EU4GREEN

REGIONAL CONFERENCE ON CLIMATE CHANGE ADAPTATION IN AGRICULTURE AND FORESTRY

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ABBREVIATIONS

ADA ....Austrian Development Agency
EU ....European Union
EU4Green / EU4Green……….EU 4 Green Recovery Initiative
IPA ....Instrument for Pre-accession Assistance
PES ....Payments for Ecosystem Services
SWG ....Standing Working Group (Regional Rural Development Standing Working Group)
UBA ....Umweltbundesamt GmbH (Environment Agency Austria)
WB ....Western Balkans

1. INTRODUCTION

This report summarizes the Regional Conference on Climate Change Adaptation in Agriculture and Forestry, held in Tirana, Albania, on 7–8 May 2026 under the EU4Green Recovery initiative: Support the Implementation of the Green Agenda for the Western Balkans. The conference was organized as a regional knowledge-exchange and policy-dialogue event focused on climate adaptation in agriculture, forestry and related land and water-management systems across the Western Balkans.

The event brought together representatives of Western Balkan economies, public institutions, experts, researchers, practitioners, forestry and agricultural stakeholders, development partners and regional organizations. It provided a platform for examining current and projected climate risks, sharing scientific and practical knowledge, discussing adaptation measures and identifying priorities for regional cooperation. In line with the reporting approach, this document focuses on the thematic content, key findings and policy-relevant results of the conference, while retaining only the essential contextual information needed to understand the event, its participants and its purpose.

The conference was framed by the Green Agenda for the Western Balkans and by the need to strengthen alignment between regional adaptation priorities and wider European climate and environmental policy objectives. Discussions focused on strengthening resilience in agriculture, forestry and rural landscapes, with particular attention to climate-risk assessment, soil health, agroforestry, adaptive forest management, economic aspects of adaptation, advisory systems, data and monitoring, financing and cooperation among Western Balkan economies.

2. CONFERENCE THEMES AND KEY FINDINGS

The conference confirmed that climate adaptation in the Western Balkans has become an urgent policy and development issue. Across the two-day programme, participants emphasized that agriculture and forestry are already affected by rising temperatures, water stress, more frequent extreme events and growing pressure on soils and forest ecosystems. The discussions consistently pointed to the need for integrated responses that connect agriculture, forestry, water management, disaster-risk reduction and environmental governance.

A strong message emerging from the conference was that adaptation cannot be treated as a series of isolated sectoral measures. Participants stressed the importance of preventive and landscape-based approaches, including sustainable soil management, adaptive forestry, agroforestry, improved water retention, stronger monitoring systems and better use of scientific data in planning. The economic sessions further underlined that adaptation should be understood as an investment that reduces long-term losses and supports more stable rural livelihoods.

The content presented in the following sections reflects these main findings in more detail. It summarizes the evidence and discussion on climate risks, soil health, agroforestry, governance, practical measures, economic dimensions and participant priorities for future action. Taken together, the conference results point to a clear regional agenda: stronger implementation capacity, better coordination, improved data and advisory systems, and sustained cooperation across Western Balkan economies.

The structure of the report follows the approach agreed: the main chapters provide concise thematic summaries and conclusions, while detailed speaker papers and supporting materials are placed in the annexes for further reference.

2.1. Climate change risks and projections in agriculture and forestry

This section presented the regional climate-risk context for agriculture and forestry in the Western Balkans, combining observed hazard trends, recent disaster experience and medium-term climate projections. It established the analytical basis for the report by showing how the region's geographic, ecological and socio-economic characteristics create high exposure to multiple and interacting climate hazards.

The session led by Professor Ivan Blinkov, underscored that the Western Balkans, compared to the EU average, have a significantly higher proportion of agricultural land and forested areas, which increases the strategic importance of climate-sensitive sectors for livelihoods, food security, territorial cohesion and overall socio-economic stability. This structural dependency on natural resources makes rural economies especially vulnerable to climate variability and extremes, while also reinforcing the need for robust adaptation strategies that integrate land use, ecosystem management and disaster risk reduction.

The regional hazard profile presented during the session showed that floods remain the most frequently recorded and historically most damaging type of natural disaster in the Western Balkans. However, the analysis also highlighted a clear and growing intensification of other hazard types, including droughts, wildfires, landslides, soil erosion and heat-related extremes. Importantly, the presentation underlined that these hazards are increasingly not isolated events, but interconnected processes that often occur in sequence or simultaneously, amplifying their overall impact on ecosystems, infrastructure and rural livelihoods.

To illustrate the magnitude of recent climate-related impacts, particular attention was given to the catastrophic 2014 flood events in Serbia and Bosnia and Herzegovina, which resulted in extensive damage to infrastructure, agriculture, settlements and economic assets across large parts of the region. In addition, the 2024 wildfire season was highlighted as a recent example of the increasing frequency, spatial extent and severity of fire events, demonstrating how prolonged heat and drought conditions are already reshaping risk patterns and placing additional pressure on forest ecosystems, emergency response systems and rural communities. These examples served to contextualize future risk projections within already visible and recurring patterns of climate-related damage.

The presentation then moved to forward-looking climate projections for the period 2046–2065, which indicate a consistent and significant shift in regional climate conditions. These projections suggest a marked decrease in frost and icing days, alongside a strong increase in the number of very hot days and a substantial extension of heatwave duration and intensity. Such changes are expected to be particularly pronounced in lower-altitude, inland, coastal and south-eastern parts of the region, where temperature extremes are already more frequent. At the same time, projections indicate an overall increase in the number of dry days, contributing to longer and more severe drought episodes, particularly during the summer season.

Precipitation patterns are expected to become increasingly variable and less predictable. While overall annual precipitation trends may vary by sub-region, a key feature highlighted in the presentation is the growing intensity of extreme precipitation events. This includes more frequent episodes of heavy and very heavy rainfall, which are expected to increase flash flood risks, accelerate soil erosion processes and contribute to higher incidence of landslides, particularly in mountainous and degraded areas. The combination of longer dry periods followed by intense rainfall events was identified as a particularly critical driver of hydrological instability and land degradation across the Western Balkans.

The implications of these projected climate changes for agriculture are substantial and multifaceted. The presentation highlighted expected reductions in crop yields due to heat stress, moisture deficits and increased evapotranspiration, as well as growing water scarcity during key growing periods. In addition, more frequent extreme weather events are expected to increase production volatility and economic uncertainty for farmers. Soil erosion, loss of soil fertility and degradation of arable land were identified as additional long-term risks, particularly in areas with steep terrain or unsustainable land management practices. The expansion and increased persistence of pests, diseases and plant pathogens under warmer conditions were also accentuated as a growing challenge for agricultural productivity and food security.

For the forestry sector, the presentation stressed that climate change is expected to significantly alter forest ecosystem dynamics, with increased exposure to heat and drought stress leading to declining forest vitality in vulnerable areas. Rising fire risk was identified as one of the most immediate and visible threats, with potential for large-scale and high-intensity wildfires becoming more frequent under prolonged dry and hot conditions. In addition, changes in temperature and precipitation regimes are expected to affect species composition, forest regeneration processes and overall biodiversity levels. These pressures may also reduce the capacity of forests to provide essential ecosystem services, including carbon sequestration, water regulation, soil protection and recreational value.

A particularly important message of the plenary session was that the scale of potential future damage in the absence of adequate adaptation measures is likely to increase significantly by mid-century. The presentation stressed that economic losses, environmental degradation and social impacts could rise substantially if current vulnerabilities are not addressed through systematic and proactive intervention. At the same time, it was underlined that well-designed adaptation strategies, including nature-based solutions and forest-based interventions, can generate substantial co-benefits across environmental, economic and social dimensions, contributing not only to risk reduction but also to sustainable development and rural resilience.

In this context, the plenary strongly reinforced the need for a shift from reactive disaster response towards preventive and risk-informed planning approaches. It highlighted the importance of strengthening climate data systems, improving risk modelling capacities and enhancing early warning mechanisms as essential components of effective adaptation policy. Furthermore, participants emphasized the necessity of integrating climate risk considerations into land-use planning, agricultural policy, forestry management and infrastructure development in a coherent and coordinated manner.

Overall, the session provided a comprehensive scientific and analytical foundation for the subsequent discussions of the conference, clearly demonstrating that climate risks in the Western Balkans are intensifying, becoming more complex and increasingly interlinked. It underscored that effective adaptation requires not only sectoral measures, but also systemic, cross-sectoral and long-term planning approaches aimed at strengthening the resilience of landscapes, ecosystems and rural economies.

For further reference, see Annex 1: Ivan Blinkov, *Climate Related Natural Hazards: Current Status, Future Trends and Prospections and Their Impacts*.

2.2. Soil health, agroforestry and forestry adaptation pathways

This section examined soil health, agroforestry and adaptive forest management as mutually reinforcing pathways for climate resilience in the Western Balkans. It brought together scientific evidence, policy perspectives and practical examples to show how sustainable soil management and integrated land-use systems can strengthen ecosystem resilience, support food security and reduce climate vulnerability across rural landscapes.

Dr Dragana Vidojević presented soil as a critical and finite natural resource that underpins food security, ecosystem stability and climate resilience. She reiterated that healthy soils—defined as soils in good chemical, biological and physical condition—are essential for maintaining agricultural productivity and supporting a broad range of ecosystem services. These services include water regulation, carbon sequestration and storage, nutrient cycling, biodiversity preservation and maintenance of overall landscape functionality. The presentation stressed that soils should not be viewed only as a production substrate, but as dynamic living systems that play a central role in environmental stability and climate resilience.

Attention was given to the role of healthy soils in the context of climate adaptation. The session highlighted that soils with strong biological activity and higher organic matter content are more capable of retaining water during prolonged drought periods and absorbing excess precipitation during intense rainfall events. As climate variability increases, these functions become critically important for reducing agricultural vulnerability, limiting flood impacts and maintaining stable productivity under increasingly unpredictable conditions. Healthy soils were therefore presented as one of the most important natural buffers against climate extremes and environmental degradation.

The presentation further highlighted that soil degradation represents a growing transboundary challenge throughout the Western Balkans. Processes such as erosion, land degradation, soil sealing associated with infrastructure development and urbanization, contamination and the progressive loss of soil organic carbon are already reducing the productive capacity and adaptive potential of agricultural systems in many parts of the region. These degradation trends are particularly pronounced in mountainous and semi-arid areas, where unsustainable land-use practices and increasing climate stress further accelerate soil instability and loss of fertility.

Climate change was identified as an important multiplier of these pressures. More frequent heavy rainfall events increase erosion intensity and nutrient runoff, while prolonged droughts contribute to soil compaction, reduced biological activity and loss of organic matter. Participants discussed how the combined effects of climate stress and unsustainable land management can create long-term cycles of degradation that become increasingly difficult and costly to reverse. This reinforced the urgency for stronger institutional attention to soil protection and the need for more systematic integration of soil health into climate adaptation and agricultural development policies.

A key message emerging from the session was that improving soil organic matter represents one of the most effective, accessible and economically feasible adaptation measures available for agriculture. Sustainable soil management practices—including conservation tillage, crop rotation, cover cropping, composting, organic matter enhancement and erosion prevention measures—can significantly strengthen soil structure, increase water retention capacity and improve resilience to both droughts and floods. Such measures also contribute to carbon sequestration, biodiversity enhancement and long-term productivity gains, creating multiple environmental and economic co-benefits.

However, despite these recognized benefits, implementation across the Western Balkans remains uneven and limited in scale. The discussion highlighted several structural barriers, including insufficient soil monitoring systems, weak integration of soil protection into national agricultural and environmental policies, fragmented institutional responsibilities and limited technical capacities within advisory and extension services. In many countries, participants noted that soil health is still not sufficiently prioritized within broader climate adaptation planning, despite its central importance for long-term resilience. This gap points to the need for stronger policy mainstreaming, clearer institutional mandates and more systematic support for practical soil-management measures.

The policy dimension of soil protection was also extensively addressed during the session. It was underlined that soil health is increasingly recognized at European Union level as a strategic component of climate, biodiversity and environmental policy. Frameworks such as the European Green Deal, the EU Soil Strategy for 2030 and the new Soil Monitoring Law aim to ensure that all soils reach a healthy condition by 2050 while supporting both climate adaptation and mitigation objectives across sectors. These policy initiatives place stronger emphasis on soil restoration, systematic monitoring and integration of soil considerations into agricultural, environmental and climate governance systems.

For the Western Balkans, these evolving EU frameworks were identified as particularly important reference points for future policy alignment and institutional strengthening. Participants discussed how approximation with EU environmental standards can support the development of more coherent national soil protection systems, improve monitoring methodologies and facilitate access to technical and financial support mechanisms linked to climate and environmental objectives.

Attention was given to regional cooperation through the Green Agenda for the Western Balkans and the emerging Soil Partnership platform, which brings together national experts and institutions to exchange knowledge, harmonize methodologies and promote sustainable soil management practices. This regional dimension was identified as essential for addressing shared environmental pressures and for developing coordinated approaches to common challenges such as erosion, watershed degradation and land-use pressures that affect multiple economies in the region.

