

Climate Volatility and Agrarian Productivity: Assessing the Macro-Economic Vulnerability of Pakistan

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Abstract

Climate instability has arisen as a critical factor of agricultural productivity, specifically in developing countries such as Pakistan's economy, where agriculture is essential to maintain economic stability and livelihoods. This study investigates the relationship between climate volatility and agrarian productivity and evaluates its wider economic implications. Secondary data and qualitative analytical framework are being used for this purpose, this research dives into how fluctuations in temperature, changing rainfall patterns, and extreme weather events are affecting crop yields, rural farmers income and overall national performance of country. The findings provide data that climate related disruptions in agriculture largely contribute to vulnerability in economics by affecting food security, exports of country, employment and dynamics of inflation. The study shows Pakistan's heavy dependence on climate-dependent agriculture intensifies macroeconomic instability. The research at the end provides policy recommendations which aim at improving climate resilience by adapting innovations in technology, strong institutional reforms and sustainable agriculture practices.

Keywords: Climate Volatility; Climate instability; Agriculture productivity; Pakistan; Macroeconomic vulnerability; Climate change; Food security; Economic growth

Introduction

Climate Crises has become one of the most pressing and destructive challenge globally, which is considerably affecting sustainability of environment, economy and livelihoods. Its impacts are severe specifically in developing countries that are largely dependent on natural resources and agriculture that is what their economic structure is based on. (IPCC, 2022). Among the most climate vulnerable countries Pakistan exists in the world due to its geographical location, limited adaptive capacity and heavy reliance on agriculture as primary economic sector (German watch, 2021). Approximately 19-22% agriculture contributes to GDP of Pakistan and employs around 37-40% of labor force, making it an important part of the national economy (Government of Pakistan, 2023). The sector however is highly sensitive to climate intensity, which includes rising temperatures, intense rainfall, severe floods, and droughts. Previous studies indicate that increase in temperature and irregular and intense rainfall patterns have negatively impacted the major production of crops such as, wheat, rice, cotton (khan et al., 2010; Hussain & Bangash, 2017). Climate volatility causes disruption of agriculture cycles, which affects planting and periods of harvesting, availability of water, and fertility of soil. These disruptions lead to reduction of productivity and it increases the uncertainty in output of agriculture (Gorst et al., 2018). Furthermore, extreme events of weather such as the destructive floods in Pakistan have caused

large-scale destruction of crops, damaged the infrastructure and economic losses (World Bank, 2022). Agriculture productivities declining implications extend beyond the sector of agriculture. Output reduction contributes to food insecurity, pressure of inflation, imbalance of trade, and increased poverty levels. Shocks related to climate can have multiplier effects across the country as agriculture is closely linked with other sectors (Ahmed & Schmitz, 2011).

Aim of this study is to analyze relationship between climate volatility and agrarian productivity in Pakistan to assess its macroeconomics implications. By reviewing existing literature and data, insights are provided in this study into how climate instability affects economic vulnerability and explores policy measures to enhance resilience.

