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Crop Pattern, Waterlogging and Salinity Nexus in Semi-Arid Region of Punjab, India

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This research explores the intricate dynamics of cropping patterns and their influence on waterlogging and salinity in the semi–arid region of Indian Punjab. Examining the timeframe from 1991–92 to 2020–21 in the southwestern districts of Punjab, the study identifies notable shifts in the cultivation areas of major crops. There is an increase in the cultivation of rice, wheat, and vegetables, while cotton, fruits, oilseeds, and pulses experience declining trends. From 1991–92 to 2020–21, the area under rice cultivation increased by 41.05% in Bathinda, 53.27% in Faridkot, 39.52% in Ferozepur, and 4.21% in Fazilka, while cotton cultivation declined by 23.45%, 36.70%, 27.17%, and 2.13%, respectively. The expansion of irrigated areas, driven by both canal and tubewell irrigation, accompanies these shifts. However, the intensified irrigation and cultivation of high water requirement crops contributes to a rise in the water table, resulting in increased waterlogging and salinity in Fazilka, Sri Muktsar Sahib, and Faridkot districts, posing threats to soil health and crop yields. Correlation analysis indicates a significant positive correlation between rice, wheat, and vegetable cultivation and salt–affected waterlogged areas, exacerbating waterlogging and salinity due to the high water requirements of these crops. In contrast, cotton and fruit cultivation display a significant negative correlation with waterlogged areas. This thorough analysis underscores the urgency of adopting sustainable agricultural practices and collaborative irrigation management to effectively address waterlogging and salinity challenges. A joint effort involving farmers and policymakers is imperative to promote sustainable agriculture and enhance crop productivity in the region.

Keywords: Degradation, Irrigation, Production, Soil, Sustainability

Introduction

Agriculture has long been the backbone of human civilization, providing sustenance, economic prosperity, and cultural identity to countless communities around the world.[1–3] However, the escalating challenges posed by environmental degradation, climate change, and natural resource depletion are profoundly altering traditional agricultural practices.[4–5] Among these challenges, waterlogged and salt–affected areas have emerged as critical factors impacting crop productivity and dictating shifts in cropping patterns.[6] Over the years, anthropogenic activities and climatic variations have led to the deterioration of once–fertile lands, rendering them waterlogged or salt–affected.[7] Salts in soil arise from the accumulation of soluble salts, such as sodium chloride, magnesium sulfate, and calcium sulfate, which hinder plant growth by osmotic stress and toxicity.[8]

Waterlogging prevents the aeration of the root–zone and leads to secondary soil salinization, as salts become trapped in the soil.[9] Poor–quality water for irrigation, improper irrigation practices, and poorly drained soil contribute to rising water tables, waterlogging, and salinization of croplands.[10] These waterlogged conditions have adverse effects on plant physiology, such as reduced oxygen availability, nutrient deficiency, and altered microbial activity, which significantly affects crop growth as well as yield.[11] Globally, approximately 20% of irrigated land suffers from waterlogging and secondary soil salinization, primarily caused by excessive irrigation or inadequate sub–surface drainage.[12] Salt-affected soils cover 6.73 million hectares in India, while Punjab faces 1.51 lakh hectares of salt-affected waterlogged areas. Semi–arid regions with high evaporation rates are particularly susceptible.[13] Waterlogging negatively impacts agricultural activities and rural settlements, posing a serious environmental hazard observed worldwide[14], including China, Pakistan, Bangladesh, India and other countries. The detrimental effects of waterlogging extend to land degradation and soil erosion, which have socio–economic implications and affect land resources.[15,16] In India, thousands of hectares of irrigated land are lost each year due to

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waterlogging caused by natural drainage barriers, construction activities, and infrastructure development. The issue of salinization, which is a significant environmental soil hazard caused by natural and human activities, leads to land degradation and desertification worldwide.[17,18] The high concentration of Total Dissolved Solids (TDS) and Sodium Adsorption Ratio (SAR) in irrigation water creates a shallow impermeable crust that results in waterlogging and cropland degradation.[19] The adverse impacts of waterlogging and salinization on soil structure, plant growth, and crop yield have been studied by.[19] These problems have particularly affected arid and semi–arid regions, impacting agricultural activities and causing land degradation.[20] In India, where agricultural practices rely heavily on irrigation canals due to changing climatic conditions and unpredictable monsoons, salinity has become a significant challenge.[21] The development of a vast canal network initially raised the groundwater table, leading to waterlogging and salinity issues due to poor land management and inadequate drainage systems.[22] The global extent of waterlogged and salt–affected areas has been steadily increasing, directly impacting agriculture and food security.[23] In many regions, farmers have been forced to adapt their cropping patterns to cope with the challenges posed by these conditions. The implications of such alterations in cropping practices extend far beyond individual farms, influencing local economies, biodiversity, and sustainable land use.[24] Understanding the complex interplay between waterlogged and salt–affected areas and their influence on cropping patterns is essential for formulating effective mitigation and adaptation strategies.[25] It requires a multidisciplinary approach that combines insights from agronomy, soil science, soil and water engineering, hydrology, and climate studies.[26] Through such comprehensive research, we can identify sustainable agricultural practices that can maximize yields, environmental degradation, and secure food production in these challenging landscapes.

The research delves into the dynamic interplay between agricultural practices, environmental challenges, and the imperative need for sustainable solutions to safeguard global food security amid escalating issues of waterlogging and salinity. The findings will underscore the urgency of adopting responsible agricultural practices and implementing effective management strategies for irrigation sources to address the pressing challenges posed by waterlogging and salinity. Through comprehensive research, the study aims to identify and explore the impact of changes in cropping patterns on waterlogging and salinity in the southwestern districts of Indian Punjab.

The current research primarily focuses on the southwestern districts of Punjab. There is a lack of a micro–level spatial analysis that dissects the variations within these districts concerning temporal dynamics and long–term trends, which were not assessed in terms of the complex relationships between cropping patterns, irrigated areas, waterlogging, and salinity. Addressing the above research gap this study sheds light on the evolving dynamics of cropping patterns and their implications on waterlogging and salinity in southwestern Punjab. This study's findings will facilitate the formulation of targeted and effective policies to address the challenges posed by waterlogging and salinity in the region. Through comprehensive research, the study aims to identify and explore the impact of changes in cropping patterns on waterlogging and salinity in the southwestern districts of Indian Punjab.

