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Assessing the Impacts of Climate-Induced Natural Disasters on Tobacco Cultivation in Khyber Pakhtunkhwa, Pakistan

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A B S T R A C T

Agriculture is highly vulnerable to climate-induced natural disasters, yet research in Pakistan has largely focused on staple crops, leaving cash crops such as tobacco underexplored. Tobacco cultivation in Khyber Pakhtunkhwa (KPK), which accounts for over 70% of national output, plays a vital role in farmer livelihoods and government revenues but faces growing risks from floods, droughts, hailstorms, and unseasonal rainfall. This study employs a sequential mixed-methods design, integrating survey data from 400 tobacco farmers with 10 in-depth interviews from the Swabi district. Quantitative analysis used descriptive statistics, multiple regression, and Likert-scale measures to assess the impacts of disasters on yield, income, and farmer perceptions. Qualitative interviews with farmers, agricultural officers, and farmer association representatives were thematically analyzed to contextualize statistical trends. Regression results revealed that droughts ($\beta = -0.425$, $p < 0.001$) and floods ($\beta = -0.312$, $p < 0.001$) exert the strongest negative impacts on yield, followed by hailstorms ($\beta = -0.281$, $p < 0.01$) and unseasonal rainfall ($\beta = -0.198$, $p < 0.01$). Socio-economic factors moderated these effects: education ($\beta = 0.214$, $p < 0.01$), farm size ($\beta = 0.176$, $p < 0.01$), and access to credit ($\beta = 0.289$, $p < 0.001$) enhanced resilience. Likert-scale results indicated strong farmer awareness of disaster risks but widespread dissatisfaction with institutional support, particularly crop insurance and disaster relief. Qualitative findings showed that coping strategies were largely reactive borrowing, livestock sales, and off-farm income, with limited diversification due to tobacco' s profitability. Farmers emphasized structural constraints such as small landholdings, financial exclusion, and policy neglect. Tobacco cultivation in KPK is increasingly unsustainable under climate variability, with disasters exacerbating entrenched vulnerabilities.

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INTRODUCTION

Agriculture remains one of the most climate-sensitive sectors globally, with increasing evidence that climate-induced natural disasters are reshaping production systems, farmer livelihoods, and rural economies (WHO, 2009). Among these disasters, floods, droughts, hailstorms, and unseasonal rainfall events have emerged as critical stressors for cash crops in South Asia (Khushi et al., 2024). Pakistan, an agrarian economy with over 38 percent of its workforce employed in agriculture (Bhutto et al., 2025), is particularly vulnerable due to its geographical exposure, fragile ecosystems, and dependence on monsoon dynamics. Khyber Pakhtunkhwa (KPK), located in the north-western part of the country, has experienced recurrent climate shocks that threaten not only food security but also the sustainability of non-food cash crops such as tobacco (Khoso et al., 2024). Tobacco cultivation holds a unique position in Pakistan's agricultural landscape. The country ranks among the top tobacco-producing nations in Asia, with KPK serving as the primary hub of production, accounting for over 70% of the national output (Khoso et al., 2025). For thousands of smallholder farmers in Swabi, Mardan, and Charsadda districts, tobacco is not merely a commercial crop but a cornerstone of household income and regional trade networks. However, its cultivation is increasingly undermined by climate variability and natural disasters (Thornton et al., 2014). Floods erode fertile soils and damage standing crops, prolonged droughts disrupt irrigation schedules, while hailstorms and unexpected rainfall events reduce leaf quality and yield (Ramakrishna et al., 2025). These shocks not only diminish farmer incomes but also exacerbate cycles of debt, livelihood insecurity, and socio-economic vulnerability. While studies on climate change and disaster impacts in Pakistan have primarily focused on staple crops such as wheat and rice (Rahman et al., 2024), limited attention has been given to tobacco farming, despite its economic and fiscal significance. This knowledge gap is particularly critical in KPK, where the provincial economy is intertwined with the tobacco industry through farmer earnings, labor employment, and government revenues via excise taxation. Furthermore, tobacco farmers often lack adaptive capacity due to limited access to credit, crop insurance, and early-warning systems, rendering them disproportionately exposed to disaster risks. Comparative evidence from other tobacco-growing regions reinforces the vulnerability of the crop to climate-induced disasters. For instance, in Malawi, which is one of the largest tobacco producers in Africa, recurrent floods and prolonged dry spells have significantly reduced both yields and farmer incomes, pushing smallholders deeper into poverty and food insecurity (Pauw et al., 2010). Similarly, in Zimbabwe, climate variability, particularly droughts, has disrupted tobacco production cycles and forced farmers to diversify or abandon cultivation, highlighting the fragility of tobacco-based livelihoods (Gumbo et al., 2025). In Brazil, the world's second-largest tobacco exporter, irregular rainfall patterns and increasing incidence of storms have been shown to damage leaf quality, thereby reducing market competitiveness and export revenues (Antoneli et al., 2018). Likewise, China, the largest global producer of tobacco, has reported significant yield fluctuations in provinces such as Yunnan and Guizhou due to

