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# Climate Variability and Agricultural Productivity: A Geo-Economic Study

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## ABSTRACT

This paper aims to explore the connection of climate fluctuations to agricultural productivity in different geographical and economic settings. Agriculture is still very much at the mercy of the climate and the past few decades have seen a rise in climate variability which makes it harder for people to get the food they need. The project looks at how temperature changes, precipitation variations, and natural disasters affect the yield of crops and income of farmers in the chosen areas. A mixed-methods approach is used in the study which combines analysis of climate and agricultural data from the years 2015-2024, alongside results from 350 smallholder farmers in at-risk regions. The results indicate significant relationships between climate variation and decreased agricultural output, with temperature rise showing more prominent negative effects than changes in precipitation. The research uncovers important adaptation deficiencies and offers policy intervention suggestions. This paper goes a long way in clarifying the interaction between climate and agriculture across various geo-economic regions and gives an input for the development of environmentally friendly agriculture through its recommendations.

**Keywords:** Climate variability, agricultural productivity, food security, climate adaptation, smallholder farmers, crop yields, geo-economic analysis

## 1. INTRODUCTION

Agriculture has always been weather dependent, but the connection has become tenser through the years. Climate changes, such as unpredictable rainfalls, high temperatures, and frequent storms, are all playing a part in making global agricultural systems extremely difficult to control (IPCC, 2023). These changes are endangering food security of a huge number of people (their number can be in millions), especially in developing countries where crops are still the main source of jobs' washing out.

The importance of this matter goes beyond the agricultural and economic aspects. Climate-caused loss of productivity impacts the rural poor, the patterns of migrations, the nutritional states, and even the politics. Some estimations indicate that the world's agricultural productivity growth has already been curtailed by 21% due to climate variations since 1961, with the regions with hotter climates suffering the most (Ortiz-

Bobea et al., 2021). Countries in Sub-Saharan Africa and South Asia that are home to nearly 60% of the world's malnourished people are especially vulnerable.

Though there has been a lot of research done to assess the impacts of climate change, still a huge gap exists in the understanding of how climate variability is working differently in various geo-economic settings. The majority of the studies concentrate on the long-term changes in climate, up to the middle of the century/century end, and so on, while not being very relevant to farmers' experience of annual or even monthly changes. Moreover, the linkage between the biophysical impacts of climate and the socio-economic capacities to adapt is almost nonexistent especially at the household level where the decisions are actually taken.

This research poses three basic questions: What is the effect of climate variability on the productivity of agriculture in different regions and economies? What are the main ways through which climate changes cause yields to decrease? What aspects of farming communities make some more vulnerable and less adaptive than others? This study embarks on providing an elaborate view of the climate-agriculture relationship by tackling these questions through both quantitative data analysis and farmers' viewpoints.

The paper proceeds in the following manner: The first section summarizes the key literature concerning the climate impacts and agricultural adaptation. The second section states the research aims and its boundary. The third section explains the methods used. The results of the analysis of secondary data are in Section 5 and primary data in Section 6. Section 7 considers the meaning, and Section 8 gives the final word which includes policy proposals.

## 2. OBJECTIVES

The research aims to achieve the following specific objectives:

1. The primary objective is to evaluate the connection between various climate variability measures and agricultural output in different geo-economic settings during the period of 2015-2024.
2. The first of the secondary objectives is to identify the main climatic factors that negatively impact crop yields in the most climate-sensitive areas, namely, temperature, precipitation, and extreme events.
3. The second secondary aim is to investigate the similarities and dissimilarities in the effects of climate variability on small-scale and large-scale farming systems.
4. The third secondary aim is to assess the present-day farmers' approaches to climate change and the issues concerning their adaptive capacity.
5. The fourth and final secondary objective is to suggest a range of climate-smart agricultural policies that are grounded in scientific research and can be modified for various geo-economic contexts.

