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A geostatistical analysis of soil salinity and its impact on wheat yield in Gujranwala District

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Abstract

This study applies geostatistical analysis to examine how soil salinity affects wheat yield in the Gujranwala area in the context of changing rainfall patterns and climate change. The goal of the research is to determine the geographical and temporal patterns of soil salinity and how they affect agricultural productivity, with a particular emphasis on wheat cultivation. Despite the use of comprehensive geostatistical techniques and statistical analysis, the study finds a strong negative relationship between wheat production and soil salinity as determined by electrical conductivity (EC). As geostatistical techniques such as Linear Regression Rate (LLR) assess the influence of soil salinity on wheat yield, Inverse Distance Weighting (IDW) examines the distribution of salt in the soil. Finding hotspots for extremely salinized soil emphasizes the need for precise controls and thoughtful land management. Increasing soil salinity monitoring, encouraging targeted irrigation, looking into crops that can withstand salt, enhancing drainage, and teaching farmers how to manage soil salinity are some of the recommendations. This geostatistical analysis concludes that there is a notable negative link between Gujranwala wheat yield and soil salinity, which offers important information to land managers, policymakers, and agricultural experts. Understanding soil salinity dynamics enables proactive measures to enhance agricultural output.

1. Introduction

Worldwide, 20% of total cultivated land and 50% of irrigated areas are under salt stress. In Pakistan, about 14% of irrigated lands have deteriorated with salinity, while 64% yield losses are reported due to salinity. As a result, only roughly 23 Mha of land are left that may be used for agriculture (Irum and Ehetisham-ul-Haq, 2017). According to estimates, there are 14 billion ha of usable land on the planet, 6.5 billion ha of which are semi-arid and arid zones. This semi-arid and dry region has a 1 billion hectares salt-affected area (Balal et al., 2013). Salinity in soils is divided into primary and secondary salinity, with primary salinity resulting from the weathering of primary minerals or the parent material, and secondary salinity resulting from improper use of the soil and irrigation techniques that cause the rise of highly salinized ground water and its contribution to the salinization process.

The country’s economy is dependent on the agricultural sector (Khan et al., 2013). Almost 20% of national income contributes in the gross domestic product (GDP) and 43.7% accounts for total employment. 66% of the population of the country resides in non-urban areas and their income depends directly or indirectly on the agriculture sector (Abdullah et al., 2015). The agriculture sector recorded a growth of 2.67% during the year 2019–2020. In Pakistan, the salt-affected area is 4.5 Mha (Aslam, 2016). This situation is particularly alarming, given Pakistan's reliance on the pressures put on regional food items by growing populations and farming exports. In Pakistan, salinity has impacted about 5.7 million hectares of land, including about 2 million hectares of abandoned agricultural land that could be extremely productive in the canal areas. In addition, a 62% decline in agricultural output has been connected to soil salinity. Salinity of the soil has significantly impacted Pakistan's agricultural sector, resulting in lower yields and lower farmer incomes. Due to its strong nutritional value, which includes providing carbohydrates, nutrient-rich fiber, and vitamins, wheat is a staple crop in many temperate regions and is in high demand. To do a geostatistical analysis of the Gujranwala district's soil salinity and its impacts on wheat yield from

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2000 to 2020 is the major objective of this work in light of the Gujranwala district's high soil salt content may be having a severe influence on wheat yields and quality, which might have significant consequences for the area's farmers as well as the general public.

2. Method

The data will be analyzed using statistical software and geostatistical tools. The study will also review relevant literature on soil salinity and wheat yield to provide context and support the analysis. To analyze Soil Salinity impact on wheat yield in District Gujranwala, a methodology based on GIS and remote sensing techniques was employed. The method include two criteria analysis of Soil Salinity. These criteria include; Impact of Soil Salinity on Wheat Yield. The following steps were taken in the analysis process: The Soil samples data of Physiochemical parameters of soil and Wheat Yield data from 2000 to 2020 taken from Principal Scientist of the Gujranwala Soil and Water Testing Laboratory and the Directorate of Crop Reporting Service, Agriculture Department Lahore. The Linear Regression Model and IDW analysis is performed. All the analysis are applied in spatial and temporal domains with in extent of Gujranwala district and years 2000 to 2020 of Gujranwala district.