Building on the discussion on soil resilience, agroforestry was further elaborated by Professor Nikolčo Velkovski as one of the most promising integrative adaptation pathways linking agriculture, forestry and climate resilience. Agroforestry systems—defined as the deliberate integration of trees and shrubs with crops and/or livestock—were presented as multifunctional land-use systems capable of delivering environmental, economic and social benefits simultaneously. Participants noted that many forms of agroforestry already exist throughout the Western Balkans in traditional agricultural landscapes, including silvopastoral systems, orchards combined with grazing, shelterbelts and hedgerows.

Despite their widespread presence, these systems remain insufficiently recognized within formal policy, statistical and support frameworks. The session highlighted that agroforestry is often not categorized as a distinct land-use type within national statistics, creating important data gaps that reduce its visibility in both agricultural and forestry policy development. This lack of recognition also constrains access to targeted support mechanisms, advisory services and investment incentives, thereby limiting the more systematic promotion of agroforestry as a climate adaptation approach.

Evidence presented during the session demonstrated that the land-use structure of the Western Balkans—characterized by large shares of agricultural land, pastures and forests—creates strong opportunities for expanding agroforestry systems. Such systems are particularly relevant in transitional and mosaic landscapes where agricultural and forest ecosystems are closely interconnected. Participants agreed that agroforestry can strengthen resilience not only at farm level, but also across wider landscapes by improving ecological connectivity and stabilizing environmental processes.

From a climate adaptation perspective, agroforestry provides numerous benefits, including improved soil protection, reduced erosion, enhanced water infiltration and retention, regulation of local microclimates and increased biodiversity. Trees integrated into agricultural systems can reduce wind exposure, moderate temperature extremes and improve moisture conditions for crops and livestock. Agroforestry systems were also recognized for their contribution to carbon sequestration and more efficient land use, while diversified production systems can improve economic resilience and reduce dependency on single-income agricultural activities.

The session further highlighted the multifunctional role of agroforestry within forestry landscapes. Agroforestry approaches can help stabilize degraded areas, improve management of forest edges and reduce pressure on natural forest ecosystems by providing alternative sources of biomass, fodder and income generation. Importantly, participants concluded that agroforestry should not be interpreted as a substitute for sustainable forest management or forest conservation, but rather as a complementary landscape-based adaptation approach that supports broader ecosystem resilience.

The discussion was further strengthened by a forestry adaptation perspective presented by Mr. Stephan Graeber from Environment Agency Austria. Drawing on Austrian experience, the presentation illustrated how forestry systems across Europe are increasingly exposed to intensifying climate pressures, including droughts, bark beetle outbreaks, storms and wildfires. This comparative perspective added practical value to the session by showing how adaptation responses in one context can provide useful lessons for strengthening resilience planning in another.

The Austrian examples demonstrated that forests already face substantial climate-related stress, with recent wildfire events, storm damage and forest decline highlighting the urgency of adaptation measures. Future projections presented during the session indicate hotter conditions, more severe droughts, shifting habitats and increased occurrence of extreme weather events. In response, Austrian adaptation strategies increasingly focus on forest conversion toward more resilient mixed-species forests, ensuring continuity of forest cover and supporting natural regeneration processes.

Attention was given to adaptive tree-species selection and assisted migration approaches. Austrian experiences showed how seed provenances from regions with climate conditions similar to projected future Austrian climates—including parts of the Balkans—are being considered to strengthen forest resilience. This example highlighted the importance of regional cooperation, scientific research and long-term planning in developing effective adaptation responses.

The Austrian presentation also introduced practical implementation tools such as dynamic forest classification systems, fire databases, forest monitoring systems and dedicated financing frameworks supporting adaptation and wildfire preparedness. These examples illustrated how adaptation requires not only technical measures, but also institutional coordination, research capacity, financial support and effective communication with practitioners and land managers.

A strong concluding message emerging from the combined discussions was that agriculture, forestry, soil systems and water management are deeply interconnected and therefore require holistic and landscape-based adaptation approaches. Participants agreed that climate adaptation in the Western Balkans cannot rely solely on isolated technical interventions, but must increasingly focus on integrated land management, stronger institutional coordination, evidence-based policymaking and long-term investment in ecosystem resilience.

Overall, the second plenary session demonstrated that soil health, agroforestry and adaptive forest management are mutually reinforcing pillars of climate resilience. By combining regional experience from the Western Balkans with practical examples from Austria, the session provided participants with both conceptual understanding and concrete implementation perspectives. It ultimately reinforced the importance of integrated adaptation pathways that connect soil protection, landscape management, forestry resilience and long-term institutional support in order to strengthen agricultural and forest systems under changing climate conditions.

For further reference, see Annex 2: Dragana Vidojević, *Managing Soil Health to Support Climate Change Adaptation*; Annex 3: Nikolčo Velkovski, *Agroforestry Systems in the Western Balkans (WB6) and Their Role as an Adaptation Pathway in Forestry*; and Annex 4: Stephan Graeber, *Challenges and measures in forest adaptation – Examples from Austria*.

In line with the agreed methodology, the Conference then continued with thematic group work designed to deepen the discussion and capture more focused policy and practice-oriented perspectives.

2.3. Policy and governance perspectives

The breakout group on policy and governance focused on the current state of climate adaptation policies in the Western Balkans and explored ways to strengthen institutional coordination, policy coherence and long-term implementation mechanisms. Participants exchanged experiences from different countries and institutions, noting that climate adaptation is increasingly recognized as a strategic priority at both national and regional levels. Adaptation objectives are gradually being incorporated into national development plans, agricultural and rural development strategies, environmental protection frameworks, forestry policies and water management plans. However, despite this progress, participants agreed that adaptation measures remain fragmented and are still too often implemented through isolated sectoral initiatives rather than through integrated and coordinated governance approaches.

A major point of discussion concerned the institutional and administrative barriers that continue to slow effective implementation. Participants noted that responsibilities for climate adaptation are frequently divided among multiple ministries, agencies and local authorities, often without sufficiently clear coordination mechanisms or communication channels. This fragmentation can produce overlapping mandates, inconsistent implementation of measures and difficulties in aligning priorities across agriculture, forestry, water management, biodiversity protection and rural development. In addition, many public institutions continue to face shortages of technical expertise and qualified staff capable of designing, implementing and monitoring adaptation measures, particularly at the local level where climate impacts are often most directly felt.

The group also identified limited financial resources as one of the key barriers to scaling up adaptation efforts. Participants stressed that while numerous strategic documents acknowledge the importance of climate resilience, dedicated financing mechanisms for adaptation remain insufficient. Access to international climate finance, EU funds and investment programs was recognized as important, but participants stressed the need for stronger national budgeting processes and better integration of adaptation priorities into public investment planning. Attention was given to the importance of ensuring that future agricultural, infrastructure and rural development investments are climate-resilient and aligned with long-term sustainability objectives.

Another important challenge discussed was the lack of harmonized monitoring systems, reliable datasets and coordinated information-sharing mechanisms across the region. Participants noted that climate-related data, risk assessments and vulnerability analyses are often collected using different methodologies, making regional comparison and coordinated planning more difficult. The discussion highlighted the need for interoperable information systems, stronger cooperation between scientific institutions and public authorities, and improved access to climate and environmental data for policymakers, farmers, local communities and other stakeholders. Strengthening early warning systems and improving the availability of localized climate information were also identified as priorities for enhancing preparedness and adaptive capacity.

The breakout group further stressed the importance of mainstreaming climate adaptation into broader economic development and investment frameworks rather than treating it as a separate environmental issue. Participants agreed that adaptation considerations should be systematically integrated into agricultural policies, land-use planning, infrastructure development, disaster risk reduction strategies and public procurement processes. In this context, stronger cross-sectoral cooperation and policy alignment were seen as essential for building long-term resilience and avoiding maladaptation.

Education, advisory services and capacity building were also recognized as critical components of successful adaptation governance. Participants prioritized the need to strengthen agricultural extension services, vocational education and research institutions in order to support farmers, local authorities and businesses in adopting climate-resilient practices and technologies. Greater involvement of universities, research centres and civil society organizations was considered important for improving awareness, knowledge transfer and innovation.

Finally, the discussion highlighted the value of regional cooperation and existing regional platforms for facilitating dialogue, exchange of good practices and technical collaboration among Western Balkan countries. Participants underlined that many climate-related challenges transcend national borders and therefore require coordinated regional responses. Enhanced cooperation in data sharing, joint research initiatives, policy learning and development of common methodologies was identified as an important pathway for strengthening adaptation governance and accelerating the transition toward more resilient and sustainable rural and environmental systems across the region.

2.4. Practical adaptation measures and field approaches

The second breakout group concentrated on practical implementation approaches and field-level solutions for strengthening climate resilience in agriculture and forestry across the Western Balkans. The discussion brought together representatives of public institutions, research organizations, agricultural experts and practitioners who exchanged experiences regarding the challenges and opportunities related to the application of adaptation measures on the ground. Participants underlined that, although awareness of climate risks is increasing, implementation of concrete adaptation practices remains uneven across the region and is often constrained by limited financial resources, insufficient institutional support, lack of technical expertise and varying levels of awareness among farmers, forest managers and local communities.

A significant part of the discussion focused on the importance of sustainable soil management as a foundation for long-term agricultural resilience. Participants agreed that healthy soils are essential for maintaining productivity under changing climate conditions, improving water retention, reducing erosion and increasing resistance to droughts and extreme weather events. Conservation tillage practices, reduced soil disturbance and the protection of soil cover were highlighted as important measures for preserving soil structure and moisture. Crop rotation and diversification were also identified as key tools for improving soil fertility, reducing pest and disease pressures and minimizing the vulnerability associated with monoculture production systems. In addition, the incorporation of organic matter through composting, manure application and cover crops was recognized as an effective way to enhance soil quality, carbon sequestration and overall ecosystem resilience.

Water management emerged as another major topic of discussion, particularly in light of increasingly frequent droughts, irregular precipitation patterns and growing pressure on water resources across the region. Participants stressed the need for integrated water management approaches that combine efficient irrigation systems, rainwater harvesting, improved drainage and landscape-level water retention measures. Nature-based solutions such as wetland restoration, retention ponds, buffer zones and improved watershed management were viewed as particularly important for reducing flood risks and maintaining water availability during dry periods. Participants noted that many rural areas still lack sufficient infrastructure and technical support for modern and efficient water management practices, highlighting the need for greater investment and institutional assistance.

The breakout group also examined adaptive forestry practices and the role of forests in strengthening ecosystem resilience and supporting climate adaptation. Discussions highlighted the increasing exposure of forests to droughts, wildfires, pests and disease outbreaks, all of which threaten biodiversity, ecosystem services and rural livelihoods. Participants recalled the importance of sustainable forest management approaches that promote species diversity, mixed forest stands, natural regeneration and improved monitoring systems. Strengthening forest resilience through better planning, risk assessment and restoration measures was considered essential for maintaining ecological stability and protecting vulnerable landscapes.

Agroforestry received particular attention as one of the most promising adaptation measures capable of delivering multiple environmental, economic and social benefits simultaneously. Participants highlighted that integrating trees into agricultural systems can improve soil stability, reduce erosion, regulate local microclimates, enhance carbon storage, support biodiversity and diversify farm production and income sources. Agroforestry systems were also recognized for their potential to improve water retention and reduce the negative impacts of heat stress on crops and livestock. Despite these advantages, participants noted that agroforestry remains insufficiently recognized and promoted within many national policy frameworks and agricultural support programs. Existing regulations, land-use policies and subsidy schemes in some countries were described as barriers to wider adoption, particularly where agricultural and forestry sectors continue to be managed separately without integrated planning approaches.

Throughout the discussion, participants repeatedly stressed the importance of bridging the gap between scientific research, practical implementation and policymaking. While a significant amount of technical knowledge and research already exists within the region, participants observed that this knowledge often does not reach farmers, local authorities and practitioners in a sufficiently accessible or practical form. Strengthening agricultural extension and advisory services was therefore identified as a major priority. Participants emphasized the need for more targeted training programs, demonstration sites, farmer-to-farmer learning initiatives and practical guidance tailored to local conditions and production systems.

The group also highlighted the value of regional cooperation and knowledge exchange in accelerating implementation of climate adaptation measures. Participants noted that many countries in the Western Balkans face similar environmental pressures and institutional challenges, making regional learning and collaboration highly beneficial. Sharing successful pilot initiatives, technical methodologies, research findings and policy experiences was seen as an important way to support innovation and avoid duplication of efforts. Greater cooperation between universities, research institutions, ministries, local governments and producer organizations was considered essential for creating more coordinated and effective adaptation systems across the region.

In conclusion, the breakout group agreed that practical adaptation in agriculture and forestry requires not only technical solutions, but also stronger institutional support, adequate financing, improved education and continuous collaboration among all stakeholders. Participants agreed that building resilient agricultural and forestry systems will depend on combining sustainable land management practices with stronger governance, knowledge transfer and long-term investment in climate-resilient rural development.

2.5. Economic perspectives on climate change adaptation

This section examined the economic dimensions of climate change adaptation in agriculture and forestry, emphasizing that climate change is not only an environmental challenge but also a major economic risk for production systems, value chains and rural livelihoods.

