

ANALYSIS OF LAND AND WATER DEGRADATION, ITS DRIVERS, AND REMEDIAL STRATEGIES FOR SOUTH PUNJAB, PAKISTAN

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ABSTRACT

Land and water degradation pose a significant risk to agricultural productivity, rural livelihoods, and food security in South Punjab, Pakistan. This study explored the effects of degradation through a quantitative cross-sectional survey of 300 farm families in five districts (Bahawalpur, Multan, Vehari, Rahim Yar Khan and Dera Ghazi Khan). Findings indicate that the most pernicious forms of land and water degradation are soil salinity (Mean = 3.95, SD = 0.82) and groundwater depletion (Mean = 3.90, SD = 0.81). Further, over-exploitation of groundwater (Mean = 4.05, SD = 0.78), overuse of agrochemicals (Mean = 3.91, SD = 0.81), and erratic rainfall/droughts (Mean = 3.88, SD = 0.82) are detrimental as well. It also has socioeconomic implications, the most significant of which are the reduction in crop yield (Mean = 4.12, SD = 0.79) and the increase in production costs (Mean = 3.95, SD = 0.82). Both the chi-square and logistic regression analysis indicated that farmers' perception of degradation is contingent on education, farm size, and contact with extension workers (Nagelkerke $R^2 = 0.28$, overall accuracy = 70.3%). To achieve conservation of resource, some remedial practices such as efficient irrigation systems, soil reclamation methods and cultivation of salt-resistant crops needs to be promoted. The paper emphasizes the need for concerted technological, institutional, and policy action to reduce degradation and enhance agricultural resilience in South Punjab.

Keywords: Land degradation, Water depletion, Soil salinity, South Punjab, Sustainable agriculture, Remedial strategies.

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1. INTRODUCTION

Punjab province of Pakistan is blessed with large canal irrigation systems and fertile alluvial soils, so called bread basket heart of the country. However, in recent decades, land and water degradation is increasingly becoming a threat to the region which endangers its long-term sustainability (Amanat et al., 2023). Degradation occurs in various forms, including soil salinity, waterlogging, declining soil fertility, overuse of groundwater, and water pollution from agricultural and industrial effluents (GoP, 2025; Haider et al., 2024). Such problems not only limit agricultural output but also impose additional poverty and vulnerability upon agricultural communities.

Land and water degradation is even more acute in underprivileged regions, such as the South Punjab, which has a multifaceted problems such as prevalent poverty and declining agricultural productivity due to anthropogenic factors. The rapid growth of the population and the increasing intensity of the agricultural sector have put a strain on soil and water resources, leading to unsustainable practices such as over-irrigation, irrational use of agrochemicals, and uncontrolled groundwater pumping in most instances (Kang and Kang, 2019). Global warming has also exacerbated these issues, making them even more severe as the temperature increase becomes increasingly unpredictable. Drought and flood environments are causing further degradation, which is likely to continue. Though irrigation by canals has played a life-saving role in the region, it has caused secondary salinization and waterlogging in most districts due to the absence of drainage and effective irrigation water management schemes (Aalirezai et al., 2021).

The socioeconomic implications of degradation are disastrous. Major agricultural crops in South Punjab, are directly affected by reduced soil productivity and water quality. Smallholder farmers, who constitute the largest portion of the population in the area, are disproportionately affected as they typically lack the means to adopt remedial technologies or switch to sustainable practices. Additionally, the degradation of land and water has a more intensive

impact on food security, rural employment, and environmental welfare in the region (Kang et al., 2020).

To address these problems, we must not only possess a basic understanding of the forces which cause degradation, but also the policies that can be employed to address the effects. It has been noted that integrated soil fertility management, conservation agriculture, high irrigation efficiency, rainwater harvesting, and the use of salt-tolerant crop varieties have been included in some of the remedial measures (Bansal et al., 2024). Other options, which are potentially effective but must be adopted on a large scale, include lining irrigation channels, simultaneous surface and groundwater extraction, saline soil rehabilitation, and enhancement of extension services in the South Punjab context (GOP, 2025; Mahmood, 2024). The proposed research will discuss the extent and nature of land and water degradation in South Punjab, its primary causes and formulate effective remedial solutions which can be adopted within the socioeconomic and ecological context of the region. The study expands the literature on sustainable resource management in arid and semi-arid regions, providing practical implications for policymakers, extension agencies, and farm communities. Study's objectives include: identify the extent and the nature of land and water degradation in South Punjab, to identify the most significant factors that lead to land and water degradation and to evaluate the corrective actions.