Materials and Methods

The southwestern part of Punjab is comprised of six districts: Faridkot, Sri Muktsar Sahib (1995), Ferozepur, Fazilka (2011), Bathinda, and Mansa (1992). Geographically, these districts are located between the northern latitudes of 29°30′ to 31°07′ and the eastern longitudes of 73°55′ to 75°46′ (Fig. 1). This region is situated in the Indo–Gangetic alluvial plain, covering a total geographical area of approximately 1,491,220 hectares, which accounts for about 34% of the state's total area and encompasses approximately 32.4% of the entire cropped area. Canal water serves as the primary source of irrigation in this region, with government canals irrigating around 83.13% of the net area, while groundwater extracted through tubewells contributes 12.47%. The southwestern districts play a significant role in the state's crop production, with substantial contributions to cotton (98.3%), wheat (33.2%), and rice (30.55%). Over the years, district reconfigurations occurred, with Mansa being established in 1992 from Bathinda, Sri Muktsar Sahib emerging in 1995 by separating from Faridkot, and Fazilka district being formed in 2011 from Ferozepur district.[27]

The data was collected from Statistical Abstract of Punjab and Department of Agriculture and Farmer

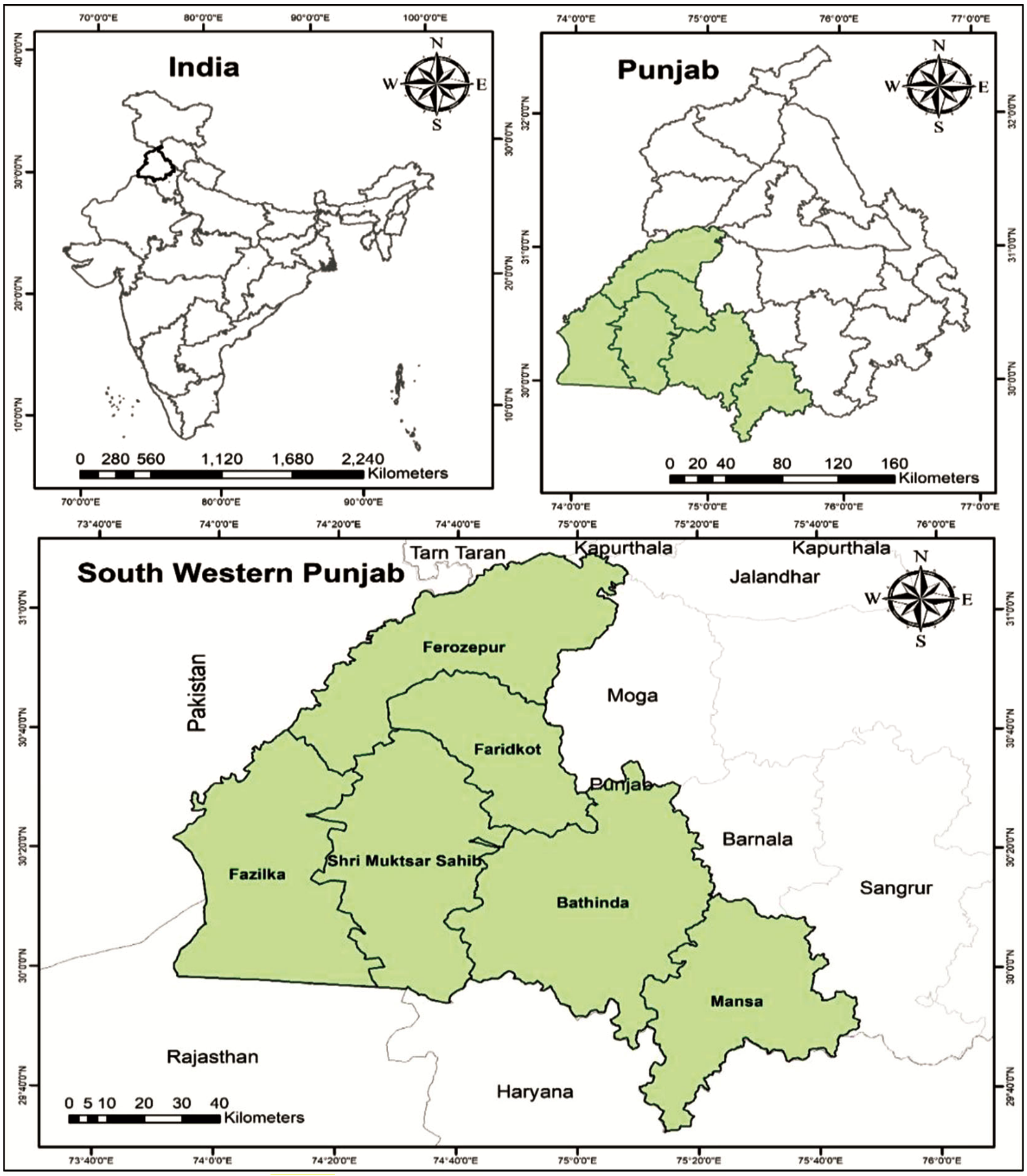

Fig. 1 — Location map of the study area

Welfare, Punjab. The cropping and irrigated area were noted from Statistical Abstract of Punjab for different years. The Karl Pearson correlation coefficient(r) (Eq. (1)) was obtained to investigate the relationship between cropping pattern, irrigated area, waterlogged and salt–affected area.[28]

$$r = \frac{n(\sum_{i=1}^{n} xy) - \sum_{i=1}^{n} x \sum_{i=1}^{n} y}{\sqrt{\left[n\sum_{i=1}^{n} x^2 - \left(\sum_{i=1}^{n} x\right)^2\right]\left[n\sum_{i=1}^{n} y^2 - \left(\sum_{i=1}^{n} y\right)^2\right]}} \quad \dots (1)$$

where,
x and y = variables x and y with
n = observations,
r = correlation coefficient

r value that ranges from –1 to 1, where –1 represents a perfect negative correlation between the variables, 0 indicates no correlation, and 1 represents a perfect positive correlation.