Professor Aleksandra Martinovska Stojčeska presented a structured analysis of how climate change is already reshaping the economic performance of agriculture. She emphasized that climate impacts are transmitted through three key channels: reduced biological productivity, increased input requirements and greater uncertainty in production systems. These combined pressures lead to lower yields, higher production costs and increased income volatility for farmers.

At the global level, agriculture absorbs a significant share of economic damages from climate-related disasters, estimated at approximately 26% of total losses. In addition, long-term productivity impacts are already evident, with climate change contributing to a decline in agricultural productivity over recent decades. Projections suggest that future warming will further reduce food availability and intensify pressure on food systems.

The presentation highlighted that climate impacts extend beyond farms and propagate through the entire food system. Disruptions in production can lead to cascading effects along value chains, including higher operating costs, damage to infrastructure and assets, increased transaction costs and negative impacts on livelihoods and food security. This broader perspective underscores the need to assess climate impacts not only at farm level but across the entire agri-food system.

A key message of the session is that adaptation should be understood as an economic investment in risk reduction rather than solely an environmental response. Evidence shows that adaptation measures can generate multiple benefits, including avoided losses, improved productivity and greater income stability. Empirical studies demonstrate that adaptation can increase farm revenues and reduce vulnerability to climate shocks, while also stabilizing income streams over time.

At a broader scale, adaptation investments often show strong economic returns, with benefit–cost ratios typically ranging from 2:1 to 10:1. However, adaptation does not eliminate all risks, and residual impacts remain unavoidable. Studies indicate that adaptation can offset approximately 20–50% of potential damages, depending on the context and level of investment.

The session also emphasized that adaptation involves upfront costs, while most benefits accrue over time. This requires a long-term perspective in policy planning and investment decisions. The economic value of adaptation therefore lies not only in productivity gains but also in reducing risks, stabilizing incomes and preventing large losses during extreme events.

Despite the clear economic rationale for adaptation, implementation remains constrained by several barriers. These include limited access to finance, insufficient institutional capacity, lack of data and information systems, and weak integration of adaptation into broader development strategies. In addition, there are limits to adaptation, implying that not all climate impacts can be avoided and that prioritization of measures is essential.

In addition to agricultural systems, the session also addressed the economic implications of climate change for the forestry sector. Professor Leonidha Peri highlighted that forestry in the Western Balkans represents a structurally important yet economically undervalued sector, providing both market and non-market benefits, including timber, bioenergy, carbon sequestration, biodiversity conservation and watershed protection.

Climate change is increasingly affecting forest ecosystems through rising temperatures, changing precipitation patterns and more frequent extreme events. These impacts translate into economic losses through reduced timber productivity, increased disturbance risks such as wildfires, pests and diseases, and higher management costs.

The session emphasized that climate-induced disturbances represent a major economic risk for forestry. At European level, disturbance-related losses are projected to increase significantly, with potential reductions in timber value of up to 40% under severe climate scenarios. In the Western Balkans, these risks are particularly pronounced due to the combination of high forest cover and relatively low economic productivity, making the sector both vulnerable and underutilized.

Wildfires were identified as a key driver of economic losses. Recent data show that large areas of forest land are affected annually, with direct damage costs ranging from several hundred to several thousand euros per hectare. Climate change also contributes to drought-induced productivity losses and the spread of pests, which further reduce forest growth and economic returns.

A central message of the presentation is that adaptation in forestry is strongly economically justified. Preventive measures—such as fuel management, monitoring systems and improved forest planning—are significantly less costly than reactive responses such as fire suppression and post-disaster recovery. Evidence indicates that preventive investments can generate returns several times higher than their initial costs, highlighting the economic efficiency of proactive approaches.

However, despite the clear economic case, adaptation in the forestry sector faces substantial barriers. The region is characterized by limited financial incentives, weak integration of ecosystem services into economic systems and insufficient participation in carbon markets. As a result, forest owners often rely primarily on timber revenues, which discourages investment in broader adaptation measures.

The presentation concluded that strengthening the economic role of forestry requires improved policy frameworks, better valuation of ecosystem services and stronger integration with EU climate policies. Forests should be understood not only as ecological assets but also as strategic components of climate risk management and sustainable economic development.

The session concluded that effective climate adaptation requires a balanced approach combining short-term, low-regret actions with longer-term structural changes. Priority should be given to measures that reduce risks, enhance resilience and deliver economic benefits over time, while strengthening enabling conditions such as knowledge systems, financial instruments and governance frameworks.

For further reference, see Annex 5: Aleksandra Martinovska Stojčeska, *Economic Perspectives on Climate Change Adaptation in Agriculture*; and Annex 6: Leonidha Peri, *Economic Perspectives on Climate Change Adaptation in Forestry*.

2.6. From climate hazards to adaptation measures

This section focused on how climate-risk assessment, data-driven planning and land-management approaches can be translated into concrete adaptation measures for agriculture and forestry in the Western Balkans. It highlighted the need for increasingly detailed risk analysis and long-term management strategies in response to intensifying environmental pressures across the region.

The session opened with a presentation by Professor Ordan Čukaliev, who introduced a comprehensive framework for understanding the relationship between climate hazards, exposure, vulnerability and overall risk. His presentation explained how climate impacts are not determined solely by the occurrence of extreme events themselves, but by the interaction between environmental pressures, the sensitivity of ecosystems and production systems, and the capacity of institutions and communities to respond. Through practical examples and conceptual models, he demonstrated how droughts, heatwaves, floods, storms, erosion processes and biological threats such as pests and diseases increasingly interact to create complex and cumulative risks for agriculture, forestry and rural areas.

Attention was given to the growing frequency and intensity of droughts and heatwaves, which are already reducing agricultural productivity, weakening forest ecosystems and increasing pressure on water resources throughout the region. Flood risks were also highlighted as a major concern, especially in areas characterized by degraded landscapes, unsustainable land management and insufficient water retention infrastructure. In addition, the presentation addressed biological risks linked to climate change, including the spread of invasive species, plant diseases, forest pests and ecosystem imbalances that can significantly affect biodiversity and food production systems.

Professor Čukaliev stressed that effective adaptation requires a systematic and science-based approach supported by reliable climate data, vulnerability assessments, predictive modelling tools and operational early warning systems. He underlined that many adaptation measures fail or remain ineffective because they are implemented without sufficiently detailed understanding of local risk dynamics and ecosystem interactions. According to his presentation, improving climate resilience therefore depends on strengthening monitoring capacities, expanding meteorological and hydrological observation systems and improving access to localized climate projections that can support planning and decision-making at both national and local levels.

The presentation further underlined the importance of integrating risk assessments into agricultural planning, forestry management, infrastructure investments and disaster risk reduction strategies. Participants discussed how climate-related risks should increasingly be incorporated into land-use planning, water management policies and public investment frameworks in order to avoid maladaptation and reduce long-term economic losses. Early warning systems for droughts, floods, fires and pest outbreaks were identified as particularly important tools for improving preparedness and reducing vulnerability among farmers, forest managers and local communities.

The second major presentation was delivered by Professor Nenad Petrović, who provided a comprehensive forestry perspective focused on transforming climate-related risks into long-term management and restoration solutions. His presentation showed that forests throughout the Western Balkans are becoming increasingly vulnerable to climate change due to rising temperatures, prolonged drought periods, changing precipitation patterns and more frequent extreme weather events. He noted that these pressures are accelerating forest degradation processes and contributing to a growing number of wildfires, forest dieback episodes, pest outbreaks, erosion and landslides.

Professor Petrović argued that traditional reactive approaches to forest protection are no longer sufficient under rapidly changing climate conditions. Instead, he emphasized the need for preventive, ecosystem-based and risk-reducing management strategies that are integrated into long-term forest planning and governance systems. According to his presentation, adaptation should focus not only on responding to disasters after they occur, but on strengthening the resilience and regenerative capacity of forest ecosystems before major disturbances emerge.

A central part of the discussion focused on adaptive forest management and close-to-nature forestry approaches. Participants explored management models that prioritize mixed-species forests, natural regeneration processes and structural diversity as ways to increase ecosystem stability and reduce vulnerability to climate stress. Avoidance of large clear-cuts was highlighted as particularly important for maintaining soil stability, protecting biodiversity and preserving water regulation functions within forest landscapes. Greater reliance on ecological processes, selective harvesting methods and landscape-level planning was presented as a more sustainable alternative to intensive and simplified forestry practices that may increase long-term risks.

Afforestation and restoration measures were also extensively discussed as important adaptation and mitigation tools. Professor Petrović emphasized the potential for afforestation on suitable degraded or marginal agricultural land, particularly in areas affected by erosion, declining productivity or depopulation. Reforestation and restoration of degraded forest ecosystems were described not only as environmental measures, but also as investments in long-term landscape resilience, carbon sequestration, water retention and disaster prevention. Participants noted that properly designed afforestation initiatives can contribute simultaneously to climate adaptation, biodiversity conservation and rural development objectives.

The plenary session additionally addressed several structural and institutional challenges that continue to limit the implementation of science-based adaptation approaches across the region. Participants repeatedly highlighted the lack of consistent long-term environmental datasets, insufficient climate modelling capacity and limited technical infrastructure available to public institutions and research organizations. In many countries, monitoring systems remain fragmented, while cooperation between scientific institutions, forestry agencies, meteorological services and policymakers is often insufficiently coordinated. Limited staffing, inadequate financial support for research and weak institutional capacities were identified as major barriers to more effective adaptation planning and implementation.

Despite these challenges, the session also highlighted significant opportunities for strengthened regional cooperation. Participants agreed that many climate-related risks affecting forests and agricultural landscapes transcend national borders and therefore require collaborative responses at the regional level. Areas identified for enhanced cooperation included joint afforestation initiatives, development of common methodologies for risk assessment and monitoring, regional training programs for practitioners and public institutions, and stronger exchange of scientific knowledge, technical expertise and good practices.

The discussion further emphasized the importance of developing innovative financing mechanisms capable of supporting long-term adaptation investments. Participants noted that adaptation in forestry and land management often requires substantial upfront investment while generating benefits over longer timeframes. Improved access to international climate finance, EU support instruments and regional funding initiatives was therefore seen as essential for scaling up restoration, afforestation and ecosystem-based adaptation measures across the Western Balkans.

In concluding remarks, participants agreed that climate adaptation in agriculture and forestry must increasingly move beyond short-term or isolated interventions toward integrated, ecosystem-based and science-driven management approaches. The final plenary session reinforced the understanding that building long-term resilience will require stronger cooperation between science, policy and practice, combined with sustained investment in institutional capacity, regional collaboration and nature-based solutions capable of addressing the growing complexity of climate risks in the region.

For further reference, see Annex 7: Ordan Chukaliev, *From Climate Hazards to Adaptation Measures in Agriculture*; and Annex 8: Nenad Petrović, *From Climate Hazards to Adaptation Measures in Forestry*.

2.7. Participant insights from the interactive poll

The interactive Mentimeter session was designed to move the discussion from diagnosis toward action by asking participants to reflect on what is already working in the Western Balkans, what should be prioritized over the next three years, which barriers continue to slow adaptation uptake, and where regional cooperation could generate the greatest added value. This format helped capture immediate perceptions from participants while complementing the more detailed discussions held during the plenary and breakout sessions.

The polling structure covered perceptions of climate hazards, preparedness levels, adaptation practices already delivering results, urgent policy needs, major trade-offs, and concrete opportunities for regional action. The responses confirmed a strong shared awareness of the urgency of climate adaptation across the region. Wildfires, droughts, floods and heatwaves were consistently identified as the most damaging hazards, while forest management measures, advisory services, water retention, climate-resilient agricultural systems, soil-health practices and agroforestry were seen as approaches with particularly high adaptation potential.

Participants assessed current preparedness levels in both agriculture and forestry as only moderate or low, pointing to a clear gap between awareness and implementation capacity. They also stressed that the most urgent barriers remain limited finance, weak advisory support, insufficient climate data and forecasting, fragmented coordination and limited political prioritization. At the same time, the interactive exercise highlighted strong support for practical regional cooperation through shared climate and weather data systems, early warning systems, advisory and training networks, joint research and innovation, demonstration farms and living labs, stronger fire-prevention cooperation and closer policy alignment with EU frameworks.

2.8. Key messages from the interactive poll

Several messages emerged clearly from the poll. First, participants see adaptation as inseparable from resilience, risk management and institutional capacity building, which suggests that climate adaptation is already understood as a cross-cutting development issue rather than a narrow environmental topic.

Second, the strongest priorities for the coming period relate to water management and drought preparedness, stronger farmer and forest-manager support systems, improved climate data and forecasting, and broader investment in prevention rather than compensation.

Third, participants recognized that many adaptation measures involve policy trade-offs, especially between productivity and biodiversity, irrigation expansion and sustainable water use, and short-term priorities versus long-term resilience.

These findings reinforce the need for integrated planning and more transparent policy choices. Finally, the poll confirmed broad interest in concrete regional initiatives that could realistically be advanced within the next two to three years, including common climate-information systems, regional training and advisory networks, exchange of practical solutions, joint research, pilot and demonstration activities, and cooperative approaches to wildfire prevention and response.