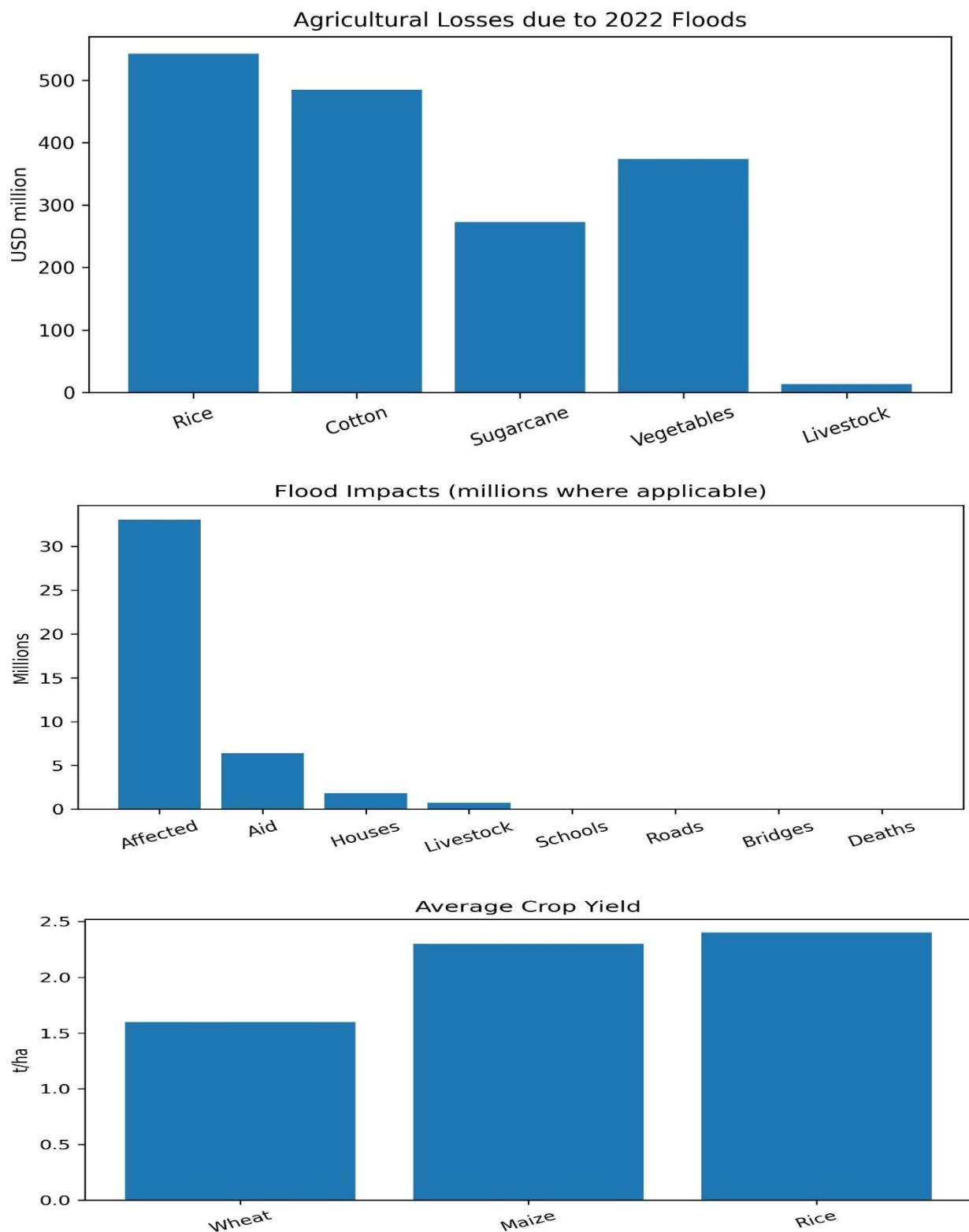
Literature Review

Climate Change and Agricultural productivity

Climate crises and change directly affects agricultural productivity through increase in temperature, change in rainfall patterns and extreme weather events occurring frequently. Inherently agriculture is dependent on climatic conditions, making it extremely vulnerable to changes in environment. Rising temperatures globally have altered growing seasons and reduced production of crops, specifically in tropical and sub-tropical regions (IPCC, 2022). In Pakistan, studies show 1°C increase in temperature can greatly decrease the productivity of wheat, this shows the sensitivity of crops to climatic conditions (Hussain & Bangash, 2017).

Temperature and fluctuating rainfall patterns

Temperature and irregular rainfall patterns are major determinants of agricultural productivity. In these factors' variability affects growth cycle of crops, availability of water, and moisture level of soil. Research indicates that intense and irregular rainfall patterns and prolonged droughts have decreased agricultural output in Pakistan's rainfall-dependent regions. (Khan et al., 2020). Additionally, heavy rainfall and flooding can damage crops reduce fertility of soil which is further affecting production (World Bank, 2022).



