UN environment programme

Climate Risk Analysis for Transboundary Mountain Protected Areas of the Western Balkans

Ecosystem-Based Adaptation – From Risk Assessment to Management Action

Funded by BMUV

Federal Ministry
for the Environment, Climate Action,
Nature Conservation and Nuclear Safety

International Partnerships Austria

Implemented by UNEP in partnership with FEA & Zoï

Forestry and Environmental Action fea

zoï environment network

Publication Information

Title

Climate Risk Analysis for Transboundary Mountain Protected Areas of the Western Balkans:
Ecosystem-Based Adaptation - From Risk Assessment to Management Action

Editorial and Production team:

Forestry and Environmental Action - FEA
Zoi Environment Network

Core team

Ajla Dorfer
Belma Nahić
Samir Husić
Viktor Novikov
Otto Simonett

Supervision

United Nations Environment Programme (UNEP)
Sonja Gebert
Iskra Stojanova

Date of publication

March 2026

Project Context

This assessment has been carried out under a broader initiative aimed at integrating climate considerations into biodiversity conservation, with a particular focus on three selected transboundary protected areas in the Western Balkans.

The project is funded by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and implemented by the United Nations Environment Programme, with the support of local partners, while climate models and indicators were provided by a project “Climate proofing for Sustainable Development in the Western Balkans”, funded by Austrian Development Cooperation.

Acknowledgements

The authors would like to express their sincere appreciation to the management authorities and staff of all participating protected areas for their collaboration, provision of data, access to documentation, and support during field consultations and stakeholder engagement processes. This analysis draws on expert inputs from eight protected areas across six economies:

- **Anela Stavrevska Panajotova** – Shar Mountain National Park, North Macedonia
- **Arlinda Gashi** – Sharri National Park; Bjeshkët e Nemuna National Park, Kosovo*
- **Dejan Radošević** – Drina National Park, Bosnia and Herzegovina
- **Jelena Dragović** – Prokletije National Park, Montenegro
- **Ranko Milanović** – Tara National Park, Serbia
- **Valmira Bozgo** – Korab–Koritnik Nature Park; Albanian Alps National Park, Albania

The report also benefited from contributions by experts from the University of Natural Resources and Life Sciences Vienna (BOKU), who supported the development of climate infosheets and ensured scientific robustness and methodological consistency, in particular:

- BOKU University, Institute of Meteorology and Climatology, Department of Ecosystem Management, Climate and Biodiversity

  - **Benedikt Becsi**
  - **Mimi Amaichigh**
  - **Herbert Formayer**

- GeoSphere Austria

  - **Fabian Lehner**

The authors also acknowledge all stakeholders who participated in consultations and contributed valuable local knowledge and perspectives.

List of Abbreviations

ADA	Austrian Development Agency
BOKU	University of Natural Resources and Life Sciences Vienna
CBD	Convention on Biological Diversity
EbA	Ecosystem-Based Adaptation
EU	European Union
FEA	Forestry and Environmental Action
FGD	Focus Group Discussion
FWI	Fire Weather Index
GBF	Kunming-Montreal Global Biodiversity Framework
GCF	Green Climate Fund
GEF	Global Environment Facility
GWL	Global Warming Level
IBA	Important Bird Area
IPA	Instrument for Pre-Accession Assistance (European Union funding instrument for candidate and potential candidate countries)
ISRBC	International Sava River Basin Commission
IUCN	International Union for Conservation of Nature
KII	Key Informant Interview
KEPA	Kosovo* Environmental Protection Agency
MESPI	Ministry of Environment, Spatial Planning and Infrastructure (Kosovo*)
NAP	National Adaptation Plan
NAPA	National Agency of Protected Areas (Albania)
NbS	Nature-Based Solutions
NDVI	Normalised Difference Vegetation Index
NTFP	Non-Timber Forest Products
NP	National Park
PA	Protected Area
RAPA	Regional Agency of Protected Areas (Albania)
RCP	Representative Concentration Pathway
SPEI	Standardised Precipitation-Evapotranspiration Index (indicator of drought severity)
SSP	Shared Socioeconomic Pathway
TBPA	Transboundary Protected Area
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WB-CPP	Western Balkans Climate Change Proofing Platform
WFD	Water Framework Directive
WWF	World Wide Fund for Nature

Contents

Introduction
Background and Context

The mountain ecosystems of the Western Balkans rank among the most biodiverse and ecologically significant landscapes in Europe. Stretching across the Dinaric Arc from the Julian Alps in the northwest to the Shar Planina and Prokletije massifs in the southeast, these highlands support species and habitats that have survived Europe's Pleistocene glaciations, harbour extraordinary levels of endemism, and provide critical water, food, and climate regulation services for millions of people. Eight national parks and nature parks across the 6 economies - Albania, Bosnia and Herzegovina, Kosovo*[1] , Montenegro, North Macedonia, and Serbia - protect the core of this natural heritage.

These protected areas are now confronting one of the most formidable challenges in their history: a rapidly changing climate that is simultaneously reshaping their ecological foundations and the socio-economic conditions of the communities that depend on them. Temperature increases of 1.5-4 °C are projected by the end of this century depending on global emission trajectories. Summer droughts that currently occur once every 15 years are projected to become two-year events. April snowpack - the freshwater reservoir that feeds mountain springs and rivers through the summer - is at risk of total disappearance at mid-elevations by the time the current generation of park management plans expires. Wildfire risk is expanding upslope into higher-elevation habitats that have never historically burned.

[1] All references to Kosovo are made without prejudice to positions on status and are in line with United Nations Security Council Resolution 1244 (1999) and the International Court of Justice Opinion on the Kosovo declaration of independence

Geographic and Institutional Scope

The analysis covers three transboundary protected area clusters encompassing a total of approximately 365,300 hectares of protected mountain landscape across six economies:

Cluster	Protected Areas	Economies	Total Area
Tara-Drina Corridor	NP Tara (Serbia); NP Drina (Bosnia and Herzegovina)	Serbia, Bosnia and Herzegovina	**31,300** ha
Bistra-Korab / Shar Mountain	NP Shar Mountain (North Macedonia); NP Sharri (Kosovo*); Korab-Koritnik Nature Park (Albania)	N. Macedonia, Kosovo*, Albania	**171,500** ha
Albanian Alps - Prokletije - Bjeshkët e Nemuna	NP Albanian Alps (Albania); NP Prokletije (Montenegro); NP Bjeshkët e Nemuna (Kosovo*)	Albania, Montenegro, Kosovo*	**162,500** ha

Together, the parks are embedded in a broader landscape supporting approximately 650,000-700,000 people in surrounding municipalities - from the Adriatic lowlands of Albania to the Kosovo* Plain, from the Drina valley in eastern Bosnia to Vojvodina's plains. Their ecological functions - carbon sequestration, water regulation, biodiversity corridors, natural hazard buffering - extend far beyond their boundaries. This is why climate change in these protected areas is not only a conservation concern, but a development and human security issue.

Nature Protection in the Western Balkans

Map produced by Zoï Environment Network, March 2026

Observed Climate Change in the Western Balkans 1970–2020

Note: The climate change map on this page presents long-term historical trends using aggregated periods (1920–1970 and 1970–2020) to illustrate broader temporal shifts. These periods differ from the standard observation baselines used in the factsheets and the WB-CAP platform, which rely on more recent and methodologically harmonized reference periods. Therefore, the map serves an illustrative purpose and should be interpreted as complementary context rather than directly comparable data.

Methodological Approach

This analysis was commissioned by UNEP and synthesises BOKU Vienna downscaled climate projections, field evidence, stakeholder consultations, and the management reality of eight protected areas to produce findings that are both scientifically grounded and operationally relevant.

The analysis integrates four evidence streams:

- **BOKU downscaled climate projections:** High-resolution regional climate model simulations downscaled specifically for the Western Balkans domain, presented at four Global Warming Levels (GWL1.5, 2.0, 3.0, and 4.0 °C above pre-industrial baseline) and accessible through the WB-CPP platform (wbcpp.neopix.dev). These projections cover temperature, precipitation, drought, snow, wildfire weather, and extreme event indicators.
- **Desk research:** Review of management plans, biodiversity assessments, socio-economic studies, flood risk reports, and development strategies for all eight protected areas and their surrounding municipalities, drawing on available documentation from 2020-2025.
- **Focus group discussions:** 174 participants across six focus groups in all three clusters, engaging farmers, herders, tourism operators, guesthouse owners, NTFP collectors, and community members to document observed climate change impacts and community-level vulnerabilities.
- **Key informant interviews:** interviews with park managers, rangers, municipal officials, energy operators, hunters, fishers, and civil society representatives, capturing institutional perspectives on governance challenges, management plan limitations, and adaptation priorities.

What the climate projections show

The BOKU climate projections, downscaled specifically for the Western Balkans domain and presented across 4 Global Warming Levels (GWL), show a consistent and alarming pattern across all three transboundary clusters. These are not model artefacts - they are robust signals that appear under all scenarios examined:

Climate Hazard & Trend	Key Impacts on Protected Areas and Their Communities
Temperature rise	+1.8-1.9 °C already locked in under GWL2.0; +4.1-4.4 °C possible by end of century under GWL4.0. The Sharr and Prokletije massifs face the strongest warming signal (+4.4 °C). This is faster than the European average.
Drought intensification	The most severe signal. Drought events that currently occur once every 15 years are projected to occur every 2 years by GWL4.0. In the Tara-Drina corridor, drought intensity increases up to 5×. In the Sharr/Korab cluster, up to 4×. Springs are drying, rivers recording extreme low flows in summer, and reservoir levels approaching biological minimums.
Snow cover collapse	Total loss of April snowpack is possible at mid-elevations (below 2,000 m) under GWL4.0. Snow cover duration is already declining at 14+ days per decade. This is not only a tourism issue - snowmelt is the primary source of summer river flow and spring recharge for over 350,000 urban residents in Tetovo, Gostivar, Prizren, and Kukës.
Wildfire risk explosion	Very strong increase in fire weather index (FWI) high-risk days region-wide. Fire risk is expanding above 2,000 m - habitats that have never historically burned. A January wildfire has already been documented in Albanian Alps. No tri-national fire management protocol currently exists.
Extreme precipitation intensification	Paradoxically, while average summer precipitation declines, daily extreme events intensify: +8% in Tara-Drina, +13% in Sharr/Korab, +14% in Albanian Alps-Prokletije. On steep, degraded terrain this means more destructive flash floods and landslides - as demonstrated by the 2015 Tetovo event (6 fatalities, $21 million damage) and 2014 Sava/Drina floods ($2 billion damage across Serbia and BiH).
Very hot days increasing	In lower-elevation areas, very hot days (>35 °C) increase by up to 20 per year at GWL4.0. This affects visitor comfort and safety, outdoor labour, and lowland agriculture in municipalities surrounding the parks.

Structure of this report

This report is organised in three chapters. Together they form a progression from evidence to profiles to action - designed to be used both as a reference document and as a practical tool for protected area managers, planners, and national authorities.

Chapter 1 - Climate Risk Analysis

Chapter 1 constitutes the scientific foundation of the report. For each of the three transboundary protected area clusters, it presents the BOKU climate projections across key indicators (temperature increase, very hot days, drought intensity and frequency, snow cover change, extreme precipitation, and wildfire risk), synthesises observed and documented climate impacts from field research and the literature, constructs impact chains linking climate drivers to ecological and socio-economic consequences, and identifies the most climate-vulnerable points in each landscape. The chapter concludes with a comparative synthesis of risk levels across clusters and identifies priority entry points for ecosystem-based adaptation investment.

Chapter 2 - Protected Area Profiles

Chapter 2 provides detailed profiles of each of the eight national parks and nature parks, organised by cluster. Each profile covers: the park's basic characteristics and legal/institutional status; IUCN category; management plan status and period of validity; ecological and biodiversity values; climate characteristics and observed or projected climate change impacts; accessibility and population context; key risks and pressures; existing and planned infrastructure, particularly tourism-related; and a summary table of the main stakeholder groups engaged in consultations, including their concerns and perspectives. The profiles are designed to serve as reference documents for park-specific planning while remaining comparable.

Chapter 3 - EbA and NbS Recommendations

For each cluster, this chapter proposes a set of ecosystem-based adaptation and nature-based solution measures for integration into protected area management plans, paired with a stakeholder engagement table identifying specific roles for communities, park administrations, authorities, international organisations, and the private sector - with particular attention to tourism operators. The chapter then provides cross-cutting and economy-specific recommendations.

Summary for Decision-Makers

Climate change is not a future risk for the mountain protected areas of the Western Balkans - it is a present and accelerating reality that is already altering ecosystems, threatening water and food security, shortening winter tourism seasons, and amplifying natural hazards. The eight national parks covered by this analysis are located at the front line of climate impacts in Europe.

The decisions made in the next five years - on management plan revisions, infrastructure, institutional coordination, and ecosystem restoration - will determine whether these landscapes remain functional as biodiversity refugia, water towers, and economic assets for their communities by mid-century.

Ecosystem-based adaptation is the most cost-effective strategy available:

- **it simultaneously protects biodiversity**
- **reduces disaster risk,**
- **secures water supplies,**
- **and supports community livelihoods.**

What this means for protected areas

Climate change is not affecting all parts of these protected landscapes equally. Six specific impacts stand out as decision-critical priorities:

1. Forest ecosystem collapse risk: Pančić spruce (*Picea omorika*) - the globally rare conifer protected by National Park Tara and found almost nowhere else - is experiencing bark beetle outbreaks amplified by drought. Chestnut groves in Kosovo* are failing. Spruce and fir stands across the Shar massif are under thermal and moisture stress. If current trends continue, forest dieback will accelerate irreversibly. Proactive mixed-species enrichment planting and refugia designation are needed now, before stressed trees become monoculture victims.

2. Freshwater systems and biodiversity under acute stress: Rivers that form the ecological backbone of all three clusters - the Drina, Lumbardhi, Jadar, Leshnica, and their tributaries - are recording extreme low flows, disappearing in summer, or being diverted by small hydropower schemes. The Drina's flagship species, the huchen (*Hucho hucho*), is in decline. Glacial lakes in National Park Shar Mountain show declining surface areas. Alpine peatbogs at Crveni Potok (NP Tara) and elsewhere are desiccating. These trends require flow restoration and hydrological protection measures.

3. Tourism economy is built on stranded assets: All three clusters contain ski infrastructure operating on the assumption of reliable winter snowpack. BOKU projections make clear that reliable natural snow below 2,000 m will be increasingly rare or absent by mid-century. Tourism strategies that rely on winter sports are stranded assets within one management plan cycle. Decision-makers must begin the transition to climate-resilient, four-season tourism models now, before investment is further locked into climate-incompatible infrastructure.

4. Overtourism is destroying the asset it depends on: National Park Albanian Alps received 558,000 visitors in 2023 - a tenfold increase in a decade - with no wastewater treatment, insufficient waste infrastructure, and hundreds of unpermitted guesthouses. This trajectory degrades the very ecosystem that tourism depends on. The 2025 demolition controversy demonstrated the political fragility of unregulated tourism governance. Carrying capacity frameworks and green tourism standards are not optional - they are existential for the tourism economy.

5. Community water security is at stake: Over 350,000 urban residents in Tetovo, Gostivar, Prizren, and Kukës depend on mountain spring and river systems that are under dual stress from climate change and hydropower diversion. In Srebrenica, municipal water restrictions already occur daily in summer. Water-tower protection - through spring restoration, micro-retention, and catchment management within the parks - directly serves national development goals and EU water policy obligations.

6. Cross-border governance gaps are creating dangerous vulnerabilities: Not a single tri-national wildfire protocol exists for the Prokletije massif. No joint early warning system covers the trilateral mountain massif. Floating waste from Bosnia and Herzegovina accumulates in Perućac Lake in Serbia with no bilateral management mechanism. Bark beetle does not respect national borders, and neither does flood water. Climate adaptation in these landscapes cannot succeed within single-country governance frameworks.

Five Priority Actions for Decision-Makers:

1. Integrate climate risk into all management plan revisions: every management plan revision should include climate projections and at least 1-5 EbA priority measures.

2. Establish multi-national coordination mechanisms for all three clusters: Create joint fire management protocols, shared snow and water monitoring networks, coordinated early warning systems, and harmonised tourism standards. The institutional architecture for this exists (Drina Task Force, Drin Coordinated Action, Peaks of Balkans Consortium) - it needs to be resourced for climate functions.

3. Invest in EbA pilots with the highest co-benefits: spring restoration, riparian revegetation, peatbog rehabilitation, and mixed-species forest enrichment. Estimated cost: €70,000-230,000 per pilot, with benefit-cost ratios of 5:1 or higher.

4. Apply the WB-CPP platform as the standard climate tool in PA planning. The platform is free, accessible, and covers all six economies on a consistent basis.

5. Stop approving climate-incompatible infrastructure in and around the parks: ski resort expansion without independent climate assessment, small hydropower that further depletes river systems.

Turning Climate Risks into Action:

Ecosystem-based Adaptation (EbA)
Transboundary Dinaric Mountain Protected Areas

CLIMATE DRIVERS

- **RAPID WARMING** ↑
  up to 4.4°C
- **FREQUENT DROUGHTS** ↑
  from 1-in-15 years → every 2 years
- **SNOWPACK COLLAPSE** ↑
  < 2000 m disappearing
- **EXTREME DAILY RAINFALL** ↑
  8-14% increase
- **WILDFIRE EXPANSION** ↑
  to altitudes 2000+ m

ECOSYSTEM IMPACTS

- **FOREST DIEBACK & PEST OUTBREAK**
  e.g Pančić spruce endangered by bark beetle outbreak
- **DRYING SPRINGS & WATER SCARCITY**
  350.000+ people affected
- **FLOODS & LANDSLIDES**
  fatalities and economic loss
- **LOSS OF ENDEMIC SPECIES & HABITATS**
  e.g Pančić spruce
- **COLLAPSE OF SNOW-DEPENDENT SYSTEMS**
  winter tourism affected

Multiple hazards are converging simultaneously

IMPLEMENTATION ENABLERS

- Integrate climate projections into ALL PAs management plans
- Establish multi-national cross-border PAs governance

EbA MEASURES

A. FOREST-BASED EbA

- mixed-species forest restoration
- reducing bark beetle vulnerability
- maintaining carbon storage and ensuring habitat for endemic species

B. WATER & WETLAND EbA

- restoring springs and water retention
- constructing small water-retention basins
- peatbog and wetland rehabilitation

C. LANDSCAPE & BIODIVERSITY EbA

- riparian (riverbank) vegetation restoration
- pasture rehabilitation and invasive species control
- maintain ecological corridors and traditional land-use systems

CO-BENEFITS

REDUCES DISASTER RISK
floods, wildfires, landslides

SECURES DRINKING WATER
for >350,000 people

SUPPORTS RURAL LIVELIHOODS
& traditional land use
(€1 → ~€5 avoided damage)

MAINTAINS BIODIVERSITY HOTSPOTS
& ecosystem integrity

PROTECTS TOURISM ASSETS
& avoids high-risk investments

Stop climate-incompatible investments (ski-centers, hydropower projects)

Apply the WB-CPP climate platforms as the standard planning tool

1. Climate Risk Analysis for Transboundary Mountain Protected Areas of the Western Balkans

This chapter presents a comprehensive climate risk analysis for the three transboundary protected area clusters covered by the UNEP project "Climate Proofing for Sustainable Development in the Western Balkans". The analysis integrates downscaled BOKU climate projections with socio-economic and ecological evidence to characterise current and projected climate hazards, identify impact chains, and frame adaptation priorities for each cluster.