Taken together, the two conference days provided a comprehensive overview of environmental, economic and institutional dimensions of climate adaptation in agriculture and forestry. Day 1 focused primarily on climate risks, soil health, agroforestry and governance, while Day 2 deepened the discussion through economic analysis and practice-oriented adaptation approaches. Across all sessions, participants consistently stressed that the main barriers to implementation remain linked to financing, institutional capacity, weak data systems and limited coordination. At the same time, the conference confirmed strong regional interest in integrated solutions, preventive action and closer cooperation across sectors and economies.

3. CONCLUSIONS

The Conference clearly demonstrated that climate change is already exerting significant and widening impacts on agriculture and forestry in the Western Balkans, affecting productivity, increasing risk exposure and generating growing economic pressures. Both sectors are highly vulnerable because of their strong dependence on climate-sensitive natural resources, which makes adaptation not a secondary environmental consideration, but a strategic requirement for sustainable development, rural stability and long-term economic resilience in the region. A central message emerging from the discussions was that climate adaptation should not be approached solely as an environmental obligation. Rather, it should be understood as a strategic investment and a risk-management framework capable of reducing losses, protecting livelihoods and strengthening the resilience of production systems and ecosystems. Evidence presented during the Conference confirmed that well-designed adaptation measures can generate substantial benefits through avoided damages, improved productivity and more stable long-term outcomes.

The event also highlighted the importance of integrated approaches that connect agriculture and forestry within broader landscape-management systems. Agroforestry, nature-based solutions and close-to-nature forest management were identified as particularly effective approaches because they can simultaneously address soil degradation, water management, biodiversity conservation, climate mitigation and adaptation needs. At the same time, participants repeatedly pointed to persistent regional gaps, including insufficient data and monitoring systems, weak institutional coordination, limited financial resources and inadequate technical capacity for implementation. These findings indicate that stronger policy frameworks, improved governance arrangements and more robust support mechanisms are required in order to move from strategic recognition to practical action.

Another important conclusion is the need to shift from reactive to preventive approaches. Current systems still tend to focus on responding to climate impacts after they occur, rather than reducing risks in advance. Strengthening preventive measures such as improved land management, early warning systems, afforestation and adaptive forest management can significantly reduce long-term costs and improve resilience. Regional cooperation was identified as a key enabling factor, since many challenges faced by Western Balkan economies are shared and can be addressed more effectively through joint knowledge exchange, coordinated solutions and more efficient use of resources. Participants underlined the importance of strengthening research, advisory services, training systems and pilot initiatives that can support implementation at local level.

Finally, the Conference confirmed that effective climate adaptation requires a sustained combination of policy, science and practice. While substantial knowledge, experience and technical understanding already exist across the region, the central challenge now lies in implementation and scaling. Addressing this challenge will require not only financial investment, but also stronger institutional capacities, broader stakeholder engagement and long-term political commitment. Overall, the event provided a solid foundation for continued regional work on climate adaptation in agriculture and forestry and reinforced the importance of timely, preventive and coordinated action for ensuring resilience, sustainability and economic stability in the Western Balkans.

Building on the discussions across all sessions, several policy implications emerge for advancing climate change adaptation in agriculture and forestry in the Western Balkans. Together, these implications translate the main findings of the Conference into a more action-oriented framework for policymakers, institutions, practitioners and regional partners. They highlight the need to combine investment, governance reform, knowledge systems, advisory support and regional cooperation in order to strengthen implementation and scale up adaptation responses across the region.

1. Treat adaptation as a strategic investment, not a cost

A central conclusion of the Conference is that adaptation should be understood as an economic investment in risk reduction and resilience. While adaptation requires upfront financial resources, its benefits—particularly in terms of avoided damages, stabilized incomes and reduced vulnerability—justify these investments over the long term. This perspective is essential for aligning national policies with EU climate and development frameworks.

2. Strengthen integrated and cross-sectoral approaches

Climate risks affect agriculture, forestry and water systems simultaneously. Effective adaptation therefore requires integrated approaches that connect these sectors at policy and implementation levels. Nature-based solutions, agroforestry systems and sustainable soil management practices provide practical entry points for such integration.

3. Improve data, monitoring and knowledge systems

A consistent message across sessions is the lack of reliable and harmonized data, particularly in areas such as soil health, agroforestry and climate risk assessment. Strengthening monitoring systems, investing in data infrastructure and improving access to climate information are critical for evidence-based decision-making.

4. Enhance advisory systems and capacity building

The gap between available knowledge and implementation capacity remains a major barrier. Strengthening advisory services, farmer training, extension systems and research–practice linkages is essential to support the adoption of adaptation measures at local level.

5. Increase and diversify financing mechanisms

Limited access to finance remains one of the key constraints to adaptation. Public funding, EU instruments and private-sector engagement need to be mobilized and better coordinated. Innovative financial instruments, including risk-sharing mechanisms, insurance schemes and targeted subsidies, can support investment in adaptation measures.

6. Promote regional cooperation and knowledge exchange

Given the shared challenges across the Western Balkans, regional cooperation offers significant opportunities for improving efficiency and impact. Joint initiatives in data sharing, training, research, early warning systems and pilot projects can accelerate progress and reduce duplication of efforts.

7. Prioritize implementation and scaling of proven solutions

While many adaptation measures are already known, their implementation remains limited. Policy focus should shift from awareness-raising towards scaling up practical solutions, including soil management practices, water retention systems, agroforestry approaches and adaptive forest management.

8. Strengthen the economic role of forestry in climate adaptation

Forestry should be recognized as a strategic sector for climate adaptation, not only for its environmental functions but also for its economic potential. Policies should aim to increase productivity, improve forest management and enhance the resilience of forest ecosystems to climate risks.

9. Develop economic instruments for ecosystem services

There is a strong need to introduce and expand economic instruments such as payments for ecosystem services (PES), carbon pricing mechanisms and incentive schemes for forest owners. These tools can help internalize the value of non-market forest benefits and make adaptation measures economically viable.

10. Shift from reactive to preventive forest management

Current forest management systems in the Western Balkans are still largely reactive, particularly in relation to wildfire management. Policies should prioritize preventive approaches, including fuel management, landscape planning and early warning systems, which are significantly more cost-effective than post-disaster responses.

11. Promote close-to-nature forest management

Forest policies should prioritize the transition from conventional management practices towards close-to-nature approaches that enhance resilience, biodiversity and long-term productivity. These systems provide a cost-effective and sustainable response to increasing climate risks.

12. Develop afforestation strategies based on climate projections

Afforestation programs should be expanded, particularly on low-productivity agricultural land, but must be based on sound scientific evidence. This includes climate-adapted tree species selection, site-specific planning and long-term monitoring systems.

13. Invest in research, modelling and knowledge transfer in forestry

Significant gaps remain in understanding how forest ecosystems will respond to future climate conditions. Investments in research, modelling tools and simulation systems are required, alongside stronger training programs, demonstration sites and knowledge-exchange platforms.

4. Annexes

The annexes contain the detailed speaker papers and supporting materials referenced in the main body of the report. They are included to provide further technical background while keeping the main report focused on thematic summaries, findings and conclusions.

Annex 1: Climate-related natural hazards: current status, future trends, projections and impacts

Author: Prof. Dr. Ivan Blinkov
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Climate-related natural hazards are extreme weather and environmental events, and climate changes would significantly amplify their frequency and intensity. If there are vulnerable human communities, infrastructure, or ecosystems, these hazards could become disasters.

By their onset and duration climate related hazards could be acute and chronic. According to the related factor, there are 4 categories: temperature related, wind related, water related and solid mass related. For the territory of WBCs, the following hazards are the most relevant:

- Acute - Temperature related (heat wave, cold wave frost, wildfire); Wind related (changing wind patterns), Water related (drought, heavy precipitations, various floods); Solid mass related (landslide, avalanche).
- Chronic - Temperature related (changing temperature, temperature variability, heat stress); Wind related (storm), Water related (water stress, changing precipitations patterns and type, hydrological variability, see level rise); Solid mass related (soil erosion, other soil degradation).

In total, WBCs cover 207993 km^2 and around 17 million people live there.

Dinaric Alps and Shara-Pindus massif are between the most rugged and extensively mountainous area of Europe. Lithological structure is highly heterogenous. Greate part of region consist of carbonate rocks (in BIH even 70%, Montenegro 66%...) Silicate rocks are dominant in Serbia, North Macedonia. Soil pattern is highly heterogenous too but dominate automorphic soils, while hydromorphic soil an halomorphic soil occurs in an insignificant percentage (Blinkov et al., 2022).

Hydrographically, Western Balkans countries belong to 3 basins as follow:

- Black Sea basin (Serbia, Kosovo, Bosnia and Herzegovina, Montenegro, North Macedonia),
- Adriatic Sea basin (Bosnia and Herzegovina, Montenegro, Albania, Kosovo, North Macedonia) and
- Aegean Sea basin (North Macedonia, Serbia, Kosovo).

With a specific annual runoff of 44 l/sec. km^2, Montenegro has the highest runoff, followed by Albania with more than 30 l/sec.km^2, BiH-23.4 l/sec.km^2, North Macedonia-7.8 l/sec.km^2, Kosovo-11 l/sec.km^2 and Serbia-5.7 l/sec.km^2. For example, Serbia has just 1,500 m^3 of water per capita yearly, compared to Montenegro, which has more than 30,000 m^3 of water per capita yearly. (Dragovic et al., 2017)

The WBC experiences a range of climates in accordance with of the size of their geographic area. Albania has a Mediterranean climate with mild, wet winters and hot, dry summers, as occurs with the southern part of Montenegro and the coastal and lowland areas of Bosnia and Herzegovina. The climate in the remaining areas of Bosnia and Herzegovina ranges from temperate continental to alpine. The far north of Montenegro has a continental climate, and the central and northern parts have some characteristics of mountain climate, but with Mediterranean Sea influences on temperature and precipitation. The climate of Serbia varies from temperate continental in most areas, to continental in the mountains and warm continental in the south-west. The climate in North Macedonia varies from sub-Mediterranean, moderate continental/sub-Mediterranean to continental and alpine on the highest mountain (Blinkov et al., 2022 ibid)

Compared to EU27, the Western Balkan Countries have higher

- Percent of agricultural land (44% vs 36.9%)
- Percent of forests (40,5% vs 37,8%) and forest (ha) per capita (0,47 vs 0,35).

According to the latest available data by World Bank for 2025, the estimated share of GDP for agriculture and forestry in the region is: Albania: ~23% (highest in WBC) Kosovo: ~7.5% – 10%. Montenegro: ~3.43% – 5.5%. Serbia: ~6%. North Macedonia: ~5.97% – 7.6%. Bosnia and Herzegovina: ~4.25%.

Within the database of EmDat in the period 2000-2026 are recorded 141 disastrous events, out of them 72 flood events and floods (riverine or torrent) are the most disastrous hazard in all countries in the WB.

The 2014 cataclysmic floods caused losses and damages in Serbia 1,5-2.0 billion Euros out of them 228 ME in agriculture In Bosna and Hercegovina the losses and damages were 1,3 billion euros (255 ME in agriculture) plus 86 victims. (May et al., 2022)

Although only 5 wildfire events are recorded in EmDat database, wildfires cause permanent losses and damages.

The 2024 was perhaps the worsen in the newest history, when 265231 ha forests and other land were burned. (EC – JRC, 2025).

The Western Balkan countries cover 207,787 km2 or 3.5% of the territory of Europe. The mean annual erosion intensity in the Western Balkans is 7.03 t/ha and varies from 2.7 (Kosovo) up to 18.7 t/ha (Albania). The total annual soil losses are $143.5x10^6$ t. Therefore, 7.7% of the total annual soil losses in Europe occur in the Western Balkans and the average erosion intensity in the Western Balkans is 2.42 times higher than the European average. (Blinkov., 2015).

According to the DRMKC., Inform risk index for the year 2006 for 5 WBCs is low, except for Bosnia and Hercegovina that is medium.

Future change of climate indices and indicators for the period 2046 -2065 vs baseline 1986-2005 according to Vukovic and Vujadinovic-Mandic (2018) will be:

- significant decrease of frost days throughout the whole region by 10-20 days according to RCP4.5 and 20-30 days according to RCP8.5 scenario in major part of the region;

- significant decrease of icing days throughout the whole region by 5-10 and 10-20 days according to RCP4.5 and RCP8.5 respectively;
- significant increase of very hot days in parts of lower altitudes (10-20 days), but most pronounced in coastal and near coastal areas and central to south-eastern part of North Macedonia (20-30 days);
- duration and frequency of heat waves appearance have significant increase over the low altitudes, coastal and near coastal areas and parts of North Macedonia, reaching values of +1 heat wave each year and with increased duration over 5 days or more;
- increase of dry days is 5-10 days over a major part of the territory, with significant change in southern parts (within Albania and North Macedonia); the change is most pronounced during JJA;
- change of annual sum of precipitations in major part of the area within the interval from -5% to +5% in favour of precipitation increase, and in some parts of up to about 10% increase. Albania and western parts of North Macedonia show decrease
- number of days with very heavy precipitation shows noticeable increase throughout the region, significant over the north parts of Serbia (Vojvodina), while in regions which already have large number of such days the increase is much lesser relative to the present values;
- very heavy rain percentage has most increase over the region where these events are not common (north Bosnia and Herzegovina, Serbia, Kosovo, parts of North Macedonia), even of around 30% during DJF and MAM, while during JJA the decrease is seen over the southern part of the region increase in Vojvodina becomes significant;

Situation for end of the century will be worsened.