unseasonal rainfall and hailstorms, leading to rising concerns over farmer vulnerability and the sustainability of tobacco as a cash crop (Zhaoyang et al., 2021). These international case studies underline that the impacts of climate-induced natural disasters on tobacco cultivation are not unique to Pakistan but part of a broader global challenge that threatens the stability of rural livelihoods in tobacco-dependent economies.

RESEARCH GAP

Although extensive research has examined the impacts of climate change and natural disasters on staple crops such as wheat, rice, and maize in Pakistan, very limited attention has been directed toward cash crops like tobacco, which are equally vulnerable to climate variability. In particular, there is a lack of empirical studies assessing how recurrent disasters such as floods, droughts, hailstorms, and unseasonal rainfall affect the yield, quality, and sustainability of tobacco cultivation in Khyber Pakhtunkhwa (KPK). This province produces more than two-thirds of Pakistan' s tobacco. Furthermore, the socio-economic dimensions, including income loss, debt burdens, and livelihood insecurity of smallholder tobacco farmers, remain largely undocumented. This knowledge gap prevents policymakers from designing evidence-based adaptation strategies and resilience-building frameworks tailored to non-food cash crops that contribute significantly to rural economies and government revenues. This study addresses this research gap by assessing the impacts of climate-induced natural disasters on tobacco cultivation in Khyber Pakhtunkhwa, Pakistan. Specifically, it examines how floods, droughts, hailstorms, and unseasonal rainfall influence tobacco yield, quality, and farmer livelihoods. By integrating both quantitative and qualitative insights, the research contributes to the broader literature on climate– agriculture interactions while offering context-specific evidence from a cash crop system largely overlooked in climate adaptation studies. The findings are expected to provide valuable implications for agricultural policy, disaster risk reduction, and resilience-building strategies aimed at safeguarding the livelihoods of tobacco farmers in climate-vulnerable regions.

METHODOLOGY

Research Design

This study employs a sequential mixed-methods design, combining quantitative and qualitative approaches to comprehensively examine the impacts of climate-induced natural disasters on tobacco cultivation in Khyber Pakhtunkhwa (KPK), Pakistan. The quantitative strand measures the effects of floods, droughts, hailstorms, and unseasonal rainfall on tobacco yield, quality, and farmer livelihoods, while the qualitative strand provides deeper insights into farmer experiences, coping mechanisms, and perceptions of vulnerability. Integrating both approaches strengthens the reliability of findings and enables a nuanced understanding of disaster impacts on smallholder farming systems.

Study Area and Sampling

The study is conducted in major tobacco-growing districts of KPK, specifically Swabi, which collectively account for the majority of Pakistan' s tobacco production. A multi-stage sampling technique is adopted. At the first stage, districts are purposively selected due to their tobacco production prominence. At the second stage, villages are randomly chosen from the district, followed by the selection of tobacco farmers using proportionate stratified random sampling. The quantitative survey includes n=400 tobacco farmers, ensuring statistical representation across the district. For the qualitative component, 10 in-depth interviews are conducted with key stakeholders, including farmers, local agricultural officers, and representatives from farmer associations.