Three transboundary mountain complexes are assessed, spanning six economies and encompassing eight nationally designated protected areas, including seven national parks:

- **Albanian Alps - Prokletije - Bjeshkët e Nemuna** (Albania, Montenegro, Kosovo*),
- **Bistra-Korab / Shar Mountain** (Albania, North Macedonia, Kosovo*),
- **Tara-Drina corridor** (Serbia, Bosnia and Herzegovina).

Climate projections are based on BOKU-generated, bias-adjusted and downscaled scenarios covering temperature, precipitation, snow cover, wildfire risk (FWI), drought intensity (SPEI), and extreme precipitation. Results are presented for four Global Warming Levels (GWL1.5, GWL2.0, GWL3.0, GWL4.0) relative to the pre-industrial baseline (1850-1900) and compared to observed conditions for the reference periods 1981-2010 (temperature) and 2001-2020 (all other indicators).

© National Park Tara (Management Authority)

Tara-Drina Corridor
(Serbia & Bosnia and Herzegovina)

1.1 Geographic and Ecological Context

The Tara-Drina corridor links National Park Tara (Serbia) and National Park Drina (Bosnia and Herzegovina) along one of Europe's last wild river systems. National Park Tara covers 24,992 ha in the Dinaric Alps (elevation 291-1,591 m), dominated by 80% forest cover including the critically rare Pančić spruce (*Picea omorika*). National Park Drina (6,315 ha, elevation 290-1,265 m) protects the middle Drina canyon in Republika Srpska, notable for its limestone habitats and endemic species including the Derventa knapweed. Together, these parks sit within a wider landscape that also contains the Bajina Bašta hydropower system - Serbia's second largest - and is proposed as the transboundary Drina UNESCO Biosphere Reserve.

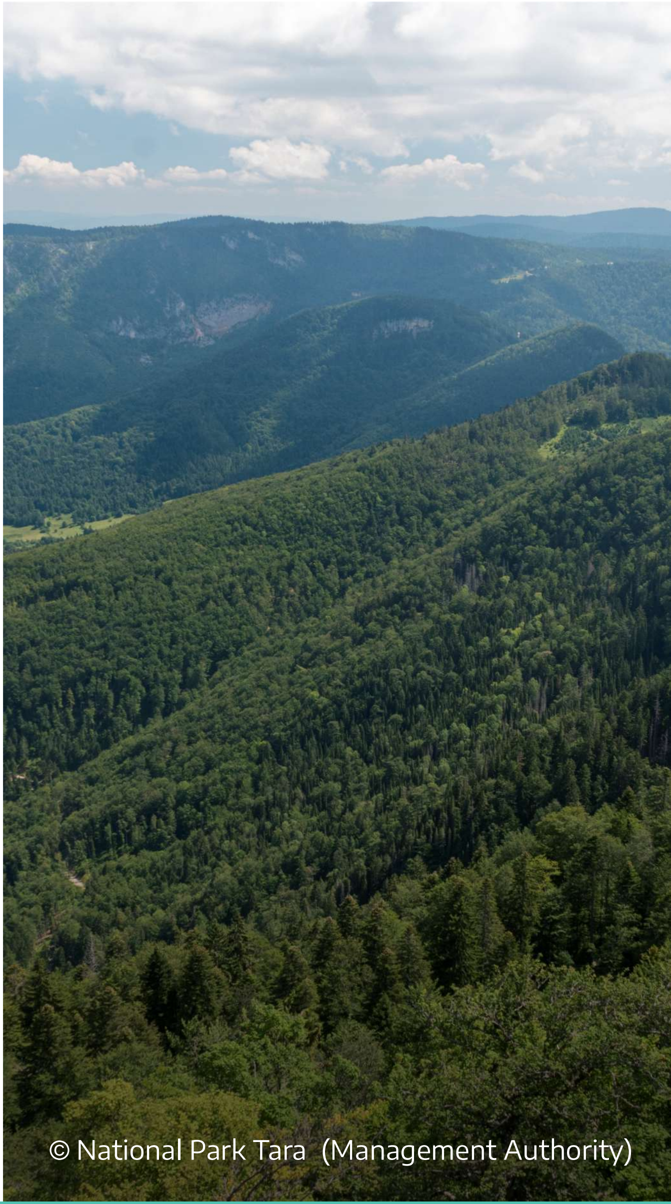
The Drina River serves simultaneously as international boundary, ecological corridor, hydropower resource, and tourism asset. The Perućac and Zaovine reservoirs inside or bordering both parks have altered local microclimate, river regimes, and sediment transport - creating a complex baseline against which climate change now acts.

1.2 Observed Climate and Recent Trends

Meteorological monitoring at National Park Tara was interrupted for several decades (stations closed mid-1980s, recently re-established). Available data from Zlatibor district (1961-1990) characterises the baseline: mean January temperature -2 °C, July/August ~18 °C, annual precipitation in a Mediterranean-influenced regime with maximum in November-January and minimum in August. Snow cover typically persists November-March, extending to April at elevations above 1,000 m. Tropical days (≥30 °C) average only 1.3 per year, concentrated in July-August.

Stakeholder consultations and key informant interviews across the 2024-2025 field campaign document the following observed shifts already perceptible to park managers and local communities:

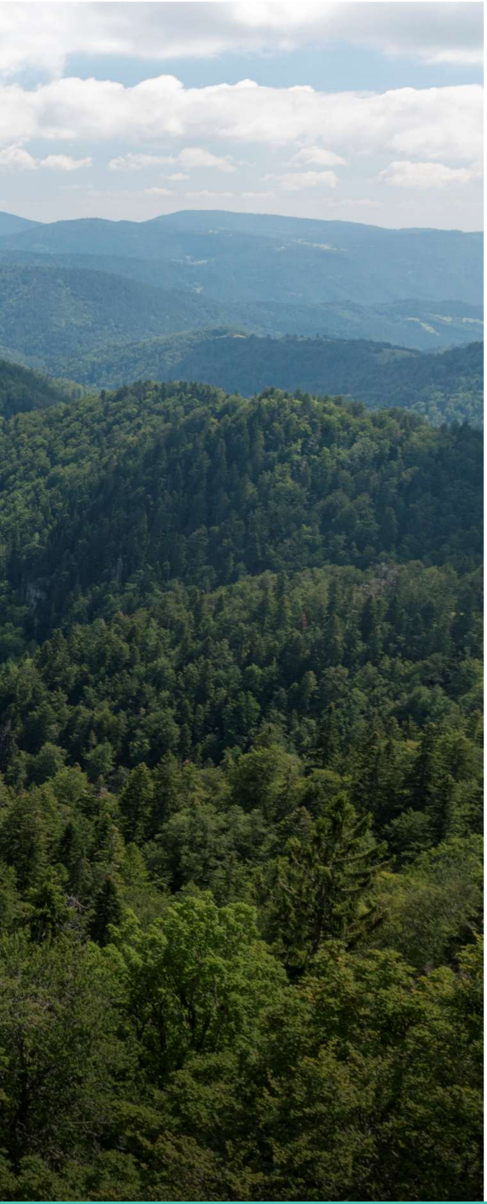
- Snowy winters have become rare: participants across all focus groups described consistent shortening and thinning of snow cover over the past decade.
- The number of days above 30 °C is rising, with heat episodes now extending into early autumn.
- Spring flooding has intensified: documented major flood events include the catastrophic 2014 floods that caused severe road and infrastructure damage, and recurring landslide episodes in Sućeska, Luka, and surrounding areas.
- Forest stress signals are accelerating: bark beetle outbreaks (primarily *Ips typographus* in Norway spruce), patches of Pančić spruce dieback, and peatbog desiccation at Crveni Potok are documented in park management records.
- Aquatic ecosystems are degrading: summer minimum flows in the Jadar, Drina tributaries, and Štedrić have fallen sharply; huchen (*Hucho hucho*) populations are declining while invasive pumpkinseed (*Lepomis gibbosus*) is spreading.
- The Zaovine reservoir approached biological minimum levels in recent summers, threatening downstream flow and aquatic biodiversity.



1.3 Climate Projections

BOKU provided bias-corrected, downscaled projections for the Tara-Drina area under four Global Warming Levels (GWLs), drawing on a multi-model ensemble. Key findings are summarised below.

Climate indicator	GWL 1.5	GWL 2.0	GWL 3.0	GWL 4.0
Air temperature increase (vs 1981-2010)	+1.2 °C	+1.8 °C	+2.8 °C	+4.1 °C
Very hot days >35 °C / year	Marginal	Marginal	Up to +10 days	Up to +20 days (northern slopes)
Growing season duration	+7 days	+15 days	+35 days	+55 days
Snow cover days (>10 cm in April)	Marginal reduction	-2 to -5 days	-7 to -12 days	Total disappearance possible
Meteorological drought intensity (SPEI)	Moderate increase	2× more intense	3-4× more intense	Up to 5× more intense; 15-yr event every 2 yrs
Extreme daily precipitation change	No clear trend	+3%	+5%	+8% (flash flood/landslide risk)
Wildfire risk (FWI high-risk days)	Low increase	Moderate increase	Moderate-strong	Most notable on southern & NW slopes



Several projection details are particularly significant for management planning:

- Snow cover: The Tara plateau currently hosts moderate but reliable winter snowpack. Under GWL4.0, snow cover in April is projected to virtually disappear, ending the viability of winter sports infrastructure and eliminating the spring water buffer that currently sustains lowland communities through summer.
- Heat extremes: While baseline tropical days are rare, the increase to up to 20 additional very hot days per year under GWL4.0 - concentrated in the northern part of the complex - will fundamentally alter visitor comfort in summer and accelerate forest moisture stress.
- Drought: Climate projections indicate a strong increase in meteorological drought intensity (SPEI) under higher warming scenarios. Under GWL4.0, drought intensity could become up to five times stronger, with events that historically occurred roughly once every 15 years potentially occurring as often as every two years. This represents the most severe projected hazard for both ecosystems and livelihoods in the Tara-Drina corridor. Springs serving small settlements are already reporting summer failures.
- Flash floods: The 8% intensification of extreme daily precipitation, while moderate in absolute terms, acts on steep karst and degraded slope terrain to increase landslide and flash-flood risk - as the 2014 Sućeska event demonstrated.

1.4 Climate Impact Chains

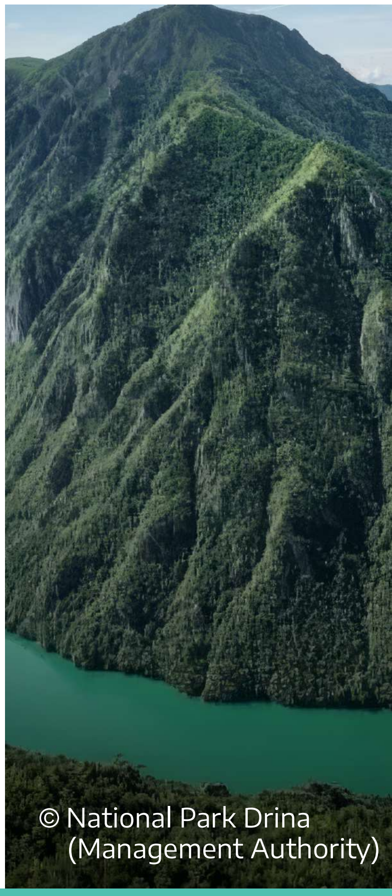
Based on the BOKU projections, desk research, and stakeholder evidence, the following impact chains were synthesised for the Tara-Drina corridor.

Element	NP Tara (Serbia)	NP Drina (BiH)
Climate Drivers	Warming +1.8 °C (GWL2.0) ? +4.1 °C (GWL4.0); snow loss; prolonged summer drought (up to 5× more intense); rising fire-weather days on southern & northwestern slopes.	Same temperature trend; up to 20 extra very hot days/year; warmer winters reduce snowpack retention; irregular precipitation with drier summers.
Environmental Impacts	Risk of total April snow loss (GWL4.0); bark beetle outbreaks in spruce; Pančić spruce (*Picea omorika*) dieback; peatbog desiccation (Crveni Potok); reduced spring water buffer; ecosystem shift toward thermophilous species.	River flow variability in Drina, Jadar, Sućeska; more frequent flash floods and erosion; reduced fish spawning; deteriorating canyon aquatic habitats; loss of endemic riparian flora.
Socio-Economic Pressures	Shorter winter tourism season; visitor concentration in summer (~100,000 annual visitors); post-COVID surge in illegal construction; ATV damage to forest roads; weak wastewater management.	Emerging tourism under pressure from illegal shoreline structures; cross-border floating waste (Perućac Lake); hydropower operations altering flow; water restrictions in Srebrenica summer (3pm-6am daily).
Consequences	Declining winter tourism revenue; increased wildfire damage to forests; bark beetle expansion threatening irreplaceable endemic spruce populations; reduced water security for Bajina Bašta municipality.	Income instability for fishers and guides; water scarcity in small settlements; degraded aquatic ecosystems; infrastructure damage from floods/landslides (roads blocked in Sućeska for extended periods).
Adaptation Entry Points	Mixed-species reforestation replacing monoculture spruce; bark beetle biocontrol and pheromone monitoring; peatbog protection and hydrological restoration; seasonal visitor management.	Riverbank and micro-wetland restoration; small water-retention structures; improved waste and wastewater management in tourism zones; regulation of lake shoreline construction.

1.5 Priority EbA Pilot Zones

The impact chain analysis identifies six priority ecosystem-based adaptation pilot locations across the Tara-Drina corridor, with indicative cost ranges based on regional benchmarks:

Pilot Location	Park	Intervention	Cost Estimate
Open grassland habitats - Tara plateau	NP Tara	Mechanised pasture management and restoration to maintain semi-natural meadow biodiversity and prevent forest encroachment	**€90-120k**
Drina Canyon slopes	NP Tara	Slope stabilisation and targeted habitat restoration for endemic Serbian bittercress (*Cardamine serbica*)	**€80-100k**
Visitor flow management - Tara core zone	NP Tara	Ecosystem-sensitive zoning and carrying capacity enforcement to reduce summer pressure	**€70-90k**
Jadar River micro-wetlands	NP Drina	Small water-retention basins and riparian vegetation restoration for erosion and flood control	**€90-110k**
Žlijebac-Sućeska slopes	NP Drina	Reforestation with mixed species on landslide-prone slopes	**€80-100k**
Klotjevac-Luka zone	NP Drina	Wildfire prevention infrastructure and riparian forest recovery along fire-prone ridgelines	**€100-130k**

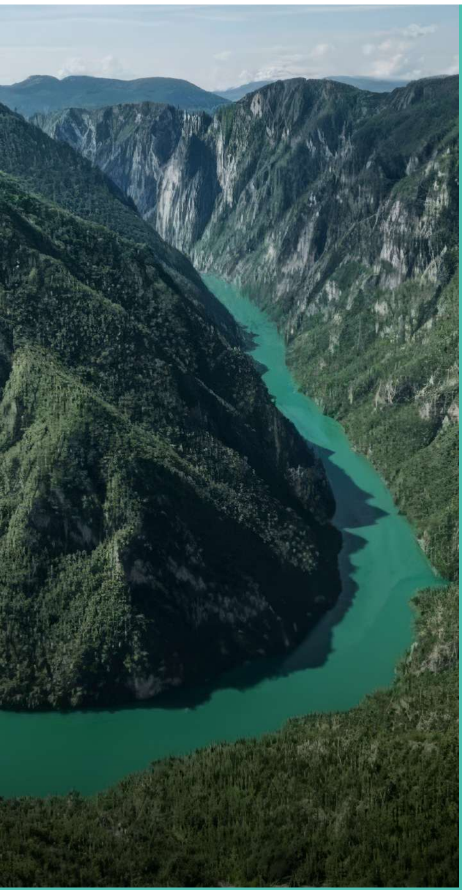


1.6 Transboundary Climate Vulnerabilities and Coordination Priorities

The Tara-Drina corridor shares a common river system and contiguous forest landscape, yet management remains nationally siloed. The following transboundary risks and coordination gaps were consistently raised across stakeholder consultations:

- **Cross-border floating waste:** Seasonal waste accumulation in the Perućac reservoir - arriving from upstream in BiH and from Serbian bank communities - is a major ecological and reputational threat with no bilateral management mechanism.
- **Shared wildfire risk:** The northern faces of the Drina watershed cross into both countries; fire ignition and spread follows no administrative boundary. No joint early-warning or response protocol exists.
- **Hydropower impacts:** The Bajina Bašta HPP system (Perućac and Zaovine reservoirs) is managed by Serbia's EPS but directly impacts the National Park Drina in BiH through altered flow, thermal stratification, and floating debris. The proposed Drinjača HPP and other planned BiH projects add further cumulative risk.
- **Fish passage:** Huchen (*Hucho hucho*) populations are declining across the Drina catchment due to barriers from existing and planned hydropower. No transboundary restoration protocol exists.
- **Tourism standards:** Divergent national regulations allow facilities banned on one side of the border to proliferate on the other, undermining conservation objectives in both parks.

Recommendations for Tara-Drina Corridor



- **Establish a joint Tara-Drina Transboundary River Management Group with representation from both park authorities, national water agencies, and municipal governments.**
- **Develop a shared early-warning system for wildfires, floods, and bark beetle outbreaks, building on BOKU climate-risk projections and existing meteorological stations.**
- **Negotiate a bilateral floating waste interception protocol and harmonised ecotourism standards aligned with the proposed Drina Biosphere Reserve management framework.**
- **Integrate BOKU drought and snow projections into both parks' next management plan revisions, establishing climate-biodiversity indicators as mandatory monitoring outputs.**

Bistra-Korab / Shar Mountain
(Albania, North Macedonia, Kosovo*)

2.1 Geographic and Ecological Context

This transboundary complex spans the Sharr-Korab massif across three economies, encompassing three protected areas: National Park Shar Mountain (North Macedonia, 62,705 ha, elevation 450-2,748 m), National Park Sharri (Kosovo*, 53,271 ha), and Korab-Koritnik Nature Park (Albania, 55,550 ha, elevation 410-2,350 m, including Albania's highest peak, Korab at 2,751 m).

