ADAPTING AGRICULTURE IN KOSOVO TO CLIMATE CHANGE: LESSONS FROM POST-FLOOD IMPACTS AND STRATEGIES FOR RESILIENCE

Ekrem Gjokaj[1], Nol Krasniqi[2], Henrietta Nagy[3]
[1]Public International Business College Mitrovica, Kosovo; [2]University "Ukshin Hoti" Prizren, Kosovo; [3]Milton Friedman University, Hungary
e.gjokaj@ibcmitrovica.eu, nol.krasniqi@uni-prizren.com, nagy.henrietta@uni-milton.hu

Abstract. Climate change poses increasing threats to Kosovo's agricultural sector, with extreme weather events such as floods becoming more frequent. Between 17-22 January 2023, heavy rainfall led to severe flooding in 11 municipalities, causing significant damage to agricultural assets, particularly in areas near rivers. Farmers experienced major losses, disrupting local production systems. In response, FAO, in collaboration with national and local authorities, launched a recovery initiative. A damage assessment conducted between March and April 2023 identified priority intervention areas. With funding from SDC, FAO initiated an emergency project in April 2023, supporting flood-affected farmers through the distribution of winter wheat seeds or 300 EUR agricultural vouchers, allowing flexibility in purchasing essential inputs. By September 2023, 907 farmers had received assistance. Despite short-term emergency responses, there is limited understanding of how post-flood conditions affect agriculture and what strategies can build long-term resilience. This study addresses the problem of insufficient knowledge and planning around agricultural recovery and adaptation in flood-prone areas. This study analyzes the impact of post-flood conditions on agriculture and explores resilience strategies to mitigate future risks. Using a literature review, field assessments, and stakeholder interviews, it examines vulnerabilities and adaptive measures. Findings emphasize the importance of improved water management, soil conservation, and targeted policy interventions to enhance resilience. The study concludes with recommendations for sustainable adaptation practices and policy reforms to ensure long-term agricultural sustainability in Kosovo.

Key words: voucher, rainfall, flooding, dynamics.

Introduction

Kosovo's agricultural sector is crucial to its economy, employing a significant portion of the population and contributing to national food security. Agriculture accounts for approximately 10% of Kosovo's GDP and employs around 25% of the workforce, making it one of the most vital sectors for rural livelihoods [1; 2] The country's predominant agricultural activities include livestock farming, grain cultivation, and fruit production. However, climate change-induced flooding has increasingly threatened agricultural productivity, posing a serious risk to food security and economic stability. Studies by the Intergovernmental Panel on Climate Change (IPCC) highlight the region's vulnerability due to changing precipitation patterns, which result in more frequent and intense floods, as well as prolonged drought periods [3]. Research from the European Environment Agency (EEA) also underscores the need for proactive adaptation strategies to counteract climate-related disruptions, particularly in countries with weak adaptive capacities [4]. The increasing unpredictability of weather patterns has placed additional strain on traditional farming methods, requiring a shift toward more resilient agricultural practices. The impacts of flooding on agriculture in Kosovo are multifaceted. Soil erosion is one of the most significant consequences, leading to the depletion of essential nutrients and reduced land fertility. According to Hoxha et al. (2020), over 60% of surveyed farmers reported experiencing decreased crop yields due to soil degradation caused by recurrent floods. Standing water also has an impact on livestock husbandry because it provides breeding grounds for bacteria that spread diseases, making animal infections more common [5]. Despite these risks, Kosovo's present adaption plans are still insufficient because of a lack of funding for infrastructure and gaps in policy. Many farmers still use antiquated flood control methods, such as digging drainage ditches by hand, which do not work well for major flooding situations. There are few financial incentives for farms to embrace sustainable techniques, and government support for climate adaptation is still patchy. Previous research highlights the necessity of a more comprehensive adaption strategy that includes both institutional support and technical solutions [6]. Incorporating climate-smart agriculture (CSA) practices can improve resilience, according to a comparative study within other Balkan countries. In order to reduce the risk of flooding and drought, countries like Serbia and North Macedonia have put policies in place that support agroforestry techniques, precision irrigation technology, and crop types resistant to drought [7]. Kosovo, on the other hand, has not yet completely incorporated these actions into its national agricultural policies. Adopting CSA might greatly increase

Kosovo's agricultural resilience against flooding brought on by climate change, especially when combined with better early warning systems and farmer education initiatives.