Source: Adapted from IPCC (2022); World Bank (2022)

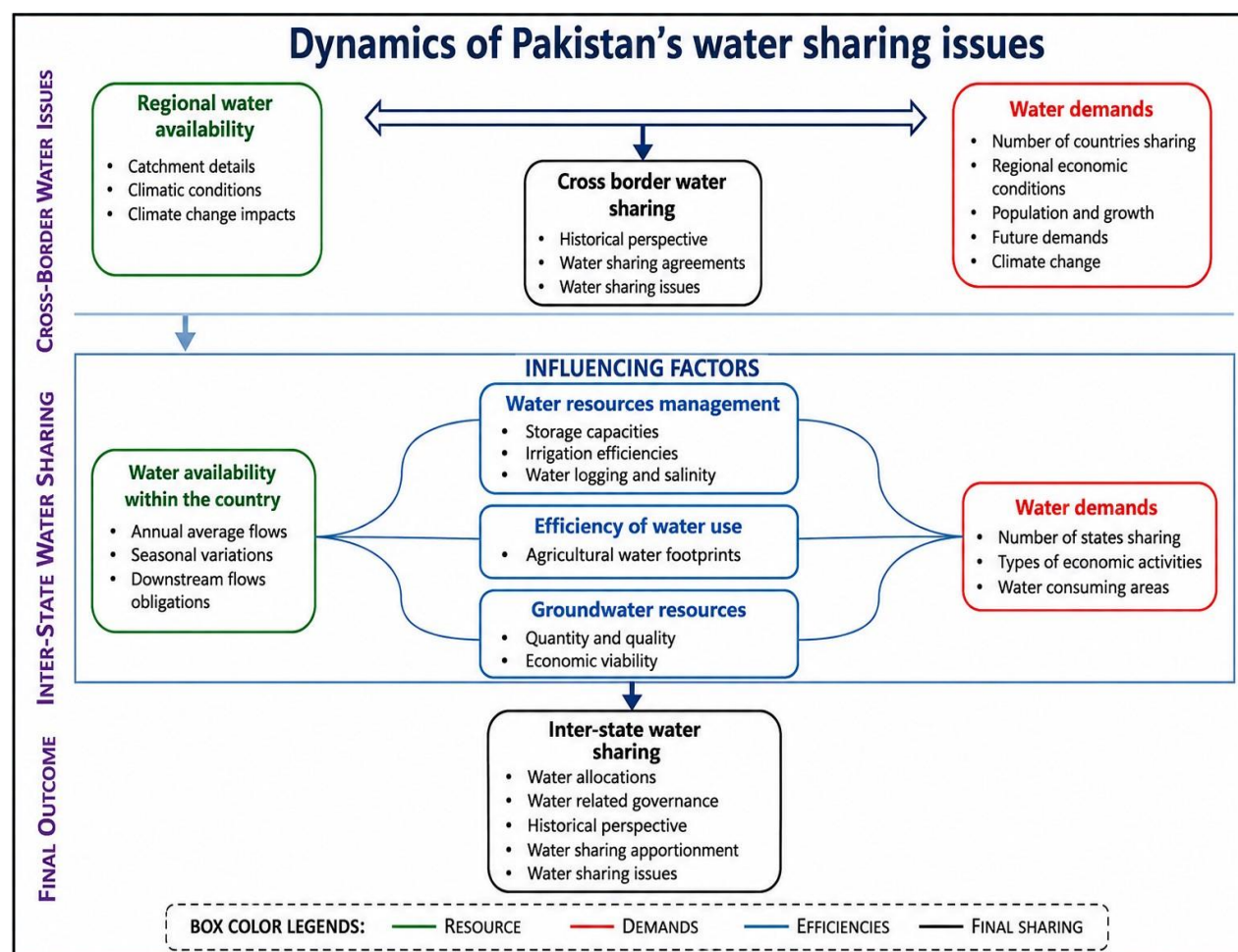
Agricultural Productivity and Climate Change

Agricultural productivity overall evaluates how effectively the output is being produced through agricultural resources. Climate volatility creates a negative impact as TFP is decreasing and input