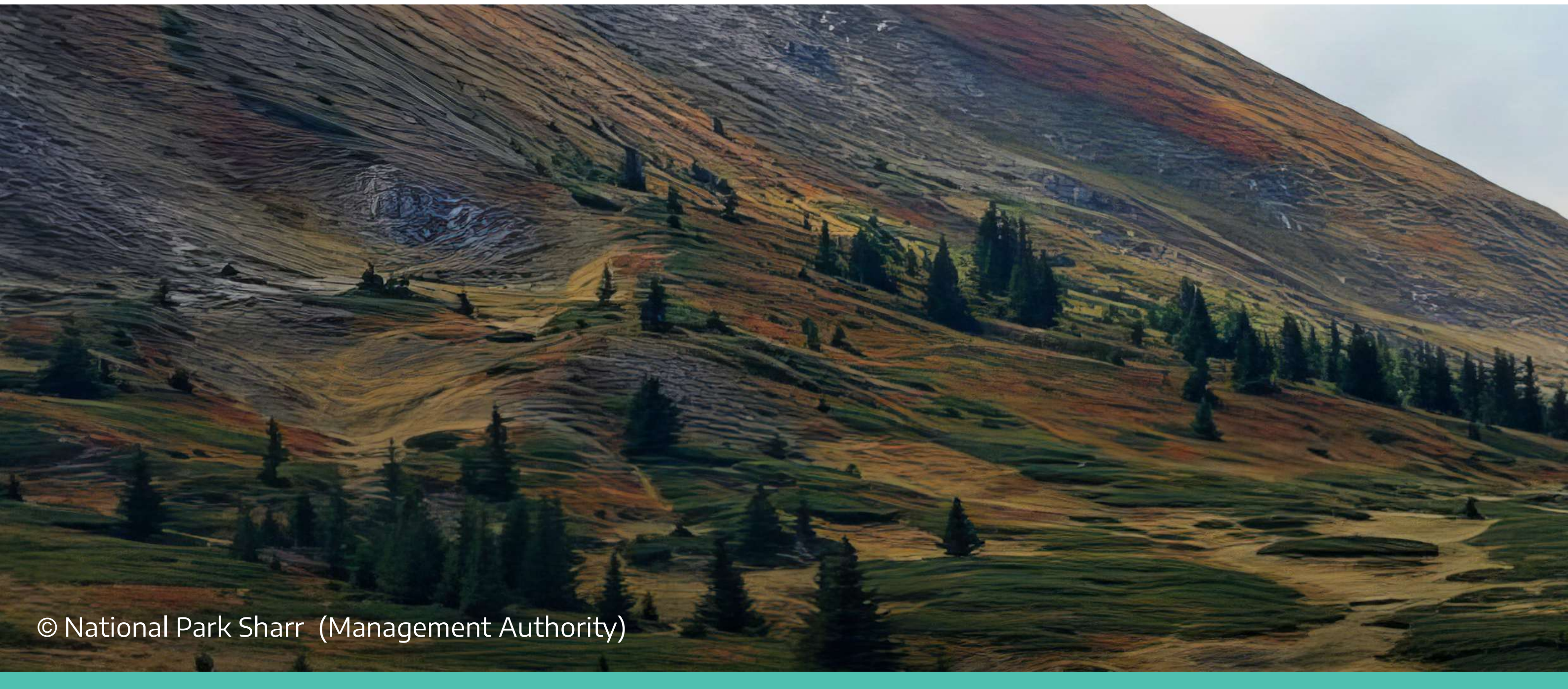
The complex forms a biodiversity hotspot with 1,260+ vascular plants in National Park Shar Mountain alone, 128 bird species, 40 glacial lakes, and extensive alpine pastures and peatbog systems. The area is also the backbone of regional water supply: the Sharski Vodi system diverts more than 50% of the Shar mountain rivers into the Mavrovo reservoir, generating approximately 12% of North Macedonia's electricity. This pre-existing hydrological modification creates a complex vulnerability context for climate change impacts on water resources.

2.2 Observed Climate and Recent Trends

Baseline climate data from Popova Šapka (1,780 m) shows an annual mean temperature of 4.8 °C, annual precipitation approximately 700-1,250 mm, and a maximum recorded temperature of 30.6 °C. Snow cover at Brezovica (Kosovo* side) can reach 3 m at peak season, with up to 117 snowy days recorded; the Dragash subalpine zone averages 120 snow-cover days at lower elevations and up to 280 days in high alpine zones.

Observed changes reported across all three economies in this cluster include:

- Shortened and delayed winter ski seasons: focus groups from all three economies consistently describe unreliable snow conditions at Popova Šapka and Brezovica, with years of near-zero natural snow.
- Glacial lake surface reduction: long-term observations at the 40 glacial lakes of Shar Mountain document declining surface area and water volume.
- Pasture degradation from ATV and snowcat use: as natural snow thins, motorised winter transport scars alpine meadows, accelerating erosion and habitat degradation.
- Springs and rivers drying: Luma River springs (Korab-Koritnik), the Zhupa-Lepenc-Lumbardhi basin (Sharri), and rivers in Shipkovica-Brodec highlands are reported intermittently dry in summer.
- Flash flood damage: the August 2015 flash flood in Tetovo (triggered by less than two hours of torrential rain) caused six fatalities, an estimated $21.5 million in damage, and buried sections of Shipkovica village in boulders, illustrating extreme flood vulnerability.
- Forest pest expansion: chestnut and spruce stands in Korab-Koritnik Nature Park and National Park Shar Mountain show stress-related dieback and pest pressure.
- Abandonment of traditional grazing practices leading to pasture undergrazing and progressive encroachment of woody vegetation (including juniper and other shrub species), resulting in the loss of open habitats and increased wildfire risk.



© National Park Sharr (Management Authority)

2.3 Climate Projections

BOKU projections for the Bistra-Korab / Shar Mountain complex reflect the exposed high-elevation character of this massif, with some of the strongest drought intensification signals across the entire Western Balkans study area.

Climate indicator	GWL 1.5	GWL 2.0	GWL 3.0	GWL 4.0
Air temperature increase (vs 1981-2010)	+1.25 °C	+1.8 °C	+3.1°C	+4.4 °C
Very hot days >35 °C / year	Marginal	Marginal	Low-moderate increase	Moderate increase across area
Growing season duration	+10 days	+20 days	+40 days	+55 days
Snow cover days (>10 cm in April)	-1 to -3 days	-3 to -7 days	-7 to -12 days	-14 days or more
Meteorological drought intensity (SPEI)	Moderate increase	2-3× more intense	3-4× more intense	Up to 4× more intense; 15-yr event every 2 yrs
Extreme daily precipitation change	No clear trend	+4%	+8%	+13% (flash flood & landslide risk)
Wildfire risk (FWI high-risk days)	Low-moderate increase	Moderate increase	Strong increase	Strong increase; region-wide elevation expansion

Source: BOKU downscaled projections. GWLs vs pre-industrial baseline; indicators vs 2001-2020 reference.

Critical projection findings for this cluster:

- **Drought - regional peak hazard:** With up to 4× drought intensification and frequency rising from a 15-year to a 2-year return period under GWL4.0, the Sharr complex faces the most severe projected drought signal in the study area. This is especially critical given that mountain springs supply drinking water to Tetovo (218,920 inhabitants in surrounding municipalities) and Gostivar.

- **Snow loss and ski viability:** The projected loss of more than 14 snow-cover days in April by GWL4.0 directly threatens the economic model of Popova Šapka and Brezovica ski resorts, both of which are expanding rather than adapting. Ski infrastructure investment under current plans will likely be stranded by mid-century.

- **Wildfire expansion:** The very strong increase in wildfire risk days at GWL4.0, combined with land abandonment and fern overgrowth, creates extreme fire hazard conditions. Post-fire erosion on steep slopes generates secondary flood and landslide risks.

- **Extreme precipitation:** The +13% intensification of daily precipitation extremes at GWL4.0 is the highest among the three clusters. Given the 19 documented critical torrents in the Upper Vardar basin (flood damage modelled at €74 million for a 100-year return event), this projection implies sharply rising infrastructure and livelihood losses.

2.4 Climate Impact Chains

Based on the BOKU projections, desk research, and stakeholder evidence, the following impact chains were synthesised for the Tara-Drina corridor.

Element	NP Shar Mountain (N. Macedonia)	NP Sharri (Kosovo*)	Korab–Koritnik Nature Park (Albania)
Climate Drivers	Temperature +1.8 °C (GWL2.0) → +4.4 °C (GWL4.0); heatwaves and dry spells; snow loss; strongest extreme precipitation intensification of the study area (+13% at GWL4.0).	Summer droughts 4× more intense and 8× more frequent (GWL4.0); shortened and unreliable winter snow season; rising wildfire risk, region-wide.	Longer dry season; 10–25% less summer precipitation; increased erosion risk; rising wildfire frequency.
Environmental Impacts	Glacial lake surface reduction; high-altitude pasture degradation; chestnut and spruce stress; torrential flood damage; river valleys run dry downstream of Sharski Vodi diversions.	Forest stress and pest spread in oak and beech zones; pasture degradation by ATVs; drying of springs (Zhupa – Lepenc – Lumbardhi basin); invasive common juniper (*Juniperus communis*) spread.	Drying of springs along Luma River slopes; loss of vegetation buffer; erosion; reduced groundwater recharge; wildfire damage in low-altitude scrub zones.
Socio-Economic Pressures	Declining winter tourism at Popova Šapka; ski expansion plans conflicting with climate reality; ATV/snowcat damage to alpine pastures; weak parking and cable-car infrastructure concentrating visitors.	Uncontrolled construction around Brezovica ski zone; water and waste stress in villages; community pressures from Dragash, Prizren, and Shtërpce municipalities.	Traditional grazing declining; youth outmigration and labour shortages in agriculture; limited tourism services; weak institutional capacity of protected area management authorities.
Consequences	Reduced winter tourism revenue; water rationing in Tetovo during summer; infrastructure damage from flash floods (modelled €74M for 100-yr event); stranded ski investment.	Increased wildfire risk and pasture productivity loss; soil erosion; declining yields; migration from mountain communities; loss of ecosystem service value.	Declining rural livelihoods; youth outmigration across mountain communities in the Shar massif (Kosovo*, Albania and North Macedonia); deteriorating spring water access; ecosystem degradation accelerating depopulation spiral.

2.5 Priority EbA Pilot Zones

Pilot Location	Park	Intervention	Cost Estimate
Leshnica River rehabilitation	NP Shar Mountain	River renaturalisation, bank vegetation, micro-retention for low-flow augmentation	**€200-230k**
Popova Šapka alpine pastures	NP Shar Mountain	Rehabilitation of ATV/snowcat-damaged pastures; native species revegetation	**€120-150k**
High-ridge zone above Popova Šapka	NP Shar Mountain	Forest health restoration and fire-risk reduction in transition zone	**€80-100k**
Brezovica ski zone - eco-drainage	NP Sharri	Water-saving and eco-drainage systems to reduce ecosystem stress from resort operations	**€90-110k**
Zhupa-Restelica corridor	NP Sharri	Pasture rehabilitation and erosion control on degraded alpine slopes	**€80-100k**
Lumbardhi i Brodit - riparian restoration	NP Sharri	Riparian vegetation recovery and stream channel stabilisation	**€90-120k**
Luma River springs - Korab slopes	Korab-Koritnik	Spring revitalisation, buffer vegetation, reforestation and slope stabilisation	**€80-130k**
Agricultural terraces above Zapod	Korab-Koritnik	Soil retention terracing and climate-smart irrigation for eroded slopes	**€90-110k**

2.6 Transboundary Climate Vulnerabilities and Coordination Priorities

- **Shared water tower:** The Shar massif functions as the primary freshwater source for Tetovo, Gostivar, Prizren, and Kukës - collectively over 350,000 people. Declining snow cover and increased summer drought directly translate to urban water insecurity with no current transboundary monitoring protocol.

- **Divergent ski investment strategies:** North Macedonia is planning cable-car reconstruction at Popova Šapka; Kosovo* has significant uncontrolled development around Brezovica; On the Albanian side, development pressures relate more to broader tourism and land-use change than to major ski infrastructure. None of these plans incorporate any climate projections on snow reliability loss, risking coordinated stranded investment.

- **Transboundary wildfire:** The forest and scrub landscapes connecting National Park Shar Mountain, National Park Sharri, and Korab-Koritnik create contiguous fire corridors. No joint fire-monitoring or early-response coordination exists.

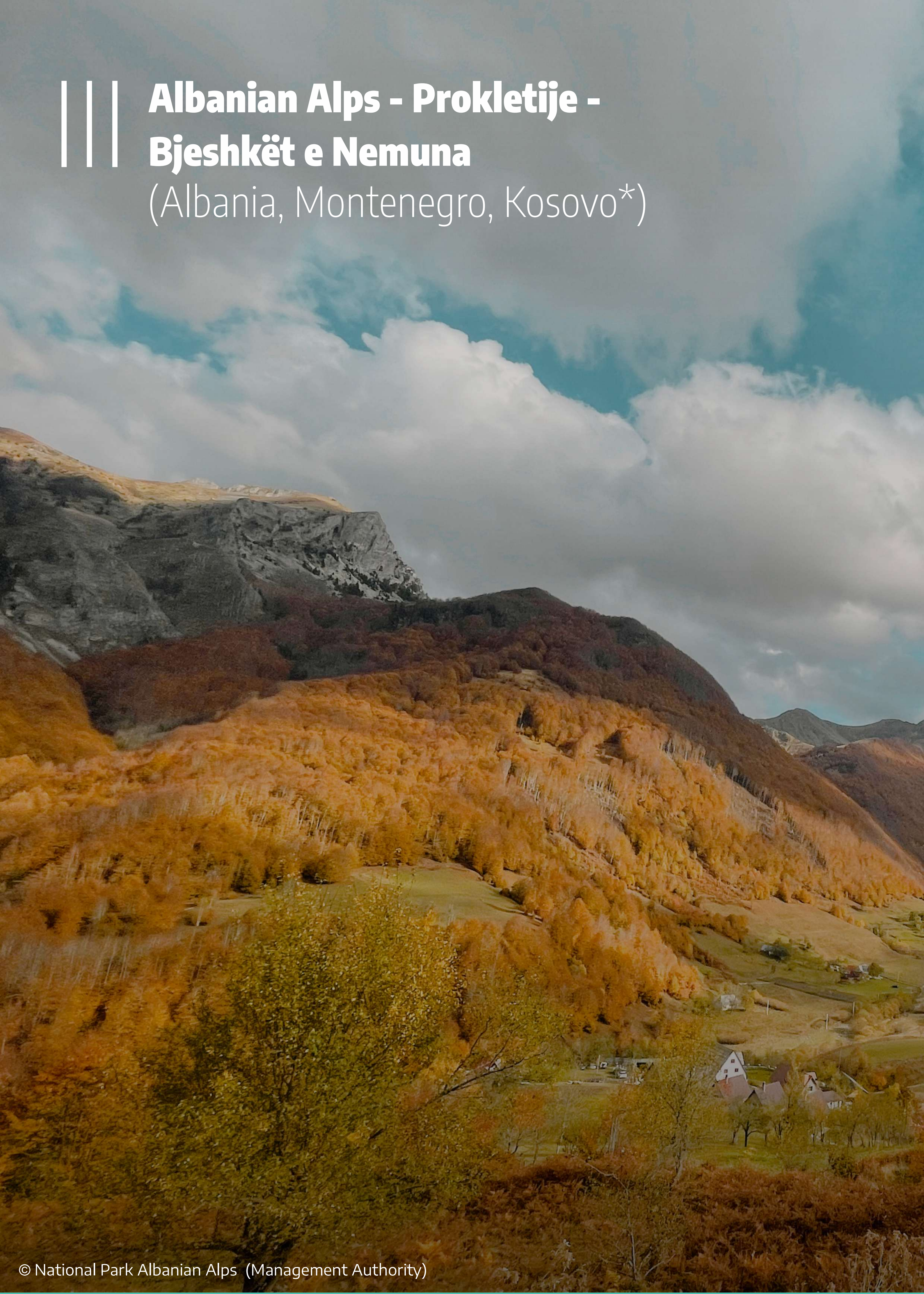
- **Invasive species spread:** common juniper (Juniperus communis) and other scrub invasives are expanding across all three parks due to pasture abandonment and climate stress. Control requires coordinated management at the landscape scale.

Recommendations for Sharr/Korab Cluster

- **Establish a joint snow and water monitoring network across the Shar massif, connecting existing stations in all three economies and sharing data in real time - critical for both hydropower management and municipal water security.**
- **Commission an independent climate-viability assessment of all planned ski infrastructure investment (Popova Šapka cable car, Brezovica expansion) against BOKU GWL2.0 and GWL4.0 snow projections before any further capital is committed.**
- **Develop a regional fire management coordination mechanism encompassing all three national park authorities, supported by a shared early-warning platform using FWI projections.**
- **Create a cross-border pasture restoration and invasive species control programme, linked to NTFP certification schemes that can sustain local livelihoods while reducing ecosystem pressure.**
- **Promote climate-resilient tourism development across the Shar massif, including stronger controls on unsustainable construction (especially in ski zones) and support for diversified, low-impact tourism models.**

Albanian Alps - Prokletije - Bjeshkët e Nemuna

(Albania, Montenegro, Kosovo*)



3.1 Geographic and Ecological Context

The Prokletije-Albanian Alps complex is the largest and most ecologically diverse of the three transboundary clusters, spanning the tri-border zone of Albania, Montenegro, and Kosovo* across four protected areas: National Park Albanian Alps (Albania, 82,845 ha, elevation 350-2,694 m), National Park Prokletije (Montenegro, 16,630 ha, elevation 1,100-2,534 m), National Park Bjeshkët e Nemuna (Kosovo*, 63,028 ha, elevation 750-2,656 m).

