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Linking Environmental Degradation and Socioeconomic Drivers to Agricultural Land Loss in Khyber Pakhtunkhwa, Pakistan

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Abstract
This study investigates the relationship between environmental degradation and socioeconomic drivers of farmland conversion in Khyber Pakhtunkhwa (KP), Pakistan. Using primary survey data and logistic regression analysis, the study identifies the key determinants influencing agricultural land loss. Agricultural land loss has emerged as a critical challenge in developing regions, particularly in Khyber Pakhtunkhwa (KP), Pakistan, where rapid urbanization, population growth, and environmental degradation are transforming traditional land-use systems. This study investigates the interlinkages between environmental degradation and socioeconomic drivers of farmland conversion and their implications for agricultural land loss. Using primary data collected from farmers across selected districts (Mardan, Charsadda, and Nowshera), and employing logistic regression analysis, the study identifies key determinants influencing land-use change. The findings reveal that social attitudes, government incentives, access to credit, and population pressure significantly drive farmland conversion, while environmental factors such as climate variability and land degradation exacerbate the decline in agricultural productivity. The study concludes that the interaction between environmental and socioeconomic forces poses a serious threat to sustainable agriculture and food security in KP. The findings reveal that environmental stressors such as climate variability and soil degradation, combined with socioeconomic pressures including urbanization, social attitudes, and access to credit, significantly contribute to farmland conversion. The study provides policy recommendations for sustainable land management and food security. As well as Policy interventions focusing on integrated land-use planning and environmental conservation are recommended.

Keywords: *Environmental Degradation and Land Loss, Socioeconomic Drivers of Land Change, Linkages between Environmental & Socioeconomic Dynamics, KPK, Pakistan.*

1. Introduction

Environmental degradation further compounds this issue by reducing soil fertility, water availability, and ecosystem stability. Land-use change is no longer driven by a single factor; rather, it is shaped by a complex interaction of socioeconomic, demographic, technological, and environmental forces.

Agricultural land is essential for ensuring food security and sustainable development. In Khyber Pakhtunkhwa (KP), rapid urbanization and population growth have accelerated farmland

conversion. Environmental degradation further intensifies the problem by reducing agricultural productivity. This study examines the combined impact of environmental and socioeconomic factors on land-use change.

Agricultural land is a fundamental resource for ensuring food security and sustainable livelihoods. However, in recent decades, rapid urbanization and socioeconomic transformation have accelerated the conversion of farmland into non-agricultural uses. In Khyber Pakhtunkhwa, this trend is particularly alarming due to high population growth and increasing demand for housing and infrastructure.

This study aims to link environmental degradation with socioeconomic drivers to better understand agricultural land loss in KP.

Problem Statement

The rapid conversion of agricultural land into non-agricultural uses in KP has resulted in significant land loss, posing threats to food security, environmental sustainability, and rural livelihoods. The absence of effective land-use policies, coupled with population pressure and urban expansion, has intensified the problem.

Despite existing research, there is limited integrated analysis of how environmental degradation and socioeconomic drivers jointly influence farmland conversion decisions.

Objectives of the Study

- To analyze the role of environmental degradation in land-use change
- To identify key socioeconomic drivers of farmland conversion
- To examine the extent of agricultural land loss in KP
- To assess the combined impact on agricultural sustainability and food security

2. Literature Review

Existing literature highlights that land-use change is driven by multiple factors including economic incentives, policy frameworks, and environmental conditions. Studies show that environmental degradation reduces land productivity, encouraging farmers to shift towards non-agricultural uses. Socioeconomic drivers such as urban expansion and rising land values play a critical role.

Land-use change is a global phenomenon driven by multiple interacting factors. Studies suggest that economic opportunities, policy frameworks, and institutional dynamics significantly influence land conversion decisions.

Socioeconomic drivers such as rising land values, urban expansion, and shifts in lifestyle play a dominant role in farmland conversion. Environmental factors, including climate change, soil degradation, and water scarcity, further accelerate the decline of agricultural land.