2. MATERIALS AND METHODS

2.1. Research Design

A quantitative cross-sectional survey research method was used in this paper to investigate the extent, causes, consequences and remedies to the issues of land and water degradation in South Punjab, Pakistan. The research was conducted in five purposely selected agricultural districts of South Punjab, where agriculture is highly prone to degradation issues that involve waterlogging, soil salinity, declining fertility, dwindling groundwater water and pollution.

2.2. Study Population

Multistage random sampling method was used to collect the data. In stage one, districts were selected purposively. Then, two tehsils were selected in every district. Next, three villages were selected randomly from each tehsil. Final, final, were selected randomly to reach a sample size of 300 respondents, which was deemed to be statistically appropriate, according to the sample size determination of [Krejcie and Morgan \(1970\)](#).

2.3. Data Collection

Data was collected through the questionnaire. To achieve clarity and reliability of items in a questionnaire, a structured questionnaire was developed into four parts. The first part assessed the extent and degree of land and water degradation, salinity, waterlogging, fertility, groundwater reduction, and pollution on a 5-point Likert scale. The second part explained natural and artificial factors of depreciation, such as climatic fluctuations, overuse of irrigation, overuse of fertilizer and pesticides, and overuse of tube wells. The third part was a review of socioeconomic and environmental impacts caused by degradation on crop yields, household income, food security and soil productivity. The fourth section collected the information on remedial strategies, which included practices used by farmers, including the application of gypsum, crop rotation, laser land leveling, and improved irrigation practices, and their perception of limiting factors and performance.

2.4. Data Analysis

The data were analyzed through SPSS software. To explain the extent of degradation and enactment of remedial actions, the data were summarised using descriptive statistics (frequency, percentages, means, and standard deviation). The ranking of drivers and remedial strategies was made based on the mean score ranking analysis. The chi-square tests were used to examine the relationships between socioeconomic factors and farmers' perceptions. The independent samples t-test and ANOVA were employed to compare the means of the results between groups (i.e., small and large farmers or low and high levels of education). In addition, the likelihood of reporting degradation as a serious threat was estimated using binary logistic regression in a model that included age, education, income, farm size, and contact with extension as predictors. The study was conducted in a highly ethical way.

Farmers were informed of the objectives of the research and were assured that they could contribute on a voluntary basis. The answers were anonymous and confidential, and the study was conducted in accordance with the accepted principles of ethical research in the social sciences, as recommended by Creswell and Creswell (2018).

3. RESULTS AND DISCUSSION

3.1. Demographic Characteristics

The demographic characteristics of the sampled respondents (n = 300) in South Punjab (Table 1) present a

socioeconomic portrait that justifies the perceptions and reactions of the respondents to land and water degradation. The majority of respondents were men (92%), a characteristic of farming in rural Pakistan, where women's contributions to farming remain informal and unrecorded (Bhattacharyya et al., 2015). Age-wise, most farmers fell within the age brackets of 31-45 years (36) and 46-60 years (30), indicating that middle-aged and experienced farmers continue to participate actively in agriculture. Other reports of natural resource management in Punjab also revealed the same age distribution (Mahmood, 2024). Education attainment was also involved, with one-third of respondents illiterate, and only 18 percent of respondents have higher education than secondary school certificate. This indicates an illiterate or less educated farmers in rural South Punjab, having implementation in the adoption of advanced land and water conservation methods (Bansal, 2024). The size distribution of farms showed that 42 percent of the respondents were small-scale farmers (having less than 5 acres) and only 24 percent were large-scale farmers (with greater than 12 acres). It is also part of the national trend of land fragmentation and smallholder-farming systems (Gop, 2025).