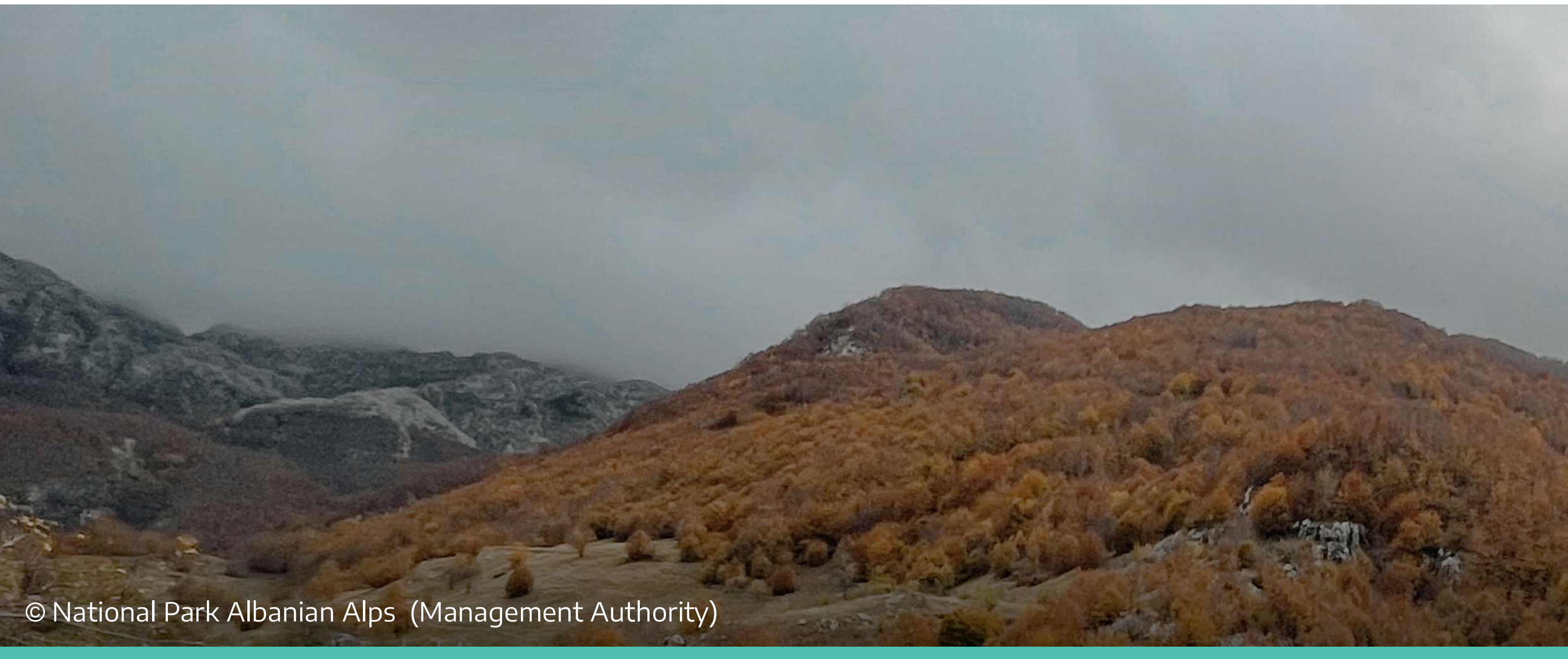
The Albanian Alps alone harbour approximately 1,650 vascular plant species, 46 mammals, and 137 birds, with 44 habitat types. The complex protects Europe's last stands of Balkan pine and hosts apex predators including the brown bear and Balkan lynx. The iconic Peaks of the Balkans trail (192 km) crosses all three economies and has driven a 10-fold increase in tourist arrivals to the Albanian Alps within a decade - reaching 558,000 visitors in 2023 - generating both economic opportunity and intense ecological pressure.

3.2 Observed Climate and Recent Trends

The National Park Albanian Alps sits in a northern Mediterranean mountain climate with annual precipitation up to 1,760 mm, heavy snowfall (up to 3–4 m in some basins), and 110–140 precipitation days per year. Bjeshkët e Nemuna receives similar precipitation, with snow persisting 60–210 days depending on elevation. Prokletije's highest sections exceed 2,500 m and are characterised by an Alpine climate regime.

Stakeholder observations and scientific monitoring document the following trends already visible across the cluster:

- Significantly reduced snow cover across all three parks, with traditional winter starting later and ending earlier — winter months described by herders as 'almost gone.'
- More frequent and severe summer droughts: springs in Valbona, Theth, and Kelmend valleys show periodic drying; the Lumbardhi and Deçanit rivers show reduced summer flow.
- Rising wildfire frequency: up to 35 additional high-risk wildfire days per year are projected for this cluster under GWL4.0; recent January wildfires indicate the fire window is expanding.
- Forest pest emergence: processionary caterpillars are more frequently reported in pine stands in the Albanian Alps; bark beetle outbreaks are intensifying in spruce stands in Prokletije.
- Common juniper (*Juniperus communis*) encroachment: invasive shrub expansion into degraded high-altitude pastures documented in Bjeshkët e Nemuna, particularly Rugova Gorge slopes.
- Tourism pressure compounding ecological stress: 2025 demolition of nearly 100 unpermitted guesthouses in Thethi triggered civil unrest, illustrating the acute tension between rapid tourism growth and governance capacity.
- 20,000 seasonal NTFP collectors active in Bjeshkët e Nemuna: the largest of any park in the study, creating intense seasonal pressure on medicinal plants, berries, and water resources.



3.3 Climate Projections

Climate indicator	GWL 1.5	GWL 2.0	GWL 3.0	GWL 4.0
Air temperature increase (vs 1981-2010)	+1.3 °C	+1.9 °C	+3.1°C	+4.4 °C
Very hot days >35 °C / year	Marginal increase	Marginal increase	Low-moderate increase in lower zone	Moderate expansion in foothills
Growing season duration	+10 days	+22 days	+42 days	+60 days
Snow cover days (>10 cm in April)	-1 to -3 days	-3 to -7 days	-10 to -14 days	>-14 days; below 2,000m snow may vanish entirely
Meteorological drought intensity (SPEI)	Moderate increase	up to 2× more intense	3× more intense	Up to 3× more intense; 15-yr event every 2 yrs
Extreme daily precipitation change	No clear trend	+4%	+9%	+14% (landslide & flood risk)
Wildfire risk (FWI high-risk days)	Low-moderate increase	Moderate increase	Strong increase	Very strong; high risk zones expand above 2,000m

Source: BOKU downscaled projections. GWLs vs pre-industrial baseline; indicators vs 2001-2020 reference.

This cluster shows the highest extreme precipitation intensification in the study (+14% at GWL4.0), acting on steep limestone and unconsolidated slope terrain to generate the greatest flash flood and landslide risk.

Key projection findings:

- **Snow cover:** Below 2,000 m, April snow cover may vanish entirely under GWL4.0. Given that most tourism infrastructure, trails, and settlements lie below this threshold, this projection has direct implications for both winter tourism and year-round water availability from snowmelt.
- **Wildfire:** Extreme wildfire risk zones expanding above 2,000 m under GWL4.0 are particularly alarming given the concentration of rare and endemic biodiversity at high elevations. The first-ever recorded January wildfire in the Albanian Alps signals that fire seasonality is already shifting.

- **Extreme precipitation:** At +14% intensification - the strongest signal across all three clusters -the already-documented risk of flash floods and landslides in the Theth, Valbona, and Grebaja valleys will intensify. Existing trail and road infrastructure lacks the drainage to handle extremes.
- **Drought:** While drought intensification is moderate (up to 3×) relative to the Sharr complex, the combination with high summer visitor numbers creates acute water security risk, particularly for dispersed mountain communities that depend on springs without backup supply.

3.4 Climate Impact Chains

Element	NP Albanian Alps (Albania)	NP Prokletije (Montenegro)	NP Bjeshkët e Nemuna (Kosovo*)
Climate Drivers	Strong warming (+1.9 °C at GWL2.0, +4.4 °C at GWL4.0); longest growing season extension in cluster (+60 days); highest extreme precipitation intensification (+14%); wildfire risk expanding above 2,000 m.	Similar warming trajectory; up to 35 additional high-risk wildfire days per year at GWL4.0; reduced summer precipitation; snow cover loss accelerating in the 1,100–2,000 m range.	Summer droughts up to 3× more frequent under GWL4.0; 10–30% less summer precipitation; extreme rain events elevating erosion and flash-flood risk.
Environmental Impacts	Snow cover loss at lower elevations; disruption of snowmelt hydrology; flash flood and landslide risk on steep trails; invasive species establishment in degraded bilberry belt zones.	Spruce and fir dieback from bark beetle outbreaks; wetland and bog drying; shifts in species composition toward drought-tolerant scrub; forest fire damage.	Reduced summer flows in Lumbardhi and Deçanit rivers; erosion and juniper encroachment on high-altitude slopes; decline in aquatic fauna from combined HPP and drought impacts.
Socio-Economic Pressures	Overtourism (10× decade growth, 558,000 visitors in 2023); unregulated construction; waste and wastewater overload; 2025 demolition controversy; infrastructure inadequate for visitor loads.	Growing hiking and mountaineering tourism; inadequate sewage in Grebaja Valley; limited institutional staff and budget; ski resort proposals conflicting with adaptation priorities.	20,000 seasonal NTFP collectors; water diversion by residents altering river flow; weak regulation of construction and tourism; minimal park budget (€240,000 in 2023).
Consequences	Water stress and summer shortages; flash flood damage to trails and infrastructure; tourism quality degradation from overcrowding and waste; social conflict over governance.	Forest fires and habitat loss; tourism season shift; declining ecosystem services; limited institutional capacity to respond to emerging climate risks.	Income instability for NTFP collectors and herders; loss of ecosystem services; biodiversity decline from combined climate and human pressures; water security risk.

3.5 Priority EbA Pilot Zones

Pilot Location	Park	Intervention	Cost Estimate
Subalpine slopes - Theth and Valbona valleys	NB Albanian Alps	Revegetation and erosion control in degraded subalpine shrub and bilberry habitats (400–800 m)	**€120-150k**
Spring restoration - Theth and Valbona	NB Albanian Alps	Spring revitalisation and small water-retention structures for village water security	**€100-120k**
Tourism zone - Theth corridor waste & sewage	NB Albanian Alps	Pilot-scale nature-based wastewater treatment (constructed wetlands) combined with improved waste collection and composting to reduce pollution pressure during peak visitor season.	**€80-100k**
Grebaja Valley - ecosystem-based planning	NP Prokletije	Regulation of temporary structures; ecosystem-sensitive zoning enforcement	**€90-110k**
Prokletije mountain area - forest fire & pest	NP Prokletije	Wildfire risk reduction and bark beetle monitoring network	**€70-90k**
High-use recreation areas - solid waste	NP Prokletije	Waste infrastructure and management upgrade in high-use recreation areas of NP Prokletije (e.g. Grabaja Valley), with lessons applicable to other tourism hotspots across the Prokletije/Bjeshkët e Nemuna massif.	**€90-110k**
Lumbardhi and Deçanit riparian restoration	NP Bjeshkët e Nemuna	Riparian vegetation recovery and river bank stabilisation	**€90-120k**
Deçan valley - grazing zone rehabilitation	NP Bjeshkët e Nemuna	Grazing zone restoration and erosion prevention for degraded slopes	**€80-100k**
Rugova Gorge slopes- juniper & NTFP zones	NP Bjeshkët e Nemuna	Juniper control, NTFP management zones, and community benefit sharing frameworks	**€70-90k**


© National Park Prokletije (Management Authority)

3.6 Transboundary Climate Vulnerabilities and Coordination Priorities

- **Wildfire coordination:** This cluster has the most severe projected wildfire expansion in the entire study, with risk extending above 2,000 m. Forest fires cross national boundaries by definition, yet no tri-national early-warning, monitoring, or response protocol exists for the Prokletije-Albanian Alps area.
- **Water management:** The Valbona, Shala, Cem, and White Drin river systems originate in this cluster and cross multiple national boundaries before reaching the Adriatic and Aegean. Climate-driven reductions in snowpack and summer flows will cascade through all downstream users; harmonised basin management is currently absent.
- **Tourism governance divergence:** Albania's rapid tourism growth (558,000 visitors in 2023) contrasts sharply with Montenegro and Kosovo's* much smaller visitor numbers. The resulting pressure asymmetry - with most environmental impact concentrated on the Albanian side of the same mountain system - demands jointly developed carrying-capacity frameworks.
- **NTFP overharvesting:** 20,000 seasonal collectors in Bjeshkët e Nemuna may cross into Albanian Alps territory, yet there is no harmonised regulation of collection zones, species quotas, or certification standards.
- **Peaks of the Balkans trail:** The 192 km cross-border trail is a flagship tourism product shared by all three economies. Climate-driven trail damage (floods, landslides, erosion) and visitor pressure require a jointly funded trail maintenance and climate-proofing programme.

Recommendations
for Prokletije/Albanian Alps Cluster

- ✓ **Establish a tri-national wildfire monitoring and early-warning system for the Prokletije massif, incorporating the BOKU FWI projections and connecting national fire-fighting authorities.**
- ✓ **Develop a harmonised carrying-capacity and visitor management framework for the Peaks of the Balkans trail, incorporating climate risk zones and adaptive trail maintenance standards.**
- ✓ **Create a joint spring and watershed monitoring network to track snowpack, spring flow, and river discharge trends — providing early warning for water security risks in downstream communities.**
- ✓ **Negotiate a tri-national NTFP certification and collection quota framework that protects medicinal plant and bilberry populations from combined climate and harvesting pressure, while sustaining community livelihoods.**
- ✓ **Align economies' protected area management plan revisions with climate projections, establishing shared climate-biodiversity monitoring indicators tracked through a joint annual reporting.**

IV **Comparative** Synthesis

The three transboundary clusters share a common broad trajectory of warming and increasing hydro-climatic variability, yet the relative severity and nature of hazards differ significantly across the Western Balkans mountain landscape. The table below compares projected climate risks at GWL2.0 and GWL4.0 across clusters.

Climate hazard	Tara-Drina Corridor	Sharr / Korab	Prokletije / Albanian Alps
Temperature increase (GWL4.0)	+4.1 °C	+4.4 °C	+4.4 °C
Snow cover loss (April, GWL4.0)	Total disappearance possible	-14 days or more	>−14 days; loss below 2,000 m
Drought intensification (GWL4.0)	Up to 5× (highest in study)	Up to 4x	Up to 3x
Extreme precipitation (GWL4.0)	+8%	+13%	+14%
Wildfire risk trend	Moderate increase	Very strong increase	3× more intense
Water security risk	Medium-high	Very high (urban supply)	High (springs, dispersed settlements)
Tourism pressure	Moderate-high	High (ski conflict)	Very high (overtourism)

Across all three clusters, the following cross-cutting priorities emerge:

- **Snow loss and hydroeconomic risk:** All eight protected areas will experience significant reductions in April snow cover under GWL2.0-4.0. Winter tourism currently underpins local economies in all three clusters; without proactive diversification, economic contraction is inevitable by mid-century.
- **Drought frequency shift:** The shift from 15-year to 2-year drought return periods across all clusters by GWL4.0 represents a fundamental change in climate regime, not merely an incremental increase in aridity. Management plans and infrastructure designed for current conditions will be maladapted.
- **Flash flood and landslide amplification:** Extreme precipitation intensification (8-14%) acting on steep, degraded mountain terrain will increase hazard exposure substantially. Investment in ecosystem-based erosion control and early-warning systems is both cost-effective and urgently needed.
- **Wildfire season expansion:** The expansion of high-risk wildfire days - including above 2,000 m in the Prokletije-Sharr complex - demands a step-change in transboundary fire governance that currently does not exist in any of the three clusters.

The recommended EbA pilot investments across 3 clusters total approximately €2.13-2.69 million for the 23 identified pilot actions. Embedding climate-biodiversity indicators into existing protected area management monitoring systems - including minimum temperature and precipitation thresholds, snow-cover duration, NDVI vegetation health, bark-beetle incidence, and spring flow rates - will enable adaptive management to respond systematically to the climate trajectories documented in this analysis.

1. Protected Area Profiles

This chapter provides detailed profiles of the eight protected areas covered by the assessment, drawing on desk research, stakeholder mapping, and field evidence from focus group discussions and key informant interviews.

Each profile describes the park's basic characteristics, ecological and biodiversity values, climate characteristics and observed or projected impacts, accessibility and population context, key risks and pressures, existing and planned infrastructure with a focus on tourism, and a summary of the main stakeholder groups and consultation insights.

Cluster I

National Park Albanian Alps (Albania)

© National Park Albanian Alps (Management Authority)

ALBANIA

Economy	Albania
IUCN Category	II - National Park
Area	82,844.65 ha
Elevation Range	350-2,694 masl
Established	2022 (official designation)
Management Authority	National Agency of Protected Areas (NAPA) / RAPA Shkodër & Kukës
Management Plan	In preparation
2023 Budget	Budget managed centrally by NAPA; not publicly disaggregated per park

Ecological and Biodiversity Values

The Albanian Alps National Park is one of the most biodiverse mountain protected areas in Europe, harbouring approximately 1,650 vascular plant species of which 65 are IUCN-threatened (9 Critically Endangered, 32 Endangered, 24 Vulnerable). It contains 21 endemic and 72 sub-endemic plant taxa, representing one of the highest levels of floristic endemism in the Dinaric Arc.

The fauna is equally impressive: 46 mammal species (including brown bear, Balkan lynx, wolf, and chamois), 137 bird species, 45 amphibians and reptiles, and 7 fish species. The park encompasses 44 distinct habitat types providing refuges for ancient, endemic and relict species. Pančić spruce (*Picea omorika*) and Balkan pine represent globally significant forest refugia.

© Sonja Gebert

The park sits at the heart of the Peaks of the Balkans landscape - a cross-border natural corridor connecting Albanian, Montenegrin, and Kosovar* mountain ecosystems. This transboundary connectivity is critical for apex predator populations and for ecological resilience under climate change.


© Sonja Gebert

Climate Characteristics and Climate Change Impacts

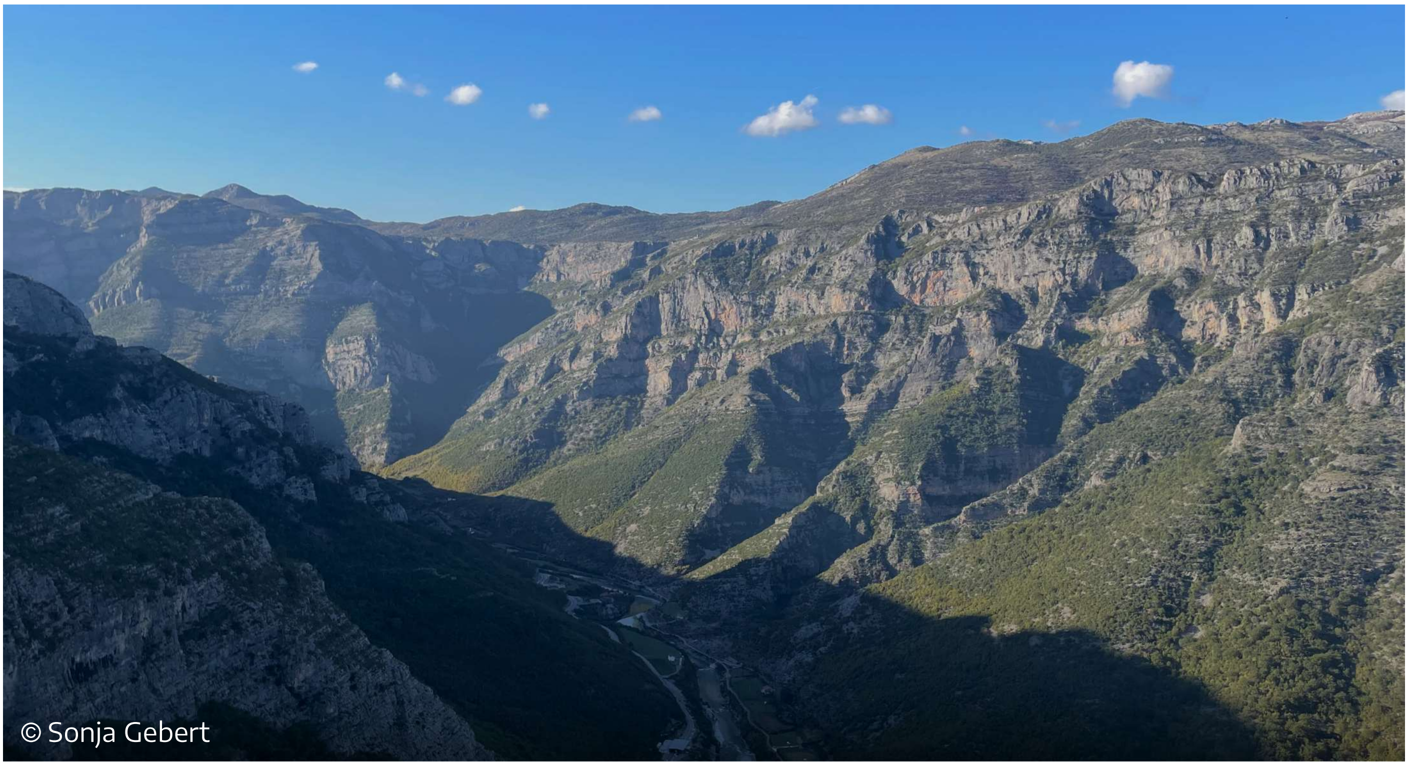
The Albanian Alps experience a northern Mediterranean mountain climate, characterised by annual precipitation up to 1,760 mm (dominated by autumn-winter rains and snow), 110-140 precipitation days annually, and snowfall accumulation of 3-4 m in some basins. Mean January temperatures at higher altitudes reach ?8 °C; summer temperatures range 15-21 °C depending on elevation.