To calculate the salinity levels of the soil samples, process them. This could include: Adjusting and utilizing instruments to gauge pH and electrical conductivity (EC). Steps consist of: GIS data importation into ArcGIS or QGIS software. Generating themed maps of the research area's various salinity levels. To evaluate the association between historical crop yield data and soil salinity, process and analyze the data. Typical actions include: Arranging the yield data according to the soil salinity levels at each location. Calculating various salinity ranges' mean, median, and variance statistical metrics. Finding the association between yield and salinity using statistical tests, such as correlation analysis. Correlation coefficients are calculated to express the direction and intensity of correlations. Regression analysis is used to model how salinity affects crop productivity. ANOVA should be used to compare crop yields at various soil salinity levels. Due to its applicability for investigating the linear correlations between variables, linear regression was selected for the study on the geo-spatial evaluation of soil salinity and its impact on wheat crop output in the Gujranwala District, Pakistan.

2.1. Study Area

Gujranwala is centrally located in Punjab, Pakistan, with geographical coordinates ranging from 31º to 32º N latitude and 73º to 74º E longitude (Figure. 1). The study area is bordered by Gujrat and Mandi Bahauddin to the north, Sheikhpura to the south, Hafizabad and Pindi Bhatian to the west, connecting it to Jhang, Chiniot, Sargodha, and Faisalabad to the southwest. Covering a total area of 3622 km² (1390 sq mi), Gujranwala is characterized by a typical altitude of 226 meters (744 feet) above sea level.

Positioned within the fertile plains of Punjab, Gujranwala benefits from irrigation through canals. The region is a part of Rachna Doab, which slopes from the northeast to the southwest and is traversed in its eastern portion by the Upper Chenab Canal. Throughout the year, the geographic area of Gujranwala witnesses' significant seasonal variations. The summer months, spanning from June to September, experience high temperatures ranging from 36 to 42 degrees Celsius (108 °F) (Kundu et al., 2018).

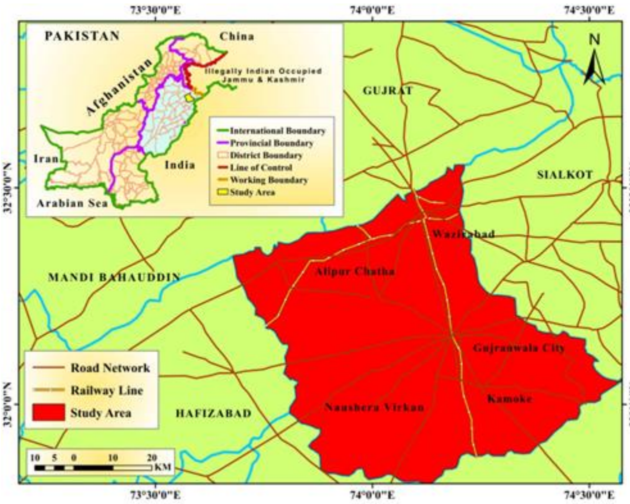

Figure 1. Location of study area.

3. Results

An adequate statistical linear regression analysis was run on the data to establish the association between crop yield and salinity (ECe) in a farming area. In this study, the linear regression analysis was computed using the statistical program SPSS. In this situation, wheat yield was the dependent variable, and linear regression was used to estimate its value based on the measured EC, which served as the independent variable. While the independent variable is sometimes referred to as the predictor variable, the dependent variable is sometimes called the outcome variable. It provides statistics that evaluate a regression model's performance. It evaluates how effectively the independent variables (predictors) provide explanation for variation in the dependent variable (wheat yield). The correlation coefficient (R) in the present study is -0.935a, showing a very significant negative correlation between the predictors and Wheat Yield. An R Square value of 0.875 indicates that the model's predictors can explain around 87.5% of the variation in wheat yield. In context of the complexity of the model and the size of the sample, the Adjusted R Square value of 0.871 indicates that the predictors represent around 87.1% of the variation in wheat yield. The difference between the estimated and actual Wheat Yield numbers in the present case is averaged out to be 1.434 standard errors of the estimate. The F Change statistic of 237.795 shows the model's overall significance, indicating that the variables jointly influence considerably to explaining Wheat Yield. The analysis revealed a strong negative correlation (r = .933) between EC and Wheat yield, and the regression model was able to account for 87% of the variance. This indicates that the model was well-suited for the data and statistically significant, as evidenced by a significant F-value of 55 and a p-value of less than .0005. Figure 3.10 illustrates a negative correlation between EC and wheat yield over the study period from 2000 to 2020. Specifically, electrical conductivity demonstrated an increasing trend, while wheat yield exhibited a decreasing trend.