These conditions will increase floods, landslides, erosion, drought, wildfires, coastal hazards. Heavy rainstorms are projected to become more common and more intense due to higher temperatures, with flash floods expected to become more frequent across Europe. In some regions, certain risks such as early spring floods could decrease in the short term with less winter snowfall, but the increased risk of flash flooding in mountain areas overloading the river system may offset those effects in the medium term. (EEA., 2025).

The Fire Weather Index (FWI) in Europe shows a clear, long-term trend toward higher fire danger, characterized by longer, more intense fire seasons and expanding geographical risk. Driven by rising temperatures and decreased humidity, the area at risk of extreme fire weather has doubled since 1971, with 2025 seeing high burn areas and permanent increase in the future period up to the end of the century (Hetzer et al., 2026).

There is a global increasing trend in soil erosion towards the end of the 21st century, with the highest increase projected in semi-arid regions (Eekhut and de Vente., 2022).

Around 30% of agricultural land and 45% of total land in the Western Balkans are affected by soil erosion, though there is limited official data and no comprehensive monitoring system in place (Zdruli *et al.*, 2022)

Climate change poses a critical threat to agriculture in the Western Balkans, driving reduced yields, water scarcity, and increased frequency of extreme weather events. Key impacts include intensified summer droughts, late spring frosts, increased soil erosion, and the emergence of new pests and pathogens, directly threatening food security and regional livelihoods Climate change impacts exacerbate existing weaknesses in agriculture sectors in the Western Balkans, posing a threat to food security and economies. Climate change in the Western Balkans is causing severe stress on forests through increased heatwaves, prolonged droughts, and higher temperatures, leading to accelerated tree mortality and reduced biodiversity. Rising temperatures are driving the intrusion of subtropical climates northward, - significantly increasing forest fire risks, defoliation, and disease, particularly in southern and coastal areas. The nature of climate change can cause the following: - Uncertainty in forest management; - Global changes: nitrogen deposition, socio-economic, market trends, LCU changes; - Impact on other forest values – NWFP, wildlife habitats, biodiversity. (WBG., 2024).

The extent of future economic losses will depend both on the action taken to mitigate climate impacts, to implement climate adaptation actions and to increase the resilience of exposed assets. Without investments in climate adaptation, the annual expected damages in WBCs are estimated to rise to 8.9% of GDP in the year 2050 (lower bound estimate) under RCP 4.5. (EC., 2025).

Generally, strategies to combat climate-related hazards requires two approaches: mitigation (reducing greenhouse gas emissions to slow climate change) and adaptation (building resilience to withstand unavoidable extreme weather, floods, droughts, heatwaves etc.).

The undiscounted costs (expressed in US 2020 dollars) of proposed policy actions and investments for adaptation in the WB6 countries include US$37 billion, out of them, US$6.0 billion (Albania), US$6.8 billion (Bosnia and Herzegovina), US$2.8 billion (Kosovo), US$5.7 billion (Montenegro), US$6.4 billion (North Macedonia), and US$9.5 billion (Serbia). (European Commission: Directorate General for Climate Action., 2025).

Forest based solutions are recognized as a critical, cost-effective, and scalable approach to mitigating climate change and deliver environmental and social benefits (Ray et al., 2024).

An excellent example of forest-based solution are erosion and torrent control works and suitable forest management that convert harmful barelands with high erosion processes and frequent torrent flood on Vodno Mt. in Skopje into huge green space and high protective area from erosion and torrent floods (Blinkov I., 2021)

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Annex 2: Managing soil health to support climate change adaptation

Author: Dr Dragana Vidojević, Soil Expert

Soil is a limited natural resource, and its availability is decreasing. Although the Western Balkan region is characterized by some of the most fertile soils in Europe, soil is finite and its capacity to support biomass production, ecosystem functions and ecosystem services is under growing pressure. Soil degradation represents a transboundary issue requiring responsible engagement by all stakeholders to ensure sustainable soil management and support achievement of the 2030 Agenda for Sustainable Development. Initial assessments of soil degradation status and trends in the region indicate that the main degradation processes in the Western Balkans include land take, soil sealing, contamination, organic carbon loss and erosion.

Healthy soils are soils in good chemical, biological and physical condition that can provide ecosystem services vital to people and the environment, including safe and sufficient food, biomass, clean water, nutrient cycling, carbon storage and habitats for biodiversity. Healthy soils are more resilient and better adapted to climate change. Managing soil health is therefore a critical foundation for climate change adaptation, as healthy soils enhance water retention, reduce vulnerability to droughts and floods, and sustain ecosystem productivity under increasing climate variability.

Healthy soils are essential for agricultural productivity, plant pest resistance and food quality and safety. They are also critical to the long-term viability and profitability of the farming sector. The European Green Deal, Farm to Fork Strategy, EU Biodiversity Strategy for 2030, EU Climate Adaptation Strategy and EU Soil Strategy for 2030 have all elevated soil health within the EU policy agenda. These frameworks recognize soil as a key asset for environmental sustainability, food security and climate resilience, and as an important solution for both climate change mitigation and adaptation.

One of the key priority actions relevant for the Western Balkans is to enhance biodiversity in agricultural soils in order to increase soil organic carbon. This is particularly important for mineral soils, which dominate the region’s agricultural landscapes and are increasingly affected by degradation processes, including loss of fertility and reduced carbon sequestration capacity. Improving soil organic matter through sustainable land management strengthens soil structure, water retention and resilience to climate extremes.

Implementation remains challenged by limited monitoring, weak policy integration and capacity gaps, underlining the need for stronger science–policy links and regional cooperation. The EU Soil Monitoring and Resilience Law emphasizes capacity building, knowledge sharing, independent science-based advice, training and continuous policy improvement. It also promotes research and innovation adapted to local soil, climate and land-use conditions, and requires locally relevant information based on soil health assessments.

The Green Agenda for the Western Balkans and the revised Green Agenda Action Plan aim to integrate soil protection into other policy areas and to establish a regional soil partnership. The Soil Partnership for the Western Balkans, initiated under the leadership of SWG, provides a platform for exchange of knowledge, data, best practices and experience related to sustainable soil management. It brings together nominated soil experts from Albania, Bosnia and Herzegovina, Kosovo, North Macedonia, Montenegro and Serbia and supports regional networking, capacity strengthening and harmonization of soil protection approaches.

Climate change impacts on soils in the Western Balkans are already evident and are expected to intensify in the coming decades due to the high sensitivity of agricultural systems and increasing exposure to extreme events. Adaptation is essential to reduce negative impacts on soils and ensure sector resilience. However, the adaptive capacity of farmers remains constrained by structural challenges, including an ageing workforce, labour shortages caused by rural outmigration, low levels of formal education and specialized knowledge, small and fragmented farm structures, outdated machinery and limited uptake of sustainable soil-management practices.

National assessments across the Western Balkans highlight several critical gaps and priorities for improving soil health and sustainable land management. A key challenge is the lack of comprehensive and reliable data on soil status, which underscores the urgent need for strengthened and sustained investment in soil monitoring systems. Land-use change, soil erosion and loss of soil organic carbon remain major threats affecting agricultural productivity and resilience to climate change.

Soil has largely been overlooked in environmental and agricultural policies in recent decades, pointing to the need for stronger policy coherence and better integration of soil management into relevant sectoral strategies. Aligning national strategic frameworks with the objectives of the new EU soil policy is essential. Low awareness among stakeholders remains a major barrier to adoption of sustainable soil-management practices, while capacity building is a top priority for both human and technical capacities across all stakeholder groups, from policymakers to farmers.

There is also a clear need to demonstrate the tangible benefits of improved soil and land-management practices, particularly in terms of productivity, climate resilience and ecosystem services. Demonstrating these benefits can support wider uptake, improve stakeholder awareness and strengthen informed policy action across the Western Balkans.

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Annex 3: Agroforestry systems in the Western Balkans and their role as an adaptation pathway in forestry

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Abstract. Agroforestry, the deliberate integration of trees and shrubs with crops and livestock, links agricultural and forestry land-use systems and is increasingly relevant for climate adaptation in regions with mixed rural landscapes. This paper, based on a presentation delivered at the EU4GREEN workshop, summarises the current status, geographic distribution and adaptation potential of agroforestry across the Western Balkans (WB6: Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia and Serbia). It documents the persistence of traditional practices despite the absence of harmonised monitoring, presents land-use evidence indicating substantial potential, and concludes that agroforestry should be promoted not as a replacement for forest protection but as a cross-sectoral, complementary adaptation pathway integrated into forestry, agricultural and climate policies.

Keywords: *agroforestry; Western Balkans; climate adaptation; silvopastoral systems; protective forest belts; forestry policy.*

1. Introduction

Agroforestry connects agriculture and forestry through land-use systems that combine trees and shrubs with crops, pastures or livestock on the same management unit. Beyond its production role, it has growing significance for the socio-economic development of rural areas and for climate-change adaptation, particularly in regions with diverse land-use mosaics such as the Western Balkans (Bojović et al., 2024). This short paper outlines the current status, structural potential and adaptation relevance of agroforestry across the WB6 economies and draws on a regional review, country-level practical guides developed under the AGFORWEB initiative, and the comparative IAMO study of agriculture in the Western Balkans.

2. Current status and monitoring of agroforestry in the WB6

Agroforestry is practised across the Western Balkans mainly through traditional and locally adapted systems – silvopastoral systems, orchards combined with grazing, scattered trees on farmland, hedgerows and shelterbelts (Bojović et al., 2024). However, it is not yet recognised or monitored as a separate, harmonised land-use category in the WB6: national statistics describe agriculture, pastures and forests as separate categories, while agroforestry as such remains invisible in the data.

Scientific attention to the topic also remains limited. A Scopus-based search by Bojović et al. (2024) for 2000–2023 identified only a small number of indexed publications on agroforestry-related terms in the WB6, with no indexed results retrieved for North Macedonia and Montenegro and only a handful for Serbia. The IAMO comparative study of agriculture in the region (Volk, 2010) further notes that land-use data are imperfect in several WB countries, which makes a robust regional baseline for agroforestry difficult to construct. The main gap is therefore not the absence of suitable land but the absence of harmonised monitoring of the practices that already exist.

At the same time, the structural conditions are clearly present. Agricultural land combined with permanent meadows and pastures accounts for between 18 and 49 per cent of national territory across the WB6 (Table 1), with North Macedonia showing the highest combined share and Montenegro the lowest. Forests and forestry biomass cover an additional 32–61 % of territory. According to the IAMO comparative report, agricultural area in the broader Western Balkan region ranges from about 23 % in Croatia to 66 % in Serbia, against an EU-27 reference of 40 %, and several countries display a strong dominance of grasslands – a structural feature directly relevant for silvopastoral systems (Volk, 2010, pp. 22–23).

3. Geographic distribution and documented case studies

Although harmonised monitoring is lacking, available country guides document a clear geographic pattern of three dominant system types (Belanović Simić & Lukić, 2023; Ivezić et al., 2023; Čurović et al., 2023):

- **Protective forest belts (agrisilvicultural)** are concentrated in lowland plains addressing wind erosion, particularly in Vojvodina (northern Serbia), with comparable practices documented in the central lowlands of North Macedonia.
- **Agrosilvopastoral systems** combining trees, crops and livestock are characteristic of Slavonia (Croatia) and Vojvodina (Serbia).
- **Silvopastoral systems** are dominant in Dalmatia (coastal Croatia), Montenegro and the hilly-mountainous areas of Albania, Kosovo, Bosnia and Herzegovina and North Macedonia, including the use of high-altitude summer pastures (katuns).

These systems are not abstract. In 1951–1961, around 42,000 poplar seedlings were planted in Sinjsko polje (Croatia), forming about 140 km of tree lines for wind protection (Ivezić et al., 2023); the drained Čepić polje (~1,800 ha) is protected by Euro-American poplar windbreaks; the Kumparička farm in Istria practises silvopastoralism with around 300 goats grazing on 200 ha of oak forest, with certified organic cheese production; the Karlić truffle plantation in Buzet relies on around 2,500 mycorrhized oak seedlings combining timber and high-value non-timber products; and in Montenegro, more than 2,000 households still use mountain katuns for transhumant livestock keeping (Čurović et al., 2023).

4. Agroforestry as a climate-adaptation pathway in forestry landscapes

Agroforestry is not only a production model but a landscape-level land-management approach. The FAO has emphasised that agroforestry systems can improve soil fertility, protect crops and livestock from wind, restore degraded land, conserve water and prevent erosion (FAO, 2024). Properly designed systems support adaptation by enhancing soil protection, water conservation, microclimatic regulation, biodiversity and landscape resilience.

From a forestry perspective, agroforestry is particularly relevant because it operates at the landscape level. It can reduce pressure on forests, stabilise vulnerable slopes, improve the management of forest edges and support more resilient rural land-use systems. The new EU Forest Strategy for 2030 emphasises forest protection, restoration and resilience in response to climate change and weather extremes (European Commission, 2021), and agroforestry options sit naturally within that framework.