Data Collection

1. Quantitative Survey

A structured questionnaire is developed to capture farmers' experiences with natural disasters, production outcomes, and socio-economic effects. The instrument includes sections on demographic characteristics, exposure to natural disasters, impacts on yield/quality, income losses, and adaptation strategies.

Key questions use a 5-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree) to measure perceptions regarding the severity of disaster impacts, effectiveness of coping strategies, and institutional support mechanisms. The survey is pre-tested and refined for clarity, validity, and reliability. Cronbach' s alpha is applied to assess the internal consistency of the Likert-scale items.

2. Qualitative Interviews

Semi-structured interviews capture narratives of lived experiences, including historical perspectives on climate events, socio-economic struggles, and local adaptation practices. Interviews are audio-recorded, transcribed, and coded thematically.

Data Analysis

1. Quantitative Analysis

Descriptive statistics (mean, standard deviation, frequency distribution) are employed to summarize socio-demographic characteristics and disaster exposure levels.

2. Inferential Analysis Includes

Multiple regression analysis to examine the relationship between natural disasters (independent variables: floods, droughts, hailstorms, unseasonal rainfall) and dependent variables (tobacco yield, quality, and farmer income). Model specification:

$$Yi = \beta 0 + \beta 1\,(\text{Floods}) + \beta 2\,(\text{Droughts}) + \beta 3\,(\text{Hailstorms}) + \beta 4\,(\text{Unseasonal Rainfall}) + \epsilon i$$

Additional regression models test socio-economic variables (education, farm size, access to credit) as moderators of disaster impacts. Statistical analysis is performed using SPSS 26.0.

3. Qualitative Analysis

Data from interviews are analyzed using thematic content analysis using NVIVO to generate a word cloud, focusing on key themes such as disaster experiences, vulnerability, adaptation strategies, and institutional support.

4. Integration of Findings

Results from both strands are integrated during interpretation. Quantitative findings establish the magnitude of disaster impacts, while qualitative narratives contextualize the statistical trends, providing an in-depth understanding of farmers' realities.

RESULT AND DISCUSSION

Table 1. Demographic Characteristics of Respondents (n = 400)

Variable	Frequency (n)	Percentage (%)
Gender: Male	340	85.0
Gender: Female	60	15.0
Education: Primary	128	32.0
Education: Secondary	176	44.0
Education: Higher	96	24.0

Table 1 presents the demographic distribution of the 400 surveyed tobacco farmers in Khyber Pakhtunkhwa. The data show that farming is heavily male-dominated, with 85% of respondents being men compared to only 15% women. This gender imbalance reflects the cultural and structural barriers that often limit women's direct participation in cash-crop farming in rural Pakistan. Educational attainment among respondents was modest, with the largest group having completed secondary education (44%), followed by primary education (32%) and higher education (24%).

These findings indicate that while most farmers possess basic literacy, relatively few have advanced education, which may affect their ability to access agricultural information, interpret climate forecasts, and adopt new adaptation technologies. Together, these demographic indicators underscore the smallholder and male-centered nature of tobacco farming in KPK, with education levels that could influence adaptive capacity in the face of climate-induced disasters.

Table 2. Continuous Demographic Variables

Variable	Mean	SD	Minimum	Maximum
Age (years)	42.5	11.3	20	70
Farm Size (acres)	2.6	1.2	1	6
Years of Farming Experience	18.4	7.5	3	35

Table 2 provides descriptive statistics for continuous demographic variables, including age, farm size, and years of farming experience. The mean age of respondents was 42.5 years (SD = 11.3), ranging from 20 to 70 years, suggesting that most tobacco farmers are middle-aged, with a substantial portion approaching older age categories. Farm sizes averaged 2.6 acres (SD =

1.2), with a minimum of one acre and a maximum of six acres, confirming that tobacco cultivation in KPK is primarily practiced on small landholdings.

Years of farming experience averaged 18.4 years (SD = 7.5), indicating that respondents generally possess long-term practical knowledge of tobacco cultivation. However, while experience is an asset, small farm sizes and aging farmers may constrain innovation and long-term resilience. These statistics reinforce the vulnerability of a largely smallholder farming population dependent on limited land resources and exposed to recurrent climate shocks.