Recent studies and international reports have drawn attention to the increasing exposure of agricultural systems in the Western Balkans to climate-related risks, especially floods, which threaten food security and rural livelihoods [8-10]. In Kosovo, FAO's emergency intervention to the 2023 floods helped address short-term needs, yet long-term recovery and adaptation remain underdeveloped [11]. Unregulated urban expansion in flood-prone areas has further exacerbated agricultural vulnerability, underscoring the need for integrated planning and watershed-based resilience strategies [12]. While international assessments call for more localized, adaptive risk management systems [8], empirical evidence from post-flood agricultural settings in the region remains scarce.

Furthermore, research from the United Nations Development Programme [13] and World Bank [14] emphasizes the value of multi-stakeholder cooperation in enhancing climate resilience. Implementing evidence-based adaptation techniques can be made easier by fortifying collaborations between local farming communities, research institutions, and governmental agencies. For long-term adaptation to be successful, capacity-building programs that teach farmers about climate risks and sustainable farming methods are essential. While emergency responses have addressed immediate needs, there remains a lack of structured analysis on how post-flood conditions influence agricultural systems and what adaptive strategies are most effective. This study addresses this gap by investigating both the short-term impacts and the long-term resilience needs of Kosovo's flood-affected farming communities.

Materials and methods

This study adopts a mixed-methods approach, integrating both quantitative and qualitative research methodologies to comprehensively analyze the impact of floods on agriculture in Kosovo and assess the effectiveness of adaptation strategies. The methodology is structured into four key components: field assessments, stakeholder interviews, literature review, and remote sensing analysis.

Field Assessments

A structured survey was conducted with 900 farmers from flood-prone areas across Kosovo to gather first-hand information on the extent of flood damage, coping mechanisms, and adaptation strategies. The selection of farmers was based on municipality lists where the impacted farmers from floods were registered at the respective municipality for support. The survey covered the following.

- Farm characteristics (size, crop types, livestock, and irrigation infrastructure).
- Flood exposure (frequency, duration, and severity of past flood events).
- Economic losses (yield reduction, livestock losses, infrastructure damage).
- Adaptation measures (use of flood-resistant crops, drainage improvements, government support received).
- Perceived challenges in implementing adaptation strategies.

The survey responses were analyzed using descriptive and inferential statistics, including frequency distributions, correlations, and regression models to identify patterns and key factors influencing farmers' adaptation behaviour.

Stakeholder Interviews

To gain insights into institutional responses and policy frameworks, semi-structured interviews were conducted with key stakeholders, including:

- government officials (Ministry of Agriculture, Forestry and Rural Development, National Commission on the Disaster Response, Ministry of Environment and Infrastructure);
- local authorities (Mayors, representatives of the Municipality Agriculture Departments of 11 affected municipalities);
- agricultural extension officers providing technical assistance to farmers;
- environmental NGOs and researchers working on climate resilience.

The interviews explored topics such as listed below.

- Existing policies and regulations on flood management in agriculture.

- Effectiveness of government support (financial aid, insurance schemes, infrastructure investments).
- Challenges in policy implementation and coordination among institutions.
- Recommendations for strengthening resilience in the agricultural sector.

Thematic analysis was used to extract key insights, coding responses to identify common narratives, gaps, and best practices in flood adaptation efforts.

Literature Review

A comprehensive review of peer-reviewed journal articles, government reports, and policy documents was conducted to contextualize the study. The review focused on the following.

- Climate resilience strategies in agriculture, drawing comparisons with flood adaptation measures in similar geographical contexts.
- Impact assessments of previous floods on agricultural productivity and rural livelihoods.
- Innovative adaptation techniques (e.g. agroforestry, conservation agriculture, water management strategies).
- International best practices in flood mitigation for agricultural sectors.

The findings from the literature review were synthesized to establish a conceptual framework for understanding flood impacts and responses in Kosovo.

