



Spatiotemporal Patterns of Soil Salinity in Jhang District (2015-2025)

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Abstract:

Water logging and salinity are major problems to agricultural practices across the globe especially in agrarian developing nations like Pakistan. The central question of the research was to assess the effect of waterlogging and salinity on the yielding of popular crops in District Jhang between 2015 and 2025. The United States Geological Survey (USGS) provided the data of remote sensing at Landsat 8 in October 2015 and in October 2025, having a 30-meter spatial resolution, free of charge. This study was based on calculating different spectral indices using Landsat reflectance bands and GIS, along with remote sensing. The Soil Salinity Index (SSI) was used to evaluate the level of salinity, as well as its impact on crop production in the study area. Vegetation health was measured by the Soil Adjusted Vegetation Index (SAVI). In 2015, the values of SAVI varied between -0.135285 and 0.538007 whereas in 2025 they varied between -0.110472 and 0.49923, showing that there is a change in the values with time. The SAVI maps indicate that the most values of vegetation are concentrated in the eastern and southeastern areas of the district, and the central and western area represents a low vegetation vigor. Likewise, the salinity maps show that the eastern and southeastern areas have more salinity as compared to the central and western areas, which are relatively less salty. In general, the results show that there were evident spatial and temporal differences in soil salinity and vegetation health in District Jhang.

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 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, 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 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:

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 o C(Hassan et al., 2025).

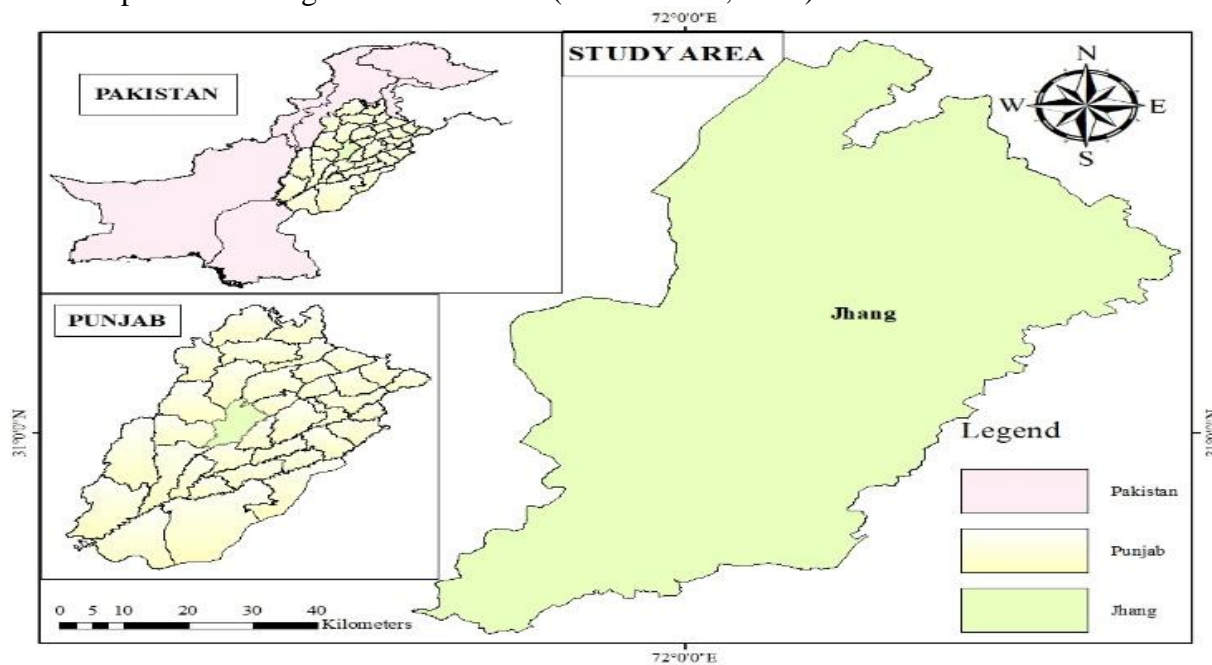


Figure: 1 showing study Area

Data Collection:

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.

Salinity Change Detection:

The variation observation of salinity and water logging typically considers the judgment of two or more remotely sensed images, which are always consistent with regard to the scale, respective classification and accuracy. There are many change detecting methods that can be used with the help of which the user can choose an approach that suits the image best. Multiple Change detection analysis, as well as GIS and Remote Sensing practice, hold over potential when it comes to the exploration and prediction of the changes in the agricultural crops yield that can be

observed in case of Multan district . Similarly the water logging and salinity has also significantly decreased the wheat production of Muzaffargarh district. The technique of supervised classification was useful in the creation of water logging maps in three years. The most popular method of the superimposed classification was used to make change in the area maps with equal interval of 10 years. The changes were interpreted and known through the creation of bar graphs, pie graphs, tables and maps. Soil-Adjusted Vegetation Index (SAVI): It is defined as the share of the red bands to the closest infrared (NIR) band: the total of the red change in the NIR was separated into two, namely salinity index (SAVI). The following list was salinity index. The equation employed to investigate the indicators of the salt and the soil vegetation is given as;