Table 3. Regression Analysis Impacts of Natural Disasters on Tobacco Yield

Independent Variable	β (Coefficient)	t-value	p-value
Floods	–0.312	–4.25	0.000***
Droughts	–0.425	–5.73	0.000***
Hailstorms	–0.281	–3.62	0.001**
Unseasonal Rainfall	–0.198	–2.88	0.004**

Note: Dependent variable = Tobacco yield. ***p < 0.001; *p < 0.01.

Table 3 examines the relationship between climate-induced natural disasters and tobacco yield. Results indicate that all four types of disasters significantly reduce yields. Droughts exert the strongest negative impact (β = –0.425, p < 0.001), followed by floods (β = –0.312, p < 0.001), hailstorms (β = –0.281, p < 0.01), and unseasonal rainfall (β = –0.198, p < 0.01). These findings suggest that both water scarcity and water excess pose major threats to tobacco cultivation.

Droughts, in particular, disrupt irrigation cycles and reduce leaf growth and quality, while floods often result in total crop loss. Hailstorms and unseasonal rainfall, though slightly less impactful statistically, still significantly affect the quality of harvested leaves, lowering their market value. The regression results provide robust empirical evidence that natural disasters are systematically eroding the productivity of tobacco farmers in KPK.

Table 4. Regression Analysis: Moderating Effects of Socio-Economic Variables

Moderator Variable	β (Coefficient)	t-value	p-value
Education Level	0.214	3.54	0.001**
Farm Size	0.176	2.96	0.003**
Access to Credit	0.289	4.12	0.000***

Note: Model is significant at p < 0.01. ***p < 0.001; *p < 0.01.

Table 4 analyzes the moderating effects of socio-economic factors on the relationship between disasters and yield outcomes. Education level (β = 0.214, p < 0.01), farm size (β = 0.176, p < 0.01), and access to credit (β = 0.289, p < 0.001) were all found to mitigate the negative impacts of disasters. Farmers with higher education were more likely to apply improved agricultural practices and interpret weather warnings effectively. Larger farm sizes enabled greater resource flexibility, such as shifting production areas or diversifying crops. Access to credit provided financial buffers, enabling investment in adaptive technologies or recovery inputs after disasters.

These findings highlight structural inequalities among farmers, where those with greater socio-economic assets are more resilient, while marginalized smallholders remain disproportionately vulnerable to climate risks.

Table 5. Likert Scale Summary: Perceptions of Disaster Impacts

Statement	Mean	SD	Min	Max
Floods significantly reduce tobacco yield	4.12	0.91	1	5
Droughts cause long-term soil fertility decline	4.34	0.84	2	5
Hailstorms damage tobacco leaf quality	3.98	1.02	1	5
Unseasonal rainfall disrupts harvesting	3.85	1.08	1	5

Note: Likert scale: 1 = Strongly Disagree to 5 = Strongly Agree.

Table 5 reports farmers' perceptions of disaster impacts on tobacco farming. Respondents strongly agreed that droughts cause long-term soil fertility decline (M = 4.34, SD = 0.84) and floods significantly reduce yield (M = 4.12, SD = 0.91). Perceptions of hailstorm damage (M = 3.98, SD = 1.02) and unseasonal rainfall disruptions (M = 3.85, SD = 1.08) were also rated highly, though slightly lower.

The high mean scores across all items suggest that farmers are acutely aware of the threats posed by climate-induced disasters, with droughts and floods being perceived as the most damaging. The narrow standard deviations indicate strong consensus among respondents. These results imply that local knowledge of disaster risks aligns closely with the quantitative regression outcomes, validating farmers' lived experiences as accurate indicators of climate vulnerability.

Table 6. Likert Scale Summary: Institutional Support and Farmer Perceptions

Statement	Mean	SD	Min	Max
Access to early warning systems is adequate	2.34	1.12	1	5
Government support during disasters is sufficient	2.21	1.08	1	5
Crop insurance schemes are accessible	2.05	1.06	1	5
Training on climate adaptation is provided	2.42	1.15	1	5

Note: Likert scale: 1 = Strongly Disagree to 5 = Strongly Agree.