Result and Discussion

The information about land used for various crops and their irrigation sources for seven years from 1991–92 to 2020–21 is presented below. Rice, wheat, cotton, pulses, oilseed, fruits, vegetables, barley, sugarcane, bajra, and maize crops were chosen for the impact analysis on waterlogging and salt–affected area. The information about area irrigated by canal

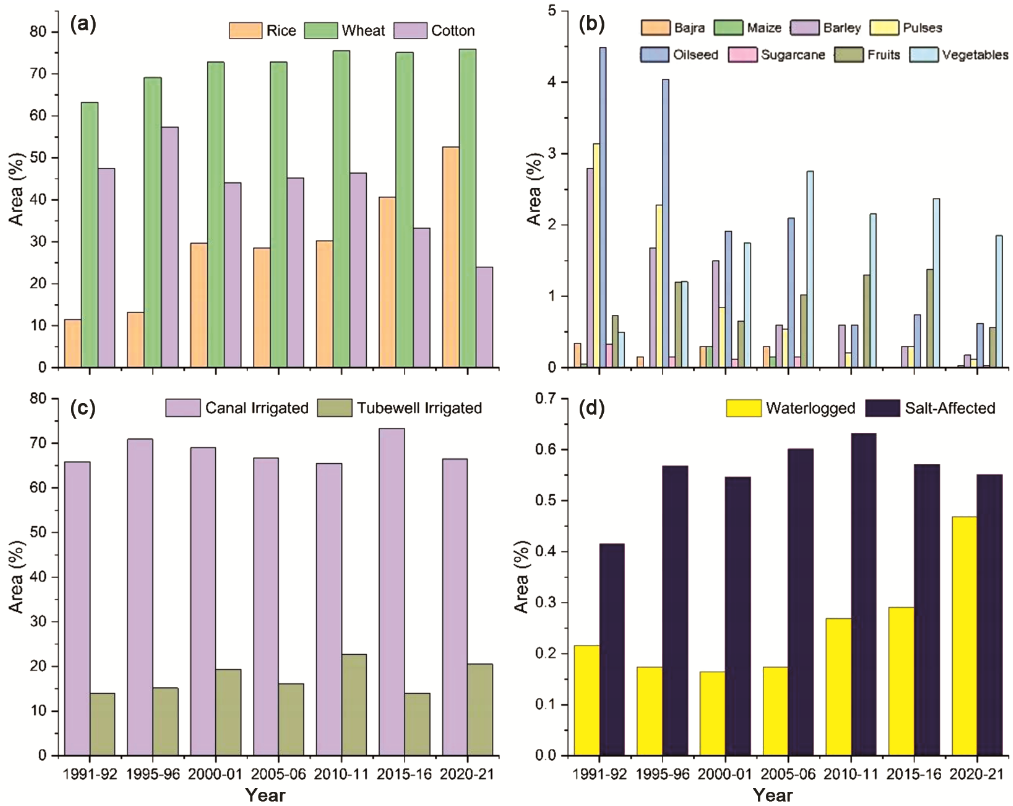

Fig. 2 — Area under: (a) major crops, (b) minor crops, (c) irrigation sources, (d) waterlogging and salinity in Bathinda district

and tubewell was collected from Statistical abstracts of Punjab and presented. The correlation coefficients between crops sown and irrigation water source (canal and tubewell irrigation) on waterlogging and salinity were obtained and described below.

Impact of Cropping Pattern and Irrigation Type on Waterlogging and Salinity in South western District

Bathinda District

The area under rice, wheat and vegetables was observed with increasing trend while cotton, fruits, oil seeds, pulses and other cereal crops decreasing from the period 1991–92 to 2020–21 in Bathinda district (Fig. 2a,b). The increase in area under rice cultivation was found to be highest (41.05%) followed by wheat (12.61%) and vegetables (1.87%) from the year 1991–92 to 2020–21. However, cotton was once a major crop in this district, presently the area is decreased from 47.46% in 1991–92 to 24.01% in 2020–21 (Fig. 2a), which is 23.45% decrease in area. Due to change in cropping pattern, the irrigated area was increased about 94% out of this, area under canal and tubewell irrigation was increased from 65.91% and 13.98% in 1991–92 to 66.47% and 20.47% in 2020–21 (Fig. 2c). Canal irrigated area (73.29%) was found to be highest during 2015–16, resulting to increase in waterlogging and salinity from 0.22% and 0.41% in 1991–92 to 0.47% and 0.55% of TGA in 2020–21 respectively (Fig. 2d).

Faridkot District

There was a rising trend in the cultivated area of rice, wheat, and vegetables in Faridkot district from 1991–92 to 2020–21 and decrease in area of cotton, fruits, oil seeds, pulses, other cereal crops during the same period (Fig. 3a,b). Among these crops, rice cultivation showed the highest increase at 53.27%, followed by wheat at 11.14% and vegetables at 0.54%, whereas in cotton, which used to be a major crop in this district, has been declined in area from 37.58% in 1991–92 to 0.88% in 2020–21 (Fig. 3a), reflecting a decrease of 36.70% in the cultivation area. This change in cropping patterns has resulted in an 87% increase in the irrigated area, with canal and tubewell irrigation accounting for 38.78% and 47.62% respectively in 2020–21, from 59.04% and 27.04% in 1991–92 (Fig. 3c), leading to an increase in waterlogging and salt–affected areas from 0.11% and 0.07% of the total geographical area (TGA) in 1991–