Among the agroforestry options most relevant for the WB6, protective forest belts deserve particular attention. They are not single-purpose structures: each belt type fulfils a primary function and provides additional secondary benefits (Belanović Simić & Lukić, 2023). Field shelterbelts primarily provide wind protection, snowdrift control and microclimate modification, while delivering increased crop yields, biodiversity and habitat connectivity as secondary benefits. Water-management belts deliver runoff control, groundwater filtration and wind protection alongside sediment control and habitat connectivity. Comparable multi-functionality applies to coastal river forest belts, bio corridors and noise- and dust-control belts.

Productivity evidence supports these claims. Long-term experimental studies indicate that properly designed agroforestry systems combining trees (e.g. poplar or walnut) with cereal crops achieve a Land Equivalent Ratio (LER) in the range of 1.3–1.6, meaning that 100 ha under agroforestry produce yields equivalent to 130–160 ha of separate monocultures (Mead & Willey, 1980; Dupraz et al., 2014). Integrated landscape management is also increasingly discussed as part of climate-adaptation and fire-resilience planning. Agroforestry is not a direct fire-prevention measure, but by combining trees, shrubs, pastures and crop areas it can contribute to broader landscape resilience by limiting erosion, supporting soil-moisture retention and improving the management of forest edges and abandoned rural land. It should therefore be considered as a complementary approach to sustainable forest management, never as a justification for converting forests into agricultural land.

5. Challenges, key messages and outlook

Implementation faces several constraints: long payback periods, the management complexity of mixed systems, weak institutional support, comparatively high initial investment costs, and the fragmentation and tenure insecurity of agricultural land in many parts of the WB6. These constraints partly explain the gap between demonstrated potential and the limited area under documented agroforestry use. Conversely, the benefits are well established – climate-change mitigation through nature-based solutions, diversified rural incomes, higher land-use efficiency, improved soil quality and biodiversity, and increased carbon sequestration.

The central messages of the presentation can be summarised as follows:

1. Agroforestry is already present in the Western Balkans but remains insufficiently monitored;
2. Most WB6 countries have a land-use structure that indicates strong potential for agroforestry-based adaptation;
3. Agroforestry can support soil protection, erosion control, water regulation, biodiversity and landscape resilience;
4. Future progress requires better data, pilot sites, advisory support and the integration of agroforestry into forestry, agriculture and climate-adaptation policies.
5. Agroforestry development can significantly enhance the socio-economic conditions of rural populations while contributing to environmental protection, biodiversity conservation, and the sustainable use of natural resources.

In short, agroforestry should be treated as a practical, cross-sectoral adaptation pathway for the Western Balkans, especially in landscapes where agriculture, pastures and forests are closely interconnected – promoted, monitored, tested through pilot areas, and integrated into the relevant policy frameworks.

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Annex 4: Challenges and measures in forest adaptation – Examples from Austria

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With around 48 % of its territory covered by forests (BML 2024), Austria ranks among the most forested countries in the EU (EUROSTAT 2021). Given the high share of mountainous terrain, they are vital for protection from natural hazards with 42 % being classified as protective forests (BML 2024). Their economic importance is also highlighted by the roughly 245,000 jobs that are created through the Austrian forestry and wood-based sector (Econmove GmbH 2025). The headlines of disasters such as storm damage (ORF 2018), unprecedented bark beetle outbreaks (ORF 2023) and forest fires (ORF 2022) in Austria over the recent years stress the already prevalent pressure on Austrian forests. Furthermore, they foreshadow what future challenges will look like and highlight the need for effective adaptation measures in order to safeguard their functions.

For Central Europe, there will be an increase in mean temperature with a sharper increase in the Alpine region (Auer et al. 2007, Bergert & Frei 2018, GeoSphere Austria 2026a). Additionally, there will be more extreme heat and droughts (GeoSphere Austria 2026b). The distribution and development of bark beetles is largely driven by temperature-related variables (Jian et al. 2025). Hence, with the changing climate in Central Europe, the developmental conditions of bark beetles such as *Ips typographus* are changed in their favour, likely leading to more generations and distribution to higher elevations (Jakoby et al. 2019). The changing conditions will have repercussions on species composition as the historical distribution of species does not align with the projected climatic conditions (Dyderski et al. 2025). In other words, species more adapted to future conditions will benefit while the distribution of those who are not will decrease. Economic and ecological damage will likely increase as forest fires (Vacik et al 2020) and storms (Mölter et al. 2016) will increase. Additionally, there will be an increase in extreme precipitation (GeoSphere Austria 2026c). The occurrence of such events in winter can lead to snow break events. There has been an increase in leaf-damaging spring frost especially in Europe and East Asia (Zohner et al. 2020). Data from the same study suggests that 35 % of Europe's forests will be increasingly threatened by frost damage in the future.

The fast pace at which these threats are emerging make it necessary to take several active adaptation measures (BML 2024). Firstly, forests should be converted into mixed forests that are adapted to future conditions. Consequently, the ongoing decrease of spruce in the species composition should continue. This will minimise the risk of large-scale damage and in turn safeguard forest continuity as well as improve overall resilience and biodiversity of forest ecosystems (Valenta et al. 2025). Forest conversion should be carried out through natural regeneration where possible, planting of adapted domestic tree species and assisted migration (BML 2024). The planting of non-native tree species should be the last resort and should be carried out under special consideration of national and EU legislation. The reduction of game damage through the regulation of their populations is essential for the success of these measures. In addition to the adaptation of silvicultural practices, the preparedness for forest fires by the associated actors and authorities needs to be strengthened.

The Austrian government adopted and acknowledged the first version of the Austrian Strategy for Adaptation to Climate Change in 2013 (BMK 2024). It consists of a context section that lays out the strategic framework with basic information and an action plan with detailed recommendations for the 14 fields of action. Involving a variety of stakeholders and authorities and taking key results of the first progress report into account, the strategy was first updated and revised in 2017. The progress of the strategy is continuously evaluated to make sure the respective fields are on track. Forestry is addressed in the action fields "Forestry sector", "Protection against natural hazards", "Crisis and disaster management" as well as "Ecosystems and Biodiversity" highlighting the interconnectedness of successful adaptation measures.

The Austrian Forest Fund act was adopted by the federal government as a response to large scale bark beetle attacks in order to finance measures to enforce climate change adaptations in the forest sector. A total of 350 million euros is made available for research and awareness raising as well as active measures such as reforestation (BML 2024). With support of the Forest Fund "Brennpunkt Wald" - a forest fire specific strategy was published by the Ministry of Forestry that encompasses three major fields of action, such as i) understanding of and research on forest fires, ii) integrative forest fire prevention and fighting forest fires and iii) raising awareness on forest fires and implement measures (BML 2022).

Since 81 % of forests in Austria are in private ownership of which most are small-scale owners with less than 200 ha[1], the Austrian government relies on landowners to enforce the implementation of climate change adaptation measures (BML 2024). Hence, research is funded that is aimed at providing practitioners as well as policymakers with sound information on climate change adaptation. A few of these projects are briefly described in the following paragraphs.

The bark beetle dashboard integrates multiple data such as the well-received PHENIPS mode (Hallas et al. 2024) l. Its results encompass spatially explicit information on current and past development of *Ips typographus* populations. Forest managers can use this information to improve decision making on forest protection measures and identify vulnerability hotspots.

Seed4Forest provides a Europe-wide tool to support in selecting climate-resilient tree species and provenances by assessing future climatic conditions (SUPERB 2025). Species suitability is determined by climate factors and projected using Species Distribution Models. The resulting maps show potential species suitability and productivity. Combined with local expertise and site-specific knowledge of experts, the tool can be a useful component in decision making.

"Dynamische Waldtypisierung Steiermark" (Dynamic Forest Site Classification Styria) is a science-based tool to support silvicultural decision making to improve site-adapted and climate change adapted forest management. It integrates a wide range of data including climate variables (temperature, precipitation, drought indices), soil properties, topography, water balance models, and vegetation ecology, combined with forest growth knowledge and ecological indicators (Vacik & Dorfstetter 2022). These data are used to show current site conditions and model future suitability for different forest types and tree species under various climate scenarios. Users can access high-resolution maps on these variables and get extensive information on recommended forest management across Styria. The project was well received throughout Austria. Therefore, other regions in Austria started similar projects that will be finalised and made public in the following years.

Research on forest fires is mostly carried out at Vienna's BOKU University. Their fire database provides geographical information as well as tables and graphs about location, size and cause of forest fires in Austria (BOKU 2026). According to the database, there have already been over 90 forest fires between January and May of 2026. A frequently updated blog on forest fires as well as further information, such as on EFFIS, is also available on the database's website.

In summary, Austrian forests need to be converted and measures have to be put in place so several actors will be prepared for more frequent forest fires. These measures ensure that the forestry sector is adapted to climate change. Strategies and legislation help create a common picture of the future. They also help assess needs and appropriate measures to reach the common picture. Consequently, funding needs can be mapped and should be provided accordingly. Additionally, strategies can act as a base to help monitor progress, which is vital in ensuring that they are on track and adapted if necessary.

Research provides a good tool to fine-tune the strategies by providing sound information for policy makers as well as practitioners who eventually carry out the measures. When creating strategies and research projects, it is important not just to zoom into one sector, i.e. forestry, but also to take the adjacent sectors into account. For instance, changing species in forests will lead to a change in species provided for the wood-based sector, which requires adaptation measures in this sector, too.

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Annex 5: Economic Perspectives on Climate Change Adaptation in Agriculture

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Introduction. Climate change is increasingly shaping the economic performance of agricultural systems. Beyond environmental impacts, it directly affects farm productivity, costs, income stability and the functioning of food systems. Evidence shows that agriculture is already under pressure from rising temperatures, changing precipitation patterns and more frequent extreme weather events, requiring a shift in how climate risks are understood and managed.

Some key insights on the economic impacts of climate change on agriculture are synthetized here, with particular emphasis on how these propagate through food systems and how adaptation can mitigate losses. We argue that adaptation should be framed not only as an environmental response, but as an economic risk management strategy.

Economic pressure on agriculture. Climate change affects agriculture through three interlinked channels: (1) reduced biological productivity, (2) increased input requirements, and (3) greater uncertainty in production and decision-making.

At the global level, agriculture absorbs approximately 26% of total economic losses from climate-related disasters (FAO, 2021). In addition to acute shocks, estimates re that climate change has already caused around 21% decline in agricultural productivity since 1961, a slowdown that is equivalent to losing the last 7 years of productivity growth (Ortiz-Bobea et al., 2021), indicating a structural impact on long-term farm income potential. Future projections further highlight the scale of the challenge: each additional degree of warming may reduce global food availability by around 120 kcal per person per day, equivalent to 4–5% of recommended intake (Hultgren et al., 2025). These pressures translate into economic consequences at farm level, including lower output and quality, higher input use (water, energy, labour) and increased planning uncertainty. As a result, farms experience declining margins, higher costs and more volatile income streams.

From farm impacts to food system effects. Climate shocks do not remain confined to farms but propagate through the entire food system (Fanzo et al., 2021; FAO, 2018; IPCC, 2023; Hertel et al., 2010; Di Falco & Veronesi, 2013). A disruption in production can trigger a cascade of effects along the value chain - from post-harvest losses and storage constraints to logistics disruptions and market instability.

This leads to multiple layers of economic impacts:

- Operating costs increase due to higher input needs and climate stress;
- Capital losses arise from damage to crops, livestock and infrastructure;
- Transaction costs grow due to higher financing needs and market risk;
- Livelihood and welfare impacts emerge through declining incomes, price volatility and reduced food access.

As highlighted in the literature, climate change affects not only production but also markets, trade and food security (IPCC, 2023; Hertel et al., 2010). Consequently, economic assessment must go beyond yield changes and incorporate income stability, risk exposure and system resilience.

Economics of adaptation. A growing body of evidence shows that adaptation can significantly reduce the economic impacts of climate change. However, its benefits are best understood when framed as resilience investments rather than simple productivity enhancements.

Adaptation generates multiple returns: avoided losses, by reducing damage in adverse years; higher productivity, under favourable conditions; income stability, by reducing variability and risk. Empirical studies confirm these effects. Adaptation has been shown to increase farm revenues and reduce downside risk (Di Falco et al., 2011; Di Falco & Veronesi, 2013). Similarly, broader analyses indicate that climate impacts on farm income are significantly moderated by adaptive behaviour (Van Passel et al., 2017). Overall, adaptation contributes to improved economic performance by stabilising income and reducing vulnerability.

At the macro level, adaptation investments often exhibit benefit–cost ratios between 2:1 and 10:1 (Global Commission on Adaptation, 2019), while agricultural research and development can yield even higher returns (Alston et al., 2010; Hurley et al., 2014; Burke et al., 2015).

Importantly, adaptation does not eliminate all losses. Evidence suggests that it can offset a substantial share, typically 20–50% of damages, depending on technological, economic and institutional conditions (IPCC, 2022; World Bank, 2024).