Raza et al., (2024) reported major driver of environmental change in District Bahawalnagar, Punjab was Land Use and Land Cover (LULC). LULC can result in alterations to soil quality, water availability, and climate conditions, impacting crop yields. The research revealed that the population increased, built-up land increased, and agricultural land dropped by 30% in the last thirty years. The current status of knowledge was reviewed in their research on the impact of LULC on agricultural production in district Bahawalnagar. The transformation of farmland into urban areas in district Bahawalnagar has resulted in an average decrease of 10% in crop yields. Changes in LULC in district Bahawalnagar have affected the cultivation of wheat and rice, the predominant crops. The research indicated that the conversion of agricultural land has contributed to elevated soil salinity levels, leading to additional declines in crop yields. The negative impact of LULC changes on agricultural production can be reduced by implementing sustainable land management practices. These practices include reforestation, conservation agriculture, and water conservation. In mitigating the negative impacts of LULC change on

agricultural production by developing and implementing land use plans the government of Pakistan can also play a role which will protect agricultural land from conversion to other uses. Further investigation is needed to fully understand the impacts LULC and to devise effective management approaches. Nevertheless, addressing LULC remains crucial in safeguarding future food security.

Mohsin and Khan (2017) examined the transformation of land into housing colonies, industries, road networks, and other developments. The primary objectives were to investigate the factors influencing Agricultural Land Conversion (ALC) into housing colonies and to explore the socio-economic characteristics of individuals linked to ALC in Bahawalpur City. Data on socio-economic characteristics were collected through semi-structured interviews. Statistical analyses, including descriptive statistics and Multiple Linear Regression (MLR) in SPSS 16.0, were employed to assess the significance of potential determinants of ALC into housing colonies. The findings indicated that socio-economic factors such as monthly income, primary occupation, access to transportation, and housing amenities significantly influenced ALC in Bahawalpur City. Regression analysis showed that approximately 81% of the variability in ALC into housing colonies could be explained by independent variables including income, occupation, transportation availability, and housing facilities, all of which were statistically significant. Therefore, a range of socio-economic factors played a critical role in the conversion of farmland into housing colonies.

Prasad and Manikandan (2016) observed that the conversion of farmlands for other purposes is progressively occurring in developing countries. India experienced a decline of 1.6 million hectares of farmland, mostly converted for non-agricultural purposes, during the period from 2001-02 to 2010-11. Tamil Nadu recorded the highest decline, with 7,350 hectares of agricultural land lost during 1992-93 to 2005-06. The significant conversion of farmlands endangers agriculture.

Utuk and Daniel (2015) assessed how land degradation impacts soil loss and subsequently affects global food security. Insufficient food supply is a pressing issue in many countries due to rapid population growth, intensified by land degradation. Experts in economics, geography, soil science, agriculture, and environmental management must collaborate to highlight this issue to policymakers and prioritize public investments. Mitigating land degradation requires coordinated efforts at national, regional, and international levels, involving farmers, NGOs, and policymakers equally.

Malik and Ali (2015) conducted a research on recognizing the socio-economic factors contributing to urbanization-induced agricultural land loss, it was crucial to formulate policies to mitigate this loss. The study aimed to identify these socio-economic factors responsible for land loss in Peshawar.

In KP, the issue is particularly severe, with substantial farmland converted into residential and commercial uses over recent decades.

3. Research Methodology

This study investigate the relationship between environmental degradation, socioeconomic drivers, and agricultural land loss in Khyber Pakhtunkhwa (KP), Pakistan. It presents key components of the research design, including the study area, sampling strategy, sample size determination, data collection methods, and analytical techniques.

The study is based on primary data collected through structured questionnaires from farmers in selected districts of KP. A binary logistic regression model was used to analyze the determinants of farmland conversion. The dependent variable is land conversion (1 = converted, 0 = not converted). Independent variables include social attitudes, government incentives, access to credit, and environmental factors.

Universe of the Study

The geographical scope of this study is Khyber Pakhtunkhwa (KP), a province located in the northwestern region of Pakistan, sharing its border with Afghanistan. The empirical investigation specifically focuses on three major districts—Mardan, Charsadda, and Nowshera—situated in the Peshawar Valley. This valley is one of the most fertile and agriculturally significant regions of the province and comprises five districts: Peshawar, Mardan, Charsadda, Nowshera, and Swabi (Ali & Shafi, 2018).