BOKU projections indicate a temperature rise of +1.3 °C (GWL1.5) to +4.4 °C (GWL4.0) relative to the 1981-2010 baseline - the highest warming projected among the three clusters. Snow cover duration is projected to decline by more than 14 days in April by GWL4.0, with total snow disappearance below 2,000 m possible. Meteorological drought is projected to intensify up to 3× and increase in frequency from once-in-15-years to once-in-2-years by GWL4.0. Wildfire risk is among the most alarming signals - extreme risk zones expanding above 2,000 m, and a documented January wildfire already signals that the fire season is lengthening. Extreme daily precipitation is projected to intensify by +14%, the highest in the study area, acting on steep karst terrain to amplify flash flood and landslide risk.

Stakeholders and communities in focus groups described less snow and more hot days, drier summers, periodic spring drying, more frequent forest fires, and expansion of pine processionary caterpillars - with chestnut and bilberry stands noticeably stressed. The 2025 field season documented recurring trail damage from intense summer rainstorms.

Accessibility and Population

The park is accessed through three main road corridors: SH20 (Hani i Hotit-Vermosh) serving the Kelmend area; SH21 (Koplik-Bogë-Theth) serving the Theth Valley; and SH22 (Bajram Curri-Valbona) serving the Valbona Valley. Key segments are paved and highly scenic, but high-altitude sections (e.g. Qafë Thore-Theth) are frequently blocked in winter, while roads to more remote valleys remain unpaved and of poor quality. The planned Lotaj-Lekbibaj road link would significantly reduce travel time between the Theth and Valbona regions.



Core population within the five administrative units directly linked to the park totals approximately 9,166 inhabitants (2023 census). Surrounding municipalities - Shkodër (102,434), Tropoja (14,189), and Malësi e Madhe (21,684) - exert the primary demographic pressure. Between 2011 and 2023, Shkodër lost over 28% and Tropoja over 30% of residents, with aging populations and severe youth outmigration. In summer, diaspora returns from Italy, Germany, the UK, and the US can temporarily double village populations. The park received 558,000 visitors in 2023.

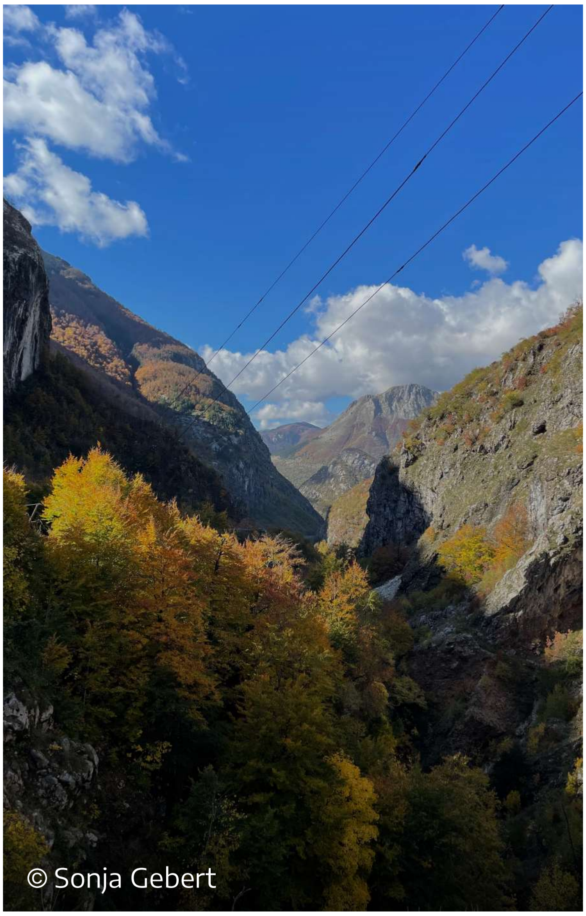
Key Risks and Pressures

- Overtourism and unregulated construction: Theth and Valbona valleys face acute overcrowding; 2025 demolition of nearly 100 unpermitted guesthouses in Thethi triggered civil unrest
- Waste and wastewater: Sewage systems largely absent; wastewater discharged untreated into Valbonë, Shala, Cem, Vermosh rivers; solid waste collection insufficient during tourism peaks
- Hydropower pressure: 9 small HPPs constructed within the park, some shut by court order; disruption of ecological flows and fish migration
- Climate-driven flash floods and landslides: +14% extreme precipitation intensification by GWL4.0; steep limestone and unconsolidated terrain; documented trail and road damage
- Wildfire: Expanding fire season (January fires); risk expanding above 2,000 m under GWL4.0
- Forest pests and biodiversity decline: Chestnut groves stressed; bilberry belt shrinking; processionary caterpillar more prevalent; spring water sources intermittently dry
- Weak governance: Land tenure uncertainty under Kanun customary law delays investment; limited RAPA staffing and budget; inconsistent regulation enforcement

Existing and Planned Infrastructure - Tourism

Tourism infrastructure is dominated by family-run guesthouses in Theth, Valbona, Vermosh-Lepushë, and Tropoja. Visitor centres exist in Valbona (not RAPA-managed) and Thethi (RAPA Shkodër-managed), but services and facilities remain underdeveloped relative to visitor volumes. The 192 km Peaks of the Balkans cross-border trail is the primary tourism draw.

No major energy or large-scale tourism infrastructure is planned within the park due to protected status. The strategic priority is the Lotaj-Lekbibaj road link. A 2025 'mountain package' law aims to formalise land ownership and resolve Kanun-related tenure uncertainty. Albania's National Tourism Strategy 2025-2030 classifies the Albanian Alps under the 'Northern Cluster' prioritising nature tourism (mountain climbing, rafting, cycling, agro-tourism).



© Sonja Gebert

Key Stakeholders - Consultations and Interview Insights

Stakeholder group	Key Representatives	Influence	Climate/ Biodiversity Engagement	Main Concerns Raised
National Authorities	NAPA (park manager), RAPA Shkodër/Kukës, National Forestry Agency, National Environmental Agency	High	Medium	Budget transparency, HPP controls, enforcement of demolition orders
Local Government	Municipalities of Tropoja, Shkodër, Malësi e Madhe	Low-Medium	Low	Infrastructure investment, land regularisation, tourism revenue
Tourism Operators	Gegest, Margjeka, Alpet guesthouses; Peaks of Balkans guides	Low	Low	Trail maintenance, permit system, visitor management
Civil Society / NGOs	Vis Albania, PONT, CNVP	Medium	Medium-High	EbA pilots, community livelihoods, sustainable tourism certification
FGD Participants	Farmers, herders, guesthouse owners (174 participants across 2 FGDs)	Low	Low-Medium	Less snow, wildfire risk, chestnut/bilberry decline, water shortages, waste
KII Interviewees	Park staff, herders, villa owners	Medium	Medium	Tourism planning instability, water scarcity shaping settlement use, guesthouse investment risk

Cluster I

National Park Prokletije (Montenegro)

© National Park Prokletije (Management Authority)

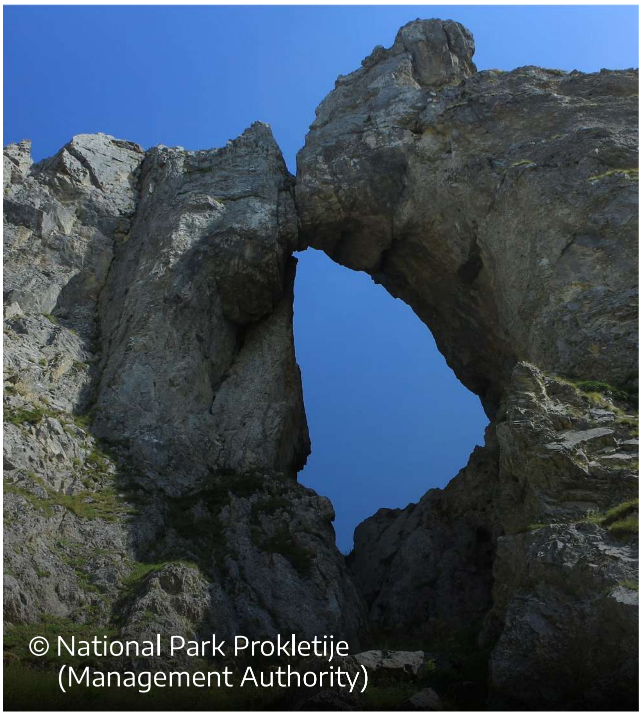
MONTENEGRO

Economy	Montenegro
IUCN Category	II — National Park
Area	16,630 ha
Elevation Range	1,100–2,534 masl
Established	2009
Management Authority	Public Enterprise for National Parks of Montenegro (JPNPCG)
Management Plan	2021–2025 (under revision; climate change mitigation to be included in new version)
2023 Budget	Consolidated within JPNPCG budget across all 5 NPs; not disaggregated

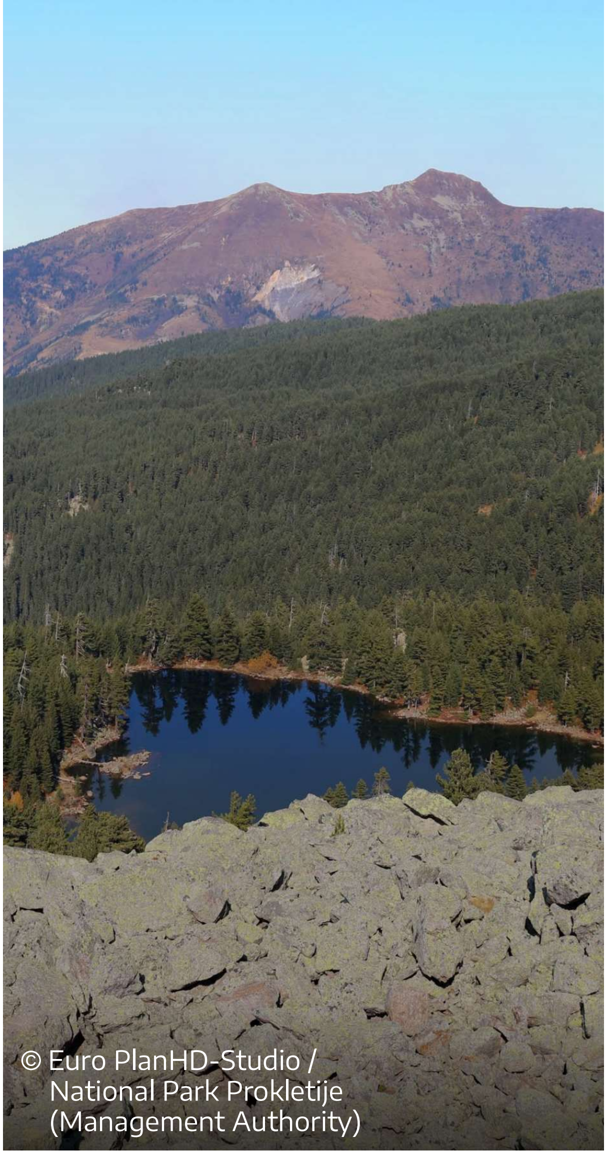
Ecological and Biodiversity Values

National Park Prokletije is designated as an Important Plant Area (IPA), Important Bird Area (IBA), and an Emerald Network site. It hosts more than 1,700 plant species — almost half of Montenegro's entire flora — including numerous endemic and relict taxa. Habitats include alpine grasslands, limestone screes, glacial lakes, bogs, high-altitude coniferous forests, and the rare Western Balkan alpine fens. Priority species include the Balkan butterwort (*Pinguicula balcanica*), Blečić's wulfenia (*Wulfenia blecicii*), and Frivald's orchid (*Pseudorchis frivaldii*).

The park protects Montenegro's most rugged mountain massif and has high geopolitical significance as a tri-border area (Albania–Kosovo*–Montenegro). Wildlife includes brown bear, wolf, Balkan lynx, eagle, capercaillie, and falcon, alongside freshwater fish of conservation importance. Several habitats remain under-researched and require priority conservation attention.



© National Park Prokletije (Management Authority)



© Euro PlanHD-Studio / National Park Prokletije (Management Authority)

Climate Characteristics and Climate Change Impacts

The Prokletije massif has an alpine climate characterised by heavy precipitation, prolonged snow cover, and frequent avalanche risk. No disaggregated climate data is available at park level, but the BOKU projections for the broader Albanian Alps–Prokletije–Bjeshkët e Nemuna cluster project warming of +1.9 °C (GWL2.0) to +4.4 °C (GWL4.0). Wildfire risk is among the strongest signals, with up to 35 additional high-risk fire days per year projected at GWL4.0.

Stakeholders in focus groups described heat waves and droughts, wildfires, and shortened snow seasons. The park's spruce and fir stands are under increasing pressure from bark beetle outbreaks intensified by prolonged drought stress. Wetlands and bogs are reportedly drying. The Grebaja Valley, the park's main tourism focal point, is experiencing more intense storm events causing trail damage.

Accessibility and Population

The park is accessible primarily through Plav and Gusinje municipalities. Roads to highland valleys (Grebaja, Ropojana, Hridsko Lake) are mostly unpaved and seasonally difficult. The Plav–Bogićevica–Dečani road reconstruction is planned to improve tourist connections with Albania and Kosovo*. Cross-border accessibility is improving through the Montenegro–Kosovo*border link near Čakor and the Albania–Kosovo* highway enhancing Valbona–Prizren connections.

No dense settlements are located in the park core; traditional summer pastoral settlements (katuns) and small villages exist on the margins in Plav and Gusinje municipalities (combined population ~13,700). Population shows modest growth (+14–16% since 2011) but is characterized by aging demographics, youth emigration, and limited economic opportunities. Summer diaspora visits temporarily increase local density.

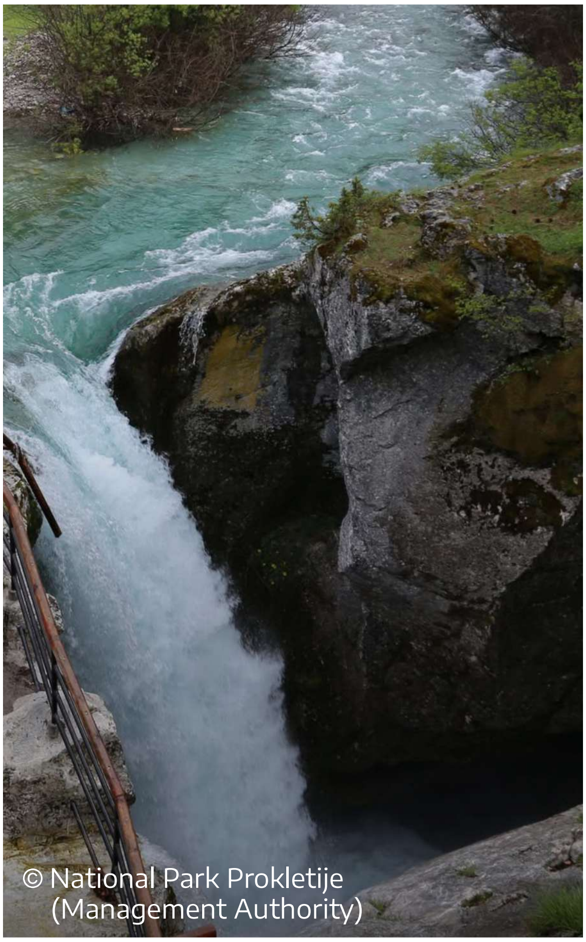

© National Park Prokletije (Management Authority)

Key Risks and Pressures

- Bark beetle outbreaks and spruce/fir dieback, intensified by drought and warming temperatures
- Wetland and bog desiccation threatening endemic and rare flora (e.g. *Wulfenia blecicii, Pinguicula balcanica*)
- Unregulated tourism facilities in Grebaja Valley: illegal chalets, solid waste, sewage gaps
- Hydropower diversions outside the park (Babino Polje) capturing water from within park
- Limited staff, insufficient monitoring capacity, and delays in sanitation infrastructure
- Proposed ski resort development (Prokletije Valbona) conflicting with climate adaptation needs
- Avalanche and landslide risk on rugged terrain, increasing with altered precipitation patterns

Existing and Planned Infrastructure - Tourism

Tourism relies on marked hiking trails (Grebaja, Ropojana, Vusanje, Hridsko Lake), private guesthouses, and renovated katuns. A visitor centre is located in Gusinje. The park is part of the Peaks of the Balkans 192 km trail. The main planned investment is reconstruction of the Plav–Bogićevica–Dečani road. No major energy projects are foreseen within the park. Visitor infrastructure is basic and has not kept pace with increasing summer tourism demand.