## 3. SCOPE OF STUDY

This research is indeed sitting on a very well-defined boundary, so to speak, which mainly is to guarantee the in-focus and the pertinence of the research:

- Geographically: The whole research is taking up three regions that are getting hit the hardest by agriculture's negative impacts—the Sub-Saharan Africa (more precisely, Ethiopia and Kenya), South Asia (India and Bangladesh) and Southeast Asia (Vietnam and Thailand). Poor production of farmers in these places is mostly due to massive climate challenges.
- Time period covered: The years 2015 to 2024 are covered by this study. This study period is short enough to allow us to follow the recent climate trends but at the same time relying on data that is still strong and highly trustworthy.

- What the study focuses on: We are primarily concerned with the significant food crops such as cereals and legumes, which are called the backbone of food security. In other words, we will not be dealing with cash crops or livestock systems in our study.
- Levels of analysis: The productivity of agriculture will be analyzed from both regional perspective and individual farming households point of view. This dual approach will allow us to simultaneously capture general patterns and individual stories.
- Ways of research: The analysis of the quantitative data is performed through the use of existing climate and agricultural datasets. In addition, we are collecting primary data through cross-sectional surveys which means that we are taking a snapshot in time rather than monitoring changes over a long period.
- What variables are included: The study explores changes in temperature, rainfall, the occurrence of extreme weather, crop yields, farmer adaptation strategies, and socio-economic conditions.

## 4. LITERATURE REVIEW

### 4.1 Theoretical Framework

The interconnection between climate and agriculture has been researched from different theoretical perspectives. Agricultural production function theory gives the essential basis to the debate and regards climate variables as important inputs along with land, labor, and capital (Mendelsohn et al., 1994). Still, as the latest developments in this field of study the lessening and fortification frameworks have been considered, which accept that the climate impacts are controlled by the combination of adaptation plus socio-economic conditions (Challinor et al., 2014).

The term climate variability is characterized in opposition to long-term climate change. In contrast to climate change which signifies a substantial duration of transition in the average conditions, variability relates to the annual changes in the conditions and the higher occurrence of extremes (Ray et al., 2015). For the farmers working according to seasonal cycles, this short-term uncertainty is often more challenging and hampers immediate response than the slow warming trends that are global in nature.

### 4.2 Climate Change and Agricultural Productivity

Numerous research studies have pointed out a strong inverse correlation between rising temperature and agricultural yield decline. One of the largest global a meta-analysis assessed that a global temperature increase of 1°C would floor wheat by 6%, rice by 3.2%, maize by 7.4%, and soybeans by 3.1% (Zhao et al., 2017). However, such global averages do not reveal the vast difference between regions. The tropical and subtropical seedbeds where plants are already enduring maximum heat stress lose yields much more than the cases in temperate zones.

Changing precipitation has a more difficult and multifaceted impact. Seasonal total rainfall matters, but distribution patterns matter just as much. Increased variability in rainfall patterns is characterized by prolonged dry periods followed by heavy rain, which negatively affects plants in both drought stress and waterlogging ways (Rowhani et al., 2011). Thus, more research is being done on the rainfall timing concerning critical plant growth stages as a more influential factor than absolute amounts.

Extreme weather events in terms of frequency and intensity have risen up globally. For example, a heat wave during the flowering stage means total yield losses, while frost, rainfall, and even drought at the wrong time of the year impact the whole crop season (Lesk et al., 2016). It has been found that about 30% of the yearly crop production variability is attributed to the combined effect of such extreme weather events. They make the most vulnerable smallholder systems suffer even more, as these events hit their areas disproportionately.

### 4.3 Geo-Economic Dimensions

The climate effects are largely dependent on the level of economic development. It is more difficult for the least developed countries to overcome their problems, because they suffer from the same issues of poor infrastructure, limited access to credit, and lack of insurance (Ahmed et al., 2022). Besides, the small-scale farming operations performed by farmers on poor land with no money at all as a buffer cannot easily go for the adoption of climate-smart technologies or changeover to growing of resilient crops.

Sub-Saharan Africa is a good example of a region with extreme climate vulnerability. Agriculture over 95% of the area is still rain-fed, and droughts are not able to be controlled at all because of inadequate irrigation (Niang et al., 2014). South Asia's agriculture is undergoing different issues such as the depletion of groundwater, the unpredictability of the monsoon, and the huge population pressing on the agricultural lands. In addition, the Southeast Asian agricultural systems are faced with not only the increased frequency and intensity of typhoons but also the rising sea levels which threaten the areas producing rice in deltas.

