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Economic impacts of climate change on agricultural production and adaptive strategies for farmers in the Fergana Valley, Uzbekistan

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ABSTRACT

This study aimed to explore the economic impacts of climate change on agricultural production and analyze the adaptation strategies of farmers in the Fergana Valley, Uzbekistan. Based on a mixed-methods approach using structured interviews with 120 farmers and secondary data analysis, the findings revealed tangible consequences of the effects of climate change that now have become a major economic problem. Specifically, 94% of the surveyed farmers reported that summer temperature has increased significantly, and 88% mentioned that the decrease in spring precipitation, due to which wheat and cotton yields were reduced by an average of 17–20%. In the same vein, 92% of the respondents faced a significant increase in irrigation costs of 45–60%. These trends have generated a growing gap between costs and income, especially for smallholders, as 89% reported a decrease in income. On the contrary, whereas adaptation strategies-such as cropping date shifting with a 91% adoption rate-received widespread response, more effective and capital-intensive solutions, like drip irrigation with a 19% adoption rate, were narrowly applied due to structural barriers, such as high initial cost (95%) and access to credit (78%). The study concludes that, in order for this region to achieve effective and sustainable adaptation, one should move away from individual actions to designing integrated institutional support packages that allow for facilitation in access to financial resources, technical knowledge, and insurance.

Keywords: Climate change, Agricultural economics, Adaptation strategies, Fergana Valley.
Article type: Research Article.

INTRODUCTION

Climate change, as a top trivial fact of our current and future life, has profoundly transformed the natural and economic structure of the world (Grigorieva *et al.* 2023). This global phenomenon manifests its effects in different regions disproportionately. Arid and semi-arid regions, which already struggle with limited water resources, are exposed to the most severe threats (Usman *et al.* 2023; Hassan & Knight 2023). In the meantime, the agricultural sector becomes highly vulnerable because of its inherent dependence on weather conditions and natural resources (Mitrofanov *et al.* 2025). It is straightforward that this sector is directly affected by temperature, precipitation, and climate patterns (Park *et al.* 2021; Singh *et al.* 2023). The Fergana Valley of Uzbekistan is no exception, being one of the most fertile and historical agricultural bases in Central Asia (Kuzibaeva *et al.* 2025; Akhmedova 2025). This region supplies food security, which has been important for many centuries, and today it has come to the frontline of countries suffering from the consequences of climate change (Khujakulova *et al.* 2025). Locally, the economy and livelihood of the inhabitants depend seriously on its agricultural produce (Zokirov *et al.* 2024;