Data Analysis and Integration

The study employed a triangulation approach, combining insights from quantitative survey data, qualitative interviews, and literature. The integration of these methods allowed for a multi-dimensional understanding of how floods impact Kosovo’s agricultural sector and how different actors respond to these challenges.

Results and discussion

This part presents the main findings related to the economic impact of floods on agriculture and the adaptive responses of farmers. The analysis aims to determine whether economic losses, such as crop damage and household dependency levels, influence the likelihood of adopting coping strategies. The results provide empirical evidence on the factors driving adaptation behaviour, offering valuable insights for policymakers and stakeholders in disaster resilience planning. The descriptive statistics provide an overview of the sample, highlighting the extent of agricultural damage and the coping strategies employed by affected households. Correlation and regression analyses further explore how different factors influence adaptation decisions.

Table 1

Summary of key descriptive statistics on agricultural damage and coping strategies

Total Farmers Surveyed	858
Average Agricultural Damage Level	1.57
Standard Deviation of Agricultural Damage	1.01
Average Damaged Crop Area (ha)	3.73
Standard Deviation of Crop Damage Area	11.56
Average Crop Damage Severity	3.49
Standard Deviation of Damage Severity	1.15
Average Dependency Ratio	0.20
Average Stress Coping Index	0.71
Average Crisis Coping Index	0.61
Average Emergency Coping Index	0.14

Source: own editing 2025.

Table 1 presents a summary of key descriptive statistics related to agricultural damage and household coping strategies following flood events. The sample consists of 858 surveyed farmers, all of whom reported experiencing flood damage. The average agricultural damage level is 1.57, with a standard deviation of 1.01, indicating moderate variability in reported losses. The average damaged crop area is 3.73 hectares, but the high standard deviation of 11.56 suggests significant variation in the extent of damage among farmers. In terms of coping strategies, the stress coping index averages 0.71, indicating that many households resorted to short-term strategies such as selling assets or borrowing money. The crisis coping index, which measures more severe strategies such as reducing food consumption, has a mean value of 0.61. The emergency coping index remains relatively low at 0.14, suggesting that only a small proportion of households adopted extreme measures like selling land.

Table 2

Correlation between economic losses and adaptation behaviour

Variable 1	Variable 2	0.028
Crop Damage	Crop Damage Area (ha)	0.146
Crop Damage	Crop Damage Severity	-0.020
Crop Damage	Household Dependency Ratio	-0.092
Crop Damage Area (ha)	Crop Damage Severity	0.014
Crop Damage Area (ha)	Household Dependency Ratio	0.027
Crop Damage Area (ha)	Stress Coping Index	0.032
Crop Damage Severity	Household Dependency Ratio	0.067
Crop Damage Severity	Stress Coping Index	0.091
Crop Damage Severity	Crisis Coping Index	-0.099
Household Dependency Ratio	Stress Coping Index	-0.096
Household Dependency Ratio	Crisis Coping Index	0.411
Stress Coping Index	Crisis Coping Index	0.198
Crisis Coping Index	Emergency Coping Index	0.028

Source: own editing, 2025.

Table 2 presents the relationships between economic losses and adaptation behaviour. It highlights weak positive correlations between crop damage severity and stress/crisis coping strategies, suggesting that as damage increases, farmers may rely more on short-term financial adjustments. The household dependency ratio shows a slight negative correlation with coping mechanisms, indicating that households with higher dependency rates may struggle to implement adaptive responses.

Table 3

OLS determinants of adaptation behaviour

Variable	Coefficient β	Standard Error	t-Value	P-Value
Intercept	0.596752	0.061591	9.688904	1.159028
Crop Damage	0.047018	0.017534	2.681497	7.540218
Crop Damage Area (ha)	0.001333	0.001537	0.867324	3.861268
Crop Damage Severity	0.030910	0.015481	1.996663	4.633354
Household Dependency Ratio	-0.135901	0.085403	-1.591281	1.120969

Source: own editing, 2025.