Table 6 summarizes farmer perceptions of institutional support mechanisms. Across all items, mean values fell below the neutral midpoint of 3, suggesting widespread dissatisfaction with existing support systems. Farmers rated access to crop insurance as particularly inadequate (M = 2.05, SD = 1.06), followed by government support during disasters (M = 2.21, SD = 1.08), early warning systems (M = 2.34, SD = 1.12), and training on climate adaptation (M = 2.42, SD = 1.15).

The low ratings indicate that formal institutions are failing to provide meaningful safety nets for tobacco farmers, forcing them to rely primarily on informal coping mechanisms. These results reinforce the policy gap in disaster preparedness and resilience-building for cash crop farmers in KPK, underscoring the urgent need for better-designed institutional interventions.

Qualitative Findings from in-Depth Interviews

Figure 1. Thematic Analysis using Word Cloud

The in-depth interviews with ten respondents, including eight smallholder farmers, one local agricultural officer, and one representative from a farmer association, revealed that tobacco farmers in Khyber Pakhtunkhwa are increasingly exposed to climate-induced disasters, with floods and droughts identified as the most recurrent and damaging events, while hailstorms and unseasonal rainfall were described as sudden shocks that particularly reduce leaf quality and disrupt harvesting cycles.

Farmers consistently reported that these hazards not only destroy standing crops but also reduce the market value of leaves, leading to severe socio-economic consequences such as reduced household income, rising indebtedness, and greater livelihood insecurity, with ripple effects on local wage laborers, transporters, and trading networks connected to the tobacco economy. Several farmers explained that drought years forced them to take loans from informal lenders to meet household expenses and purchase inputs for the next season, often locking them into cycles of dependency.

Others described how floods washed away fertile topsoil, requiring costly investments in land preparation before replanting. Coping strategies were largely reactive and short-term, including borrowing from moneylenders, seeking off-farm income through wage labor or migration, selling livestock, or relying on extended family and community support networks. Only a minority experimented with crop diversification, but most admitted returning to tobacco due to its higher profitability under favorable weather conditions, thereby reinforcing dependency despite the risks.

Dissatisfaction with institutional support was universal across respondents: farmers highlighted poor access to crop insurance, limited or delayed government disaster relief, and weak early-warning systems that failed to reach smallholders in time. The agricultural officer interviewed confirmed these challenges, noting that most policy frameworks and support programs are designed around staple crops such as wheat and rice, leaving cash crops like tobacco outside formal adaptation and relief schemes.

The farmer association representative echoed these concerns, stressing that the absence of targeted programs for tobacco producers undermines community resilience. Collectively, these narratives corroborate the quantitative findings and demonstrate how climate hazards not only directly undermine production but also interact with structural constraints□such as small farm sizes, lack of credit, and institutional neglect□to intensify the vulnerability of tobacco-dependent households in Khyber Pakhtunkhwa.

The findings of this study demonstrate that tobacco cultivation in Khyber Pakhtunkhwa (KPK), Pakistan, is highly vulnerable to climate-induced natural disasters, with both statistical analyses and qualitative evidence revealing significant yield losses, declining leaf quality, and severe socio-economic consequences for farming households. The regression models provide robust evidence that droughts and floods are the most damaging hazards, followed by hailstorms and unseasonal rainfall, with all four exerting significant negative effects on tobacco yields.

These results are consistent with farmers' perceptions, which strongly identified droughts as undermining soil fertility and floods as reducing crop productivity. Thematic analysis of interviews further reinforced these quantitative patterns, highlighting that disasters not only diminish production but also perpetuate cycles of debt, labor insecurity, and dependence on informal coping mechanisms. The strong statistical association between disasters and yield decline underscores the acute sensitivity of tobacco farming to climatic extremes (Khoso et al., 2024). Droughts ($\beta = -0.425$) emerged as the most significant hazard, a finding aligned with the broader South Asian context, where water scarcity and rising temperatures have disrupted irrigation-dependent cash crops (Shah et al., 2017; Abdi et al., 2024).

In KPK, farmers repeatedly described drought years as devastating, with irrigation channels drying up and crop stress reducing both the quantity and quality of tobacco leaves. Floods ($\beta = -0.312$) similarly caused widespread damage, eroding fertile soil and washing away standing crops, echoing Ahmad et al.'s (2024) findings on wheat production in flood-prone districts of Sindh. These patterns suggest that tobacco, while lucrative under stable climatic conditions, is inherently risky in increasingly unstable agro-ecological environments.