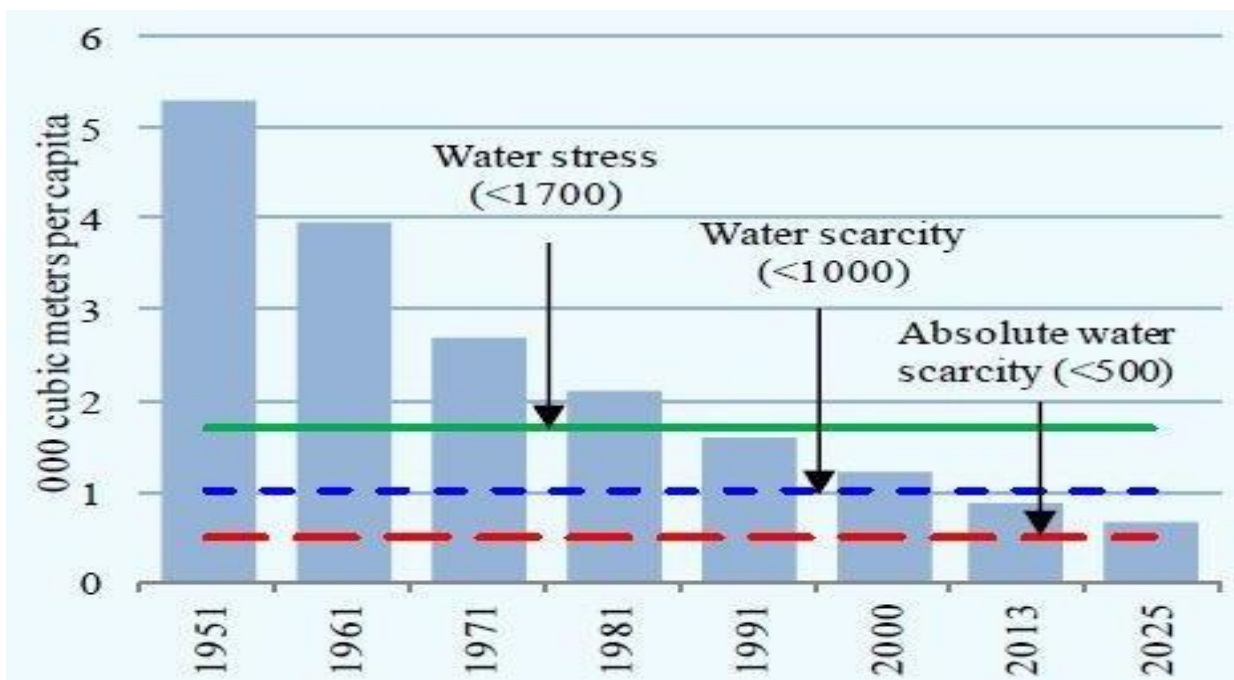
efficiency and increasing the cost of production. Climate crises has greatly decreased the overall productivity in Pakistan of agriculture, this decrease in productivity has long-term economic affects and food security issues, especially in regions which have limited access to modern technology and irrigation (Mehmood et al., 2023).

Challenges in Irrigation and Water Scarcity

Availability of water play a major role in production of agriculture, especially in Pakistan, where dependence on irrigation system is strong for most crops. Water resources are being affected through intense and changing rainfall patterns and increased glacier melting and this is caused by climate change. Previous researches show that groundwater depletion and lower river flows have decreased the production of agriculture, specifically in regions that are dry (Droppers et al., 2022). Therefore, management practices for effective water are needed to overcome these challenges.



Water stress level in Pakistan



Source: Droppers et al. (2022); FAO (2021)

Climate Change and Food Security

One major factor strongly connected to production of agriculture is food security. Change in climate reduces the production of crops, which affects the availability, affordability and access to food. Instable climate has increased food insecurity in third world countries, including Pakistan. Food prices are higher which are caused by lower food supply which mostly affects families with low income and it increases poverty and inequality (FAO, 2021).

Macroeconomic Implications of Climate Change

Economy is getting significantly affected by climate change, which includes reduced GDP growth, increased inflation, and imbalance in trade. Agriculture productivity losses decrease income of export and it increases reliance on food imports (Ahmed & Schmitz, 2011). Economic studies show that agricultural losses related to climate losses may significantly slow Pakistan's economic growth by 2050 (Khan et al., 2020).

How Does Climate Change Affect Each Type of Agriculture?