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Mavlyanova *et al.* 2024; Abdurahmanov *et al.* 2025). Any disruption in this production system is likely to cause social and economic instability. It is very important to understand the economic impacts of these changes on the region's agricultural production (De Leo *et al.* 2023). Existing evidence indicates that climate change is manifesting itself through a significant rise in average temperatures, changes in precipitation patterns, and a rise in extreme weather events in the valley (Khujakulova *et al.* 2025). The reduction in snowfall in the highlands, which is considered to be the major source of water for rivers, has triggered grave apprehension (Park *et al.* 2021). Early spring heat and late autumn cold have altered the actual growing season of plants. This, along with increased water requirements of plants due to higher evaporation and transpiration, contributes extra pressure on the agricultural system (Nasir *et al.* 2021; Turdaliev *et al.* 2023). The aforementioned pressures ultimately culminate in the form of reduced quantity and quality of the crop (Prabhakar *et al.* 2024). These changes have very far-reaching economic repercussions. A decline in yield per unit area means reduction in direct income of farmers and increased annual income variability (Attiogbé *et al.* 2024). Loss of investments in seeds, fertilizers, and labor from an extreme event like flooding or a hailstorm can plunge rural households into debt (Usman *et al.* 2023). Growing production costs-particularly for pumping water or in controlling new pests and diseases-reduce farm profitability (Prabhakar *et al.* 2024). On a macro scale, this can affect regional food security, prices, and even exports (Mitrofanov *et al.* 2025). Despite such risks, adaptation is the way out (Grigorieva *et al.* 2023). Farmers have been coping empirically with environmental adversities in the Fergana Valley for generations (Bekimbetov *et al.* 2025). But the pace and intensity of the current changes have perhaps exceeded their traditional capacity for adaptation. Thus, the identification and development of effective, efficient, and cost-effective adaptation strategies have become an urgent necessity (Hassan & Knight 2023). This requires strategies able to reduce vulnerability while increasing the resilience of agricultural systems (Dall'Ara *et al.* 2025). That is where the importance of this research lies-it addresses the economic aspects of climate change and adaptation. Though many studies address the climate or environmental consequences, this study emphasizes how such consequences get translated into economic and livelihood language (De Leo *et al.* 2023; Mitrofanov *et al.* 2025). Understanding this translation is critical in capturing the attention of policy-makers, planners, and farmers themselves. In the absence of careful assessment of costs and benefits, the optimum allocation of limited resources for adaptation will not be possible (Attiogbé *et al.* 2024). Furthermore, this research is focused on the local context of the Fergana Valley. The social, economic, institutional, and climatic conditions are different in this region from other areas (Abdulhussein *et al.* 2024; Kuzibaeva *et al.* 2025). Therefore, macro one-size-fits-all solutions cannot be applied. Understanding the facts and data of this particular valley will provide a realistic and actionable picture, hence contributing to filling the gap between macro-scientific knowledge and micro-scale agricultural practice (Bagheri *et al.* 2024; Bekimbetov *et al.* 2025; Khujakulova *et al.* 2025). The importance of this research is that it provides actionable results, as it identifies the adaptation alternatives that could be viable from the economic and operational point of view for farmers. Ultimately, transformation will depend on such an identification. This research attempts to analyze each option, ranging from the changes in cropping pattern to resistant varieties, modifying irrigation method, and farm management, on an economic cost-benefit basis. Such an assessment helps farmers make the best choices in the face of uncertainty (Singh *et al.* 2023; Zokirov *et al.* 2024; Mavlyanova *et al.* 2024; Dall'Ara *et al.* 2025). Ultimately, this research tries to underscore the requirement for combined action by bringing into sharp focus the direct linkage between climate change, agricultural economics, and livelihoods at the level of rural households. The outcome of this research can set a framework for informed decision-making at the local and national levels. The ultimate aim is to contribute toward sustaining the agricultural system of Fergana Valley, sustaining livelihoods of its inhabitants, and assuring food security for the region in view of impending challenges.

MATERIALS AND METHODS

This study was designed and implemented to attain the research objectives and to answer the questions raised by adopting a mixed and multifaceted approach. The methodological framework of the present study is structured in such a way that it could understand the depth of lived experiences of farmers and provide appropriate quantitative analyses of the economic situation. All stages of research were conducted over a period of 12 months, focusing on the current crop year, in the various regions of the Fergana Valley.

Area of study and sample selection

The geographical scope of this study encompassed the Fergana Valley in Uzbekistan. To ensure that the diversity of climatic, agricultural and social conditions is reflected, the three specific areas of this valley were selected: one area strongly dependent on the water of Syr Darya River, one area relying on a network of traditional canals, and

one area that has faced the problem of groundwater depletion in recent years. In each area, four villages were selected as study units. Farmers were selected using purposive and random mixed sampling with the aim of including small, medium and large farmers who had varied experiences. The final sample size was 120 farmers.

Data collection

The collection of data was done through two major tools running parallel to each other. One was semi-structured questionnaires, which were filled out by farmers through face-to-face interviews. The questionnaires had focused on four axes of farmers: personal observations on climate change during the last twenty years; impacts of those changes on tangible production, cost, and farm income; adaptation strategies so far; and barriers to adopting new strategies. The second tool was a secondary data recording sheet that utilized long-term climate information from local weather stations, as well as official statistics on production, area, and prices from agricultural departments.