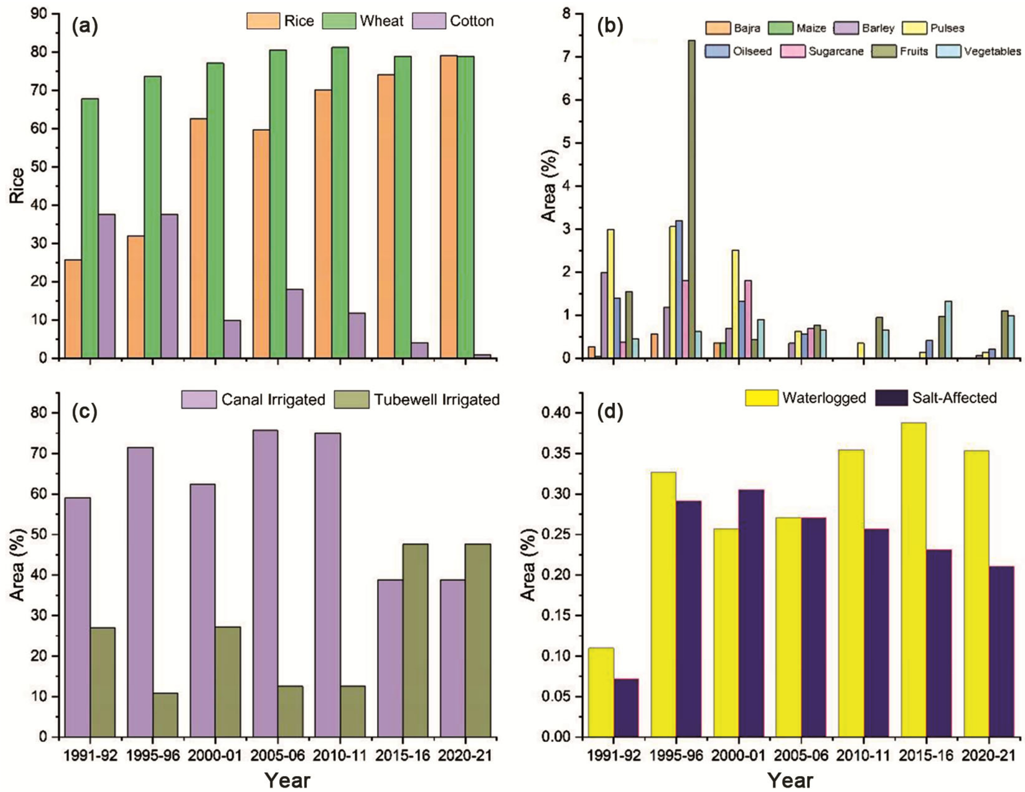

Fig. 3 — Area under: (a) major crops, (b) minor crops, (c) irrigation sources, (d) waterlogging and salinity in Faridkot district

92 to 0.35% and 0.21% of TGA in 2020–21 respectively (Fig. 3d). Other crops such as pulses, oil seed, fruits, and vegetables were grown in smaller quantities and cover less than 3% of the total area. These crops are typically grown in areas where farmers are looking to diversify their crop portfolio.

Ferozepur District

The cultivated area of rice, wheat, and vegetables was consistently increasing in Ferozepur district during the period from 1991–92 to 2020–21. On the other hand, the area under cotton, fruits, oil seeds, pulses, and other cereal crops were declined during this period (Fig. 4a,b). The rice crop showed the highest increase in area, reaching to 39.52%, followed by wheat at 15.61% and vegetables at 2.11%. However, cotton, suffered a significant decrease in area, dropping from 27.17% in 1991–92 to 0% in 2020–21 (Fig. 4a), representing a decline of 27.17% in the cultivated area. This shifting in cropping patterns resulted in a substantial expansion of the irrigated area of 92%, with canal and tubewell irrigation accounting for 20.50% and 70.71% respectively in 2020–21, compared to 40.61% and 44.33% in 1991–92 (Fig. 4c), leading to an increase in waterlogging and salt–affected areas from 0.10% and 0.28% of the total geographical area (TGA) in 1991–92 to 0.16% and 0.73% of TGA in 2020–21 respectively (Fig. 4d). Other crops like pulses, oilseeds, fruits, vegetables, barley, sugarcane, bajra, and maize cultivation were also varying in area with less than 2%. Rice wheat and cotton were the dominant crops till 2010–11 and no cotton cultivation was seen from 2015–16. The salinity was in increasing trend since 1991–92 and found highest during 2020–21 which pose a threat to soil health and crop yields.

Fazilka District

The data presented in the Fig. 5 provides insights into the changing agricultural patterns in Fazilka district for the years 2015–16, 2018–19, and 2020–21. The maximum increase was observed in the area devoted to rice cultivation (4.21%), fruits (2.26%) and cotton (2.13%). Despite being the primary crop in the past, wheat cultivation area decreased marginally from 72.82% in 1991–92 to 72.26% in 2020–21 as depicted in Fig. 5a, representing a decline of 0.56% in the area. This change in crop patterns led to a significant increase in irrigated area (88%), primarily

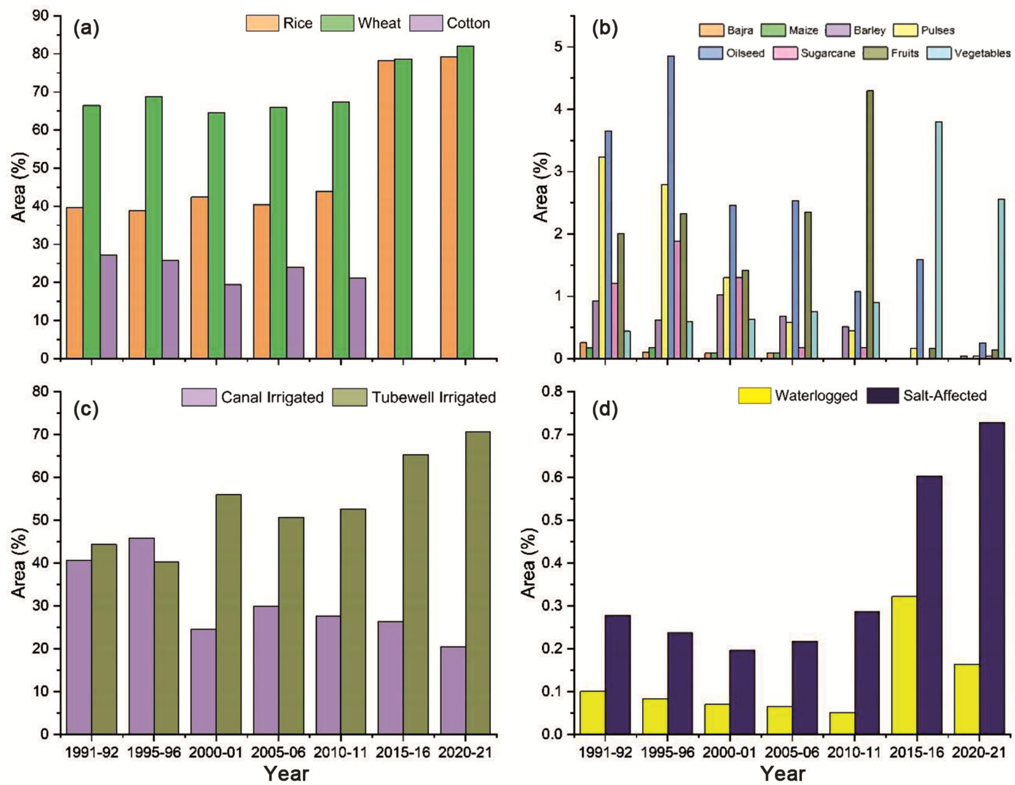

Fig. 4 — Area under: (a) major crops, (b) minor crops, (c) irrigation sources, (d) waterlogging and salinity in Ferozepur district