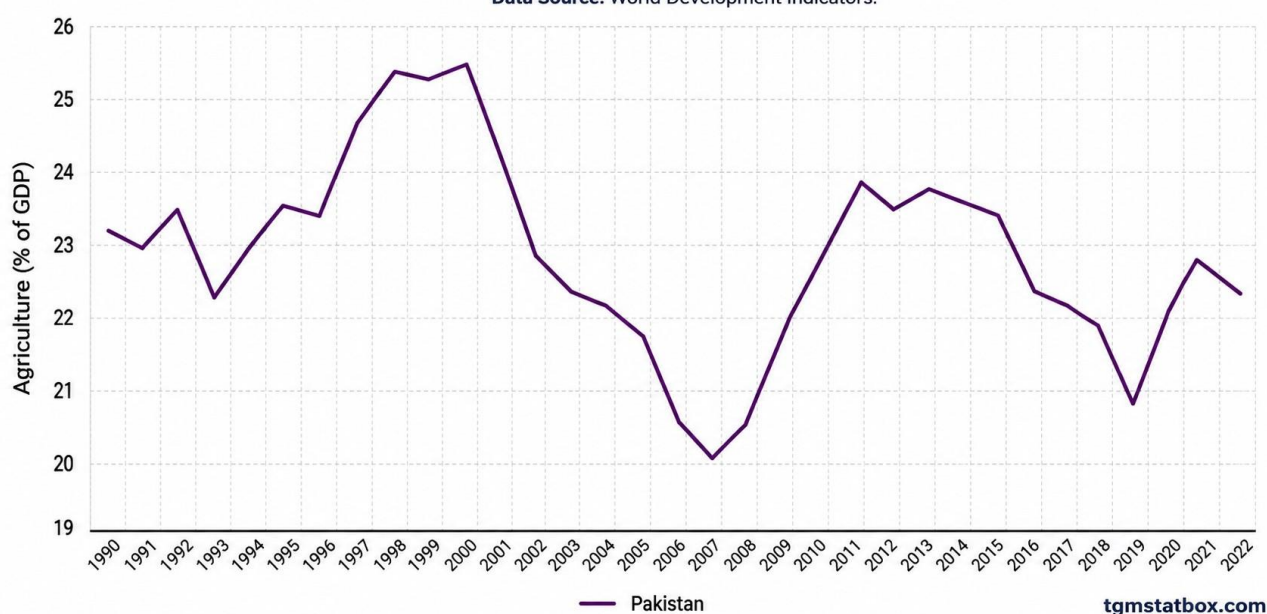
TYPE OF AGRICULTURE	CLIMATE RISKS	MAJOR IMPACTS	EXAMPLES / NOTES
1. PLANTING AND CROP PRODUCTION 	- Erratic seasons - Variability in rainfall volume - Unstable temperatures and relative humidity - Increased frequency of disaster occurrences	- Disturbed plant growth - Difficulties in estimating agricultural cost profits - Reduced yield and quality of crops	Droughts, floods, heatwaves, improved pest and disease outbreaks, and extreme weather events can damage crops and reduce productivity. 
2. LIVESTOCK 	- Change in temperatures and humidity - Variability in water quantity and quality	- Increased stress level among livestock - Low livestock reproductive rates - New and re-emerging infectious disease outbreaks	Heat stress, water scarcity, and disease increase mortality and reduce animal productivity. 
3. AQUACULTURE AND FISHERY 	- Change in water quantity and quality - Increased acidity level and temperature in water	- Mortalities - Low reproduction rates - Extinction of certain aquatic species	Ocean warming, acidification, and water pollution harm aquatic life and fisheries production. 

Source: Adapted from Attavanich, W. (2018). Scaling up Climate Ambition on Land Use and Agriculture through NDCs and NAPs (SCALA). United Nations Development Programme (UNDP) & Food and Agriculture Organization of the United Nations (FAO), 2023.