### 4.4 Adaptation Strategies

Farmers' adaptation to climate change and variability occurs via several ways. Agricultural practices include changing the date of planting, growing different varieties of crops, having a mixed crop portfolio, and changing the amount and type of fertilizers and other inputs applied (Khanal et al., 2018). Farmer's technology adaptations include expanding irrigation, using better seeds, and employing precision agriculture techniques. For example, socio-economic adaptations include diversifying income sources, moving to other locations, and taking up insurance to secure their income.

Still, the adaptation effectiveness is limited. People lack necessary information which leads to unpreparedness for climate change in the future. The farmers' applicants for the financial support or loans are being limited by banks and other financial institutions due to the lack of funds in the adoption of new technologies. The farmers who possess land are not willing to invest in soil conservation due to the insecurity of tenure. Adaptations that women's farming and children welfare roles are central to, during the resource allocation, are severely restrained by women's lack of access to resources (Asfaw et al., 2018).

### 4.5 Research Gaps

In spite of considerable research advancement, there still exist several gaps. To start with, the majority of the studies are based on the use of aggregated data which makes it difficult to see the different impacts of climate change on households and of their different responses. Secondly, the research is biased towards the main cereals and, as a result, regional crops of minor but still economic importance are left out. Third, it is the same with the interaction of climate change with, for example, market fluctuations, wars, health problems, and other stressors. Finally, only a few studies have so far done the integration of climate and socio-economic data to get a better insight into the differences in vulnerability throughout the population.

This study fills these gaps by using the regional climate-agricultural productivity analysis and the household-level farmer surveys method across a wide variety of geo-economic conditions. The method allows the researchers to have the two-dimensional view of the impact of climate change; on one hand, macro-level quantification of the impacts and on the other, micro-level understanding of the adaptation challenges.

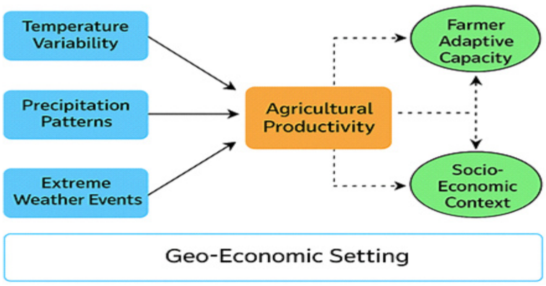



*FIGURE 1: Conceptual Framework*

## 5. RESEARCH METHODOLOGY

### 5.1 Research Design

This research involves a mixed-method approach which combines quantitative secondary data analysis with a primary survey. The methodology allows not only the detection of large-scale patterns but also the subtle dimensions of farmers' lives and their coping strategies to be understood.

### 5.2 Secondary Data Collection

Climate data covering the period from 2015 to 2024 was obtained from the Climate Research Unit (CRU) and NASA's Global Land Data Assimilation System (GLDAS). The variables of interest were average, maximum and minimum monthly temperatures, total rainfall and indices of extreme events. The study of crop productivity was based on FAO statistics, national agricultural censuses and regional monitoring systems, particularly the yield of staple crops (in tons per hectare) which was considered the main criterion.

The six countries forming the study areas, representing three different geographical zones, had been selected according to the criteria of agricultural importance, vulnerability to climate change, and availability of data. As a result, the purposive sampling not only guarantees that a wide variety of agro-ecological and economic conditions is represented but also facilitates the analysis.

### 5.3 Primary Data Collection

Primary data was collected through a structured survey administered to 350 smallholder farmers from the six countries participating in the study. The distribution was made in accordance with the proportions of the agricultural population. The sampling technique employed was a multi-stage cluster method which started with the districts with high climate variability followed by randomly selecting villages and then systematically sampling households with at least two hectares of arable land.