$$SAVI = (NIR - RED) / (NIR + RED + L) * (1 + L), L=0.5.$$

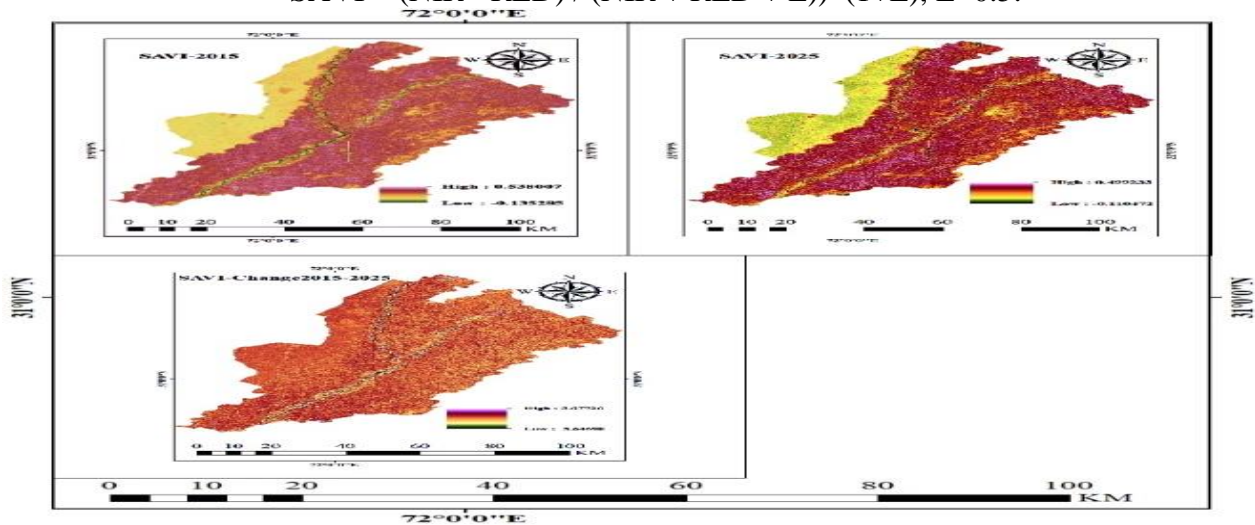


Figure 2 showing SAVI

Figure 2 shows the outcomes of Soil Adjusted Vegetation Index (SAVI) in the years 2015 and 2025 and the comparison between the changes that take place within this decade. SAVI is a significant vegetation index which minimizes the effect of soil brightness and offers a better determination of vegetation health especially where vegetation cover is sparse or uneven. The values of SAVI in the study area were between 0.538007 to a minimum of -0.135285. These values show that vegetation conditions have a lot of spatial variation. Negative or low values usually indicate non-vegetated surfaces which are either bare soil or degraded land whereas positive values are high indicating dense and healthy vegetation. The SAVI values between 2025 were between -0.110472 and 0.49923. Even though the overall pattern of distribution was similar, the small variation in the minimum and maximum value indicates that there might have been some variation on the vigor of the vegetation over time. The discoveries of change between the years 2015 and 2025 indicate a reduction of -5.64698 in certain areas and an increment of up to 3.67726 in others. This shows that there has been an improvement in vegetation conditions in some of the study area and reduced conditions in others. These differences could be linked to irrigation techniques, state of soil, salinity and a problem of waterlogging. The figure makes a clear comparison of SAVI distribution of the two years. The regions in the map which are brown in color represent greater values of SAVI absorption meaning, a stronger vegetation cover. With a change in the color gradient between brown and green, there is also a reduction in the SAVI absorption that is associated with a low vegetation density. Laterally, the eastern and northeastern areas of the study area tend to have greater values of SAVI implying that there is more health in the vegetation of these areas. Conversely, in the central and western regions, there

are scattered zones with lower values of SAVI and this implies relatively poor vegetation cover and potential environmental stress states. On the whole, Figure 2 indicates the spatial and temporal differences in vegetation health in the study area between 2015 and 2025.

Soil Salinity Index (SSI): The ratio of the red alteration in the NIR to the two red bands was the percentage of the red band that was the nearest to the red bands was known as soil salinity index (SSI). The following list was salinity index. The equation employed to investigate the indicators of the salt and the soil vegetation is given as;