Table 1: Demographic Characteristics of Respondents (n = 300)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	276	92.0
	Female	24	8.0
Age (years)	≤ 30	54	18.0
	31–45	108	36.0
	46–60	90	30.0
	> 60	48	16.0
Education Level	Illiterate	90	30.0
	Primary (1–5 years)	72	24.0
	Middle–Secondary (6–10 years)	84	28.0
	Intermediate and above (> 10 yrs)	54	18.0
Farm Size (acres)	Small (< 5 acres)	126	42.0
	Medium (5–12 acres)	102	34.0
	Large (> 12 acres)	72	24.0
Monthly Income (PKR)	< 30,000	87	29.0
	30,000–60,000	108	36.0
	60,001–100,000	63	21.0
	> 100,000	42	14.0
Extension Contact	Regular	96	32.0
	Occasional	126	42.0
	Rare/None	78	26.0

The monthly household income levels revealed that 36 percent of the total population interviewed earned PKR 30,000-60,000 and 29 percent of the population earned less than PKR 30,000. Farmers may experience low yields and less money for they produce cause earning less due to which they cannot afford to use expensive environmentally friendly technologies, including soil reclamation technology, drip irrigation, or chemical alternatives (Bansal et al., 2024). The extension contact was also skewed, with 42 percent stating that they were in occasional contact with agricultural extension agents, and 26 percent reporting rare or no contact. Limited extension contact is mentioned as one of the key barriers to knowledge and implementation of sustainable resource management practices in Pakistan (Elleuch et al., 2019).

2.2. Extent and Types of Land Degradation

Table 2 displays the views of the farmers about extent and degree of land degradation in South Punjab. The findings reveal that soil salinity and sodicity (Mean = 3.95, SD = 0.82) are the most perceived forms of degradation and are ranked first among the six indicators. This follows the earlier research observation that salinity affects over 4 million hectares of cultivated land in Pakistan, particularly in irrigated lands in Punjab, where too much canal water is being used, evaporation is excessive and the drainage systems not good (Maja & Ayano, 2021). Second was the soil erosion (wind/water), with a mean of 3.72 (SD = 0.79), indicating that the two categories of arid tract soils (sandy) could be affected by wind erosion, and that all soils under canal irrigation could be affected by water erosion. This observation aligns with that of Haque (2018), who cited erosion as one of the causes of low soil productivity in Punjab. Declining soil fertility (Mean = 3.66, SD = 0.84) was the third concern, indicating that farmers were concerned with nutrient degradation, unbalanced fertilizer application, and low organic matter (Jat et al., 2020). Waterlogging (Mean = 3.52, SD = 0.87) due to seepage problems caused by uncased canals, poor drainage, and over-irrigation was also reported to be a major issue in farmlands and had been previously indicated by the government (Mazhar, 2020).

Other categories lower ratings but significant forms of degradation included soil compaction/hardpan formation (Mean = 3.41, SD = 0.80) and loss of organic matter (Mean = 3.28, SD = 0.85). The process of soil compaction has been linked to overmechanization and overexploitation of heavy machinery, as well as degradation of organic content through burning of crop ashes and reduction in the use of farmyard manure (Khanam et al., 2020). Results indicate that farmers in the South Punjab have characterized salinity, erosion and loss of fertility as the most pressing land degradation challenges, which is consistent with national and international sources on soil degradation in irrigated agroecosystems. Such issues require integrated soil and water management practices like upgrading of drainage, planting of salt-resistant crop species, and balanced manuring, etc.

Table 2: Extent and Types of Land Degradation in South Punjab (n = 300)

Land Degradation Indicators	Mean	SD	Severity Rank
Soil salinity and sodicity	3.95	0.82	1
Soil erosion (wind/water)	3.72	0.79	2
Declining soil fertility	3.66	0.84	3
Waterlogging of farmland	3.52	0.87	4
Soil compaction/hardpan formation	3.41	0.80	5
Loss of organic matter	3.28	0.85	6

2.3. Extent and Types of Water Degradation

The perception of farmers regarding the level of water-related degradation in South Punjab is also reflected in Table 3. Findings indicate that the worst problem is groundwater depletion (Mean = 3.90, SD = 0.81). This finding is in line with the reports of Khanam et al. (2020) and Mazhar et al. (2024), who note that Punjab, the most significant agricultural area of the country, undergoes the intensive extraction of groundwater because of a large share of irrigation, the unlimited exploitation of tube wells, and the loss of the volume of canal water. The low water tables caused by excessive groundwater use have become a significant challenge to sustainable agriculture. The second most significant problem was water pollution in both surface and groundwater (Mean = 3.68, SD = 0.83). Farmers have reported contamination from agrochemicals, industrial effluents, and domestic wastewater, which significantly reduces the quality of water used for irrigation and drinking. The same results are reported by Kumar et al. (2021), who mentioned pesticide residues and heavy metals in water bodies in Punjab as a threat to the health of people and the environment.