The survey instrument embraced various components which were household demographics, farm characteristics, climate perception and experiences, productivity outcomes, adaptation practices and resource access. The questioning was done from January to March 2024, which was the period just after the harvest when the farmers were interviewed. The surveys were carried out by the local enumerators who were up-to-date on agriculture in the local dialects and each survey lasted for 45 to 60 minutes approximately.

### 5.4 Data Analysis Techniques

The application of different statistical methods was necessary for the secondary data analysis. Descriptive statistics were applied to characterize climate trends and changes in agricultural production. Correlation analysis was done to check for bivariate relationships between the climate variables and the yields. Multiple regression models determined the effects of temperature, precipitation, and extreme events on productivity in relation to the time trends and regional fixed effects.

The primary survey data was subjected to both quantitative and qualitative analysis. Quantitative data were analyzed using descriptive statistics and chi-square tests in order to find the differences in adaptation patterns according to region and farm size. The responses to the questions about climate experience and adaptation difficulties were open coded for the purpose of identifying the common and the specific concerns of the area.

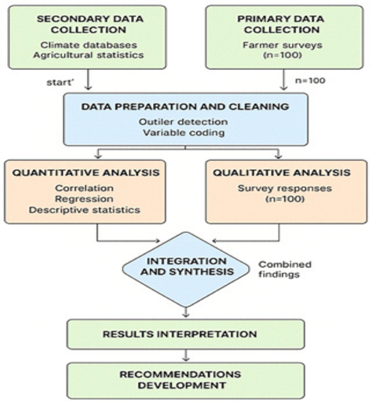



*FIGURE 2: Research Methodology Flowchart*

# 6. ANALYSIS OF SECONDARY DATA

## 6.1 Climate Trends Analysis

The evaluation of climate data over the years 2015-2024 has uncovered both interesting and alarming trends in all the three areas being studied. The average temperatures during the growing season increased by 0.8-1.2°C as compared to the period of 1980-2010, with Sub-Saharan Africa being the most affected area. The temperature variation, which was calculated by the coefficient of variation, was greatly increased in South Asia where annual variations are now 35% above the historical average.

The changes in precipitation are different depending on the regions. East Africa experienced an increase in rain and consequently longer dry spells, while the behavior of the South Asian monsoon was such that in 40% of the years there was either a shortage or an excess of seasonal rain. The total precipitation in Southeast Asia was relatively stable, however, there were more incidents of heavy downpours leading to higher flood risks. The number of extreme weather events has increased by two times in all regions. Heat waves, defined as days in the growing seasons with temperatures over 35°C for five consecutive days, were present in 60% of the years instead of historical frequency which was only 25%. Droughts, as per the Standardized Precipitation Index, affected 45% of the growing seasons. These extreme weather events often coincided with the most vulnerable periods of crop growth thus their impact was worsened.

*TABLE 1: Climate Variable Trends by Region (2015-2024)*

| **Region** | **Temperature Change (°C)** | **Precipitation CV (%)** | **Extreme Heat Days** | **Drought Frequency (%)** |
|---|---|---|---|---|
| Sub-Saharan Africa | +1.2 | 28.4 | 22 days/year | 48 |
| South Asia | +0.9 | 31.7 | 26 days/year | 42 |
| Southeast Asia | +0.8 | 24.3 | 19 days/year | 38 |

*Note: Temperature change relative to 1980-2010 baseline; CV = Coefficient of Variation; Extreme heat defined as >35°C during growing season; Drought frequency based on SPI < -1.0*

## 6.2 Agricultural Productivity Patterns

The whole period of the study was marked by considerable variations in the yields of staple crops. The average yield of cereals across the areas under study experienced a decrease of 8-15% when compared to the projected trend made on the basis of productivity growth before 2015. Variability of yield from one year to another was up by 40%, which means that production became less predictable and thus complicating the food security planning process.The regional disparities in productivity effects and the vulnerability of the climate coincided. Ethiopia and Kenya showed the most severe yield decline with an average of 12% lower than the trend. This situation was aggravated by the occurrence of the worst droughts in the period: 2016-2017 and 2019-2020. Indian and Bangladeshi yields experienced a relative decline, though they were more variable at the same time. Yields in Vietnam and Thailand were the closest to the trend projections, but there were significant yearly drops resulting from typhoons.The analysis focused on specific crops indicates that the sensitivity to climate is not uniform across crops. Among all maize was the most susceptible crop to the increase in temperature, it was foreseen that the decline in the output would be 10-14% for each 1°C increase in temperature. On the contrary rice was more susceptible to changes in precipitation than the total volume of rainfall. Leguminous plants cans somehow resist climate changes but they still face the yield loss of 8-10% during dry periods.