$$SI = NIR/Red$$

Sentinel-2: $SI = B4/B8$

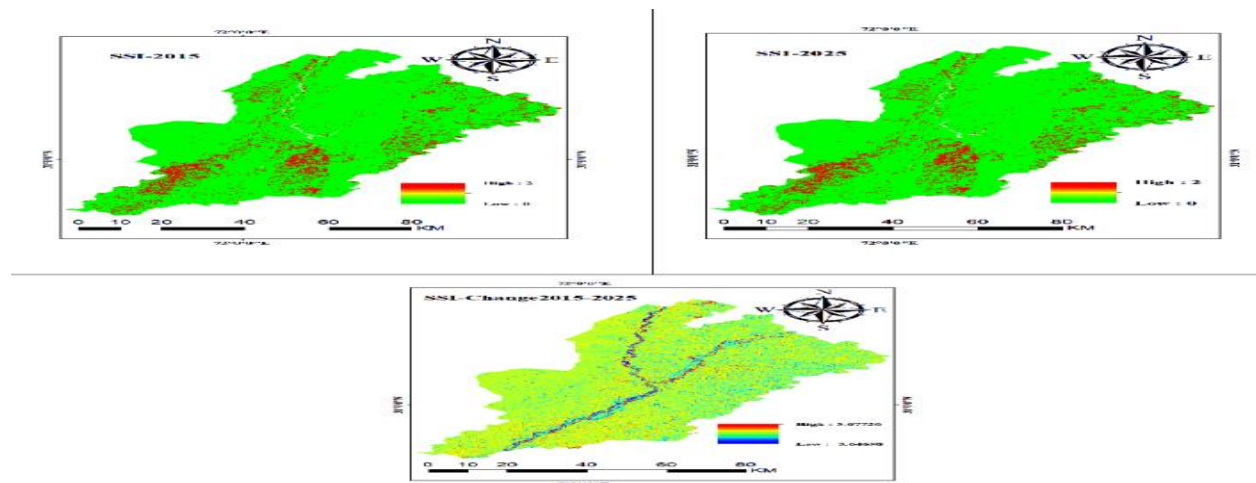


Figure 3 showing SSI

Figure 3 shows the spatial distribution of Soil Salinity Index (SSI) in the study area in 2015 and 2025 and comparing the two years. The figure illustrates a temporal variation in level of salinity and gives a clear pictorial overview on how soil salinity has changed during the ten years period. Soil Salinity Index is a valuable tool based on satellite images which is used to detect and map areas with saline infiltrations, which may adversely affect the productivity of agricultural practices. The red color in the map depicts regions which are characterized by high salinity, which is higher percentage of salt in the soil. The color gradient will change as the red shift to blue, and the blue region will indicate the low salinity. Such color scheme can be used to easily identify severely and moderately affected areas. The analysis of space shows that the eastern and northeastern regions to southeastern areas of the study area are worse hit by salinity in both 2015 and 2025. On the contrary, the relatively low salinity levels are observed in scattered regions in the central and western ones. On the whole, Figure 3 indicates that there is a significant spatial variation in soil salinity and shows the regions that need better land and water management.

Discussion

The findings of the geospatial analysis are quite definite about the heavy effects of soil salinity and the production of crops in the research area. Out of the combination of Geographic Information Systems (GIS) and Remote Sensing (RS) methods, the present study was able to evaluate and map the spatial distribution of salinity and its impact on agricultural lands (Admas et al., 2025). The use of such high-tech tools facilitated an accurate analysis of environmental stress factors on crop productivity with time. Satellite images based on salinity were also used successfully to estimate the magnitude and the magnitude of the area affected by salt (M. Zhang

et al., 2025). The research used Soil Salinity Index (SSI) to identify saline soils and soil adjusted vegetation index (SAVI) to assess the health of vegetation and vigor of crops (Obeng, 2025). The joint analysis of the values of SSI and SAVI was a comprehensive insight into the relationships between the salinity conditions and differences in crop performance within the region (Javed et al., 2025). The results indicate that RS and GIS methods are quite useful in tracking the environmental changes (GUNGOR & MOHAMED, 2025). Between 2015 and 2025, the analysis clearly showed the spatial distribution of waterlogging and salinity and its effects on the agricultural productivity in Jhang (Shakoor et al., 2025). In general, the paper proves that geospatial technologies can be useful in sustainable land management and agricultural planning in salty regions.

Conclusion:

Salinity of soil is among the significant agricultural issues in agrarian nations like Pakistan (Nadeem et al., 2025). It severely degrades the fertility of soil, minimizes water absorption by plants, and finally ends up reducing the crop yield. The work evaluated the effect of salinity on agricultural crop production in the District Jhang based on spatiotemporal data and geospatial methods. The Soil Salinity Index (SI), which is based on satellite imagery, was used to measure salinity and measure the impact of salinity on crop production and patterns of land use over time (Ty et al., 2025). The use of remote sensing was also based on the notion that correct and sound data at the strategic level is necessary in order to make estimates on the production of crops, as well as to ensure successful agricultural planning, especially in unfavorable environmental circumstances like salinity of soil. The analysis of space helped to understand how the regions that were influenced by salinity reflect the variation in the patterns and productivity of cropping (Aadiwal et al., 2025). As implied in the findings, the relative decrease in yield caused by salinity was greater in wheat and rice than in sugarcane. This difference could be explained by the fact that crops are more tolerant to saline environment (Mahajan et al., 2025). The findings of remotely sensed information, which prove the trustworthiness of geospatial analysis. In general, the paper identifies that the combination of GIS and remote sensing technology is an effective and potent method of monitoring the effect of salinity on crop production. The findings will help the decision-makers, agriculturalists and land-use planners to develop areas of priority and provide effective management measures towards the water logging and salinity influenced regions in Punjab and other Pakistan provinces (Gondal et al.).

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