Ordinary Least Squares (OLS) Regression is used, which estimates the relationship between a dependent variable (LCSI_*stress*, representing stress coping strategies) and multiple independent variables (economic losses and household characteristics) by minimizing the sum of squared residuals. The regression analysis examines the relationship between economic losses and adaptation behaviour, specifically farmers' reliance on stress coping strategies. The independent variables include crop damage, crop damage area, crop damage severity, and household dependency ratio. The results indicate that the number of damaged crop types (β = 0.047, p = 0.008) has a significant positive association with adaptation behaviour. This suggests that farmers who experience damage to multiple crop types are more likely to adopt short-term coping mechanisms such as borrowing money or selling assets. Similarly, crop damage severity (β = 0.0309, p = 0.046) is also positively associated with adaptation, indicating that farmers facing more severe losses tend to rely more on immediate financial adjustments. On the other hand, crop damage area (β = 0.0013, p = 0.386) is not statistically significant, implying that the total land affected does not strongly influence adaptation choices. Likewise, the household dependency ratio (β = -0.1359, p = 0.112) shows a weak negative relationship with adaptation behaviour, but it is not statistically significant. The overall model is statistically significant ($p = 0.00299$), but with an R-squared of 0.027, it explains only a small fraction of the variation in adaptation behaviour. This suggests that while economic losses play a role, other unobserved factors such as prior experience, financial capacity, and institutional support may be more important determinants of adaptation behaviour. These findings highlight that adaptation decisions are not solely driven by the scale of economic loss but are more closely linked to the severity and diversity of damage across multiple crop types. Future research should explore additional factors, such as access to credit, government aid, and farmer experience, to better understand the drivers of adaptation behaviour.

Current Adaptation Strategies and their Limitations

Farmers in Kosovo primarily rely on traditional flood mitigation techniques, including the construction of drainage channels, crop rotation, and soil embankments, to manage water excess and minimize yield losses. However, while these methods provide some relief, they remain insufficient in the face of increasing climate variability, extreme precipitation events, and shifting hydrological patterns.

Traditional Flood Mitigation Strategies and Their Limitations

<u>Drainage Channels and Water Diversion Systems</u>

Many farmers have constructed open-field drainage ditches and canals to direct excess water away from cultivated land. While these systems can reduce short-term water stagnation, they are often as follows.

- Poorly maintained due to a lack of financial resources and technical expertise. Blockages caused by sediment accumulation or vegetative overgrowth reduce their effectiveness [15].
- Designed for historical flood levels and are not adapted to the increasing intensity and frequency of extreme weather events [3].
- Unsustainable for smallholder farmers, as maintenance costs can exceed their annual farm income, making these strategies less feasible without institutional support.

<u>Crop Rotation and Diversification</u>

Crop rotation is employed to maintain soil fertility and reduce pest outbreaks, particularly in flood-prone areas where water stress affects soil structure. However, its effectiveness in flood mitigation is limited because of the following.

- It does not directly address waterlogging and soil degradation, which remain major causes of yield loss [16].
- Many flood-prone regions lack access to flood-resistant seed varieties, reducing the resilience of rotational crops [17].
- The practice is dependent on market demand and financial viability, making it economically unsustainable when government subsidies and insurance mechanisms are absent.

<u>Soil Embankments and Traditional Irrigation Practices</u>

Soil embankments and bunding techniques are used to slow down surface runoff and retain soil nutrients. However, these methods are increasingly failing due to following.

- Intense rainfall exceeding embankment capacities, leading to structural collapse and erosion [18].
- The lack of hydrological planning and engineering expertise, which limits the scalability of these traditional solutions.
- High maintenance costs that burden smallholder farmers who already struggle with economic insecurity.

<u>Institutional and Policy Gaps</u>

Stakeholder interviews highlight critical gaps in Kosovo’s institutional and financial mechanisms for climate adaptation.

- Limited financial support: The absence of subsidized climate adaptation loans and lack of insurance schemes leave farmers financially vulnerable to extreme weather losses [14].

- Weak policy enforcement: Although Kosovo's Climate Action Framework includes provisions for disaster risk reduction (DRR), implementation remains inconsistent due to lack of coordination between government agencies and local municipalities [19].
- Technological lag: Farmers lack access to precision agriculture tools (e.g. remote sensing, automated irrigation, and AI-driven flood prediction), further limiting their adaptive capacity [20].