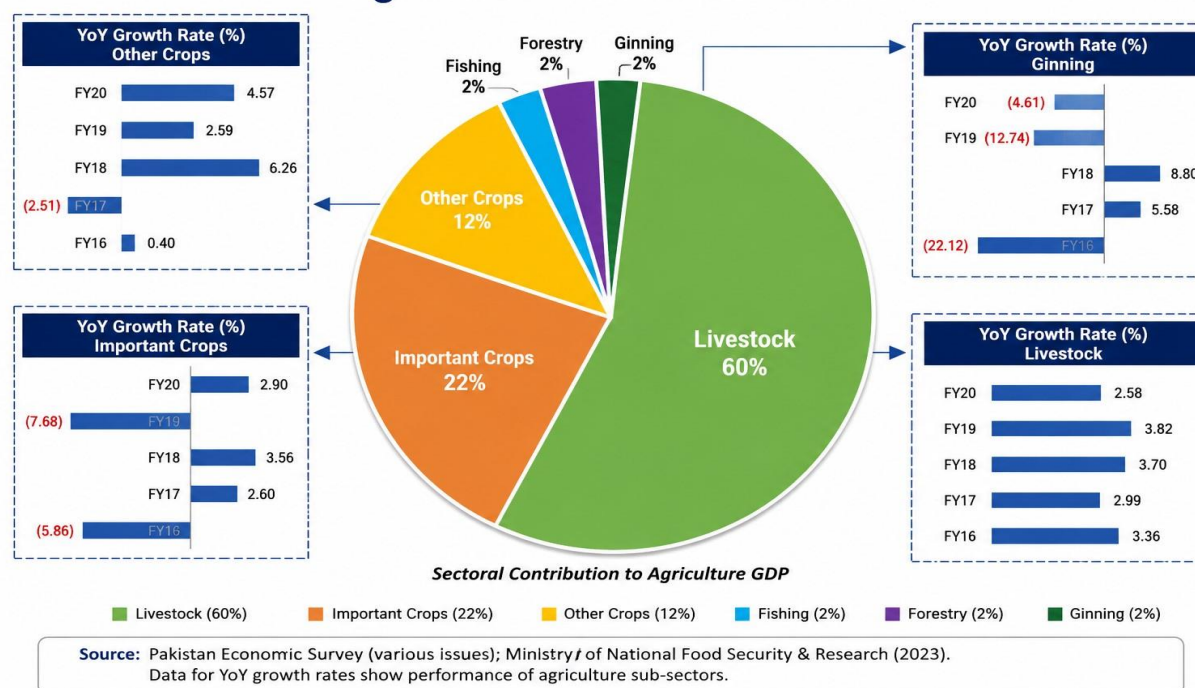


Agriculture Sector Contribution to GDP in Pakistan (1990-2022)

Data Source: World Development Indicators.



Agriculture GDP: Breakdown



Source: World Bank (2022); Khan et al. (2020)

Adaptation strategies and agricultural resilience

Adaptation strategies aids in the mitigation of effects of climate change on agriculture. It includes the adaptation of improved irrigation system climate resilient crops variety and sustainable farming practices study shows that the farmers who adopt adaptive strategies experience higher productivity and reduce vulnerability (Gorst et al., 2018). Despite the use of these strategies' barriers such as lack of financial resources, weak institutional support hinder adaptation efforts.

Institutional and policy dimensions

Strong and suitable policies and relevant frameworks are required to mitigate the challenges caused by climate in agriculture. Additionally, capital investment in research and development, fair governance and supportive policies can enhance productivity. Even though these solutions exist, Still Pakistan faces challenges in implementation of policy, coordination, and resource allocation which limits the effectiveness of climate adaptation strategies (Government of Pakistan, 2023).

Research Gap

Despite extensive research on climate change in agriculture, a significant gap remains in understanding the existing relationship between climate volatility, agrarian productivity macroeconomic vulnerability in Pakistan. Majority of the studies focus on either crop level impacts or regional productivity analysis, without any important significance on linking these findings to broader macro-economic indicator such as inflation, GDP growth, trade balance, and employment dynamics. Moreover, insufficient research still exists in cross-sectoral linkages and feedback mechanism between agriculture and the wider economy. The lack of comprehensive frameworks that incorporates climate science with economic modelling also limits relevance of the policy. This study fills this gap by integrating multidisciplinary literature to provide a holistic assessment that showcase how climate volatility influences agricultural productivity and in return contributes macroeconomic vulnerability in Pakistan.