Table 3: Extent and Types of Water Degradation in South Punjab (n = 300)

Water Degradation Indicators	Mean	SD	Severity Rank
Groundwater depletion	3.90	0.81	1
Water pollution (surface/ground)	3.68	0.83	2
Canal water scarcity	3.61	0.88	3
Decline in groundwater quality	3.50	0.79	4
Sedimentation in irrigation channels	3.42	0.86	5
Saline water intrusion	3.30	0.84	6

The third is canal water scarcity (Mean = 3.61, SD = 0.88) which showed that farmers rely on irrigation canals that may not be able to sustain agricultural water demands due to declining flows, inequitable distribution, and inefficiency in the system. Mazhar et al. (2024) also reported that a decrease in water flow in the canals has led to a dependency on groundwater by farmers, which has further depleted it. Worsening of the quality of groundwater (Mean = 3.50, SD = 0.79) was also listed as a critical problem. Salinity and nitrate pollution, as well as the increase in dissolved solids, have been extensively reported in Punjab (Lal, 2015). Siltation issues that lower the capacity and efficiency of canals were ranked fifth with a mean of 3.42 and SD of 0.86. Finally, the least ranked among the six indicators was saline water intrusion (Mean = 3.30, SD = 0.84), but this problem is also a significant concern in parts of South Punjab, where aquifers are increasingly prone to salinization. Jat et al. (2020) also observed these trends and noted that the intrusion of salty water into the soil exacerbates the soil salinity problem, ultimately leading to land degradation. These findings suggest that groundwater depletion, water pollution, and the unavailability of water in the canals are the most pressing issues among farmers in South Punjab, which is consistent with the rest of the literature on the area, suggesting that over-extraction and pollution are the two primary threats affecting farmers in South Punjab. The long-term sustainability of agriculture requires a combination of water governance reforms, effective irrigation management, and robust pollution control strategies.

2.4. Key Natural and Anthropogenic Drivers Contributing to Land and Water Degradation

Table 4 presents the significant natural and human causes which cause land and water degradation in south

Punjab. Among the natural drivers, the most extreme one was observed to be erratic rainfall and frequent droughts (Mean = 3.88, SD = 0.82), closely followed by flooding and waterlogging (Mean = 3.72, SD = 0.85). These observations reflect the significant influence of climate variability and hydrological imbalance in the mechanisms of degradation of semi-arid regions such as South Punjab. Previous researchers have also noted that abnormal rainfall patterns, droughts, and floods significantly contribute to the enhancement of soil salinity, soil erosion, and low soil fertility in the Indus Basin (Jat et al., 2020; Mazhar et al., 2024). Other natural drivers also appeared to be quite significant contributors, e.g., high rates of evapotranspiration (Mean = 3.55) and ineffective soil drainage (Mean = 3.32), which is also correlated with the literature linking arid climatic conditions and soil texture to the occurrence of salinity and waterlogging problems (Kumar et al., 2021).

Table 4: Key Natural and Anthropogenic Drivers Contributing to Land and Water Degradation in South Punjab (n = 300)

Drivers of Degradation	Mean	SD	Severity Rank
Natural Drivers			
Erratic rainfall and droughts	3.88	0.82	1
Flooding and waterlogging	3.72	0.85	2
High evapotranspiration rates	3.55	0.79	3
Climate variability and extremes	3.47	0.84	4
Soil texture/poor drainage	3.32	0.80	5
Wind erosion in arid areas	3.25	0.76	6
Anthropogenic Drivers			
Over-extraction of groundwater	4.05	0.78	1
Excessive use of agrochemicals	3.91	0.81	2
Inefficient irrigation practices	3.78	0.83	3
Deforestation and loss of cover	3.64	0.79	4
Poor land-use planning	3.51	0.82	5
Overgrazing and population pressure	3.42	0.77	6