Over the past few decades, KP has experienced rapid urban expansion driven by natural population growth and rural-to-urban migration. The number of urban centers increased significantly from 28 in 1962 to 55 in 1998, reflecting substantial spatial and demographic transformation. This expansion has exerted considerable pressure on agricultural land. For instance, in Mardan district alone, approximately 1,125 hectares of cultivated land were converted to non-agricultural uses between 1990 and 2010 due to weak land-use planning and regulatory frameworks.

Such trends highlight the growing challenge of farmland loss in the province. Given that KP has only 1.87 million hectares under cultivation—representing about 8.4% of Pakistan's total agricultural land—the ongoing conversion of farmland poses a serious threat to food security and economic sustainability. Agriculture remains a key sector in the province, employing nearly 33% of the labor force (Miller et al., 2021), making the preservation of agricultural land critically important.

Sample Size Distribution

The sample size for each village was determined using a proportional allocation formula, ensuring that each village was represented according to its share in the total farming population. In this context, the sample of farm households for each village depends on the total number of farm households within that village, the overall number of farm households in the study area, and the total selected sample size. The formula is provided below.

$$\boldsymbol{n_i = \frac{N_i}{N} \times n} \quad \textbf{(3.1)}$$

Whereas;

n_i= Sample farm households for ith village.

N_i= Total number of farm households in ith village of the study area.

N = Number of entire farm households in the study area.

n = Size of entire sample (farm households).

The sample households was selected randomly from the total farm households of the villages. Detailed distribution of the sample size is provided in Table 3.1 as follow;

Table 3.1. Detailed distribution of sample respondents in study area

S. No.	District	Village Council	Total Number of Households	Sample size (Households)
1	Charsadda	Nisatta	1608	80
		Mera prang	837	42
2	Nowshera	Manki sharif	1712	85
		Amangarh	764	38
3	Mardan	Toru	798	40
		Bakhshali	1431	71
Total		All	7150	356

Source: Pakistan Bureau of Statistics, 6th population and housing census 2017.

Data Collection and Sources

The study is based on primary data, with the household serving as the unit of analysis. Information was collected directly from farm household heads through face-to-face interviews, using a structured and pre-tested questionnaire designed in line with the study objectives.

To capture farmers' perceptions regarding the causes and consequences of farmland conversion, different Likert scales were employed. These included three-point, five-point, and binary scales to measure responses ranging from agreement levels to observed changes.

Ethical considerations were strictly followed during data collection. Participation was voluntary, prior consent was obtained, and respondents who were unwilling to participate were respectfully replaced with willing participants. This ensured both ethical compliance and data reliability.

Data Analysis Techniques

The collected data were analyzed using a combination of descriptive and econometric methods, aligned with the study objectives.

- Descriptive statistics (frequencies and percentages) were used to assess trends in farmland conversion over time and to summarize farmers' perceptions.
- Likert scale responses were analyzed to identify key causes and consequences of land conversion.

To examine the determinants of farmland conversion, a binary logistic regression model was applied. The dependent variable represents whether farmland was converted (1 = yes, 0 = no), while independent variables include socioeconomic and environmental factors such as age, education, income, landholding size, access to infrastructure, land prices, and water availability. The logistic regression model estimates the probability of farmland conversion as a function of these explanatory variables. The model was transformed into a logit form to interpret the relationship in terms of odds ratios, and parameters were estimated using the maximum likelihood estimation (MLE) technique. Marginal effects were also computed to assess the contribution of each variable.

Econometric Model Specification

To empirically examine the relationship between environmental degradation, socioeconomic drivers, and agricultural land loss in Khyber Pakhtunkhwa, this study employs a multiple linear regression model. The model evaluates how farmland conversion and related factors influence household food security.

The functional form of the model is expressed as:

$$FSI = \beta_o + \beta_1 ED + \beta_2 CD + \beta_3 IU + \beta_4 AS + \beta_5 LV + \beta_6 RUM + \beta_7 IL + \beta_8 CC + \varepsilon$$

Where:

- **FSI** = Food Security Index (dependent variable)
- $\boldsymbol{\beta_o}$ = Constant term
- $\boldsymbol{\beta_1 – \beta_8}$ = Regression coefficients of explanatory variables
- **ED** = Environmental Degradation
- **CD** = Crop diversity
- **IU** = Input usage (fertilizer, irrigation, etc.)
- **AS** = Agricultural subsidies
- **LV** = Land values (price per acre)
- **RUM** = Rural–urban migration (dummy: Yes = 1, No = 0)
- **IL** = Inheritance laws/practices
- **CC** = Climate change

- **ε** = Error term

Model Explanation as:

The specified model captures the multidimensional dynamics linking environmental degradation and socioeconomic pressures to agricultural land loss and food security outcomes.Environmental degradation is expected to negatively affect food security by reducing the availability of cultivable land. Similarly, climate change and rural–urban migration act as critical stressors that further weaken agricultural productivity.