Methodology

We have chosen qualitative research design for our research which is based on secondary data with peer-reviewed journals, government reports and international publications. Our research relay on systemic literature review and comparative analysis to examine the relationship between climate volatility and agricultural productivity in Pakistan. The study focused on descriptive and analytical framework to recreate established empirical evidence on climate effects targeting changes in temperature, variability in rainfall patterns and extreme weather events. By investigating trends across different zones, we will identify patterns and relationship between crop productivity and climate variables.

Moreover, this study has established its base on macroeconomic theories and models to test the broader economic implications of changes in agricultural productivity. Previous studies using computable general equilibrium models and economic analyses are reviewed to understand how climate induced shocks affect GDP, inflation, employment, and trade (Khan et al., 2020 Ahmed & Schmitz, 2011). The ethological approach also provides insights from resilient and adaptative literature, underscoring the role of technical innovation, institutional framework as well as policy interventions in reducing climatic impacts. This holistic approach not only comprehend the issues but also provides a strong foundation for policy suggestions.

Results and Discussions

Impact on agricultural Productivity:

The changing climatic condition of Pakistan has severely impacted its agricultural productivity. The increase I temperature shorten crop growth cycle while the erratic rainfall disturbs the planting schedules. The yield of wheat and rice have significantly dropped due to heat stress and water scarcity. Furthermore, the increment in use of pesticides have led to soil degradation and reduces productivity.

Economic Vulnerability:

The continuous decline in agricultural output have led to macroeconomic instability. The low production and low export earnings have reduced GDP growth. The deep-rooted dependence on imports have strained foreign exchange reserves and have worsen trade deficits.

Food security and Poverty

Decrement in agricultural productivity contributes to food insecurity and rising prices which results in poverty and inequality affected citizen's especially low-income households.

Structural and institutional challenges:

The weak infrastructure, limited technology and insufficient implementation of policies have made Pakistan susceptible to vulnerability. Moreover, poor farming techniques and conventional irrigation systems disrupts productivity and agricultural output.

Conclusion

Climate volatility has created numerous challenges for the agriculture sector of Pakistan and have hindered overall economic stability. The study underscores the rising temperature, erratic rainfall and hindered climatic patterns that have impacted agricultural productivity while threatening food security and rural livelihoods. The agriculture sector has extended influence affecting macroeconomic indicators such as GDP, inflation, and trade balance.

Moreover, the study highlights the significance of a holistic approach to address challenges induced by climate variation. To enhance agricultural adaptability, technical innovation as well as

institutional and policy reforms are required. Without adopting effective strategies, Pakistan is more susceptible to suffer from economic vulnerability.

Policy Recommendations

Climate-resilient agriculture

Advocating for adaptable agricultural practices is crucial to reduce the impacts of climate change. The use of heat-tolerant crops can improve production of agriculture and reduce climate vulnerability. Investment in agricultural services and research is required to implement this transition.

Water management

To avoid water crisis, an effective water management system is required for sustainable agricultural productivity. Advanced irrigation techniques such as drip and sprinkler systems can also upgrade the efficiency of water use. Furthermore, policies with focus on water conservation and advancement in infrastructure of irrigation system are necessary.

Technological innovation

The enhancement of modern farming techniques can improve agricultural adaptability and productivity. Modern technology facilities and training for farmers are important for large-scale adoption and effectiveness.

Institutional reforms

Building strong institutional framework along with suitable policies can result in effective policy implementation. Additionally, coordination between the federal and provincial governments including stakeholder involvement can significantly maximize the output and effectiveness.

Financial support mechanism

Offering financial support to farmers through credit facilities, subsidies and insurance schemes can aid in the economic risk associated with climate volatility. Moreover, climate protection coverage can provide farmers a support system.

Research and Development

In research and development investment is important to mitigate challenges related to climate in agriculture. Furthermore, collaboration between the government, international organizations and academia can strengthen and promote innovation and advance the adaptation strategies.

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