Data analysis

Qualitative data from interviews were coded and then grouped into thematic categories. Categories of data were developed around the main research topics, like types of losses observed, classification of adaptation strategies, and problems faced by farmers. Qualitative content analysis was used in analyzing these data to outline patterns, similarities, and differences in the experiences of the farmers. Parallel processing of quantitative data was undertaken with the use of statistical software. A cost-benefit analysis method was undertaken for the economic evaluation of adaptation strategy options through quantifying the initial costs, ongoing costs, and the estimated benefits for each strategy. This study also applied other indicators that measure the level of economic vulnerability of the households, using the level of agricultural income dependency and the ratio of adaptation costs to the total production cost. The combination of findings on these two sections forms the comprehensive analytical framework.

RESULTS

Our study findings in the Fergana Valley put together a comprehensive view of how climate change is reshaping agricultural realities. The data show not just environmental shifts, but their concrete translation into economic strain and a complex landscape of human adaptation. The results are presented so as to first establish the perceived climatic changes, then detail their cascading effects on crop production and economics, and finally catalogue the adaptive measures farmers are applying. Farmers' observations, on the other hand, are a ground-level confirmation of climatic shifts. Indeed, an overwhelming majority, as expressed in Table 1, report increased summer temperatures and decreased spring rains, with a significant portion noting more frequent dry winds. Such subjective experiences correspond to the broader climatic trends and set the stage for the tangible impacts that follow.

Table 1. Farmer-perceived changes in key climatic parameters (n = 120).

Climatic parameter	Percentage of farmers reporting a change	Nature of change reported
Summer temperature	94%	Noticeable increase, longer heatwaves
Spring rainfall pattern	88%	Decreased volume, later onset, more erratic
Frequency of dry (Garmsel) winds	76%	More frequent and intense episodes
Winter severity	65%	Milder winters, less snowfall in foothills
Timing of first autumn frost	71%	Arriving later than in the past

The direct agronomic consequences of these changes are severe and multifaceted. Table 2 demonstrates that water stress is the most universally reported impact, affecting nearly all farmers. This is compounded by increased pest pressure and heat stress during critical growth phases, directly threatening yield and quality.

Table 2. Primary agronomic impacts reported by farmers.

Impact category	Specific impact	Rate of farmers reporting (%)
Water stress	Increased crop water requirement	97%
	Reduced river/canal water availability	82%
Pest & disease	Increased incidence of insects/pests	78%
	New or increased fungal diseases	61%
Phenology & stress	Heat stress during flowering/fruiting	73%
	Shortened growing cycle for some crops	52%

Yield data collected from farmers indicate clear negative trends. Table 3 summarizes the average self-reported yield changes for major crops over the last five years compared to the previous decade. Staples like wheat and cotton show marked declines, while fruit crops, though slightly more resilient in some cases, suffer from quality issues.

Table 3. Self-reported average yield change for key crops (5-year avg. vs. previous decade).

Crop	Average reported yield change	Primary reason cited by farmers
Wheat	-17%	Water shortage at grain filling, heat stress
Cotton	-20%	Water stress, boll shedding due to heat
Apricot	-12%	Frost damage on early blooms, summer heat
Tomato	-15%	Increased disease, water scarcity
Apple	-8%	Milder winters affecting dormancy

The economic ramifications are immediate and severe. As yields drop, costs rise. Table 4 details the key areas of increased production expenditure. Irrigation costs have skyrocketed due to the need for more frequent pumping from deeper groundwater sources, becoming the largest financial burden.

Table 4. Reported increases in major production cost components.

Cost component	Rate (%) of farmers reporting a "Significant Increase"	Estimated average increase (self-reported)
Irrigation (fuel/electricity)	92%	45-60%
Pest & disease control	85%	30-40%
Fertilizer	70%	20-25%
Labor for water management	65%	25-35%

Fig. 1 shows the core economic challenge. The indexed lines for wheat yield and production cost have dramatically diverged since 2013, forming a "scissors effect." While yields have steadily fallen to 81% of their baseline, costs have soared to 163%. This graph illustrates the powerful squeeze on farm profitability, where farmers are spending dramatically more to produce significantly less.