Note: 5-point Likert scale (1 = Not a driver, 5 = Very strong driver)

Excessive groundwater exploitation was the most critical driving factor in the component caused by humans (Mean = 4.05, SD = 0.78) because it highlights the reliance of farmers on tubewell irrigation at a time when the canal water is in short supply. This is in line with the study by Li et al. (2021), who noted that due to unsustainable groundwater abstraction in Punjab, the water tables are lower and the water is of poor quality. Similarly, agrochemicals (Mean = 3.91, SD = 0.81) and poor irrigation methods (Mean = 3.78, SD = 0.83) are high on ranking, meaning that both the soil and water were degraded by poor management. These results can be justified by previous research, which suggests that excess use of chemical fertilizers and pesticides, conventional flood irrigation, saline soil, nutrient decline, and water contamination (Li et al., 2021; Kumar et al., 2021). The following factors are poor land-use planning, deforestation, and overgrazing. However, these have slightly lower scores, suggesting a combination of population growth with unsustainable land management (UNLP) processes has led to the existing issues (Mukherjee et al., 2018). The results demonstrate that climatic stresses, in conjunction with anthropogenic factors, are significant contributors to land and water degradation in South Punjab. The high status of anthropogenic drivers, especially groundwater over-extraction and agrochemical misuse, suggests that the policy should be aimed at controlling resource exploitation as well as the efficiency of irrigation and sustainable agricultural methods.

2.5. Socioeconomic and Environmental Impacts of Land and Water Degradation

In Table 5, findings suggest that the most significant impact was the reduction in crop yield and productivity (Mean = 4.12, SD = 0.79), which can be compared to the previous research indicating that soil salinity, soil erosion, and a shortage of water were the factors leading to the destruction of agricultural productivity in semi-arid regions of Pakistan (Mazhar et al., 2021; Lal et al., 2015). It is further observed that farmers who had to procure more inputs, such as fertilizers and pesticides, and increased irrigation, experienced an increase in production costs (Mean = 3.95, SD = 0.82). These higher costs eliminate the profitability of farms and result in the low income of families via farming (Mean = 3.88, SD = 0.85) which is consistent with the findings of Raju et al. (2018), who discovered that the degradation of land has a highly adverse effect on the economic returns of households at the farm level. Other significant impacts include soil fertility and quality (Mean = 3.81), and water quality deterioration as an irrigation and drinking medium (Mean = 3.76) are of concern. According to Murtaza et al. (2024), a serious issues in Punjab is the infiltration of agrochemicals and salt water in soil and water.(.).

Table 5: Socioeconomic and Environmental Impacts of Land and Water Degradation in South Punjab (n = 300)

Impact Indicators	Mean	SD	Severity Rank
Decline in crop yield and productivity	4.12	0.79	1
Increased production costs (inputs, irrigation, reclamation)	3.95	0.82	2
Reduced household income from farming	3.88	0.85	3
Decline in soil fertility and quality	3.81	0.80	4
Deterioration of water quality for irrigation and drinking	3.76	0.83	5
Threats to household food security (availability/access)	3.70	0.86	6
Loss of agricultural employment opportunities	3.61	0.79	7
Increased rural poverty and indebtedness	3.55	0.88	8
Negative impacts on livestock health and productivity	3.50	0.81	9
Environmental degradation (loss of biodiversity, ecosystem services)	3.42	0.85	10

Interestingly, degradation was perceived as an obstacle to the food security of the household (Mean = 3.70) since declining production and reduced soil productivity lead to a decline in the availability and accessibility of food. Mazhar et al. (2021) also observed the same. Socioeconomic effects are attributed to the shortage of agricultural working places (Mean = 3.61) and to increased rural poverty and indebtedness (Mean = 3.55), also reflecting the results of Poggio et al. (2021), who reported that declining land yields expose smallholder farmers to poverty and migration dynamics.