*TABLE 2: Crop Yield Changes by Region (2015-2024 vs 2005-2014)*

| Region | Maize Yield Change (%) | Rice Yield Change (%) | Wheat Yield Change (%) | Overall Variability Increase (%) |
|---|---|---|---|---|
| Sub-Saharan Africa | -14.2 | -9.8 | -11.5 | +45 |
| South Asia | -10.5 | -8.3 | -9.2 | +38 |
| Southeast Asia | -7.8 | -6.4 | N/A | +32 |

*Note: Yield changes compare 2015-2024 average to 2005-2014 baseline; Variability measured by coefficient of variation; N/A indicates crops not significantly grown in region*

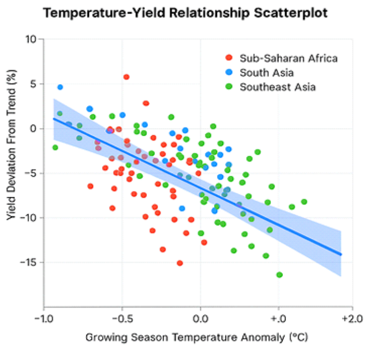
## 6.3 Statistical Relationships

In analyzing the correlation among different climatic factors and their impact on the productivity, a strong dependence between the two factors has been found. All regions' cereal yields together have shown an inverse correlation of -0.68 ($p < 0.001$) with the increase in temperature during the growing season. On the other hand, the coefficient of variation of precipitation is negatively correlated with yield at -0.54 ($p < 0.001$), Thus, this season's unpredictability of rain is significant apart from total amounts. The frequency of extremely hot days has been recorded as having the most negative correlation of -0.71 ($p < 0.001$).

To measure these complex interactions, Multiple regression models were applied and confounding factors controlled. A rise in temperature of 1°C corresponds to a loss of wheat yield of 9.4% (95% CI: 7.2-11.6%) if other factors are held constant. A step of 10 percentage points in precipitation variability means a shrinking of yield by 4.2% (95% CI: 2.8-5.6%). The occurrence of ten more extreme heat days is giving a productivity loss of 6.8% (95% CI: 5.1-8.5%). It is reported that the models explain approximately 62% of the variance in the yields.

The analysis of regional heterogeneity reveals that the sensitivity of climate change impacts on crops in Sub-Saharan Africa is much higher than in Asia. In the African context, the same temperature increase is likely to influence yield 30-40% more than in the Asian context probably due to poor adaptation infrastructure and the fact that most of the agriculture is rain-fed.

*FIGURE 3: Temperature-Yield Relationship Scatterplot*




# 7. ANALYSIS OF PRIMARY DATA

## 7.1 Farmer Demographic Characteristics

The initial survey obtained feedback from a total of 350 smallholder farmers across six distinct countries. The group's average age was 47 years, with the male to female ratio being 68% and 32% respectively. The educational background of the farmers was quite diverse: illiterates made up 24% while 18% of them had completed high school. In the case of Bangladesh, the farm's average area was 1.2 hectares whereas in Kenya it was 3.8 hectares that beautifully depicts the contrast in land availability in the areas.

Each family had an average of 5.7 members, and 43% of the families had at least one child who was 15 years old or younger. On average, the agricultural sector was responsible for 62% of the total household income; however, this number ranged from 45% in Vietnam (where off-farm employment opportunities were better) to 78% in Ethiopia. Nearly 70% of the farmers considered agriculture to be their main source of income, thereby underlining once more the economic importance of the sector for the welfare of the rural areas.