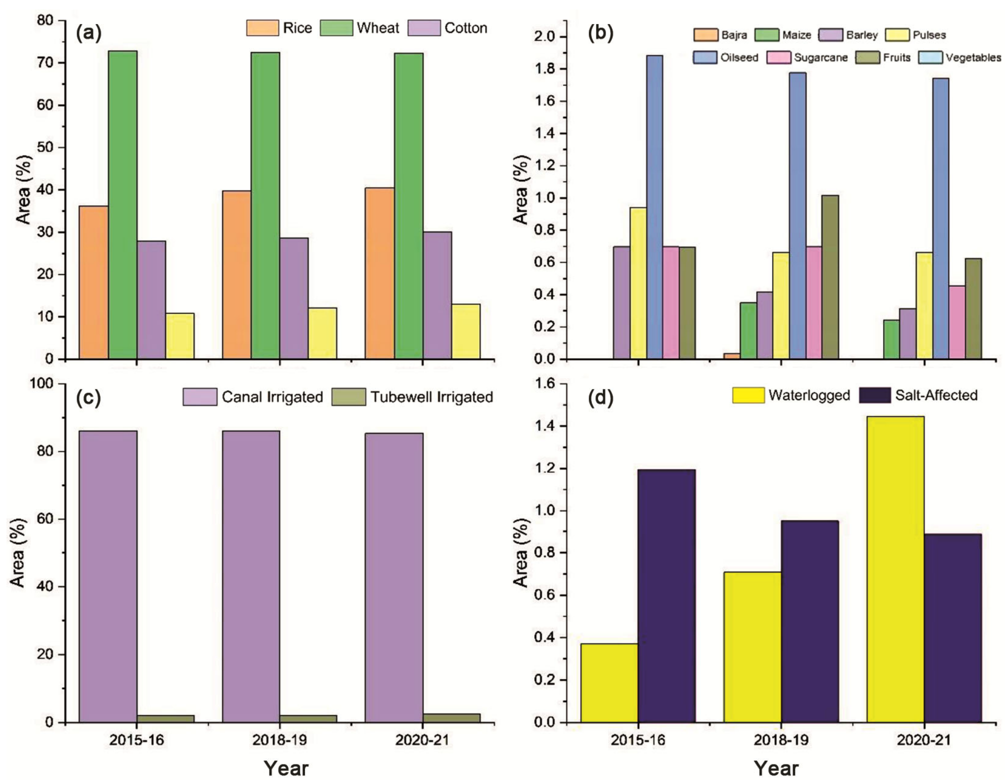

Fig. 5 — Area under: (a) major crops, (b) minor crops, (c) irrigation sources, (d) waterlogging and salinity in Fazilka district

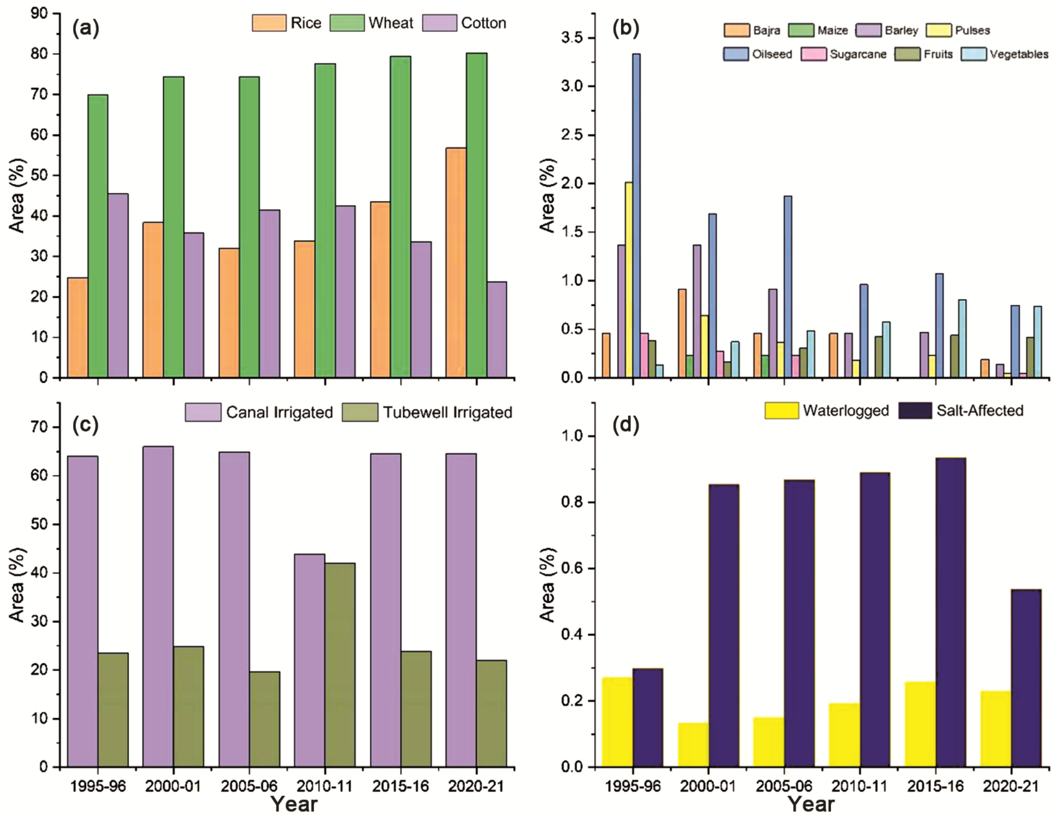

Fig. 6 — Area under: (a) major crops, (b) minor crops, (C) irrigation sources, (d) waterlogging and salinity in Mansa district