There were other ecological negative impacts on livestock (Mean = 3.50) and the negative impact on the environment through biodiversity loss and ecosystem degradation (Mean = 3.42). These findings are consistent with Pravaalie (2021), who noted that, in addition to reduced farm productivity due to land and water degradation, other, more general ecosystem services are also impaired, further adding to the fragility of farming communities. The results suggest that land and water degradation in South Punjab has a compounded impact, as it reduces crop productivity, increases the cost of agricultural production, and decreases rural income, leading to increased food insecurity and deterioration of the natural ecosystem. All this necessitated the need to develop sustainable land and water management practices, which include soil recovery, proper and effective irrigation practices, and extension services to farmers to reduce the adverse impact and ensure that agriculture in the area can be practiced sustainably in the long run.

2.6. Inferential Analysis

2.6.1. Chi-Square Tests

Table 6 presents the Chi-square test, which examines the correlations between the socioeconomic variables (age, education, income, and farm size) of farmers and their perceptions of land and water degradation in South Punjab. The results show that the farmers' perceptions were significantly correlated with age, education, and farm size, but not with farm income.

Table 6: Chi-Square Tests of Association between Socioeconomic Characteristics and Farmers' Perceptions of Land and Water Degradation (n = 300)

Socioeconomic Characteristic	Pearson Chi-Square Value (χ^2)	df	p-value	Association Strength (Cramer's V)	Result
Age group (years)	12.45	4	0.014**	0.20 (weak-moderate)	Significant
Education level	18.62	6	0.005**	0.25 (moderate)	Significant
Monthly farm income	9.38	4	0.052	0.15 (weak)	Not Significant
Farm size (acres)	21.74	6	0.001***	0.28 (moderate)	Significant

Note: *p < 0.05 = significant; **p < 0.01 = highly significant; ***p < 0.001 = very highly significant

The analysis indicates that age group strongly correlated with perceptions of degradation ($\chi^2 = 12.45$, $p = 0.014$), i.e., the older the farmer, the more degradation of land and water was reported. This is linked to the results of Ren et al. (2024) who reported that older farmers are mature and have been exposed to the impact of environmental changes over the years resulting in the development of a stronger perception of risk compared to younger people. Similarly, the level of education had a significant association ($\chi^2 = 18.62$, $p = 0.005$), and more educated farmers were more aware of issues such as soil salinity, soil fertility, and depleted groundwater. This aligns with Sunita's (2023) assertion that more literate farmers will be more aware of the issues present on the farm and will be more willing to approach environmental threats with a critical understanding. On the other hand, a statistically significant effect on farm income was not observed ($\chi^2 = 9.38$, $p = 0.052$); therefore, income levels alone do not necessarily indicate awareness of degradation. Murtaza et al. (2024) also obtained similar results and found that the impact of experiential knowledge and extended contact on the perception of soil and water degradation was more significant than the impact of economic status.

Finally, it was found that the relationship between farm size ($\chi^2 = 21.74, p = 0.001$) and larger landowners treating degradation as a serious issue was high and highly significant when compared to smallholders. This may be attributed to the fact that larger farms are more directly exposed to various forms of land and water stress, resulting in higher losses. This result supports the observations of Wang et al. (2022), who pointed out that large land owners are the most affected by salinity, waterlogging, and canal water deficit due to their dependence on extensive irrigation systems. Overall, these results suggest that demographic and structural factors are significant in the context of raising awareness among farmers about land and water degradation. The programs that would be employed to curb degradation in South Punjab, therefore, must be both education and outreach-oriented, particularly to the younger and less-educated farmers, but must also be farm-size specific.

3.6.1. Independent Samples t-tests / ANOVA

The results presented in Table 7 highlight significant differences in farmers' perceptions of land and water degradation across farm size and education levels.