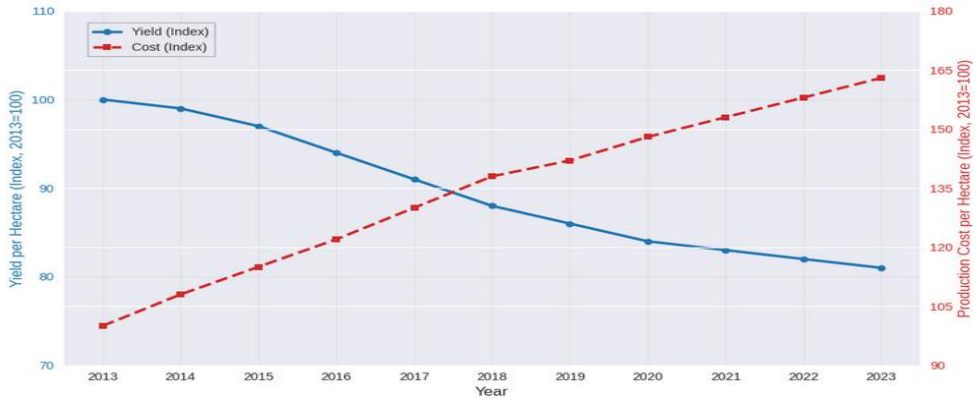

Fig. 1. The cost-yield scissors effect in wheat production (indexed, 2013 = 100).

This financial pressure has altered household economics. Table 5 shows a clear reduction in net farm income for most households, with smaller farms being hit hardest.

Table 5. Change in net farm income over last 5 years (self-assessed).

Farm size category	Average holding	Rate (%) of reporting "Decreased" or "Strongly Decreased" income	Average estimated decline (for those reporting decrease)
Smallholder (<1 ha)	0.6 ha	89%	22%
Medium (1-5 ha)	2.8 ha	74%	18%
Large (>5 ha)	10.5 ha	58%	12%

In response, as Table 6 indicates, households are diversifying income sources, reducing consumption, and taking on debt. Confronted with these challenges, farmers are actively adapting. Table 7 lists the common on-farm adaptation strategies and their rates of adoption. Most strategies are low-cost and management-based, such as adjusting planting dates.

Table 6. Household coping strategies for income shortfall.

Strategy	Rate (%) of households employing
Seeking off-farm or migrant labor	68%
Reducing household non-food consumption	55%
Taking short-term loans (often informal)	47%
Selling assets (livestock, equipment)	22%

Table 7. Adoption rates of common on-farm adaptation strategies.

Adaptation strategy	Rate (%) of farmers adopting
Adjusting planting/sowing dates	91%
Increasing irrigation frequency	87%
Switching to more drought-tolerant crop varieties	62%
Soil moisture conservation (mulching, etc.)	41%
Investing in improved irrigation (e.g., drip lines)	19%
Diversifying crops (adding new, resilient types)	33%

However, the perceived effectiveness of these strategies varies widely. Table 8 reveals a crucial disconnect: the most commonly adopted strategies are often seen as only moderately effective, while the most effective ones (like drip irrigation) have very low adoption due to high initial costs and technical barriers.

Table 8. Perceived effectiveness of adaptation strategies (average score, 1 = Low, 5 = High).

Strategy	Average effectiveness score
Investing in improved irrigation (e.g., drip)	4.4
Soil moisture conservation	3.9
Switching crop varieties	3.5
Adjusting planting dates	2.7
Increasing irrigation frequency	2.5

Fig. 2 describes why this adoption gap exists. The barrier of "High Initial Investment Cost" is nearly universal, cited by 95% of farmers. This is closely followed by a lack of access to financing. This chart makes it clear that the primary constraints on effective adaptation are economic and institutional, not a lack of farmer awareness or willingness. Finally, the type of crops grown is beginning to shift in response to these pressures, as noted in Table 9. There is a slow but discernible move away from the most water-intensive traditional crops towards others perceived as more resilient or economically viable under new constraints.