driven by an expansion of canal and tubewell irrigation, which accounted for 85.37% and 2.44% in 2020–21, respectively (Fig. 5c), resulting in a rise in waterlogging and salt–affected areas from 0.37% and 1.20% of the TGA in 2015–16 to 1.45% and 0.89% of TGA in 2020–21, respectively (Fig. 5d). The area under pulses, oilseeds, fruits, vegetables, barley, sugarcane, bajra, and maize was relatively less in this district, with each occupying less than 2% of the total area. The major crops grown in this districtwere rice, wheat, and cotton, which occupy a significant proportion of the total area. The increase in waterlogged land in recent years is a cause for concern, and measures need to be taken to address this issue. The dominance of rice, wheat, and cotton cultivation in the Fazilka district, with fruits and vegetables being grown to a lesser extent. Canal irrigation is the primary method was used for irrigating the crops, followed by tubewell irrigation. The trend of increasing area under fruits and vegetables is encouraging as it diversifies the agricultural production in the district.

Mansa District

The area of different land uses and land types in Mansa district as a percentage of the total area of the Mansa district is presented in Fig. 6. Major crops grown in the district were wheat, rice, cotton, and pulses, with canal and tubewell irrigation being the most commonly used irrigation system. Waterlogged and salt–affected lands are present in relatively small proportions. Rice and wheat cultivation was an important crops, accounting 24.66% and 69.86% in 1995–96 increased to 56.73% and 80.19% in 2020–21, respectively. However, cotton had been a major crop in this district in past, for the last fewyears, the area was decreased from 45.43% in 1995–96 to 23.64% in 2020–21 (Fig. 6a,b), which is 21.79% decrease in area. Due to change in cropping pattern, the irrigated area was increased about 87% out of this, area under canal and tubewell irrigation has increased from 63.97% and 23.52% in 1995–96 to 64.49% and 21.96% in 2020–21 (Fig. 6c), resulting to increase in waterlogging and salt affected area from 0.27% and 0.30% in 1995–96 to 0.23% and 0.54% of TGA in 2020–21 respectively (Fig. 6d). Pulses, oilseed, fruits, vegetables, barley, sugarcane, bajra, and maize cultivation account for smaller proportions, they were less than 4%.

Sri Muktsar Sahib District

The major crops grown in this district were rice, wheat, and cotton. Wheat has the largest area of cultivation, covering 63.50% in 1995–96 to 81.52% in 2020–21 of the total area, followed by rice at 7.22% in 1995–96 to 70.23% in 2020–21. Cotton covered 8.48% in 1995–96 to 10.87% in 2020–21 (Fig. 7a,b). Canal irrigation is the most commonly used irrigation system, increased from 76.62% in 1995–96 to 86.36% in 2020–21 of the total area, whereas tubewell irrigated area decreased from 3.31% in 1995–96 to neglible in 2020–21, (Fig. 7c), leading to an increase in waterlogging and salt–affected areas from 0.43% and 2.71% of the TGA in 1995–96 to 1.87% and 1.72% of TGA in 2020–21 respectively (Fig. 7d). Other crops such as pulses, oilseed, fruits, and vegetables were grown in smaller quantities and cover less than 5% of the total area (Fig. 7a,b). These crops are typically grown in areas where farmers are looking to diversify from traditional crops like rice and wheat.

Correlation Between Cropping Pattern and Irrigation Type with Waterlogging and Soil Salinity

The correlation coefficients between various crops, irrigation sources and soil salinity with waterlogging were obtained for Bathinda, Faridkot, Ferozepur, Mansa, Sri Muktsar Sahib and Fazilka districts of southwestern Punjab (Table 1). It can be observed that rice, wheat and vegetables cultivation show a significant positive correlation with the salt–affected waterlogged area in all the districts of southwestern Punjab except Fazilka because of rice is more water demanding crop which leads to waterlogging and salinity (Fig. 8(a–f)). However, cotton and fruits cultivation show a significant negative correlation with the waterlogged area because cotton was replaced with rice which enhanced the waterlogging due to flooding irrigation except Fazilka district where area under cotton was more during study period. Similarly, oilseed, barley and pulses cultivation also show negative correlations with the waterlogged area due to less water requirement crops. Sugarcane is a more water consuming crop and could not grow under waterlogging condition therefore, it showed negative correlation with waterlogging for all the district (Table 1). Other crops such as bajra and maize have non–significant or weak correlations with the waterlogged area, revealed that these crops did not enhance the waterlogging and salinity. Canal and tubewell irrigation have mixed type of correlation with