Table 7: Independent Samples t-tests / ANOVA Results for Differences in Perceptions of Land and Water Degradation (n = 300)

Socioeconomic Variable	Group Comparison	Mean Perception Score (M ± SD)	t/F-value	p-value
Farm Size	Small (<10 acres)	3.41 ± 0.72	t = 3.28	0.001
	Large (≥10 acres)	3.79 ± 0.81		
Education Level	Low (Illiterate/Primary)	3.36 ± 0.70	F = 6.42	0.002
	Medium (Middle–Matric)	3.61 ± 0.75		
	High (Intermediate & Above)	3.89 ± 0.80		

The independent samples t-test has shown that large farmers (10 acres or more) had much higher perceptions of degradation (M = 3.79, SD = 0.81) than smallholders (M = 3.41, SD = 0.72), but also has revealed that the difference between the two was statistically significant (t = 3.28, p = 0.001). This observation suggests that large-scale farmers, who have a greater stake in long-term land productivity and irrigation, are more aware of the threat of degradation. Yang et al. (2023) and Sunita (2023) draw the same conclusion, as both authors indicate that large landowners are more likely to be exposed to soil salinity, water shortages, and erosion, since they rely on large-scale cultivation. Likewise, the one-way ANOVA results showed that the perceptions between the different levels of education differed significantly (F = 6.42, p = 0.002). Farmers who were highly educated (Intermediate and above) (M = 3.89, SD = 0.80), followed by middle to matric educated farmers (M = 3.61, SD = 0.75) and finally illiterate and primary-level educated farmers (M = 3.36, SD = 0.70) were found to have the highest perception of land and water degradation. According to this trend, the educational process is leading to an increase in awareness of environmental problems. Previous studies by Wang et al. (2022) and Murtaza et al. (2024) confirm that education is a significant factor in environmental knowledge, the adoption of conservation practices, and environmental responsiveness to extension services among farmers. These results show that the perception of farmers regarding risks of degradation in South Punjab depends on the size of the farm and the level of education. The extent of degradation could be underestimated by smallholders due to a lack of technical skills and short-term survival strategies, relative to the more literate and large-scale farmers, who are more sensitive to the long-term consequences of degradation in terms of productivity and sustainability.

2.6.2. Binary Logistic Regression

Table 8 presents the results of a binary logistic regression model examining the likelihood of farmers in South Punjab perceiving land and water degradation as a “serious threat” based on socioeconomic and institutional predictors.

The model was statistically significant, with a Nagelkerke R² of 0.28, indicating that approximately 28% of the variation in perception was explained by the included variables. The overall classification accuracy of 70.3% demonstrates the model's reasonable predictive capability. Among the predictors, education level showed a highly significant positive effect (B = 0.345, p = 0.001, OR = 1.412), suggesting that farmers with higher educational attainment are 1.41 times more likely to recognize degradation as a serious issue compared to those with lower education. This aligns with prior studies that emphasize education as a key determinant of environmental awareness and risk perception in agricultural contexts (Zhuo et al., 2022; Ren et al., 2024). Farm size (B = 0.108, p = 0.008, OR = 1.114) and monthly income (B = 0.00028, p = 0.005, OR = 1.0003) were also significant, indicating that larger-scale and higher-income farmers are more likely to perceive land and water degradation as serious, potentially due to greater exposure to productivity losses and resource constraints (Prävālie, 2021; Sunita, 2023).

Extension contact emerged as another significant predictor (B = 0.572, p = 0.009, OR = 1.772), highlighting the critical role of agricultural advisory services in shaping awareness and adaptive responses to land and water degradation (Wang et al., 2022). Although age was positively associated with perception (B = 0.021), the association

was marginally non-significant ($p = 0.056$), suggesting that accumulated experience may have a slight influence on awareness, but formal education, income, farm size, and extension contact are stronger determinants. Overall, the results highlight the importance of enhancing educational opportunities, extension outreach, and access to resources in improving farmers' awareness of environmental degradation and promoting sustainable management practices.

Table 8: Binary Logistic Regression: Predictors of Perceiving Land and Water Degradation as a "Serious Threat" ($n = 300$)

Predictor Variable	B (Coefficient)	SE (Standard Error)	Wald χ^2	df	p-value	Exp(B) (Odds Ratio)	95% CI for Exp(B)
Age (years)	0.021	0.011	3.64	1	0.056	1.021	0.999 – 1.043
Education Level	0.345	0.102	11.44	1	0.001	1.412	1.149 – 1.736
Monthly Income (PKR)	0.00028	0.00010	7.84	1	0.005	1.0003	1.0001 – 1.0005
Farm Size (acres)	0.108	0.041	6.93	1	0.008	1.114	1.028 – 1.206
Extension Contact (Yes=1)	0.572	0.219	6.81	1	0.009	1.772	1.153 – 2.722
Constant	-2.012	0.762	6.97	1	0.008	0.134	—

Model statistics: -2 Log likelihood = 310.56; Nagelkerke $R^2 = 0.28$; Overall classification accuracy = 70.3%; Note: Dependent variable coded as 1 = perceives degradation as a serious threat; 0 = otherwise. SE = standard error; Exp(B) = odds ratio; CI = confidence interval.

