranspiration alone are insufficient to flush accumulated salts from the western sub-catchment. A phased sub-surface drainage program is therefore recommended as the primary engineering response:

- Installation of perforated sub-surface (tile) drains at 1.5–2.0 m depth in the delineated high-SI zone, spaced according to soil hydraulic conductivity, to lower the water table below the critical capillary-rise depth (~1.5–2 m) and interrupt secondary salinization.
- Rehabilitation and desilting of existing surface drains (e.g., branches of the Jhang–Trimmu drainage network) to restore conveyance capacity ahead of the monsoon peak, reducing the ponding evident in the low-NDWI/high-SI overlap areas.
- Selective vertical drainage (skimming tube wells) in zones where groundwater is only marginally saline, allowing conjunctive reuse for irrigation while lowering the water table a lower-cost complement to tile drainage where capital budgets are constrained.

Because the SI maps show the western belt has not improved despite twenty years of agricultural intensification elsewhere in the district, this zone should be treated as the first-priority intervention area rather than spreading drainage investment evenly across the study area.

Biological and Agronomic Interventions

Given the scale of the affected area and the capital intensity of sub-surface drainage, biological (biodrainage) and agronomic measures offer a lower-cost, scalable complement that can be implemented directly by farming communities:

- Biodrainage plantations of high-water-use, salt-tolerant tree species (e.g., Eucalyptus camaldulensis, Tamarix aphylla, Populus deltoides) along field boundaries and drain margins in the western zone, to lower the shallow water table through transpiration and simultaneously raise the local MNDVI/SI signal.
- Substitution of salt-sensitive field crops with salt-tolerant and moderately salt-tolerant cultivars (e.g., salt-tolerant wheat and cotton varieties, sugar beet, guar) in the high-SI belt, phased in as an interim measure while drainage infrastructure is built out.
- Gypsum and organic-matter (farmyard manure, green manuring with sesbania/dhaincha) soil amendment on sodic patches to displace exchangeable sodium and improve soil structure, combined with leaching irrigation once drainage outlets are functional.

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- Laser land leveling to eliminate micro-depressions that currently pond irrigation and rainfall water, a practice already associated with the visible MNDVI/SI gains recorded in the central agricultural belt between 2005 and 2025 and worth extending systematically to the western zone.

Water Management and Irrigation Reform

The widening spread between maximum and minimum MNDWI values points to increasingly uneven water distribution across the district rather than a uniform surplus or deficit. This supports a conjunctive and demand-managed approach to irrigation rather than further expansion of flood irrigation:

- Lining of the main and distributary canals traversing the study area to reduce seepage losses, which are a principal driver of the shallow, saline water table along the western fringe.
- Introduction of volumetric, rotational irrigation scheduling calibrated to crop water requirement rather than fixed turns, to prevent over-irrigation in already water-logged central tracts while ensuring equitable supply to tail-end (western) users.
- Piloting of high-efficiency irrigation (drip/sprinkler) for high-value crops on the better-drained eastern plains, freeing canal allowances that can be redirected toward leaching requirements in the saline west.
- Conjunctive use protocols pairing canal supply with treated tube-well groundwater of acceptable quality, monitored through the SI zonation, to avoid further salt loading of marginal soils.

Based Zoning and Land-Use Planning

The LULC series shows a distinct built-up cluster consolidating in the central part of the district between 2015 and 2025, in reasonably close proximity to the drainage-sensitive corridor along the river. This trend argues for formalizing the multi-temporal MNDWI–SI stack produced in this study as a standing planning layer rather than a one-off diagnostic:

  - Delineation of statutory waterlogging/salinity hazard zones from the SI and MNDWI composites, to be adopted by the local Tehsil Municipal Administration and the Punjab Irrigation Department as a constraint layer in future land-use permitting.
- Restriction of further impervious built-up expansion into the open-space/floodplain fringe bordering the river, preserving natural infiltration and drainage capacity.
- Establishment of a vegetated riparian buffer along the main river channel, using the consistently high-MNDVI corridor already visible in the 2015 and 2025 maps as the template for extension northward and southward.
- Periodic (e.g., 3–5 year) refresh of the MNDVI SI classification using freely available satellite imagery, enabling the hazard zonation to be updated as an operational monitoring tool rather than a static baseline.

Institutional and Community-Based Measures

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Sustained mitigation ultimately depends on institutional continuity and farmer participation, particularly because the persistence of the western high-SI zone across three successive decades suggests that technical measures alone have not been sufficient:

- Formation of Farmer Organizations / Water Users' Associations with direct responsibility for tertiary drain maintenance in the identified hazard zones, supported by the Provincial Irrigation and Drainage Authority.
- Targeted subsidy or credit schemes for salt-tolerant seed, gypsum, and bio drainage seedlings in the western union councils, to lower the adoption barrier for the agronomic measures recommended above.
- Integration of the remote-sensing-based monitoring framework developed in this thesis into the district's Agriculture and Irrigation extension services, so that field-level advisories can be triangulated against the satellite evidence rather than relying solely on ground survey.
- Regular inter-agency coordination (Irrigation, Agriculture, Local Government, and WASA) around a shared SI/MNDWI dashboard, ensuring drainage rehabilitation, cropping-pattern advisories, and land-use permitting are not pursued in isolation of one another.

Conclusion

None of the measures above is sufficient in isolation: engineered drainage addresses the acute hydrological cause of waterlogging but is capital-intensive and slow to scale; biological and agronomic interventions are affordable and immediately deployable but yield gradual results; water management reform addresses the upstream driver of secondary salinization but requires institutional buy-in; and land-use zoning is preventive rather than curative. Consistent with the multidynamic approach framed in this thesis, the recommended pathway is a spatially differentiated, phased program: immediate agronomic and bio drainage measures in the confirmed high-SI low MNDWI western zone, medium-term sub-surface drainage and canal-lining investment targeted at the same priority zone, and a longer-term GIS-based zoning and monitoring regime applied district-wide to prevent the emergence of new waterlogged or saline pockets as the built-up footprint continues to expand. Evaluated against the twenty-year trend documented here, success should be measured not simply by district-average MNDVI or SI improvement which the record already shows but specifically by convergence of the western zone's SI and MNDWI values toward the district mean, which would indicate that the chronic hazard identified in this study has actually been resolved rather than statistically diluted by gains elsewhere.

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