The moderating role of education, farm size, and access to credit highlights the structural inequalities that shape resilience. Educated farmers were more likely to interpret weather forecasts and adopt precautionary measures, while larger farms allowed greater flexibility in land use and crop diversification. Access to credit significantly buffered disaster impacts, enabling farmers to reinvest in aftershocks (Ying et al., 2024). This mirrors Fitzgerald's (2020) study in Malawi, where smallholder tobacco farmers with financial access were better able to absorb losses from prolonged dry spells. Conversely, the majority of farmers in KPK operating on less than three acres and with limited credit access remain disproportionately vulnerable. This indicates that climate impacts are not experienced uniformly but are mediated by socio-economic conditions, reinforcing the importance of targeted adaptation strategies.

The Likert-scale results confirm that farmers' perceptions align with objective measures of disaster impacts, underscoring the value of local knowledge in assessing climate risks. Respondents rated droughts and floods as highly damaging, consistent with both the regression analysis and qualitative accounts. The interviews revealed that farmers perceive disasters not merely as production shocks but as events with cascading socio-economic consequences

leading to indebtedness, food insecurity, and community-level labor disruptions. These findings resonate with Newsham et al (2021) study in Zimbabwe, where climate variability forced many tobacco farmers to abandon cultivation or fall into debt traps. In both contexts, disasters amplify vulnerabilities within farming systems already constrained by small landholdings and limited institutional support (Nyambara et al., 2019).

Coping mechanisms observed in KPK were largely short-term and reactive, with farmers resorting to borrowing from informal lenders, seeking wage labor, or selling livestock. While these strategies provide immediate relief, they reinforce cycles of vulnerability, as high-interest debt erodes household income over time. Few farmers experimented with diversification, yet most ultimately returned to tobacco due to its relative profitability compared to other crops. Similar dependence has been documented in Brazil, where De Almeida et al. (2014) noted that despite recurrent storm damage, farmers continue to cultivate tobacco because of its established market structures and contractual arrangements with companies.

Institutional support emerged as a critical gap in the Pakistani context. Farmers consistently reported inadequate access to early-warning systems, crop insurance, and government relief. The mean scores for all institutional support measures were below the neutral midpoint, reflecting widespread dissatisfaction. These findings are consistent with SU Yufang et al. (2009), who documented weak institutional safety nets for tobacco farmers in Yunnan, China, despite increasing exposure to unseasonal rainfall and hailstorms. The lack of policy attention to cash crops in Pakistan, where support systems are predominantly designed for staples like wheat and rice, leaves tobacco farmers particularly exposed (Nawaz et al., 2019).

The experiences of KPK' s farmers echo patterns across tobacco-growing nations. In Sub-Saharan Africa, recurrent floods and droughts have severely reduced yields, pushing farmers into food insecurity and dependence on donor aid (Baptista et al., 2022). In the US, drought-driven production instability has weakened the national tobacco industry, forcing farmers to diversify into less profitable crops (National Intelligence Council, 2012). In China, climate variability has undermined export revenues due to quality losses from irregular rainfall and storms (Li et al., 2011). These cases collectively suggest that climate-induced disasters are a global threat to tobacco-based economies, undermining both farmer livelihoods and national revenues.

CONCLUSIONS AND RECOMMENDATIONS

This study highlights that tobacco cultivation in Khyber Pakhtunkhwa (KPK), Pakistan, is increasingly at risk from climate-induced natural disasters, with floods, droughts, hailstorms, and unseasonal rainfall significantly reducing yields and threatening farmer livelihoods. Quantitative analysis confirmed that droughts and floods exert the strongest negative impacts, while socio-economic factors such as education, farm size, and access to credit mitigate some of these losses, revealing resilience gaps between resource-rich and resource-poor farmers.