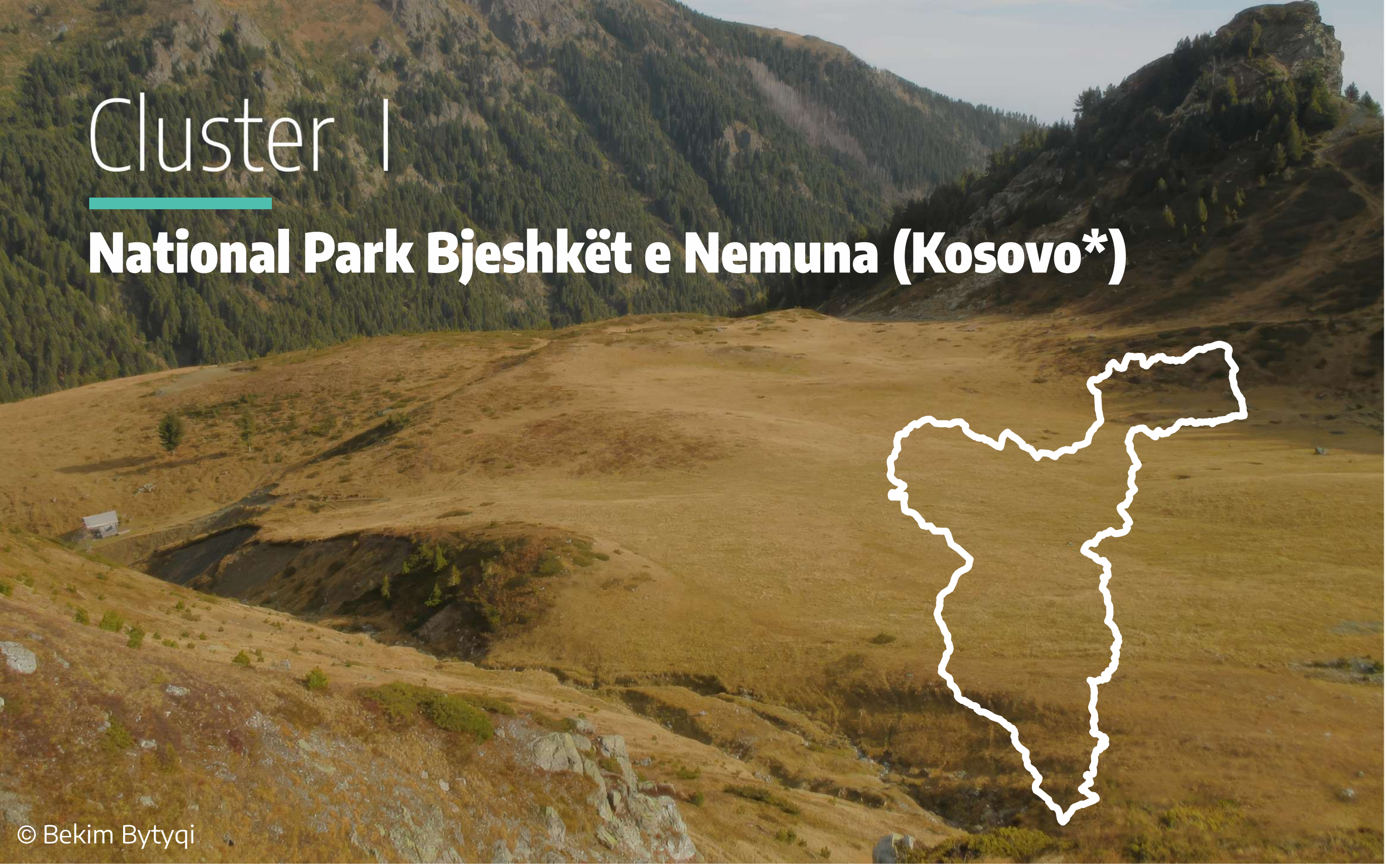

© National Park Prokletije (Management Authority)

Key Stakeholders - Consultations and Interview Insights

Stakeholder group	Key Representatives	Influence	Climate/ Biodiversity Engagement	Main Concerns Raised
Protected Area Authority	Np Prokletije Director, rangers	High	High	Staff capacity constraints, bark beetle monitoring, illegal construction
Environmental Agency	Environmental Protection Agency of Montenegro	High	High	Nature protection monitoring, regulatory compliance
Local Government	Municipality of Plav (secretary)	Medium	Medium	Road infrastructure, agrotourism support, boundary governance
Tourism Operators	5 accommodation/guiding operators (hiking, agrotourism, winter tourism)	Medium	Medium-High	Infrastructure constraints, illegal construction, Peaks of Balkans trail maintenance
Farmers/Herders	Local pastoralists, beekeepers	Medium	Medium	Support for traditional pastoral systems and traditional "katun" (seasonal pastoral settlement), climate stress on livestock, ensuring herder numbers
Fishing Society	Sports Fishing Society Plavsko Jezero	Low	High	Tourism planning instability, water scarcity shaping settlement use, guesthouse investment risk
FGD/KII Insights	Tourism operators, park staff, herders	Medium	Medium-High	Shorter winters, increased summer visits, colder nights 2025, institutional coordination gaps

Cluster I

National Park Bjeshkët e Nemuna (Kosovo*)



© Bekim Bytyqi

KOSOVO*

Economy	Kosovo*
IUCN Category	II — National Park
Area	63,028 ha
Elevation Range	750–2,656 masl
Established	2012
Management Authority	Directorate for Management of NP 'Bjeshkët e Nemuna', under Kosovo* Environmental Protection Agency (KEPA)
Management Plan	2024-2033
2023 Budget	€240,000

Ecological and Biodiversity Values

Bjeshkët e Nemuna encompasses fertile valleys, forests, and mountain ecosystems rich in biodiversity of scientific and cultural value. Approximately 1,000 endemic, relict, and endemorelict plant species are recorded, with diverse fauna featuring numerous Balkan endemics. The park protects high-altitude landscapes of the Prokletije massif — considered one of the wildest mountain areas in Europe — including the headwaters of the Lumbardhi and Deçanit rivers.

Biodiversity values include brown bear, wolf, Balkan lynx, chamois, eagle, capercaillie, and rare freshwater fish. The acacia forests unique to the Deçan valley, traditional chestnut groves, and high-altitude juniper scrub are among the most distinctive ecological communities. The park's 44 habitat types include internationally important peatbogs, springs, and limestone karst formations.

© Bekim Bytyqi


© Bekim Bytyqi

Climate Characteristics and Climate Change Impacts

The park has a mountain climate with high precipitation exceeding 130 days per year and snow persistence of 60–210 days depending on elevation. Annual precipitation ranges from 1,000 mm in foothills to 1,500 mm at higher elevations; average annual temperature ranges from 10 °C in lower areas to 5 °C above 2,000 m.

BOKU projections for this cluster indicate summer droughts becoming up to 3× more frequent by GWL4.0, with 10–30% less summer precipitation. Wildfire risk is projected to expand significantly, including into high-altitude zones. Focus group participants described mild winters, hot summers, lack of snow, rainfalls shifting in pattern, and the spread of willows (*Salix spp.*) and black poplar (*Populus nigra*) species along rivers. Documented recent impacts include drying of the Lumbardhi river (combined effects of HPP diversions and drought), near-disappearance of fish populations in Bjeshkët e Deçanit, and a January wildfire event. Acacia trees in Deçan have stopped flowering due to climate change, and chestnut disease threatens the species' regional survival.

Accessibility and Population

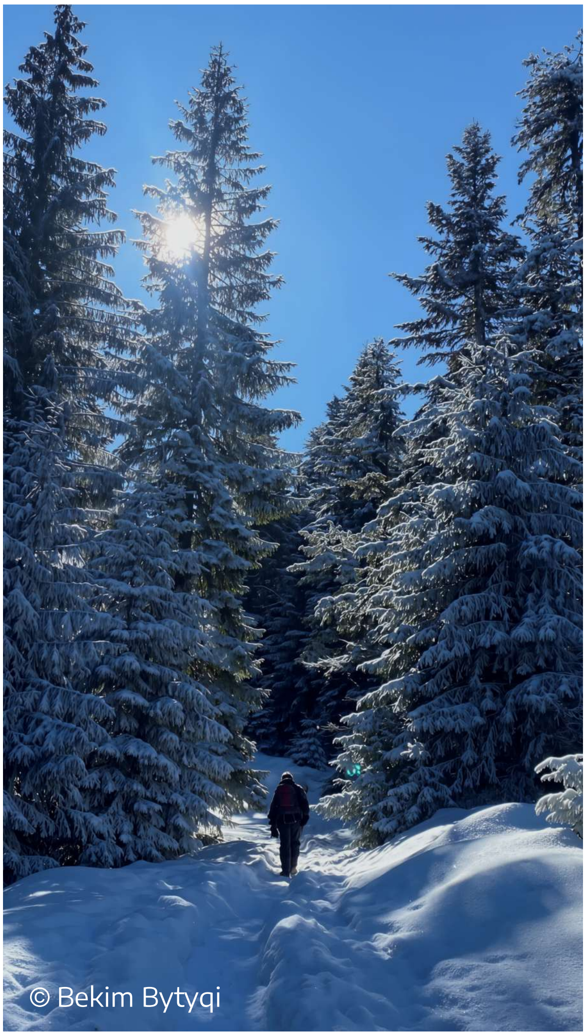
Key access is provided by the M9 road (Peja–Kuqishtë–Montenegro border, 21.5 km, paved), R106 (Peja–Rožaje), while R108 (Deçan–Montenegro border) is unpaved and in poor condition. The park covers municipalities of Istog, Peja, Deçan, Junik, and Gjakova. Settlement populations within the park declined nearly eightfold between 1948 (4,046 inhabitants) and 2011 (476 inhabitants); villages are largely abandoned, with entire settlements becoming uninhabited. Around 20,000 seasonal NTFP collectors generate the largest seasonal population influx of any park in the study.

Key Risks and Pressures

- NTFP over-harvesting: 20,000 seasonal workers collecting medicinal plants, blueberries, gentian, sage, and wild fruits — the highest collector pressure in the study area
- Hydropower impacts: Small HPPs (Kozhnjer 8.3 MW; Radac 1 MW) reduce river flows, destroying aquatic habitats; water diversion by residents further degrades Lumbardhi and Deçanit
- Forest fires: Expanding season and risk elevation; January fires now documented
- Illegal logging and construction: Waste dumping, road building, unregulated tourism facilities
- Uncontrolled expansion of riparian vegetation: common juniper (*Juniperus communis*) encroachment on pastures; willows (*Salix spp.*) and black poplar *Populus nigra* along rivers
- Limited budget (€240,000) and governance capacity relative to the park's scale
- Erosion and juniper encroachment on degraded slopes
- Chestnut disease threatening the Deçan valley groves

Existing and Planned Infrastructure - Tourism

Tourism is diverse, encompassing skiing, mountaineering, cave exploration, camping, and cultural tourism, with Peja as the main hub. The park is part of the Peaks of the Balkans trail. Visitor infrastructure exists but varies in quality; the management plan (2024–2033) emphasises sustainable pastoralism, traditional crafts, eco-tourism, and NTFP management. Investment priorities focus on infrastructure improvements, sustainable tourism, and implementation of sustainable practices. No large-scale infrastructure projects are planned within the park core. The 192 km cross-border Peaks of the Balkans trail is a flagship initiative linking Kosovo*, Montenegro, and Albania.

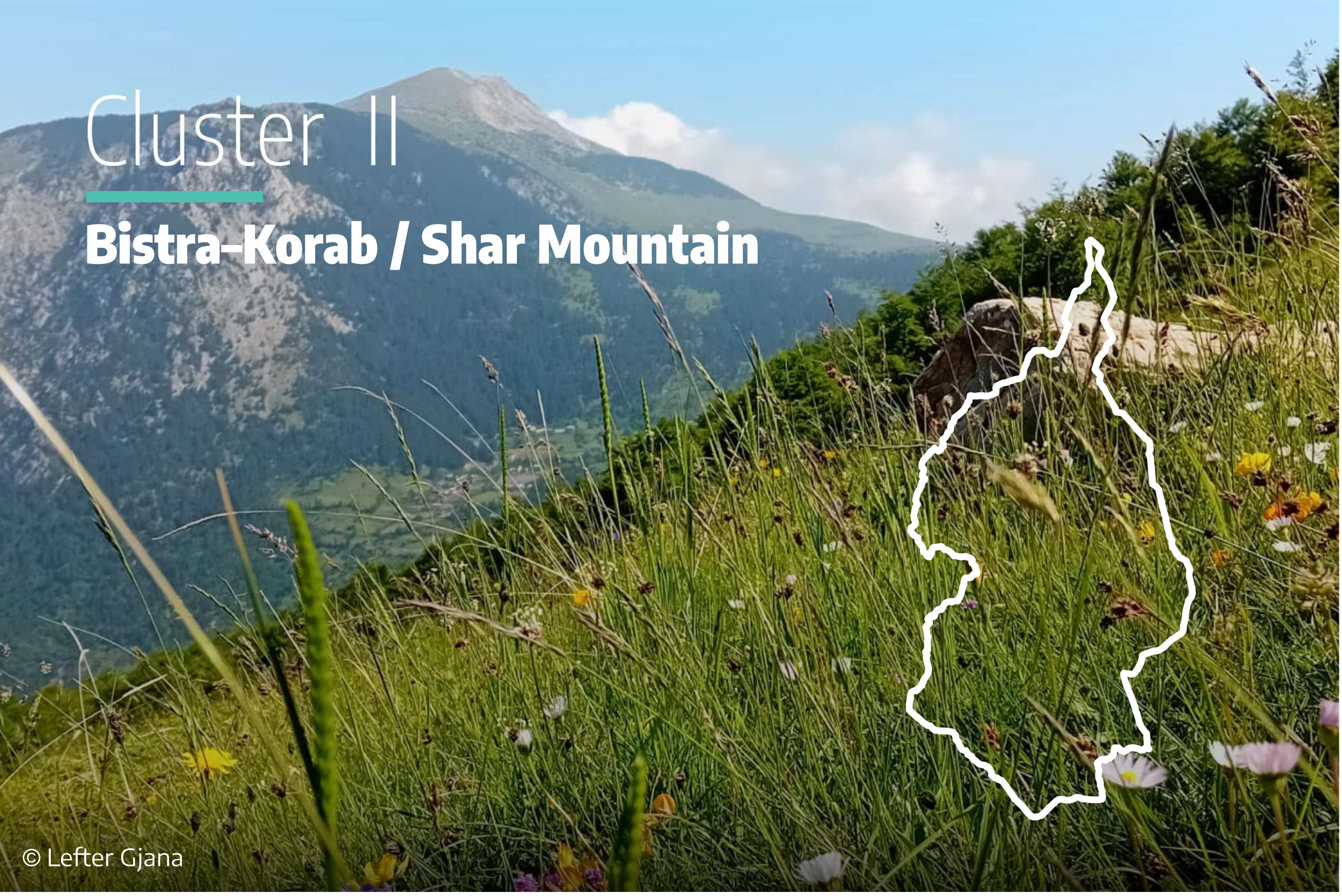

© Bekim Bytyqi

Key Stakeholders - Consultations and Interview Insights

Stakeholder group	**Key Representatives**	**Influence**	**Climate/ Biodiversity Engagement**	**Main Concerns Raised**
Park Management	NP Directorate; KEPA; rangers; nature conservation expert	High	High	River degradation from HPPs, invasive species, NTFP management, budget constraints
Forestry Agency	Kosovo* Forest Agency (Peja - management and rangers)	High	High	Forest fire risk, illegal logging, biodiversity monitoring
Hunters / Fishing	Hunting Association 'Rugova' (Peja)	Medium	Medium	Wildlife population management, hunting quotas
Agriculture/Beekeepers	SHB Aldi, Association of Beekeepers, Agriculture and beekeepers Palma	High	High	Climate impacts on bees, chestnut disease, NTFP certification
Tourism Operators	Villa Stina, local eco-tourism operators	High	High	Sustainable park development, agrotourism income, Peaks of Balkans trail
Civil Society	PONT, CNVP (development partners)	High	Medium-High	EbA implementation, livelihoods support, cross-border cooperation
FGD/KII Insights	Farmers, NTFP collectors, tourism operators	Medium	High	Acacia/chestnut decline, drying rivers, reports of unseasonal winter wildfires, invasive shrubs

Cluster II

Bistra-Korab / Shar Mountain



© Lefter Gjana

ALBANIA

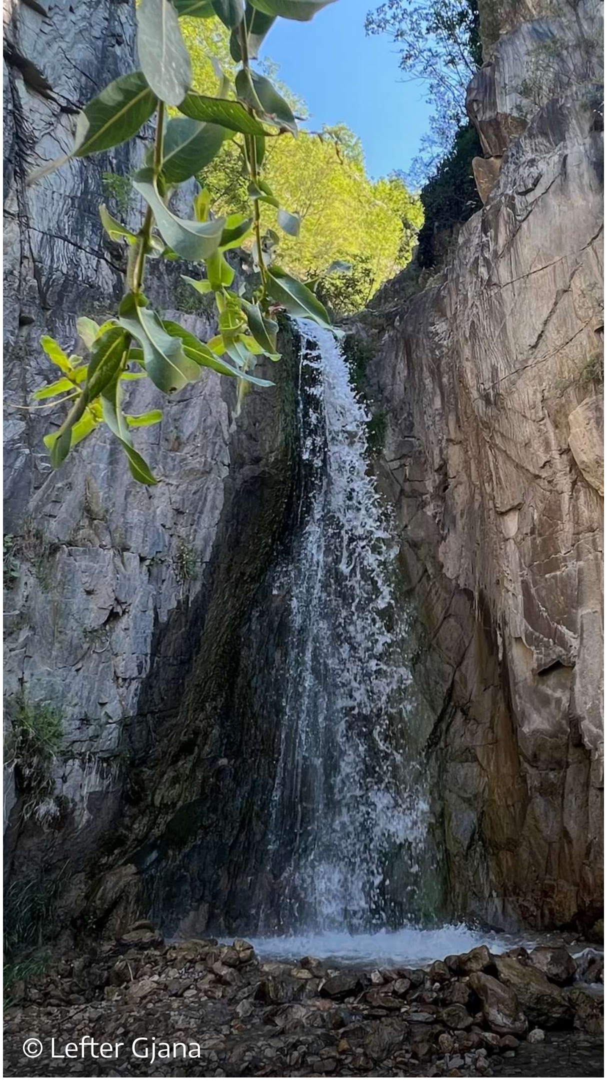
Economy	Albania
IUCN Category	IV — Habitat/Species Management Area
Area	55,550 ha
Elevation Range	410–2,350 masl (Korab peak 2,751 m)
Established	2011
Management Authority	NAPA / RAPA Dibër and Kukës
Management Plan	In preparation (existing draft from 2014–2018)
2023 Budget	Managed centrally by NAPA; not publicly disaggregated

Ecological and Biodiversity Values

Korab–Koritnik covers the Korab–Koritnik–Gjallica mountain chain in northeast Albania, forming part of the Albanid–Hellenid range. The park preserves extensive forests, alpine grasslands, glacial lakes, and high peaks including Mount Korab (2,751 m) — Albania's highest point. Over 22,000 ha of pastures and 19,000 ha of forests support major biodiversity, including large carnivores (brown bear, wolf, lynx), diverse birdlife (eagle, capercaillie, falcon), and freshwater fish.