Costs and benefits of adaptation over time. Adaptation involves upfront costs, with benefits increasing over time through reduced impacts. The economic value of adaptation is therefore determined by the balance between costs of implementing adaptation measures, and benefits in terms of avoided losses and reduced risk. Even with adaptation, residual impacts remain, as some climate risks cannot be fully mitigated (EEA, 2023). However, well-designed adaptation strategies can significantly reduce total damages, making them economically justified over the long term. This highlights the importance of adopting a cost–benefit perspective that includes risk reduction, rather than focusing solely on short-term financial returns.

What the literature agrees on. Climate change poses increasing risks to growth and agriculture in the region, yet early adaptation and targeted investments can reduce damages and strengthen resilience. Across empirical and modelling studies, three consistent findings emerge: (1) climate change causes real economic losses, through reduced output, increased costs and lower incomes; (2) adaptation reduces but does not eliminate losses, with effectiveness depending on technology, income and institutional capacity; (3) Impacts extend beyond agriculture, affecting GDP, prices, wages and food security (Khan et al., 2021; Vanschoenwinkel et al., 2016). These findings reinforce the need for integrated approaches that address both farm-level and system-level impacts. Climate action as an economic opportunity, with potential to boost productivity, create jobs and support alignment with EU frameworks, provided institutions and financing mechanisms are strengthened (World Bank Group, 2024).

Financing, limits and prioritisation. Despite strong evidence on the benefits of adaptation, implementation remains constrained by significant barriers. Financing is a major challenge, particularly as adaptation moves from incremental to more transformational measures (Watkiss, 2022). At the same time, there are limits to adaptation, including financial, institutional and biophysical constraints (IPCC, 2023). These limits imply that not all impacts can be avoided and that prioritisation is essential. Effective prioritisation requires focusing on measures that: maximise damage avoided, enhance income stability and strengthen system resilience. Low-regret actions provide immediate benefits, though transformational changes, such as structural shifts in production systems or value chains, are needed for long-term resilience.

Conclusions and policy implications. Climate change is fundamentally reshaping the economic landscape of agriculture. It increases costs, reduces productivity and introduces greater uncertainty, with impacts extending across the entire food system. Adaptation offers a viable response, but its role must be understood in economic terms. Rather than focusing solely on productivity gains, adaptation should be treated as a risk management investment that delivers value through avoided losses, income stability and resilience.

Policy responses should therefore prioritise investments based on risk reduction and long-term resilience; combine immediate low-regret actions with longer-term transformation; and strengthen enabling conditions, including knowledge systems (AKIS), finance, data and institutional capacity. Without these supporting systems, adaptation will not scale effectively. A balanced approach that integrates economic, environmental and institutional dimensions is essential for building climate-resilient agricultural systems.

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Annex 6: Economic Perspectives on Climate Change Adaptation in Forestry

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Climate change is increasingly recognized as a structural driver reshaping forest ecosystems and their associated economic systems. The presentation highlights that forestry is not only an ecological asset but also a critical economic sector, particularly in regions such as the Western Balkans (WB), where forests provide livelihoods, ecosystem services, and climate regulation functions. This paper synthesizes the key arguments from the presentation, emphasizing the economic impacts of climate change on forestry, the cost-benefit dynamics of adaptation, and the role of policy frameworks in addressing existing structural gaps.

Climate Change Impacts on Forest Ecosystems and Economic Value

Climate change affects forestry primarily through rising temperatures, altered precipitation regimes, and increased frequency of extreme events. Projections indicate temperature increases of up to 3.1°C in Albania during summer months, alongside declining and more variable precipitation patterns (WB, 2021; WB 2024). These changes directly influence forest productivity, species composition, and ecological stability (Willig et al. 2025; Sperlich et al., 2020).

From an economic perspective, these ecological shifts translate into both direct and indirect impacts. Direct impacts include reduced timber productivity due to drought stress, pest outbreaks, and wildfire damage (Seidl et al, 2025). Indirect impacts manifest through supply chain disruptions (Wand et al, 2023), increased insurance costs, and market volatility (Almeida et al, 2024). At the European level, disturbance-related losses in forestry are projected to increase from €115 billion historically to up to €247 billion under future climate scenarios, with timber value reductions reaching up to 42% (Mohr, et al, 2025); (EEA, 2025). These figures underscore the magnitude of economic risk associated with climate-induced disturbances.

Forests provide both market and non-market values. Market values include timber, non-timber forest products, and bioenergy, while non-market values encompass carbon sequestration, biodiversity conservation, watershed protection, and recreational services. Climate change threatens both categories, thereby amplifying the total economic loss beyond what is captured in traditional market metrics.

Structural Economic Context of Forestry in the Western Balkans

The WB forestry sector is characterized by relatively high forest cover (30–60%) but low economic productivity and high vulnerability (SWG, 2022). Forestry contributes only 0.5–2.5% of GDP in most WB countries, with timber productivity significantly below the EU average (1–3 m^3/ha/year compared to 4–6 m^3/ha/year). Additionally, a large share of forests is degraded or managed as coppice systems, and ownership structures are highly fragmented (SWG, 2025)

This structural context leads to a critical economic paradox: forests are economically important yet undervalued and under-managed. As a result, they are more exposed to climate risks. Southern and Southeastern Europe, including the WB, are identified as high-risk zones under warming scenarios, where disturbances such as wildfires, droughts, and pest outbreaks are expected to intensify.

Quantified Climate Risks and Economic Losses

Climate change is expected to have a strong impact on forest fire risk in Europe, as recognised by the EU strategy on adaptation to climate change (EC, 2020). Wildfires represent the most visible and economically significant climate risk in the WB. In 2025 alone, approximately 225,000 hectares burned across the region, including around 60,000 hectares in Albania (Belis et al., 2024). Direct fire damage costs range between €500 and €1,500 per hectare, increasing to €2,500 per hectare when ecosystem services are included (Silvestro et al., 2021).

Drought further exacerbates economic losses by reducing forest growth by 10–30% in dry years, resulting in long-term yield losses of €20–80 per hectare annually. Pest and disease outbreaks, such as bark beetle infestations and pine processionary moth expansion (Hallas et al., 2025; Hlásny et al, 2021), add another layer of risk, with localized damages reaching €1,000–2,500 per hectare (Silvestro et al. 2021).

These figures illustrate that climate risks in forestry are not isolated events but systemic threats with cumulative economic consequences. Importantly, the cost of reactive measures (e.g., fire suppression and recovery) significantly exceeds preventive investments.

Cost-Benefit Analysis of Adaptation

A central argument of the presentation is that climate adaptation in forestry is economically justified. Preventive measures such as fuel management, monitoring systems, and landscape planning cost between €80 and €200 per hectare annually, whereas suppression and recovery costs can reach €1,000–3,000 per hectare (Mattioli et al. 2024). This implies a return on investment of approximately 3 to 6 times for prevention (WB, 2023).

The broader economic rationale for adaptation is captured in the “triple dividend” concept: (i) avoided damages, (ii) enhanced productivity and resilience, and (iii) co-benefits such as carbon sequestration, biodiversity conservation, and job creation. Globally, adaptation investments yield an estimated return of $4 for every $1 invested, yet current funding levels remain significantly below required levels.

In the WB, the investment gap is particularly pronounced. The region requires approximately $37 billion in climate-related investments, but faces constraints such as limited public budgets, weak economic instruments, and insufficient integration into carbon markets (World Bank, 2023). This underinvestment perpetuates a cycle of vulnerability and reactive crisis management.

Policy Frameworks and Economic Instruments

The European Union provides a comprehensive policy framework for addressing climate risks in forestry, notably through the EU Forest Strategy for 2030 and the integration of forestry into broader climate policies such as the LULUCF Regulation. These frameworks emphasize multifunctional forest management, balancing economic, ecological, and social objectives.

Key economic instruments include financial incentives for forest owners and payments for ecosystem services (PES), which aim to internalize externalities and make non-market benefits financially viable. Risk reduction policies—such as fire prevention systems, pest management, and monitoring—are also central to reducing expected economic losses.

However, significant gaps exist in the WB context. Financial incentives are limited, PES schemes are largely absent, and carbon market integration is weak. Consequently, forest owners rely primarily on timber revenues, which discourages investment in adaptation measures that generate broader societal benefits.

Governance and Institutional Challenges

Effective adaptation is not solely a matter of funding but also of governance capacity. The WB region faces challenges related to fragmented institutional structures, weak enforcement of forest management plans, and inadequate data systems (SWG, 2025). These limitations result in inefficient allocation of resources, delayed responses to risks, and suboptimal management decisions.

For example, fire management systems in the WB are predominantly reactive, focusing on suppression rather than prevention. Similarly, outdated or incomplete forest inventories hinder evidence-based decision-making and increase uncertainty, which in turn discourages investment.

Strengthening governance mechanisms—through improved coordination, updated management plans, and enhanced monitoring systems—is therefore essential for unlocking the economic potential of adaptation (SWG, 2022).

Conclusions

Climate change is fundamentally transforming the economics of forestry, particularly in vulnerable regions such as the Western Balkans. The evidence indicates that without proactive adaptation, the sector will face increasing economic losses driven by disturbances such as wildfires, droughts, and pests. At the same time, adaptation offers significant economic opportunities, with high returns on investment and multiple co-benefits.

The key challenge lies not in recognizing the need for adaptation, but in overcoming financial and institutional barriers. Policy-driven economic optimization—through incentives, market mechanisms, and improved governance—represents the most promising pathway for enhancing resilience and unlocking the full economic value of forests. In this context, forestry should be viewed not merely as an environmental sector, but as a strategic component of climate risk management and sustainable economic development.

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Annex 7: From climate hazards to adaptation measures in agriculture

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Abstract

Agriculture in continental-Mediterranean transition regions, including much of the Western Balkans, is increasingly shaped by compound climate risks: late spring frost, heat waves, drought, irregular rainfall, short-duration floods, hail, soil degradation, and changing pest and disease pressure. This brief research paper develops a climate risk and vulnerability assessment (CRVA) framework for translating such hazards into scientifically defensible adaptation measures. The framework links hazard, exposure, sensitivity, adaptive capacity, vulnerability, and risk through a structured combination of agroclimatic indicators, crop phenology, local data, expert assessment, crop-model logic, and feasibility screening. It pays particular attention to maize exposed to heat and water stress around tasselling and silking, open-field vegetables exposed to combined heat and excess-water risk, perennial fruit crops exposed to frost and hail, livestock systems exposed to heat stress, and agroforestry as a nature-based adaptation pathway. The central argument is direct: adaptation cannot be applied as a generic blanket response. A measure should be recommended only when it reduces risk under plausible future climate conditions, avoids new vulnerabilities, and remains feasible within local biophysical, technical, institutional, and economic constraints.

Keywords: climate risk, vulnerability assessment, agricultural adaptation, crop phenology, irrigation scheduling, agroforestry, maladaptation

Introduction

Climate change has moved from the margins of agricultural planning to the centre of day-to-day farm risk management. Crop and livestock systems now face interacting hazards rather than isolated stresses: hot days and warm nights, drought and water scarcity, torrential rainfall and waterlogging, hail, strong winds, late spring frosts after early warming, soil erosion, salinity, and biological pressures from pests, diseases, and weeds. In the IPCC risk framework, climate impacts emerge through the interaction of hazard, exposure, and vulnerability, while adaptation reduces risk only when it is appropriately designed and implemented (IPCC, 2022). Poorly designed adaptation can have the opposite effect. It can shift exposure, increase costs, deepen dependency on scarce water, or leave farmers more vulnerable to the next extreme event.

Agriculture therefore requires a disciplined way to move from climate information to field-level decisions. It is not enough to name a hazard and list possible measures. A scientifically credible process identifies the hazard, locates the exposed crop or production system, defines the sensitive growth stage or asset, evaluates adaptive capacity, and then selects measures that reduce expected damage. The FAO/OECD vulnerability-assessment literature makes the same point from a development perspective: vulnerability is not only a function of climate stress, but also of resources, knowledge, infrastructure, institutions, and governance capacity (Fellmann, 2012). In regions where farms differ sharply in irrigation access, capital, advisory support, and data availability, this distinction is decisive.

The regional setting considered here can be described as a continental-Mediterranean transition zone. Such areas frequently combine cold-season and spring frost risk with very hot summers, irregular rainfall, steep or erosion-prone land, and water demand that peaks exactly when supply becomes least reliable. This context explains why maize, open-field vegetables, apples, livestock systems, and agroforestry buffers can be discussed within one paper. They are not a disconnected checklist. They are agricultural archetypes through which the same CRVA logic can be tested across annual crops, high-value horticulture, perennial systems, animal production, and landscape-level adaptation.

CRVA Framework for Agricultural Decision-Making

The CRVA framework begins with definitions, but its value lies in operationalization. Hazard refers to the climate event or trend itself: a heat wave, drought, frost event, heavy rainfall episode, storm, or gradual shift in water availability. Exposure refers to the crops, livestock, infrastructure, land parcels, and growth stages located in the hazard space and time window. Sensitivity captures the biological or economic response at a given hazard intensity. Adaptive capacity describes the ability to reduce damage through irrigation, drainage, protected cultivation, early warning, crop insurance, tolerant varieties, soil management, digital tools, organization, and financial resources. Vulnerability emerges where high sensitivity meets insufficient adaptive capacity.