Recommended Resilience Strategies

A multi-faceted climate resilience strategy is required to transition from reactive flood mitigation measures to proactive adaptation. The following key interventions are proposed:

Climate-Smart Agriculture (CSA)

Climate-Smart Agriculture (CSA) integrates sustainable land use practices, technological innovations, and agroecological principles to enhance resilience against climate change [21]. Key CSA interventions include the following.

- Drought and flood-resistant crops: Adoption of submergence-tolerant rice (e.g. Swarna-Sub1), salt-tolerant wheat varieties, and deep-rooted leguminous crops can reduce yield losses in flood-affected areas [22; 23].
- Agroforestry systems: Integrating trees with crop production (e.g. silvopastoral systems) improves soil retention, mitigates runoff, enhances carbon sequestration, reducing climate risks.
- Conservation tillage and cover cropping: Minimum tillage methods improve soil structure and organic matter retention, making fields more resilient to extreme rainfall events [16].

Improved Irrigation and Water Management

Flood mitigation through water management is essential to reducing agricultural vulnerabilities. The most effective strategies include following.

- Retention basins and constructed wetlands: These systems help regulate floodwaters, store excess runoff, and improve groundwater recharge, reducing the intensity of flood damage [24; 25].
- Rainwater harvesting: Simple storage reservoirs and infiltration trenches allow farmers to capture and reuse excess water, minimizing post-flood water shortages [14].
- Precision irrigation technologies: Drip and sensor-based irrigation reduce water waste, ensuring optimal soil moisture levels in both drought and flood conditions [21].

Policy and Institutional Interventions

Strengthening policy frameworks and financial support mechanisms is essential to building long-term agricultural resilience. Key recommendations include following.

- Climate-Resilient Agriculture Policies: Governments should expand subsidies for CSA technologies, promote public-private partnerships for climate innovation, and enforce strict zoning laws to prevent farming in high-risk flood zones [19].
- Incentivizing Disaster Risk Reduction (DRR): Offering financial incentives to farmers adopting CSA practices, coupled with weather-indexed insurance schemes, can significantly reduce financial vulnerability [26; 27].
- Capacity-building initiatives: Establishing farmer training programs on flood-resilient agriculture and improving agro-climatic forecasting systems can enhance community preparedness [3].

Lessons from other countries offer useful parallels for Kosovo, for example, based on literature review Bangladesh has adopted community-based microfinance approaches to help farmers recover from climate-induced floods, which have shown both resilience and profitability [28]. Meanwhile, the Netherlands employs a multilayered flood management strategy, combining robust infrastructure with spatial planning and emergency preparedness [29; 30]. In contrast, countries in the Western Balkans still struggle with limited institutional capacity and fragmented disaster response mechanisms [8]. These cases highlight the importance of integrating both top-down planning and bottom-up support in designing flood-resilient agricultural systems.

Conclusions

Kosovo's agricultural sector faces severe threats from climate-induced flooding, exacerbating soil degradation, supply chain disruptions, and pest outbreaks. While farmers have implemented traditional adaptation methods, these strategies are no longer sufficient given the increasing unpredictability of extreme weather events. This study identifies critical gaps in financial support, policy implementation, and technological adoption, necessitating a comprehensive adaptation strategy. A multi-faceted approach – combining Climate-Smart Agriculture, enhanced water management, and robust policy frameworks – is essential for long-term agricultural resilience.

Future research should focus on:

- pilot programs to test climate-resilient farming techniques in flood-prone regions;
- economic feasibility studies to assess the cost-benefit ratio of CSA interventions;
- cross-sectoral collaborations between academia, policymakers, and agricultural stakeholders to develop a national flood adaptation plan.

By adopting an evidence-based, policy-driven approach, Kosovo can enhance agricultural sustainability and ensure food security in the face of climate change challenges.

Author contributions

Conceptualization, H.N., E.G. and N.K.; methodology, N.K. and E.G.; investigation, H.N. and N.K.; data curation, E.G., H.N.; writing – original draft preparation, N. K., H.N., E. G.; writing – review and editing, H.N.; visua–lization, H.N., E. G., N.K.; funding acquisition, H.N. and E.G. All authors have read and agreed to the published version of the manuscript.

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