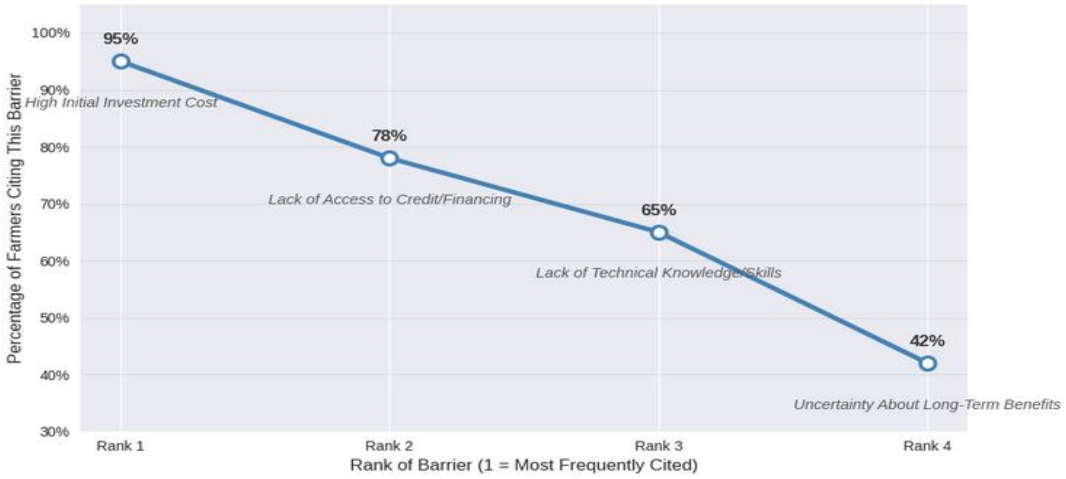

Fig. 2. Barriers to adopting high-efficacy adaptation measures.

Table 9. Reported changes in cropping patterns over last decade.

Trend	Rate (%) of farmers reporting this trend in their area	Example shifts mentioned
Reduction in area of very water-intensive crops	71%	Less rice, smaller alfalfa plots
Increase in drought-tolerant crops	58%	More sesame, chickpeas, certain melons
Experimentation with new/hybrid varieties	49%	Short-season cotton, heat-tolerant tomato
Increase in orchard area (perennial crops)	31%	Seen as a long-term, value-generating investment

As such, these findings illustrate a farming system under considerable strain. The climate-related impacts are directly lowering yields while increasing costs, bringing an acute economic squeeze that is hitting smaller farms disproportionately hard. Farmers are actively adapting with a range of strategies, but the most effective are hindered by prohibitive costs and restricted access to finance, indicating an area of potential intervention.