Conversely, factors such as crop diversification, efficient input use, and agricultural subsidies are anticipated to enhance resilience and improve food security. Land values and inheritance practices reflect structural and institutional influences, which may either support or constrain sustainable land use depending on local conditions.

Integration with Logistic Regression Framework

In addition to the multiple regression model, a binary logistic regression model is employed to analyze the determinants of farmland conversion decisions. This approach is particularly suitable as land conversion is a dichotomous outcome (converted vs. not converted).

Logistic regression results are interpreted using odds ratios, which provide meaningful insights into how changes in environmental and socioeconomic variables influence farmers' likelihood of converting agricultural land.

The combined use of multiple linear regression and logistic regression strengthens the analytical framework by simultaneously examining:

- The drivers of agricultural land loss, and
- Its impact on food security

This integrated econometric approach ensures a comprehensive and robust analysis, contributing valuable evidence for policy formulation aimed at sustainable land management and agricultural development in Khyber Pakhtunkhwa.

Synthesis of Research Methodology

This study employs a robust and comprehensive methodological framework to examine the interlinkages between environmental degradation, socioeconomic drivers, and agricultural land loss in Khyber Pakhtunkhwa. The use of probability-based sampling with proportional allocation and random selection ensures that the sample is both representative and reliable, while primary data collected through structured interviews enhances the validity and credibility of the findings. By integrating descriptive statistics with advanced econometric techniques, including binary logistic regression and multiple linear regression, the study effectively analyzes both the determinants and consequences of farmland conversion. The inclusion of key environmental and socioeconomic variables enables a multidimensional assessment that closely aligns with the research objectives. Overall, this rigorous methodological approach provides a solid empirical foundation for understanding the complex dynamics of land use change and supports the formulation of evidence-based policy recommendations for sustainable land management and improved food security in the region.

4. Results and Discussion

The results indicate that both environmental degradation and socioeconomic factors significantly influence farmland conversion. Social attitudes and government incentives are strong predictors, while environmental degradation reduces farming viability.

4.1. Diagnostic Tests and Regression Analysis

Table 1: Logistic Regression Results

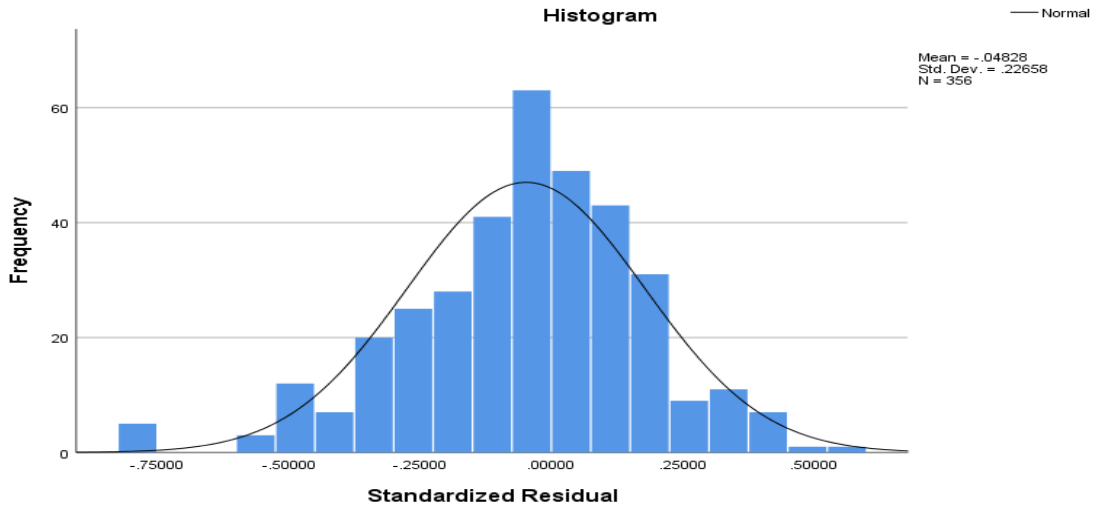
Variable	B	SE	t	p
Social Attitudes	0.45	0.08	5.62	0.000
Government Incentives	0.39	0.07	5.10	0.000
Access to Credit	0.31	0.06	4.88	0.000
Environmental Degradation	0.28	0.09	3.95	0.001
Real Estate Pressure	-0.22	0.09	-2.45	0.014