Geology includes Paleozoic and Mesozoic formations. The park has high floristic diversity with endemic and relict species, and connects the Dinaric mountain system to North Macedonia. Thermo-mineral springs in Peshkopi (Dibër side) represent a unique geo-hydrological asset. The area is recognised under the OSCE Regional Assessment as a climate-vulnerable biodiversity zone.

© Lefter Gjana


© Lefter Gjana

Climate Characteristics and Climate Change Impacts

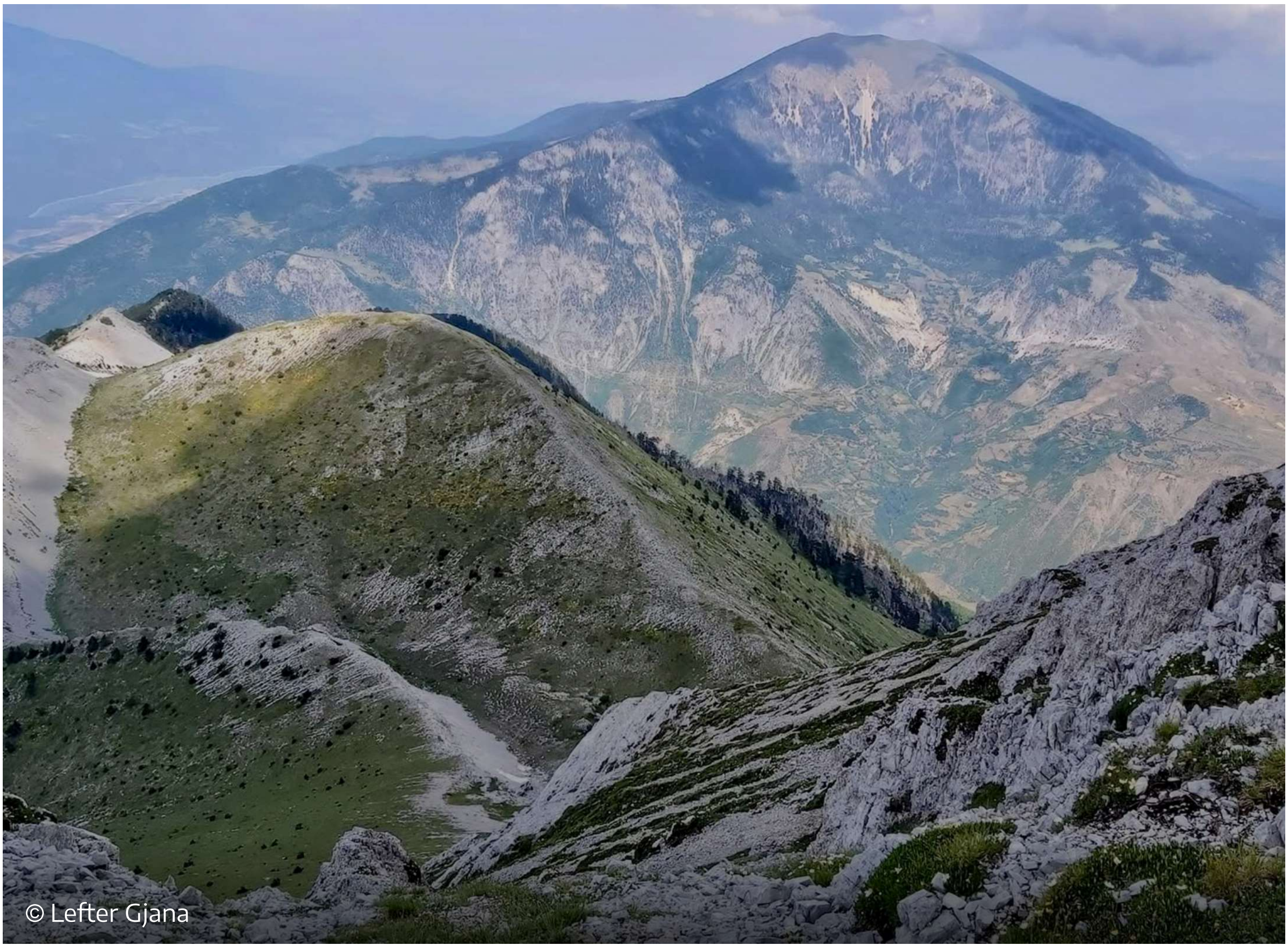
No detailed disaggregated climate statistics are available at park level. BOKU projections for the broader cluster indicate temperature increases of +1.25 °C (GWL1.5) to +4.4 °C (GWL4.0), with drought intensification up to 4× and summer precipitation declining by 10–25%. The Luma River system and springs are particularly vulnerable, with focus groups reporting reduced rainfall and snow, endangered springs, and flash floods and erosion in several villages (Zapod, Shishtavec, Çajë, Shtiqen — Kukës; Cerjan, Rabdisht — Dibër). Forest fires and erosion/landslides are increasing risk.

Stakeholders described a shift in crop composition (potatoes declining, grapes, corn, tomatoes, peppers emerging), unstable yields, and higher irrigation requirements. The Luma River shows periods of extreme low flow combined with episodic flash floods. KII participants highlighted drying springs driving village migration and reduced water availability for livestock.

Accessibility and Population

The park is reached from Peshkopi (via SH6 to Radomirë, gateway to Mount Korab) or from Kukës (via Rruga e Kombit toward the Shishtavec plateau). Road conditions vary from paved to gravel, with most mountain access routes in poor shape. Two strategic corridors — 'Rruga e Kombit' (Kosovo* to Tirana) and 'Rruga e Dibres' (North Macedonia to Tirana) — improve regional connectivity. Kukës airport was recently refurbished as an international facility but is not yet fully operational.

The park territory extends through Dibër and Kukës municipalities (combined 2023 population 86,900), both of which recorded major declines between 2011 and 2023 (−11,860 and −10,844 respectively). Total park area administrative units host approximately 42,498 inhabitants across 14 villages/units. Outmigration is pronounced, with an aging population and heavy concentration of residents aged 50+.

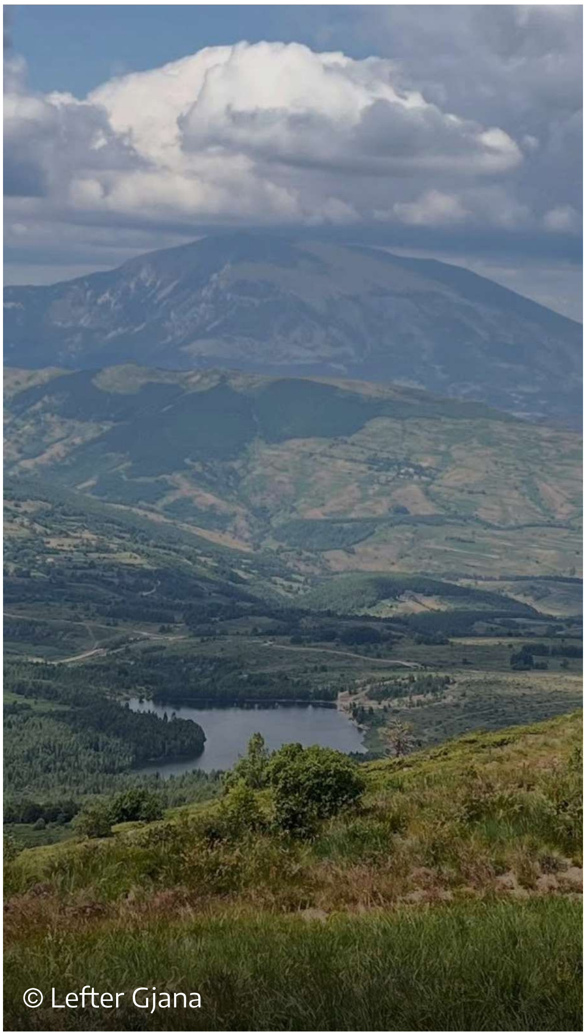

© Lefter Gjana

Key Risks and Pressures

- Illegal logging and overharvesting of medicinal plants (*Gentiana lutea, Vaccinium myrtillus*), with destructive fishing practices undermining biodiversity
- Quarrying inside the park and hydropower development (8 small HPPs including Lurë cascade, Bele, Prellë, Shoshan, Bistricë) altering river flows and sedimentation
- Large-scale Skavica HPP (250 MW) planned upstream in Kukës — expected to reshape hydrology of the entire Drin cascade
- Wildfires: increasing frequency and season length; January fires documented
- Erosion and landslides threatening settlements, especially Zapod, Shishtavec, and Çajë
- Absent management plan (preparation ongoing) limiting governance capacity
- Rural depopulation eroding traditional land-use practices that historically sustained ecological balance

Existing and Planned Infrastructure - Tourism

Tourism infrastructure is limited: small-scale family accommodation, some villas, and underused camping sites. Visitor centres in Kukës and Shishtavec, with planned facilities in Peshkopia, Radomira, and Maqellara. Trail assets include the High Scardus Trail (495 km), the Trail of Colors (13 km, Shishtavec to Çajë), and routes to Bele Waterfall. Health and spa tourism around Peshkopi thermo-mineral springs is a development priority. The Albania National Tourism Strategy 2025–2030 identifies Korab–Koritnik for health and wellness tourism development.

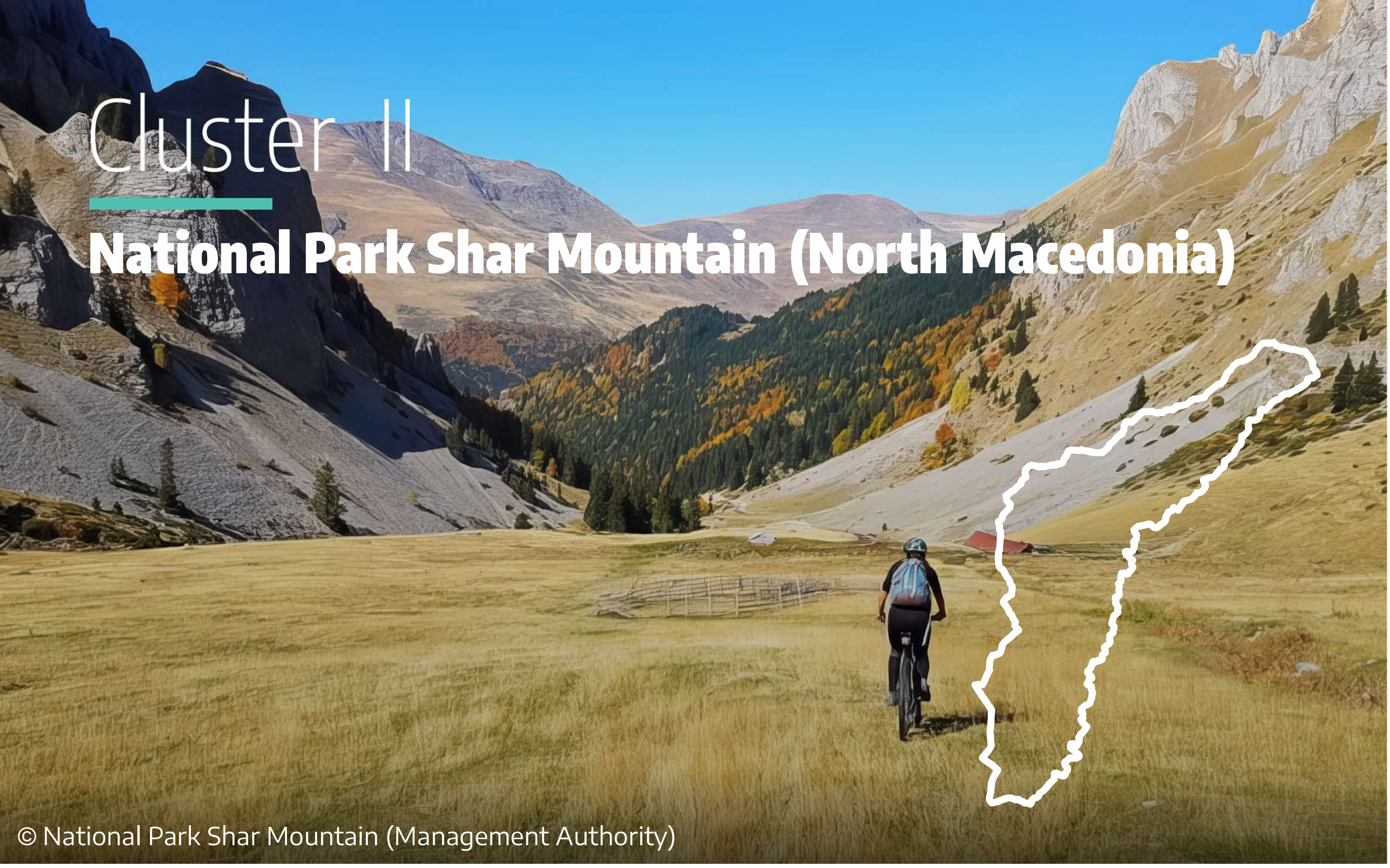


Key Stakeholders - Consultations and Interview Insights

Stakeholder group	Key Representatives	Influence	Climate/ Biodiversity Engagement	Main Concerns Raised
National Authorities	NAPA/RAPA Dibër and Kukës, National Forestry Agency	High	Medium	Absence of management plan, illegal logging, HPP proliferation, Skavica HPP risk
Local Government	Municipalities of Kukës and Dibër	Low-Medium	Low	Rural development, outmigration, agricultural support
Tourism Operators	Guesthouse Korabi Ceren; trail tourism operators	Low	Low	Trail development, visitor services, agro-tourism potential
Civil Society	Vis Albania, PONT, CNVP	Medium	Medium	EbA potential, spring restoration, community livelihoods
Hunters	Hunting Association Kukës	Low	Low	Wildlife management, sustainable hunting practices
FGD/KII Insights	Farmers, spring users, herders	Low-Medium	Low-Medium	Spring drying, crop composition shift, irrigation needs, erosion/landslide risk

Cluster II

National Park Shar Mountain (North Macedonia)



© National Park Shar Mountain (Management Authority)

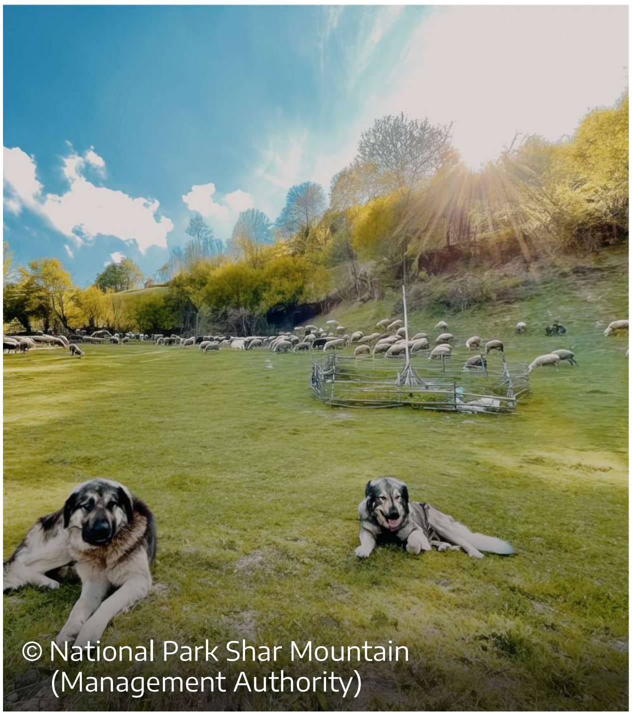
Economy	North Macedonia
IUCN Category	II - National Park
Area	62,705 ha
Elevation Range	450–2,748 masl
Established	2021
Management Authority	Public Institution 'Shar Mountain National Park' under Ministry of Environment and Physical Planning
Management Plan	2022–2032; METT-based performance tracking
2023 Budget	€400,000

NORTH MACEDONIA

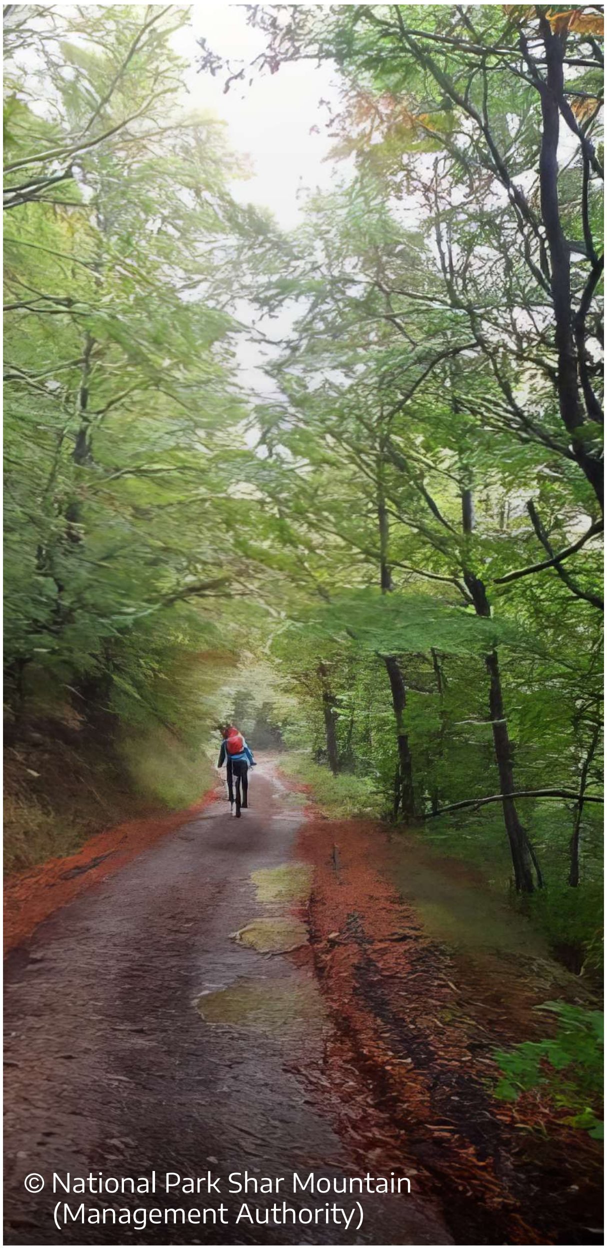
Ecological and Biodiversity Values

National Park National Park Shar Mountain is a biodiversity hotspot with 1,260 vascular plants, 128 bird species, 51 mammals, 11 amphibians, 17 reptiles, and 5 freshwater fish. It also hosts 662 diatoms, 260 mosses, 500 fungi, and 160 lichens. The park contains 40 glacial lakes, an enormous river network, and alpine landscapes — with half the territory under forest (dominated by beech, oak, fir, and pine) and half under high mountain pastures.

The Shar massif forms the border between North Macedonia and Kosovo*, extending over 60 km from Luboten peak (2,498 m) to the Mavrovo National Park. Medicinal and aromatic plants (22 species with pharmaceutical and food industry potential) represent a key economic asset. The Sharski Vodi hydropower system diverts more than 50% of mountain rivers into the Mavrovo reservoir, providing ~12% of North Macedonia's national electricity supply — creating a foundational tension between conservation and energy production.