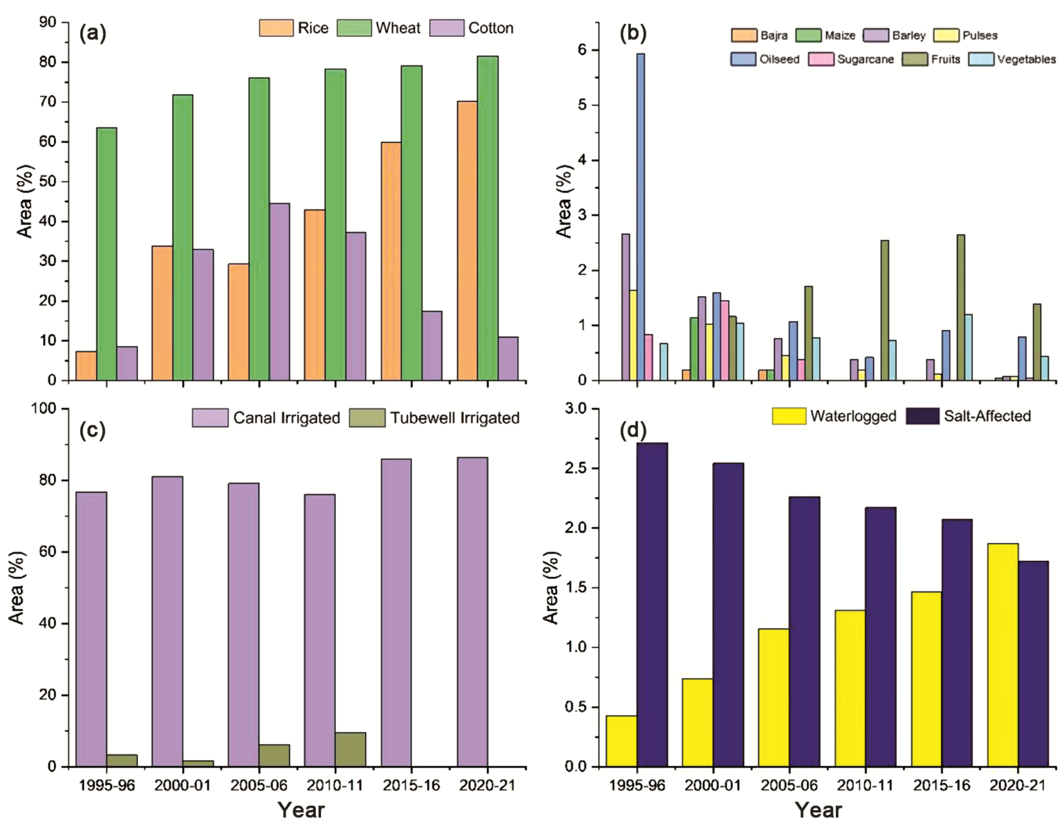

Fig. 7 — Area under: (a) major crops, (b) minor crops, (c) irrigation sources, (d) waterlogging and salinity in Sri Muktsar Sahib district

Table 1 — Correlation between cropping pattern and irrigated area with waterlogging

Variable	Bathinda	Faridkot	Ferozepur	Mansa	Sri Muktsar Sahib	Fazilka
Salt–Affected	0.931*	0.847*	0.929*	0.814*	0.430	0.943
Rice	0.732*	0.695*	0.929*	0.738	0.633	–0.082
Wheat	0.423	0.475	0.870*	0.507	0.507	–0.135
Cotton	–0.802*	–0.762	–0.917*	–0.788*	–0.215	0.457
C–Irrigated	0.129	–0.646	–0.616	0.701	0.910*	–0.719
T–Irrigated	–0.055	0.705*	0.864*	–0.752*	–0.766*	0.773
Pulses	–0.520	–0.562	–0.646	–0.436	–0.430	0.243
Oilseed	–0.474	–0.493	–0.614	–0.376	–0.386	0.003
Fruits	–0.425	–0.532	–0.832*	0.031	0.129	0.146
Vegetables	0.467	0.751*	0.902*	0.584	0.093	–0.994*
Barley	–0.499	–0.557	–0.799*	–0.415	–0.456	–0.022
Sugarcane	–0.242	–0.217	–0.672	–0.275	–0.146	–0.719
Bajra	–0.031	–0.510	–0.485	–0.486	0.189	–0.962
Maize	0.357	0.169	–0.528	0.107	0.110	–0.516

Note: * Significant at 5% level of significance

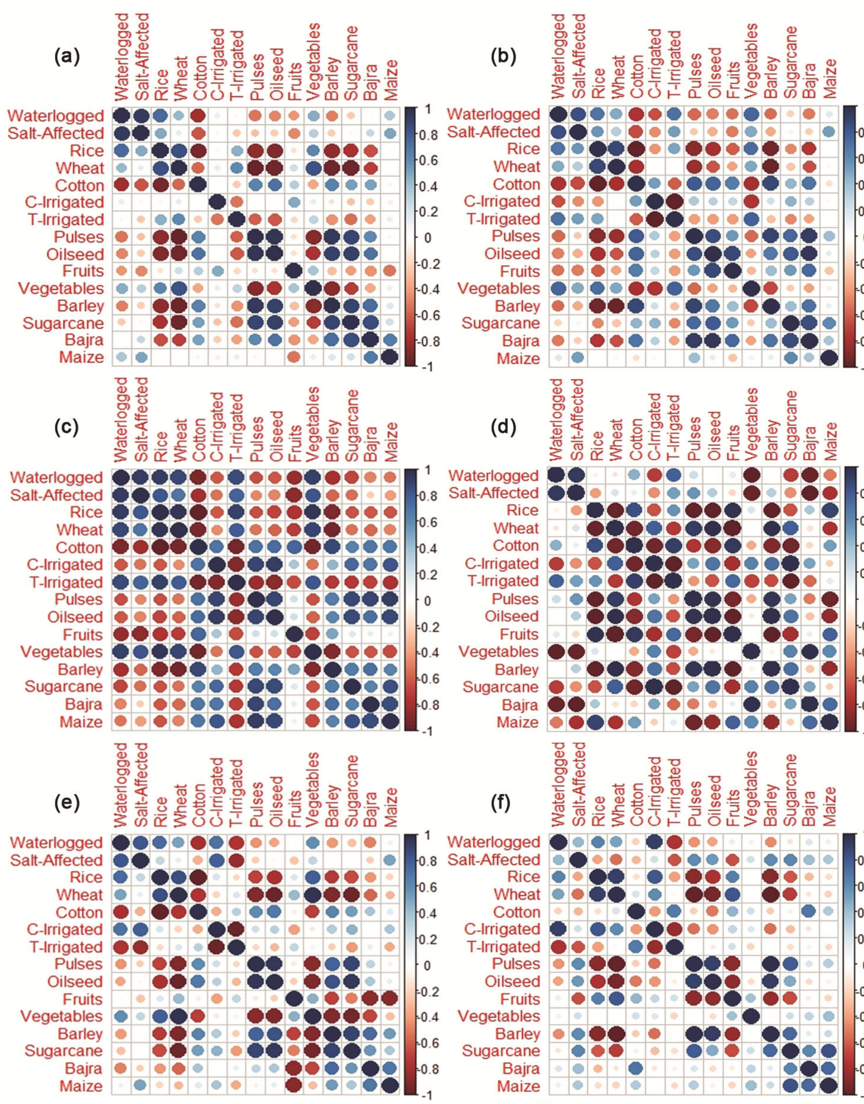

Fig. 8 — Correlation matrix of different factors in: (a) Bathinda district, (b) Faridkot district, (c) Ferozepur district (d) Fazilka district, (e) Mansa district, (f) Sri Muktsar Sahib district

Table 2 — Correlation between cropping pattern and irrigated area variable with salt–affected area