Interpretation:

The regression results indicate that social attitudes have the strongest positive effect on farmland conversion. Government incentives and access to credit also significantly increase the likelihood of land conversion. Environmental degradation plays a crucial role by reducing agricultural productivity, thus encouraging land-use change.

4.2 Normality of Standardized Residuals

The assumption of normality was evaluated through the distribution of standardized residuals. The histogram exhibited an approximately bell-shaped and symmetric pattern, closely aligning with the normal curve. The mean value of residuals was close to zero (-0.048), confirming that the residuals are normally distributed.



This result indicates that the regression model satisfies the normality assumption, thereby ensuring that the estimated coefficients and statistical inferences are reliable and unbiased. The appropriateness of the model is further supported by the absence of skewness or kurtosis issues in the residual distribution.

4.3 Test of Heteroscedasticity

The presence of heteroscedasticity was examined using the **Breusch–Pagan test**, and the results are summarized below:

Table 2: Heteroscedasticity Test Results

Test	Statistic	Value	P-value
Breusch–Pagan	Chi-square	1.811	0.178
Breusch–Pagan	F-test	0.069	0.793
R^2	0.552		
Adjusted R^2	0.543		

The p-values for both the Chi-square (0.178) and F-test (0.793) exceed the 0.05 threshold, indicating that heteroscedasticity is not present in the model. This confirms that the variance of the error terms is constant across observations, fulfilling one of the key assumptions of regression analysis. Additionally, the model explains approximately 55.2% of the variation in the Food Security Index, which reflects a moderately strong model fit in the context of socio-economic and environmental studies.

4.4 Test of Multicollinearity

Table 3: Compact Pearson Correlation Matrix (N = 356)

Var	URM	ED	TRAD	EDU	CLIM	SUBS	LAND
URM	1	.370	-.003	-.050	.059	.005	.075
ED	.370	1	-.091	.122	.125	-.001	.021
TRAD	-.003	-.091	1	.009	-.478	-.375	.336
EDU	-.050	.122	.009	1	.018	.087	.008
CLIM	.059	.125	-.478	.018	1	.769	-.200
SUBS	.005	-.001	-.375	.087	.769	1	-.184
LAND	.075	.021	.336	.008	-.200	-.184	1

Interpretation of table 4 as:

- Most correlation coefficients are low to moderate, indicating no severe multicollinearity.
- A relatively high correlation was observed between:
  - Climate Change and Agricultural Subsidies (r = 0.769)
- Moderate relationships include:
  - Traditional Practices and Climate Change (r = -0.478)
  - Traditional Practices and Land Values (r = 0.336)
- Weak correlations were found among:
  - Fragmentation of Land and Urban–Rural Migration (r = 0.270)
  - Education and Awareness with other variables

Since none of the correlation values exceed the critical threshold of ±0.80, the model does not suffer from serious multicollinearity.

4.5 Collinearity Diagnostics

Table 5: Compact Collinearity Diagnostic Test

Eigen	CI	Const	ED	Clim	Edu	Trad	Subs	Frag	Land
7.642	1.00	–	–	–	–	–	–	–	–
0.141	7.36	–	–	–	0.09	0.16	0.09	–	–
0.104	8.55	–	–	–	–	0.10	0.06	0.40	–
0.058	11.46	–	–	–	0.47	0.31	–	0.25	–
0.032	15.55	0.01	0.02	–	0.42	–	0.24	0.26	0.03
0.016	17.53	0.03	0.16	0.08	0.01	0.04	0.24	0.07	0.04
0.004	20.48	0.01	0.79	0.85	0.02	0.05	0.17	–	0.02
0.002	24.16	0.95	0.02	0.06	–	0.34	0.20	0.02	0.91