2.7. Remedial Strategies

The assessment of remedial measures for sustainable land and water management, as perceived and practiced by 300 farmers in South Punjab, is presented in Table 9. Use of salt- and drought-tolerant crop varieties received the highest mean score ($M = 3.85$, $SD = 0.79$), indicating that farmers recognize the advantages of tolerant crop varieties in alleviating soil salinity, water stress, and improving productivity. It finds a middle ground between Bansal and Jat (2020 and 2024) who highlight that one of the cost-effective methods that can be applied on a national level, especially in semi-arid areas, is the use of tolerant varieties. The use of gypsum to reclaim saline soils also ranked among the top priorities in terms of perceived effectiveness ($M = 3.78$, $SD = 0.81$) in terms of its value in ameliorating sodicity and improving the soil structure (Mazhar, 2020). Conjunctive use of surface and groundwater ($M = 3.60$, $SD = 0.82$) and crop rotation with legumes ($M = 3.65$, $SD = 0.79$) were also said to have moderate use by farmers (Mukherjee et al., 2018; Kang et al., 2020), which have been reported to enhance soil fertility, salinity accumulation, and long-term agricultural sustainability.

Table 9: Remedial strategies for sustainable management of land and water resources in South Punjab ($n = 300$)

Remedial Strategy	Mean (M)	SD	Adoption Rank	Perceived Effectiveness Rank
Gypsum application for saline soils	3.78	0.81	2	1
Crop rotation (including legumes)	3.65	0.79	4	2
Laser land leveling	3.50	0.84	5	3
Drip and sprinkler irrigation	3.42	0.88	6	4
Conjunctive use of surface and groundwater	3.60	0.82	3	5
Rainwater harvesting and storage	3.30	0.87	7	6
Adoption of salt- and drought-tolerant crops	3.85	0.79	1	2
Strengthening extension services	3.55	0.80	4	3

Laser land leveling ($M = 3.50$, $SD = 0.84$), drip and sprinkler irrigation ($M = 3.42$, $SD = 0.88$) and Rainwater harvesting and storage ($M = 3.30$, $SD = 0.87$) are relatively less common strategies might be because these are expensive to establish at first and also require high post-installation technical support (Li et al., 2021). Farmers in South Punjab are either unaware of or lack the necessary infrastructure to implement such interventions (Aalirezai et al., 2021). The results indicate that farmers are not ignorant about different remedial strategies; however, their application is subject to cost, technical support, and extension services availability. These results highlight the importance of specialized capacity-building interventions and access to resource-efficient technologies at lower costs in enhancing sustainable land and water management in South Punjab.

Conclusion

Results showed that the saline soils, depleted ground water sources, water pollution and loss of soil fertility are the most pressing issues impacting agricultural productivity and the livelihood of the farmers. They were all declared significant causes of degradation, both natural (unpredictable rain, drought, and flooding) and man-made (excessive use of underground water, poor irrigation systems, and the use of agrochemicals in large quantities). It was also found that differences in socioeconomic standing and exposure to education, in particular, were a significant factor in the perception and understanding of these issues among farmers, whereas income was a relatively minor factor. The paper also highlights the multilayered social, economic, and ecological effects of degradation, including low crop production, high production costs, food insecurity, and environmental degradation. The most appropriate solutions

for sustainable resource management included remedial interventions such as improved irrigation technology, soil reclamation, salt-resistant crops, and enhanced extension services. Lastly, the degradation of South Punjab's land and water must be addressed through policy, farmer-based capacity building, and sustainable management practices, including technological, institutional, and ecological strategies. The research results offer practical policy implications for those designing policies, agricultural extension bodies, and the agrarian communities aiming to achieve sustainable farming methods and sustainable rural livelihoods.

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