Risk should be communicated carefully. The simple teaching formula risk = hazard x exposure x vulnerability is useful because it shows that risk disappears if one component is absent. Scientifically, however, risk is better understood as a context-specific function of these components rather than as a strict multiplication. The framework proposed here treats risk as a structured decision matrix. Hazard probability and intensity are first classified; exposure is mapped by crop, site, and phenological window; sensitivity is scored using crop-specific thresholds; adaptive capacity is assessed through technical, financial, informational, and institutional indicators; and the resulting vulnerability class is combined with consequence severity to rank adaptation priorities. This can be implemented as a semi-quantitative weighted indicator matrix, supported by GIS overlays where spatial data are available, and refined through expert focus groups and stakeholder validation.

Such a structure keeps the assessment transparent. A farm may face the same heat wave as its neighbour and grow the same crop, yet risk will differ if one farm has deeper soil, functioning irrigation, good scheduling, suitable hybrids, timely forecasts, and capital for rapid action. By structuring the analytical chain around crop phenology, the CRVA framework isolates exactly when a hazard shifts from an environmental variable to an economic threat. This is also where maladaptation becomes visible. Earlier sowing, for example, may reduce heat exposure during flowering, but it can increase frost exposure during establishment or move flowering into a different future stress window. The measure is promising only after this trade-off is tested, not before.

Operational Approach and Evidence Requirements

A practical CRVA can be implemented in four linked steps. The first step is climatic characterization: observed station data, gridded climate products, seasonal forecasts, and climate projections are used to identify hazard frequency, intensity, timing, and trends. The second step is agro-ecological and production mapping: crops, parcels, irrigation infrastructure, soils, slope, drainage, livestock units, and critical calendar periods are linked to exposure. The third step is sensitivity and adaptive-capacity assessment. Sensitivity may be derived from literature thresholds, local experiments, crop models, or expert scoring, while adaptive capacity can be represented through indicators such as irrigation reliability, equipment ownership, farm capital, extension access, warning systems, labour availability, insurance, and organizational readiness. The fourth step is adaptation screening, where candidate measures are tested against climatic plausibility, agronomic feasibility, economic viability, and stakeholder acceptability.

The methodology can be qualitative, quantitative, or hybrid. A rapid advisory assessment may rely on expert panels and a transparent scoring matrix. A research-grade assessment should add GIS layers, observed agrometeorological station records, phenological observations from extension services, soil maps, water-availability data from irrigation systems, farm-management records, and crop-model simulations. Crop models remain especially useful when comparing with-measure and without-measure scenarios, but their use requires caution. Model outputs depend on cultivar parameters, soil inputs, management assumptions, weather data quality, and calibration choices (Challinor et al., 2018; Webber et al., 2014). The framework is therefore not a black box. It is a structured diagnostic process in which model results, field evidence, and local knowledge must converge before a measure is promoted.

Crop Phenology, Heat Stress, and Irrigation Timing

Phenology is the hinge between climate science and agronomic loss. Annual mean temperature matters, but farmers lose yield when a critical event meets a critical growth stage. Warming increases growing degree days, advances the start of thermal growing seasons, and can lengthen the period suitable for crop growth. These shifts open opportunities for modified sowing dates, cultivar choice, and altered rotations. They also create new risk. The earlier start of a season does not cancel late frost. A longer warm period does not guarantee enough water. And a shift in flowering date is useful only if it moves the crop away from the most damaging stress window.

Maize illustrates the point sharply. Around tasselling, silking, pollination, and early kernel set, the crop is highly sensitive to heat and water stress. Heat can reduce pollen performance, disrupt synchrony between pollen shed and silk emergence, impair fertilization, and reduce kernel number. The anthesis-silking interval is particularly important because even a short delay in silk emergence under stress can reduce successful pollination (Cárcova & Otegui, 2001). Water stress during the same period compounds the problem: high evaporative demand raises crop water requirements, while low soil moisture limits transpiration, canopy cooling, and sustained reproductive growth. In irrigated maize systems, the key question is not simply whether irrigation exists. The decisive question is whether water can be delivered at the correct stage, in the correct amount, using evapotranspiration, soil-water balance, forecast information, and observed field conditions.

Earlier sowing can be a legitimate adaptation strategy under warming, but it should be treated as conditional rather than automatically beneficial. Analysts should test whether the new sowing window increases exposure to late spring frost, whether tasseling and silking avoid future heat waves and hot nights, and whether water supply remains reliable during reproductive development. Studies of maize adaptation show that sowing-date adjustment can modify heat and moisture exposure, yet the benefits depend strongly on local climate, drought pressure, and the interaction between temperature and precipitation change (Waha et al., 2013). A robust adaptation package would therefore combine sowing-date adjustment with hybrid selection, soil-moisture conservation, irrigation scheduling, early warning, and contingency planning for water scarcity.

Subsector-Specific Adaptation Pathways

Open-field vegetable production is often exposed to multiple hazards in the same season. Pepper and similar vegetable systems may face heat-induced flower drop, poor fruit set, sunburn, irrigation stress, short-duration flooding, waterlogging, fruit rots, and higher disease pressure. Climate-change reviews of vegetables emphasize that high temperature, changing rainfall, water scarcity, flooding, salinity, and pest and disease dynamics can all reduce yield and product quality (Dumitru et al., 2023). Adaptation must therefore operate at microclimate and root-zone level: shading, mulching, precise irrigation, fertigation, drainage, raised beds, monitoring, and integrated pest management. Low tunnels and protected structures can reduce direct rainfall damage, but they can also create overheating and humidity problems if ventilation is poor. Adaptation is system design, not a single intervention.

Perennial fruit systems expose the economics of climate risk with particular force. In apples and other high-value orchards, a short frost or hail event can eliminate most of the annual income. Here, adaptation often becomes investment-based and organizational: anti-hail nets, frost-protection systems, reliable early warning, automated thresholds for protection, insurance, emergency protocols, and coordinated advisory support. A warning that frost is coming is useful only if farmers have equipment, water, fuel, labour, and decision rules for response. Information without capacity is not adaptation.

Livestock systems face climate risk through heat stress, reduced forage productivity, water scarcity, pasture degradation, and changing disease or parasite pressure. Heat stress lowers animal welfare, milk production, weight gain, and reproductive performance. Practical measures include shade, ventilation, reliable drinking water, rotational grazing, drought-resilient forage mixtures, and veterinary monitoring. The CRVA logic is the same: reduce exposure where possible, reduce sensitivity through better management, and raise adaptive capacity through infrastructure and organization.

Agroforestry and Nature-Based Adaptation

Agroforestry offers nature-based adaptation at field and landscape scale. Shelterbelts and windbreaks reduce wind speed, wind erosion, dust movement, evapotranspiration stress, lodging, and mechanical damage. Contour hedgerows and vegetative strips slow runoff, increase infiltration, and reduce soil erosion on sloping land. Riparian buffers stabilize banks, filter sediment and nutrients, improve water quality, and protect canals, drains, pumps, and field edges. Silvopastoral systems provide shade for livestock and can improve pasture resilience when combined with rotational grazing and careful water-point placement. In orchards and vineyards, hedgerows, flowering strips, cover crops, and compatible secondary crops can support pollinators and natural enemies, reduce bare-soil exposure, and diversify income.

These measures work because they act on several risk mechanisms at once: microclimate regulation, soil protection, water retention, biodiversity support, and economic diversification. Their benefits are consistent with resilience-oriented and climate-smart agroforestry literature (Sheppard et al., 2020). Still, agroforestry is not an instant remedy. It requires several years of establishment, species selection, protection from grazing, maintenance, spacing compatible with machinery, and careful placement relative to irrigation and drainage infrastructure. Monitoring should include tree survival, vegetation cover, erosion signs, sediment load, soil moisture, shaded area per livestock unit, pasture condition, pollinator activity, pesticide use, marketable yield, and secondary income.

Limitations and Research Needs

A primary bottleneck in applying the CRVA framework stems from data quality. Local agrometeorological station records are needed to characterize heat waves, frost events, rainfall intensity, dry spells, and hot nights. Phenological records from extension services and experimental farms are needed to link hazards to real crop stages. Soil maps, soil-water retention data, irrigation-system records, groundwater or reservoir availability, drainage maps, and farm-management records are required to move from general risk statements to site-specific decisions. Without these data, the framework remains useful for screening, but weaker for investment planning.

Uncertainty is compounded by the event-scale nature of agricultural damage. A seasonal projection may suggest a warmer and longer growing period, while a single late frost can destroy an early-sown crop. A wetter spring average can still contain damaging dry spells or intense rainfall events. Crop models can support decisions, but their outputs should be presented with uncertainty ranges and validated against observed yields, phenology, soil moisture, and management records (Challinor et al., 2018; Webber et al., 2014). Socioeconomic feasibility requires equal attention. Farmers' capacity to invest, water rights, energy costs, labour availability, advisory support, insurance access, and institutional coordination often determine whether technically sound measures are adopted.

Conclusion

Climate adaptation in agriculture must be evidence-based, locally grounded, and continuously monitored. The CRVA framework helps because it links climate hazards to exposed systems, biological sensitivity, adaptive capacity, vulnerability, and risk. It also forces a crucial question: does the proposed measure actually reduce future risk, or does it merely respond to today's problem while creating tomorrow's vulnerability?

Earlier sowing of maize, irrigation scheduling, frost and hail protection, vegetable microclimate management, livestock shade systems, and agroforestry can all reduce risk. None of them is automatically an adaptation. Each must be matched to the correct hazard pathway, tested against future climate conditions, and supported by sufficient data, infrastructure, knowledge, finance, and institutions. The practical rule is simple but demanding: an activity becomes an adaptation measure only when it demonstrably reduces risk without creating new vulnerabilities.

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Annex 8: From climate hazards to adaptation measures in forestry

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Modern forestry create potential as a vital instrument for climate change mitigation. However, shifting climates also present significant challenges for long-term planning, requiring forest ecosystems to adapt to rising growing-season temperatures and increasingly volatile precipitation patterns. Based on *Zittis et al. (1. 2019),* regional environmental changes paper, temperature in Southeast Europe region will rise from one to five-degree Celsius (depending on different climate scenarios) while based on *Durdjevic 2018* (2.) precipitation will be in deficit during vegetation season. Selecting tree species resilient to these projected climate scenarios is essential to ensuring the long-term vitality of forest ecosystems and meeting the ecological, social, and economic needs of future generations.

Furthermore, wood is increasingly positioned as a primary substitute for fossil fuels. As a key source of green energy, it helps reduce greenhouse gas emissions while bolstering national energy independence. Forestry sectors in central Europe and beyond introduce concept named **Close-to-Nature Forest Management** *(3. Jacobsen 2001).* Although it has been scientifically accepted at the end of the 20th century this concept has been forged in Central Europe with *Karl Gayer* (4. late 19th century) and further defined by *Alfred Moeller* (5. early 20th century), this approach is now a cornerstone of European forestry. It treats all forest functions with equal importance, seeking to achieve management goals through minimal intervention by following natural process in forest ecosystem management. By merely accelerating the natural developmental processes of the ecosystem, this concept successfully balances high-level economic, environmental, and social objectives. Its core principles include following elements:

- Following **natural processes** for stand development and regeneration.
- Prioritization **of site-adapted tree species** to ensure habitat compatibility.
- Promotion **of mixed species stands** with diverse vertical and horizontal structures.
- Elimination **of clear-cutting** in favour of continuous-cover systems.
- Emphasis **on stand stability** and long-term ecosystem resilience.
- Individual**-tree-based management**, focusing on the selection and cultivation limited number of the crop trees rather than uniform stand treatment.

Priority is given to native (autochthonous) species. Non-native species are only introduced in limited percentages where they are highly ecologically adapted, primarily in small groups where natural regeneration of native species has failed.

When concluding a production cycle, regeneration should occur in small patches over several stages. Group-selection regeneration better facilitates natural regrowth and avoids the high costs associated with large-scale artificial planting.

Emphasizing natural regeneration results in more resilient stands. Trees developed in situ from the best local specimens do not suffer from the "planting shock" often seen in nursery-raised seedlings. In all management types should be promoted mixed-species structures. This is achieved through small-group enrichment planting where natural regeneration fails, followed by targeted silvicultural care. In conifer monocultures, transitioning to mixed, multi-aged stands is recommended to minimize risks from wind throw, snow breakage, and secondary pathogens. Large-scale clear-felling must be avoided as a standard management practice. This concept should create resilient and stable forest ecosystems in future increasingly uncertain climate condition. This is very challenging issue while forestry occupy huge area and have long production period under open space. Reliable research agenda and flexible science policy interface is essential for future correction in order to create stabile forest ecosystem that could secure economic, environmental and social benefits for future generation.

Forestry can play in the future important role in mitigation of climate change using afforestation as concept on conflict free available land. In order to conduct afforestation taking in consideration climate change, additional research in the region is desirable in order to take in consideration tree species suitable to grow in changed climate condition. Beside mitigation, forestry should be adapted to the climate change by proper management strategies in order to secure vital and resilient forests which could provide good quality row material. Adaptation strategies could increase contribution of forest ecosystems to the mitigation of climate change by creating substitutive materials to the iron and other high demanding energy products. Wood as natural and low demanding energy consumption material could play important role in reduction of fossil fuel driven co2 emission into atmosphere.

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