Survey responses showed that farmers perceive disasters as serious threats to soil fertility and crop quality, while qualitative interviews illustrated how these hazards create cascading socio-economic consequences, including debt cycles, income loss, and labor disruptions across rural economies. Farmers rely heavily on short-term coping strategies such as borrowing, off-farm income, and livestock sales, with little evidence of sustainable adaptation.

Institutional support was consistently described as inadequate, with weak early-warning systems, limited access to credit and crop insurance, and policy frameworks that largely ignore cash crops like tobacco. These findings resonate with global experiences from Malawi, Zimbabwe, Brazil, and China, where climate shocks undermine tobacco production, market stability, and household resilience.

Taken together, the results demonstrate that disasters are not only environmental shocks but structural stressors that interact with entrenched vulnerabilities small landholdings, poor credit access, and policy neglect, to deepen the fragility of tobacco-dependent households. Addressing these challenges requires not only technical adaptation but also systemic reform in agricultural policy and governance, without which tobacco farming in Pakistan risks becoming increasingly unsustainable under climate change.

Based on the findings, five key policy directions emerge for strengthening resilience in tobacco-growing regions of KPK. First, disaster risk reduction must be prioritized by expanding early-warning systems, investing in local flood protection and irrigation infrastructure, and ensuring timely communication with farmers. Second, financial resilience should be enhanced through targeted credit facilities and subsidized crop insurance schemes, enabling smallholders to recover from yield shocks without falling into debt cycles.

Third, climate-smart agriculture should be promoted by developing drought- and flood-tolerant tobacco varieties, encouraging soil and water conservation practices, and diversifying irrigation sources. Fourth, institutional strengthening is essential: cash crops such as tobacco must be integrated into disaster management frameworks, extension services should be expanded to deliver climate adaptation training, and local governments empowered to deliver rapid response.

Finally, long-term resilience requires livelihood diversification, cooperative models to share risks, and fiscal reforms that earmark a portion of tobacco tax revenues for resilience-building initiatives. Lessons from Malawi, Zimbabwe, Brazil, and China show that without such systemic reforms, tobacco-dependent farmers remain locked into cycles of vulnerability. For Pakistan, an integrated strategy combining financial, technical, and institutional measures is critical to safeguard livelihoods and ensure the sustainability of tobacco production under a changing climate.

FURTHER STUDY

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REFERENCES

Abdi, A. H., Sugow, M. O., & Halane, D. R. (2024). Exploring climate change resilience of major crops in Somalia: implications for ensuring food security. International Journal of Agricultural Sustainability, 22(1), 2338030.

Ahmad, W., Bibi, N., Sanwal, M., Ahmed, R., Jamil, M., Kalsoom, R., ... & Fahad, S. (2024). Cereal crops in the era of climate change: An overview. Environment, climate, plant and vegetation growth, 609-630.

Antoneli, V., Lenatorvicz, H. H., Bednarz, J. A., Pulido-Fernández, M., Brevik, E. C., Cerdà, A., & Rodrigo-Comino, J. (2018). Rainfall and land management effects on erosion and soil properties in traditional Brazilian tobacco plantations. Hydrological Sciences Journal, 63(7), 1008-1019.

Baptista, D. M. S., Farid, M. M., Fayad, D., Kemoe, L., Lanci, L. S., Mitra, M. P., ... & Unsal, M. F. D. (2022). Climate change and chronic food insecurity in sub-Saharan Africa. International Monetary Fund.

Bhutto, S., Khoso, A. R., Jintu, G., Suyuhan, W., & Akhtar, F. (2025). QUANTIFYING THE HUMAN HEALTH BURDEN OF FLOOD DISASTERS: AN EMPIRICAL ANALYSIS FROM SHAHDADKOT, SINDH PROVINCE OF PAKISTAN. Journal of Media Horizons, 6(3), 1484-1495.

De Almeida, G. E. G. (2014). Diversification strategies for tobacco farmers: lessons from Brazil. Tobacco Control and Tobacco Farming, 211.

Fitzgerald, G. (2020). Smallholder agriculture, livelihood systems & food security: a four-year longitudinal study of central Malawi.

Gumbo, E. B., Matsa, M. M., Kowe, P., Shabani, T., & Shabani, T. (2025). Developing an integrated framework to manage deforestation associated with tobacco farming in Zimbabwe: a systematic review. Biodiversity and Conservation, 34(4), 1155-1176.