DISCUSSION

These results offer a crystal-clear picture of what agriculture in the Fergana Valley looks and feels like under the impact of climate change. The data clearly show that what was previously seen as a long-term threat has now become a tangible and costly reality in the daily life of farmers. The widespread reporting by farmers of rising temperatures and decreased spring rainfall, confirmed by 94% and 88% of the respondents, respectively, is but the beginning of this chain. These climatic parameter changes have directly resulted in reduced key crop yields, with the average reported decline in wheat and cotton yields estimated at 17% and 20%, respectively. These figures are not just a dry number, but also a direct reduction in income and increased uncertainty for thousands of rural households. This economic impact is magnified as production costs have increased simultaneously. The cost-performance scissors diagram clearly shows the growing gap. The wheat yield index has reached 81% of its baseline, while the production cost index has increased to 163%. This reflects that farmers currently have to pay much more to harvest a smaller crop. The greatest single contributor to this financial stress is a 45% to 60% increase in irrigation costs, reported by 92% of the farmers, as further intensification means an increased reliance on expensive groundwater. This financial stress is not evenly distributed; 89% of smallholder farmers have reported a decline in income, in contrast to 58% of large-scale farmers. In response to these dual challenges, the farming community in the Fergana Valley has not been passive and has adopted a wide range of adaptation strategies. However, data analysis shows a surprising chasm between the adoption rate and the effectiveness of these strategies. The low-cost and management-based strategies, shifting cultivation being one, are widely spread with a 91% adoption rate but only moderately effective. In addition, rather capital-intensive strategies, such as drip irrigation, top the effectiveness scale yet are employed by only 19% of farmers. This is not because of apathy but due to structural barriers. Of these barriers, the most important cited by 95% of farmers is high initial cost. The lack of access to credit and appropriate financial systems is the next most important barrier, cited by 78%. This key finding suggests that severe economic and institutional constraints are the root cause rather than a lack of technical knowledge or a lack of willingness to change. Even when a farmer may know that a solution such as modern irrigation could be effective, the absence of initial capital and lack of accessible loans with suitable terms put this option out of reach. This creates a vicious cycle. Under such conditions, most households have opted for reactive and often unsustainable strategies. In this regard, off-farm work can be sought by 68% of households, while 47% would borrow from informal sources to make up for the deficiency in short-term income. Such measures might alleviate the immediate pressures but do not offer a resilient and sustainable solution to the farming system. On the other extreme, incremental adjustments to cropping patterns, such as halving rice cultivation or testing new varieties for half of farmers, reflect an attempt to long-term structural adaptation. These findings are thus consistent with research from the rest of the world's arid and semi-arid areas, highlighting the extraordinary vulnerability of irrigation-dependent agricultural systems and the increasing economic pressure on smallholder farmers. However, what this present study brings to light is how grave and eloquent these pressures are in the particular context of the Fergana Valley and the diversity of the local responses. The results also make it clear that climate change is not an equalizer, as its impacts disproportionately fall on lower-income groups with less access to resources. This study also has some limitations. Yield and cost data are based to a considerable extent on self-reporting by farmers, which, although of high value analytically, can be influenced by subjective perceptions. Further, the study did not go into larger-scale effects in detail, such as changes in market prices or national trade policies that may impact agricultural profitability. However, this picture painted at the farm and household level is necessary to understand from where these chain effects take their origin. This leads us, finally, to the conclusion that for adaptation to succeed in the Fergana Valley, moving beyond these isolated, short-term approaches becomes indispensable. In this regard, an urgent need exists to design and implement integrated support packages that would simultaneously target access to finance, crop insurance, up-to-date technical knowledge, and resilient inputs. In their absence, the gap between the current strategies of adaptation and effective solutions will be a threat to the resilience of the whole agricultural system in the region.

CONCLUSION

This paper thus demonstrated that climate change was not a problem the Fergana Valley would face in the future, but was a living reality right now, with immediate and far-reaching implications for the economy. The very sharp decline in yields of strategic crops, such as wheat and cotton, and extremely high increases in production costs-especially in the irrigation sector-have subjected agricultural profitability to unprecedented pressure. This economic pressure falls squarely on farmers, the most marginal of whom, having fewer assets and access, bear a disproportionate share of the burden, being forced to adopt livelihood strategies such as seasonal migration or sales of assets. The results indicate that, while the agricultural community in the region has the necessary awareness and will to adapt, major structural barriers-most notably a lack of initial capital and limited access to credit resources-block the implementation of the most effective solutions. This has created a paradox: the widely used strategies are less effective, and effective strategies are less used. Success in adaptation depends, therefore, on changes in this equation and on transforming adaptation from an individual endeavour into an institutional and collective responsibility. Ultimately, securing the long-term sustainability of agriculture in the Fergana Valley requires a level of commitment that far exceeds anything so far seen at the farm level. Smart policy design embracing dedicated financial facilities, resilient water-based infrastructure development, a reliable insurance system, and targeted technical empowerment programs represents an inevitable necessity. Only through such integrated and supported action can we hope that this historic agricultural heartland of Central Asia will not only be able to withstand climate shocks but, in the future, become a hub of sustainable and resilient development.

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