Variable	Bathinda	Faridkot	Ferozepur	Mansa	Sri Muktsar Sahib	Fazilka
Waterlogged	0.931*	0.847*	0.929*	0.814*	0.430	0.943
Rice	0.472	0.555	0.813*	0.270	0.633	–0.408
Wheat	0.139	0.328	0.697*	0.134	0.507	0.202
Cotton	–0.620	–0.650	–0.803*	–0.336	–0.215	0.136
C–Irrigated	0.069	–0.454	–0.537	0.789*	0.910*	–0.447
T–Irrigated	–0.250	0.529	0.761*	–0.838*	–0.766*	0.519
Pulses	–0.282	–0.257	–0.470	–0.239	–0.430	0.551
Oilseed	–0.236	–0.332	–0.472	–0.060	–0.386	0.334
Fruits	–0.468	–0.501	–0.868*	–0.270	0.129	–0.191
Vegetables	0.320	0.474	0.829*	0.286	0.093	–0.974
Barley	–0.221	–0.351	–0.577	0.013	–0.456	0.311
Sugarcane	0.058	0.078	–0.544	0.019	–0.146	–0.447
Bajra	0.278	–0.233	–0.238	–0.223	0.405	–0.998
Maize	0.493	0.522	–0.407	0.503	0.364	–0.771

Note: * Significant at 5% level of significance

waterlogging. Canal irrigation showed positive correlation while tubewell irrigation negative correlation with waterlogging in Sri Muktsar sahib and Mansa districts.

Salt–affected soils are the major concern in many parts of the world, including southwestern district of Punjab, India. These soils enriched with high levels of salts, which can be harmful to plants, and reduce crop yields. In Table 2 the correlations between different crops, irrigation sources, and waterlogging and the salt–affected area in southwestern districts of Punjab are given. The dependent variable is the salt–affected area, and the independent variables are waterlogged, rice, wheat, cotton, canal irrigated, tubewell irrigated, pulses, oilseed, fruits, vegetables, barley, sugarcane, bajra, and maize.

In all districts of southwestern Punjab, except Fazilka, a positive correlation was observed between the cultivation of rice, wheat, and vegetables and the salt affected area (Fig. 8). However, the cultivation of cotton and fruits showed a negative correlation with the salt–affected area, except in Fazilka district where cotton cultivation was more prominent during the study period. Additionally, the cultivation of oilseed, barley, and pulses also shows negative correlations with the salt–affected area, as these crops require less water.

This study provides a detailed breakdown of the percentage of different crops grown in different southwestern districts of Punjab. The study highlights significant changes in cropping patterns and irrigation practices in the southwestern districts of Punjab, with a shift from cotton to rice, wheat, and vegetables. This shift has implications for waterlogging and soil salinity, and the correlations observed suggest various factors influencing these trends. The results provide valuable information about the distribution of different crops cultivated and the extent of waterlogging and soil salinity, which are critical factors affecting agricultural productivity in this region. The shift from cotton to rice, wheat, and vegetables is evident across districts, impacting irrigation and contributing to waterlogging and salinity issues. Farmers' decisions are often influenced by market demand and profitability. The shift from cotton to rice, wheat, and vegetables could be driven by changing market conditions and economic incentives. Similar findings of Sharma & Sharma[29] suggests that economic factors play a crucial role in shaping farmers' crop choices, with market demand being a key driver of agricultural decisions.[30] Changes in canal and tubewell irrigation reflect evolving agricultural practices, with varying implications for waterlogging and salinity. Technological advancements encourage shifts in cultivation practices, particularly in areas like cultivation, interculture, harvesting, irrigation methods, as well as transport and storage.[31]

While waterlogging and salinity have generally increased, the extent varies between districts, indicating the complexity of factors influencing soil health. Climate change and variations in weather patterns may contribute to shifts in cropping patterns. Changes in temperature and precipitation can affect the suitability of certain crops and influence farmers' choices. Diverse adaptations to soil conditions may influence crop choices. Different crops have varying requirements for soil nutrients, and farmers may choose crops based on soil fertility and adaptability. Studies indicate that climate change is a significant factor influencing agriculture, impacting crop choices and contributing to shifts in cultivation patterns.[32,33] Research explores the relationship between soil conditions, crop adaptations, and agricultural productivity, emphasizing the need for tailored approaches.[31,34] The correlation analysis highlights the relationships between crop choices, irrigation methods, and waterlogging/salinity. Positive correlations suggest a need for adaptive strategies in crop selection and irrigation practices. The correlations observed can be attributed to several potential reasons, including similar requirements for soil nutrients and irrigation methods, diverse adaptations to soil conditions, and farmer decision–making influenced by market demand and crop rotation strategies. Government policies, subsidies, and support programs can also shape farmers' decisions regarding crop choices and irrigation practices. Studies demonstrate the impact of policy interventions on agricultural practices, influencing crop diversification and water management strategies.[35–37] The study acknowledges the limitations in data accessibility at the district level and highlights the necessity of extending the analysis to the block or village level for a more comprehensive understanding.[38–40] Emphasizes the importance of micro–level spatial analysis for designing region–specific strategies and addressing localized challenges in agriculture.

Conclusions

The study evaluated the influence of waterlogging and salinity on cropping patterns and irrigation sources in the southwestern districts of Punjab from 1991–92 to 2020–21. Significant changes were observed in the cultivated areas of major crops, with rice, wheat, and vegetables increasing, while cotton, fruits, oilseeds, and pulses declined. Expansion of irrigated areas, particularly through canal and tubewell irrigation, led to heightened waterlogging and salinity, threatening soil health and crop yields. The analysis1 revealed a positive correlation between rice, wheat, and vegetable cultivation and salt–affected waterlogged areas, indicating their contribution to waterlogging and salinity. Conversely, cotton and fruits showed a negative correlation, suggesting a mitigating effect. Diversification of crops, efficient irrigation techniques, and collaborative efforts between farmers and policymakers are essential for managing waterlogging and salinity sustainably, ensuring improved agricultural productivity in the region.Future research areas include the need for improved micro-level data for more focused strategies, as well as the present lack of a comprehensive approach to examining the interactions between climate change, cropping patterns, and related issues.Future research, including micro–level spatial analysis, is essential for devising targeted and sustainable solutions.

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