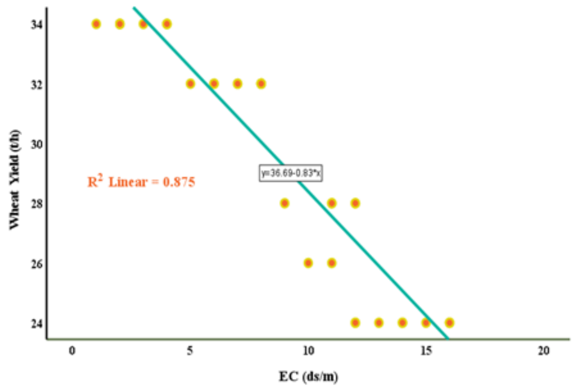

Figure 2. Scatter plot of EC and Wheat by year.

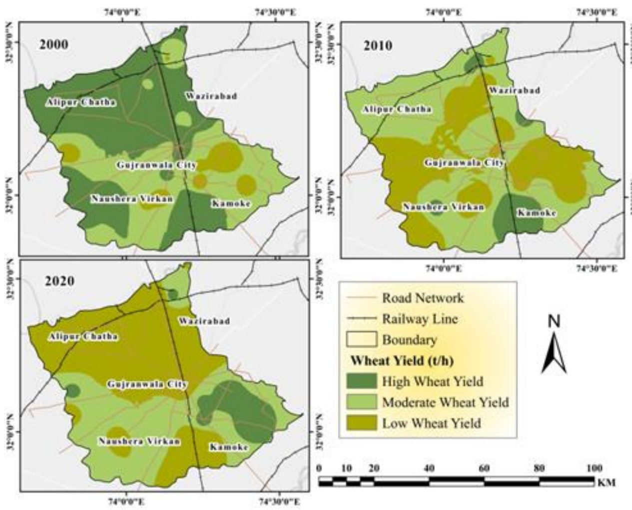

Figure 3. Wheat Productivity (2000-2020).

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4. Discussion

The analysis and interpretation of the results from the geostatistical analysis of soil salinity and its effect on wheat yield in the Gujranwala District are presented in the discussion section. It examines the consequences of the findings, addressed the study's goals, highlights its most important results, and gives perspectives into the study's general worth. Wheat production and soil salinity: The investigation showed an alarming negative association between wheat yield and soil salinity, as assessed by electrical conductivity (EC). Salt has a negative effect on agricultural output as demonstrated by a correlation between higher soil salt levels and lower wheat production. The study evaluated the extent of the reduction in wheat yield caused to soil salinity in order to quantify the impact. Authorities and farmers can use this information to better understand the financial consequences and decide on appropriate soil salinity management techniques.

This knowledge can direct focused actions and techniques of land management. Identifying potential hazards and hotspots: the study found regions that need to be immediately targeted for salinity management measures because of their high soil salinity hotspots. Furthermore, it detected locations vulnerable to the development of salinity, contributing in preventing future growth and mitigating potential effects on agricultural productivity. Adaptation strategies: In order to mitigate the negative consequences of soil salinity in the Gujranwala District, the research proposes solutions for adaptation.

5. Conclusion

Understanding the relationship between soil salinity and agricultural productivity is made possible by the geostatistical analysis of soil salinity and its effect on wheat production in the Gujranwala District. The following conclusions and suggestions can be drawn from the data: In the Gujranwala District, soil salinity has a major negative effect on wheat yield. Wheat production is negatively correlated with increased soil salinity, as measured by electrical conductivity (EC). Areas with greater salt levels and variations in salinity status over time were identified by the geographical and temporal examination of soil salinity patterns. For focused treatments and methods of land management, this information is essential.

The study emphasizes how crucial it is to put adaptation measures into effect to lessen the negative consequences of soil salinity. These tactics can include enhanced irrigation systems, methods for reclaiming land, crop choices, and salinity-reduction-focused soil management techniques. The research has consequences for policy, underlining the necessity for the creation and application of laws that support sustainable land use, water conservation, and salinity control methods.

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