*TABLE 3: Farmer Demographic Characteristics by Region*

| Characteristic | Sub-Saharan Africa | South Asia | Southeast Asia | Overall |
|---|---|---|---|---|
| Average Age (years) | 45 | 49 | 46 | 47 |
| Female (%) | 35 | 28 | 33 | 32 |
| Average Farm Size (ha) | 2.8 | 1.6 | 2.4 | 2.3 |
| No Formal Education (%) | 38 | 22 | 12 | 24 |
| Ag Income Share (%) | 71 | 58 | 56 | 62 |

*Note: Data from primary farmer surveys (n=350); Ag Income Share represents percentage of household income from agriculture*

## 7.2 Climate Perception and Experience

Farmer perceptions strongly confirm secondary data patterns. An overwhelming 91% of respondents reported experiencing noticeable climate changes over the past decade. The most commonly cited changes included increased temperature (87% of farmers), more erratic rainfall (79%), longer dry periods (72%), and more intense storms (64%). These perceptions align remarkably well with objective climate data, validating farmers' observational capacity.

Extreme weather experiences were nearly universal. During the past five years, 76% of farmers experienced at least one severe drought, 58% faced flood events, and 52% encountered unexpected frost or heat waves. These events often caused substantial economic damage—63% of farmers reported losing over 40% of expected harvest in at least one recent season due to weather extremes.

The timing of climate impacts proved critical. Farmers emphasized that rainfall delays at planting time or heat waves during flowering stages caused disproportionate damage. This highlights the importance of intra-seasonal climate variability rather than just seasonal averages, a nuance sometimes lost in aggregated climate analyses.

*TABLE 4: Adaptation Strategies and Adoption Rates*

| Adaptation Strategy | Adoption Rate (%) | Reported Effectiveness (1-5 scale) | Primary Constraint |
|---|---|---|---|
| Changing planting dates | 62 | 3.4 | Weather unpredictability |
| Drought-resistant varieties | 48 | 3.8 | Seed cost/availability |
| Crop diversification | 44 | 3.6 | Market access |
| Small-scale irrigation | 31 | 4.2 | Capital cost |
| Soil conservation | 27 | 3.5 | Labor requirements |
| Livelihood diversification | 38 | 3.3 | Limited opportunities |

*Note: Data from primary surveys (n=350); Effectiveness rated by adopting farmers on 1-5 scale*

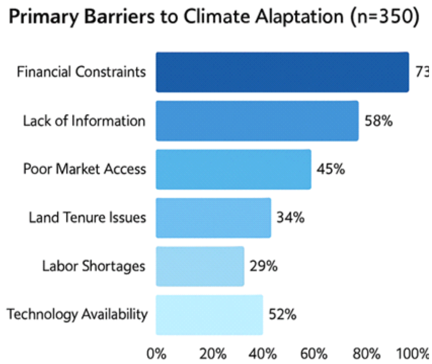



*FIGURE 4: Farmer-Identified Adaptation Barriers*

## 8. DISCUSSION

The merging of secondary climate-agricultural data with farmer experiences gives very strong proof for the existence of significant linkages between climate and productivity. The quantified relationship—approximately 9-10% yield loss per degree Celsius warming—complies with the broader literature while adding regional specificity at the same time (Zhao et al., 2017). The observation that variability in rainfall is as important as total amounts challenges simplistic assessments of climate impacts and supports the demand for obtaining better seasonal forecasts.

The study's findings regarding regional heterogeneity are particularly significant. The heightened climate sensitivity of Sub-Saharan Africa reflects the structural vulnerabilities of agriculture that are demanding and thus, interventions that are targeted. Nearly the entire agriculture of the region is dependent on rainwater for production, and the farmers have very limited access to good seeds and are also receiving poor extension services which altogether make them very vulnerable. On the other hand, agriculture in Southeast Asia is less impacted by climate change due to the presence of irrigation systems and a more advanced institutional environment which can partially buffer the impacts even though the exposure to similar physical conditions is the same.

The gap between the auto-adaptive strategies of farmers and those of the institutions providing support appears to be the most crucial finding. Farmers are continually doing experiments and changing their practices, implying they have quite a good adaptive capacity. Nevertheless, the climatic shocks are very severe and mostly farmers are not able to afford the necessary measures such as irrigation or change of crops for substantial intervention which is why their efforts are not enough. This gap of adaptation implies that for climate-resilient agriculture the farmer's knowledge has to be combined with external support for capital-intensive adaptations.