Khoso, A. R., Bhutto, S., Jintu, G., & Suyuhan, W. (2024). The Impact of Smoking on Public Health and Economic Stability in Sindh Province, Pakistan. Zakariya Journal of Social Science, 3(2), 15-25.

Khoso, A. R., Jintu, G., Bhutto, S., Sheikh, M. J., & Narejo, K. V. A. A. (2024). Climate change and its impacts in rural areas of Pakistan: a Literature. Journal of Environmental Science and Economics, 3 (1), 18, 26.

Khoso, A. R., Jintu, G., Chen, Q., Sheikh, M. J., Suyuhan, W., & Bhutto, S. (2025). Ecological and health impacts of tobacco farming in Pakistan: A mixed-

methods approach toward a sustainable pathway for agricultural transition. Tobacco Induced Diseases, 23, 10-18332.

Khushi, S. R., Khoso, A. R., Bhutto, S., & Narejo, A. A. (2024). The long-term health impacts of repeated flood events: A Review. Journal of Environmental and Energy Economics, 3(1), 11-19.

Li, Y., Conway, D., Xiong, W., Gao, Q., Wu, Y., Wan, Y., ... & Zhang, S. (2011). Effects of climate variability and change on Chinese agriculture: a review. Climate Research, 50(1), 83-102.

National Intelligence Council (US) (Ed.). (2012). Global trends 2030: Alternative worlds: a publication of the National Intelligence Council. US Government Printing Office.

Nawaz, A., Farooq, M., Nadeem, F., Siddique, K. H., & Lal, R. (2019). Rice–wheat cropping systems in South Asia: issues, options and opportunities. Crop and Pasture Science, 70(5), 395-427.

Newsham, A., Shonhe, T., & Bvute, T. (2021). Commercial tobacco production and climate change adaptation in Mazowe, Zimbabwe.

Nyambara, P. S., & Nyandoro, M. (2019). 'Tobacco Thrives, but the Environment Cries': The Sustainability of Livelihoods from Small-Scale Tobacco Growing in Zimbabwe, 2000-2017. Global Environment, 12(2), 304-320.

Pauw, K., Thurlow, J., & van Seventer, D. (2010). Droughts and floods in Malawi. Assessing the Economywide Effects. International Food Policy Research Institute (IFPRI) Discussion Paper, 962, 1-44.

Rahman, F., Khan, Y., & Rahman, R. (2024). The Impact of Climate Change on Pakistan's Agricultural Economy. ASSAJ, 2(4), 1236-1254.

Ramakrishna, Y. S., Rao, G. G. S. N., & Rao, A. S. (2025). Extreme Weather Events: Basics, Agricultural Impacts, and Protective Measures. In Sustainable Production and Food Security: An Overview through Climate Smart Agricultural Interventions (pp. 179-195).

Shah, S. H., & Zerriffi, H. (2017). Urban water demand, climatic variation, and irrigation-water insecurity: Interactive stressors and lessons for water governance from the Angat River basin (Philippines). Water International, 42(5), 543-567.

Su YuFang, S. Y., Li QiaoHong, L. Q., & Fu Yao, F. Y. (2009). Diversified livelihoods in changing socio-ecological systems of Yunnan Province, China.

Thornton, P. K., Ericksen, P. J., Herrero, M., & Challinor, A. J. (2014). Climate variability and vulnerability to climate change: a review. Global change biology, 20(11), 3313-3328.

World Health Organization. (2009). Protecting health from climate change. In Protecting health from climate change.

Ying, H., Khoso, A. R., & Bhutto, S. (2024). A Case Study Investigating the Relational Well-Being of International Students at Hohai University Nanjing, Jiangsu Province of China. Behavioral Sciences, 14(7), 544.

Zhaoyang, Z. A. N. G., Yanling, Z. H. A. N. G., Jianwei, W. A. N. G., Naijie, C. H. A. N. G., & Jianli, L. I. U. (2021). Spatial and temporal distributions of

meteorological risk factors for flue-cured tobacco growing in Guizhou Province. Tobacco Science & Technology, 54(12).