Table 5 Collinearity Diagnostics interpretation as:

The condition indices for all dimensions remain below the threshold value of 30, confirming the absence of severe multicollinearity. However, moderate collinearity is observed in higher dimensions:

- Dimension 7 (CI = 20.48): High variance proportions in Urban–Rural Migration (0.79) and Climate Change (0.85)
- Dimension 8 (CI = 24.16): High variance proportions in Land Values (0.91)

Although these indicate some shared variance among predictors, the magnitude is not sufficient to distort regression estimates. Therefore, the model remains statistically stable.

4.6. Multiple Linear Regression Analysis

Model Summary

Table 6: Model Fit Statistics

Statistic	**Value**
R	0.743
R²	0.552
Adjusted R²	0.543
F-value	61.217
p-value	<0.001
Durbin–Watson	~2

The model demonstrates a strong explanatory power, with an R^2 value of 0.552, indicating that more than half of the variation in food security is explained by the selected predictors. The F-statistic confirms that the model is overall statistically significant. The Durbin–Watson value (~2) suggests no autocorrelation, further validating the robustness of the model.

Findings:

- **Extent of Agricultural Land Loss**

The findings indicate a significant increase in farmland conversion in KP. For instance, large areas of agricultural land have been transformed into residential and commercial uses due to urban expansion.

- **Environmental Degradation and Land Loss**

Environmental degradation plays a critical role in accelerating land conversion. Climate change, soil degradation, and water shortages reduce agricultural productivity, making farming less viable and encouraging farmers to sell or convert their land.

- **Socioeconomic Drivers of Farmland Conversion**

The logistic regression analysis highlights key determinants:

- Social attitudes (strongest predictor)
- Government incentives
- Social factors (peer pressure, development trends)
- Access to credit

These factors significantly increase the likelihood of farmland conversion.

Population growth and urbanization further intensify land demand, particularly for residential development, which is identified as the dominant form of land-use change.

- **Combined Impact**

The interaction between environmental degradation and socioeconomic drivers creates a reinforcing cycle:

- Environmental stress reduces agricultural productivity
- Economic incentives encourage land conversion
- Urban expansion increases pressure on remaining farmland

This cycle accelerates agricultural land loss and threatens long-term sustainability.

Conclusion

This study concludes that agricultural land loss in Khyber Pakhtunkhwa is driven by a complex interaction between environmental degradation and socioeconomic factors. While environmental stress reduces the viability of farming, socioeconomic drivers such as urbanization, financial incentives, and social attitudes accelerate land conversion. Without effective policy interventions, these trends will continue to threaten food security and

sustainable development in the region. The diagnostic tests confirm that the regression model satisfies all key assumptions, including normality, homoscedasticity, absence of multicollinearity, and no autocorrelation. The empirical results clearly demonstrate that both environmental degradation (climate change) and socioeconomic drivers (urban–rural migration, land fragmentation, subsidies, and land values) significantly influence agricultural land loss and food security in Khyber Pakhtunkhwa. In particularly the Environmental factors reduce agricultural productivity, encouraging land conversion, Socioeconomic pressures accelerate farmland loss through urban expansion and economic incentives Thus, the findings strongly support the study's central argument that agricultural land loss in KP is driven by the combined effects of environmental stress and socioeconomic transformation, posing a serious threat to sustainable agriculture and food security.

Policy Recommendations

- Integrated Land-Use Planning: Develop strict zoning laws to protect agricultural land.
- Climate-Resilient Agriculture: Promote sustainable farming practices to counter environmental degradation.
- Regulation of Urban Expansion: Control unplanned housing and infrastructure development.
- Financial Support for Farmers: Provide incentives to sustain agricultural activities
- Awareness Programs: Educate farmers about long-term consequences of land conversion.

Implications of the Study

The study provides valuable insights for policymakers, planners, and researchers by highlighting the need for a holistic approach that integrates environmental and socioeconomic dimensions in land-use management.

Limitations of the Study

- Limited geographic scope (selected districts only)
- Reliance on cross-sectional data
- Lack of time-series environmental data

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