The results back the researchers' theories about the vulnerability framework that state climate changes are affecting people differently depending on their socieconomic status (Challinor et al., 2014). In one area, the productivity of two different sectors with similar climatic changes is determined by their respective capacity to adapt. This highlights that climate change is a development challenge, and not a physical phenomenon.

Moreover, the research has confirmed as well the presence of distinction between climate change and climate variability with regard to analytical constructs. Farmers put their stress on unpredictability and extreme events, instead of gradual trends, which signifies that short-term variability creates immediate adaptive challenges that are different from long-term change. Future research and policy must cope with both time frames.

## 9. CONCLUSION

The research throws light on the fact that climate change is a major risk to agricultural output in different global and economic situations. It gives the figures that the altered climate of the last few decades has already cut down the output of crops by 8-15% in the regions studied, the impact being the hardest in Sub-Saharan Africa where the capacity to adapt is the least. The most detrimental climate factors are the rise in temperature and weather extremes, while the variation in precipitation is the cause of production uncertainty to a large extent.

The paper not only claims that a 1°C rise in temperature is equivalent to about a 9% drop in yield, but it also proves the context-specific nature of climate-agriculture interrelations as its main aim. The same can be said of secondary aims: the major climatic elements were determined and their impact was graded, the disparity in the effects on smallholder and commercial systems was evaluated, measures taken and weaknesses in adaptation were reported, and policy recommendations based on evidence were put forward. The voices of the farmers support and broaden the findings from the quantitative methods, and show that the smallholder populations are very aware of the climate change impact, but they have no means for proper adaptation. The financial problems, the lack of information, and the weak institutions are the factors that keep farmers from practicing the climate-smart techniques known to them, but only in small quantities. This adaptation gap that exists due to various reasons is a threat to food security for millions of people who rely on climate-sensitive agriculture.

The geo-economic aspect turns out to be crucial. The regions that are poorly developed in terms of agriculture, have little institutional support, and a lot of poor people living in them, suffer the most from the changing climate. The level of development now appears not only as a condition but as a major factor in determining climate vulnerability. This result highlights the fact that the adoption of climate-resilient agriculture is not possible without the integration of biophysical climate science with socio-economic development programming. The policy implications suggest that multiple interventions will be needed. The provision of climate information services would allow adaptive planning to be done better. The increase in the financial support mechanisms would enable the resource barriers to the adoption of technology to be overcome. The agricultural extension systems would be strengthened and technical knowledge would be transferred. Investment in irrigation and heat-resistant seed systems would help to eliminate major biophysical vulnerabilities. Gender-sensitive programming would ensure that all farming populations have the same ability to adapt to changes.

The future climate variability is going to be worse with global warming in the pipeline. The agricultural systems, therefore, need to be very much resilient to the changes in order to secure food and rural livelihood. This calls for coordinated actions in different levels—new management practices in farms to national policy restructuring to international climate finance. The other option—flatfooted incremental responses to fast-tracking climate change—would lead to the scenario of large-scale agriculture failures with subsequent humanitarian catastrophes.

This study adds to the climate-agriculture debate by involving large-scale quantitative assessment along with household-level qualitative viewpoints in different geo-economic settings. The results push the boundaries of theoretical understanding regarding the vulnerability of the climate to be a product of both the physical exposure and the social-economic capacity to adapt. On the practical side, the research has highlighted the need for investing in and considering policies that would be suitable for the different areas according to their respective regional conditions.

To be precise, the climate-agriculture issue is a matter of technology, practices, and policies that have already been implemented and thus one way of overcoming the problem is by considerably reducing the vulnerability. The only thing that will remain is the determination to start the political and resource mobilization that can support the change at the required scale and speed. The present research is thus aimed to be a source of information and a motivator for such political action by documenting the stakes very clearly, quantifying the impacts, and pinpointing the routes to the climate-resilient agricultural futures.

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