© National Park Shar Mountain (Management Authority)



© National Park Shar Mountain (Management Authority)

Climate Characteristics and Climate Change Impacts

Popova Šapka (1,780 m) records a mean annual temperature of 4.8 °C, annual precipitation ~700–1,250 mm, and maximum recorded temperature 30.6 °C. The park faces 19 critical torrent systems on the Sharr hillsides, and major rivers (Pena 36.8 km, Mazdracha, Bistrica 19.2 km) present significant flood risk. The August 2015 Tetovo flash flood (less than 2 hours of rain triggered flash floods, torrents, and landslides, causing 6 fatalities and USD 21.5M in damage) is the park's defining recent climate event.

BOKU projections indicate temperature rise of +1.8 °C (GWL2.0) to +4.4 °C (GWL4.0), the strongest drought intensification in the cluster (up to 4× by GWL4.0, 15-year events becoming 2-year by GWL4.0), a very strong increase in wildfire risk days region-wide, and +13% extreme precipitation intensification at GWL4.0 (second highest in the study area).

Focus groups reported shortened winters, glacial lake surface decline, water scarcity in Tetovo and Gostivar (municipal drinking water sourced from mountain springs), hail and frost damage to fruit and blueberries, and erosion of forest roads. Key informants noted herding communities in Shipkovica and Brodec face significant challenges from less reliable snow and higher water variability.

Accessibility and Population

Tetovo and Gostivar serve as main gateways, connected by the A27 highway. Regional roads (R12068, R12039, R2234) link surrounding municipalities, while local mountain roads remain unpaved and seasonally blocked. Popova Šapka ski resort is well-connected but lacks a cable car and has weak parking infrastructure. The broader municipal area totals ~218,920 inhabitants across 8 municipalities (2021 census). The park area itself lost 42% of its population between 2002 and 2021 (from 16,612 to 9,598 in 27 villages); however, some peri-urban areas near Tetovo show significant growth.

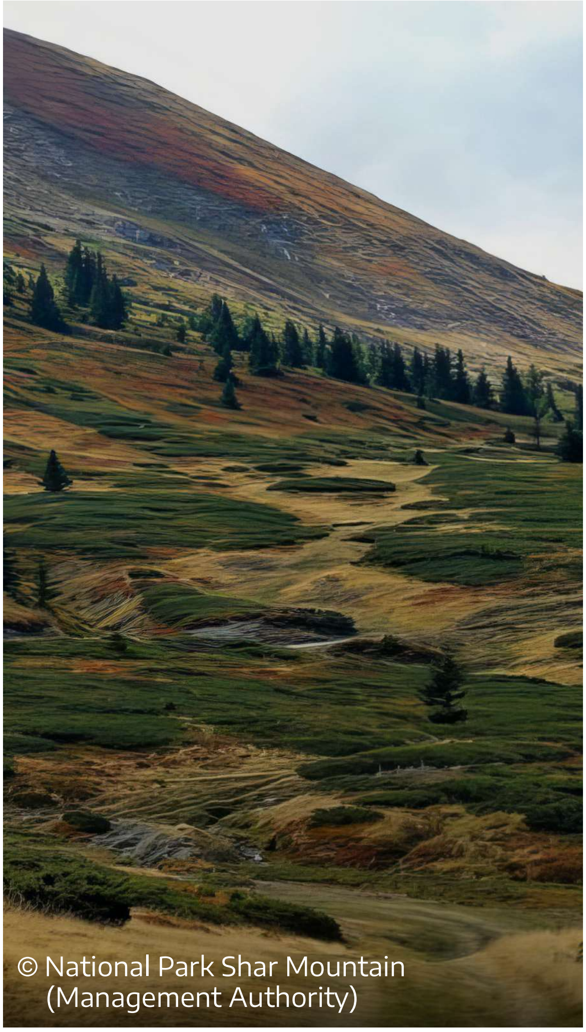

© National Park Shar Mountain (Management Authority)

Key Risks and Pressures

- Decline in winter tourism viability (Popova Šapka): Shortening ski seasons reduce winter pressure on ecosystems but undermine snow-dependent tourism models, creating a transition challenge and requiring a shift towards climate-resilient, year-round tourism
- Motorised vehicle damage: ATV and snowcat use on alpine pastures in snow-poor winters is causing severe soil erosion and habitat degradation
- Uncontrolled logging, hunting, forest fires, and unsustainable harvesting of plants and fungi
- Flash flood risk: 19 critical torrent systems; the August 2015 flood caused USD 21 million in damage and six fatalities
- Wildfire: Increasing frequency driven by land abandonment, vegetation overgrowth (including ferns), drought, and warm winds
- Sharski Vodi hydropower diversion reducing downstream river flows to near-zero levels in summer
- 14 small hydropower plants (HPPs) operating within the park territory
- Weak wastewater treatment across settlements; septic systems poorly maintained
- Uncontrolled urbanisation and illegal construction linked to tourism development (weekend houses, tourist facilities, and road expansion), combined with high visitor concentrations — particularly in winter — are placing increasing pressure on ecosystems, water resources, and waste management systems, resulting in solid waste accumulation, illegal dumpsites, and inadequate wastewater and water-supply infrastructure
- Rural outmigration and declining traditional land-use practices contributing to landscape change, reduced ecosystem management, and increased vulnerability to fire and erosion

Existing and Planned Infrastructure - Tourism

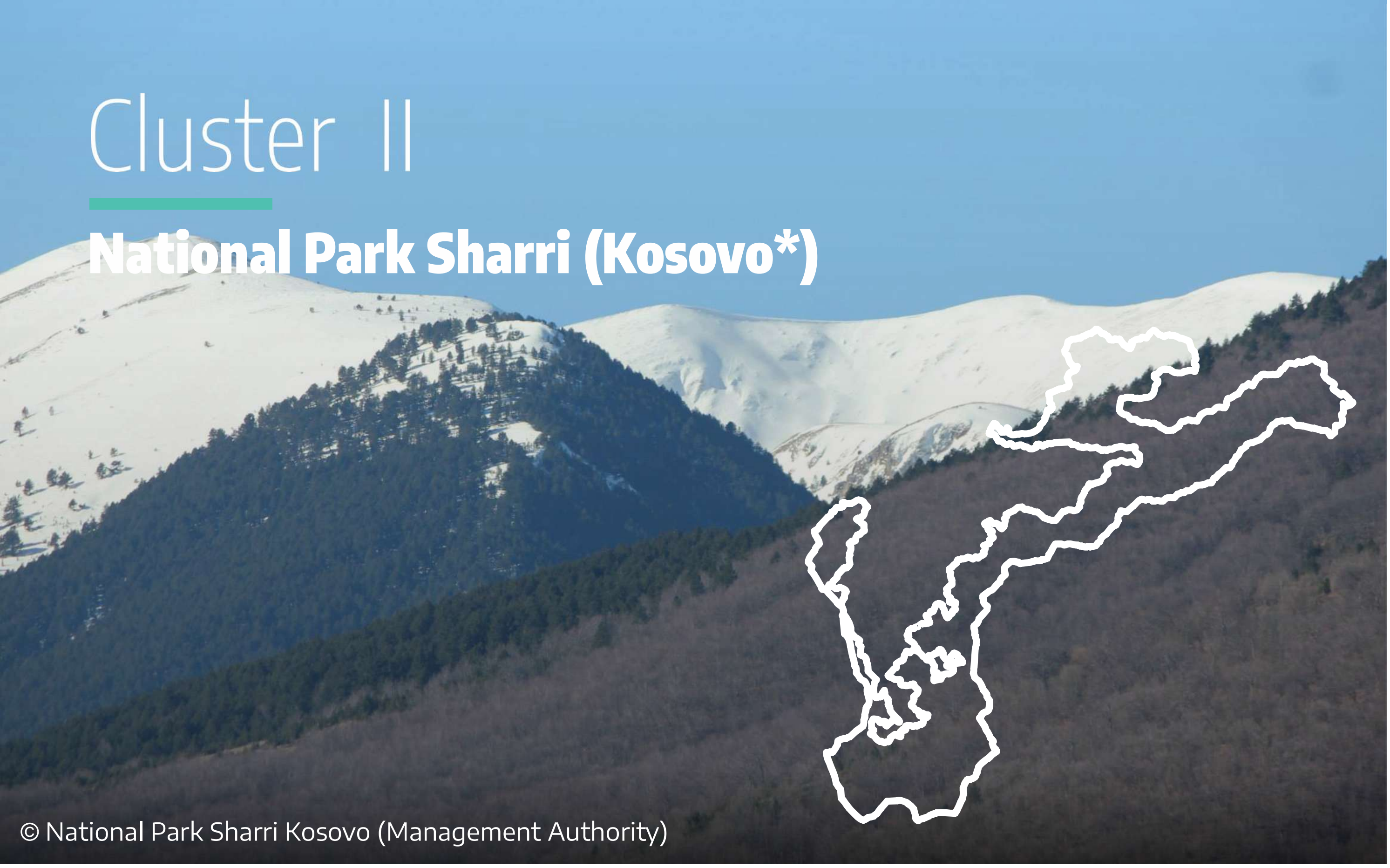
Tourism is anchored by Popova Šapka ski resort (7 hotels, scattered huts, hostels, private accommodation), with 24 hiking trails (303 km) and planned new routes. No functioning cable car currently; its reconstruction is the flagship planned investment. Tourism development is strictly regulated through park zonation — a comprehensive ban applies to new large-scale infrastructure (hydropower, mines, roads, hotels) except in the buffer zone around the ski resort (~2% of total park area). The Management Plan 2022–2031 explicitly bans HPP concessions; two additional plant contracts were paused and are in a termination process.



© National Park Shar Mountain (Management Authority)

Key Stakeholders - Consultations and Interview Insights

Stakeholder group	Key Representatives	Influence	Climate/ Biodiversity Engagement	Main Concerns Raised
Park Authority	Public Institution Shar Mountain NP	High	High	glacial lake decline, ski viability, flood risk
Ministry / Agencies	Ministry of Environment; Spatial Planning Agency; State Inspectorates	High	Medium	Regulatory enforcement, HPP concessions
Energy Utility	AD ESM (ELEM) - Sharski Vodi operator	High	Medium	Hydropower diversion conflicts with water flows and biodiversity
Ski Center	Ski Center 'Popova Šapka'	High	High	Snow reliability, cable-car investment
Hunting Federations	4 local hunting societies	High	Low-Medium	Wildlife population, hunting regulation
Tourism/Hospitality	9 hotels; Eskimo freeride; Shar Outdoors; Visit Bozovca	Low-Medium	Low-Medium	Season length, diversification, ecotourism
Civil Society	MES, Cesard, Eco-Sharr, women farmers	Low	Medium	Weak community engagement in park governance; barriers to developing local sustainable/organic production
FGD/KII Insights	Herders, municipal staff, hiking guides	Medium	Medium	Glacial lake loss, water scarcity Tetovo/Gostivar



Cluster II

National Park Sharri (Kosovo*)

© National Park Sharri Kosovo (Management Authority)

KOSOVO*

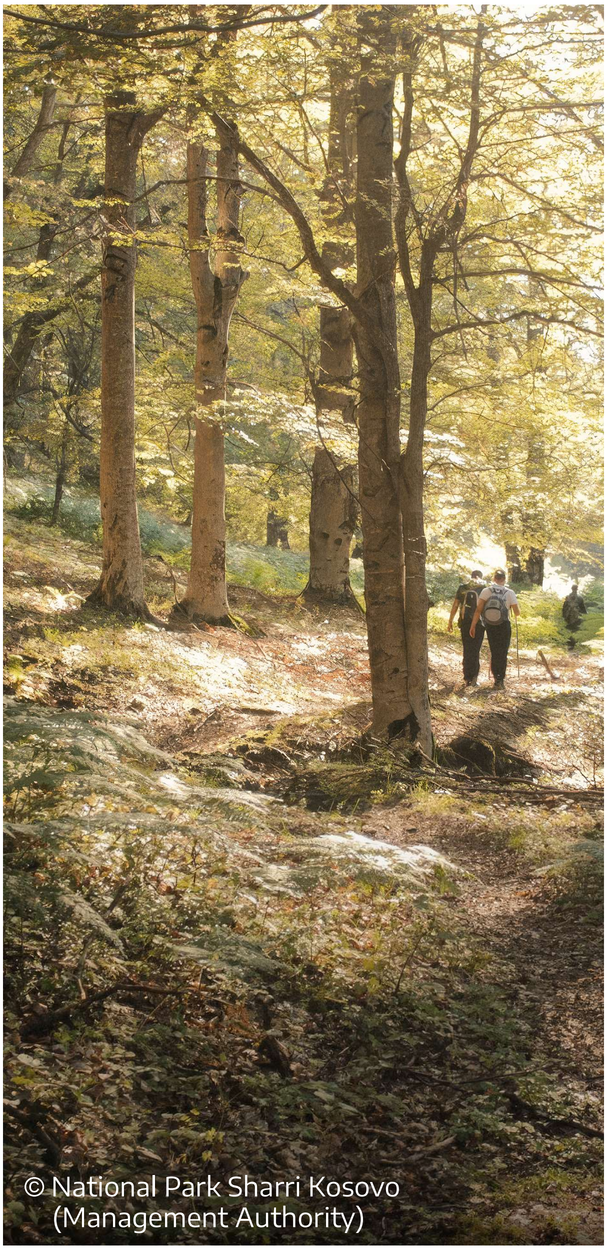
Economy	Kosovo*
IUCN Category	II - National Park
Area	53,271 ha
Elevation Range	900–2,660 masl
Established	1986 (SAP Kosovo*); reaffirmed 2008 under Law 03/L-153
Management Authority	Directorate for Administration of NP 'Sharri', under KEPA and MESPI
Management Plan	Expired (2013–2023); new plan in preparation
2023 Budget	€348,000

Ecological and Biodiversity Values

The Shar Mountain massif is recognised as one of the most species-rich mountains of the Balkans, combining preserved forests, endemic and relict flora, and diverse fauna adapted to specific high-altitude habitats. The park features ecological, geomorphological, and hydrological values alongside cultural and recreational importance. Priority fauna include 11 mammal species (including bear, wolf, lynx), 3 reptile species, 3 amphibian species, 13 bird species, and 7 butterfly species requiring special protection.

Brezovica ski resort (900–2,500 m altitude) and Prevalla health/mountain tourism zone (1,500–1,800 m) sit within the park's influence zone. High-altitude peatbogs, springs, and alpine meadows are ecologically critical. The park shares the Shar massif with National Park Shar Mountain (North Macedonia) and borders Korab–Koritnik Nature Park (Albania).

© National Park Sharri Kosovo (Management Authority)


© National Park Sharri Kosovo
(Management Authority)

Climate Characteristics and Climate Change Impacts

National Park Sharri has an alpine-continental climate with occasional moderate continental influence. Average annual temperature is ~8.4 °C; January can reach −33 °C; summer averages 18–20 °C. Annual precipitation ranges from 670–1,200 mm; 220–280 sunny days per year. Snow cover can reach 3 m depth with up to 117 snowy days recorded; the Dragash subalpine zone averages ~807 mm precipitation with snow cover up to 280 days at altitude.

BOKU projections indicate summer droughts becoming up to 4× more intense and up to 8× more frequent by GWL4.0 — the strongest drought frequency signal in the study. River basins Zhupa–Lepenc–Lumbardhi–Brod are reported drying in focus groups. KII participants described late winters and cold springs, with tourists shifting timing accordingly. Invasive common juniper (*Juniperus communis*) is spreading across degraded pastures. Brezovica's uncontrolled development is identified as both a current and future risk.

Accessibility and Population

The park is intersected by regional roads R115 (Kaçanik–Shtërpcë–Prizren) and R116 (Kaçanik–North Macedonia), alongside additional secondary roads. Border crossings exist at Vërmica (Albania–Kosovo*) and Jazhincë (Kosovo*–North Macedonia). Seasonal road closures, limited infrastructure in Dragash municipality, and unregulated crossings create accessibility challenges. Park spans municipalities of Dragash (22 villages), Prizren (13 villages), Suhareka (4), Shtërpce (9), and Kaçanik (3), with a combined population of approximately 61,426 inhabitants.


© Bekim Bytyqi

Key Risks and Pressures

- Uncontrolled and unplanned construction at Brezovica and Prevalla ski zones: habitat loss, waste, water supply degradation, and conflict with legal/spatial frameworks
- Summer drought intensification (4×) threatening springs, pastures, and mountain agriculture
- Increasing wildfire risk: fire season lengthening, risk expanding upslope
- Invasive common juniper (*Juniperus communis*) encroachment on alpine pastures
- Expired management plan creating governance vacuum
- Bee colony decline
- River flow variability and drying: Zhupa, Lumi i Brodit, Restelicë
- Fragmented management across 5 municipalities with divergent planning priorities

Existing and Planned Infrastructure - Tourism

Tourism centres on Brezovica ski resort (Kosovo's* largest, 900–2,500 m altitude) and Prevalla (1,500–1,800 m), offering winter sports, summer hiking, cycling, and health tourism. Infrastructure requires modernisation to reach international standards. No new large-scale hydropower projects are planned. Fixed broadband covers the entire park including hotels and tourist facilities. The management framework is based on the Law on Nature Protection (2010). Municipalities of Prizren, Shtërpce, Dragash, Suhareka, and Kaçanik oversee ongoing and planned investments under national legislation and spatial plans.


© Bekim Bytyqi

Key Stakeholders - Consultations and Interview Insights

Stakeholder group	Key Representatives	Influence	Climate/ Biodiversity Engagement	Main Concerns Raised
Park Management	Sharri NP Directorate (Prizren), supervisor, KEPA	High	High	Management plan renewal, Brezovica regulation, drought impacts, bee decline
Forestry Agency	Kosovo* Forest Agency (Prizren - management and rangers)	High	High	Logging prevention, fire risk, forest health monitoring
Hunting Associations	Hunting Federation Kosovo*; Hunting Association Dragash	Medium	Medium	Wildlife management, enforcement in PA
Private Forest Owners	Association 'Guri i Zi'	N/A	N/A	Private forest management, sustainable harvesting
Tourism/Eco-Tourism	Sharri Eco Tour; agri-tourism and beekeeping operators	High	High	Sustainable tourism, bee colony health, community income
Civil Society	Sharri Wild Life; Local Action Group 'Sharri'	High	High	Eco-tour coordination, community awareness, biodiversity monitoring
Research	FAO-engaged forestry researchers	Medium	Medium	Data collection, forest ecosystem assessment
FGD/KII Insights	Guides, beekeepers, women farmers, municipal staff	Medium	Medium	Late winters, bee losses, river drying, Brezovica construction pressure, tourism shift

Cluster III

National Park Tara (Serbia)

© National Park Tara (Management Authority)

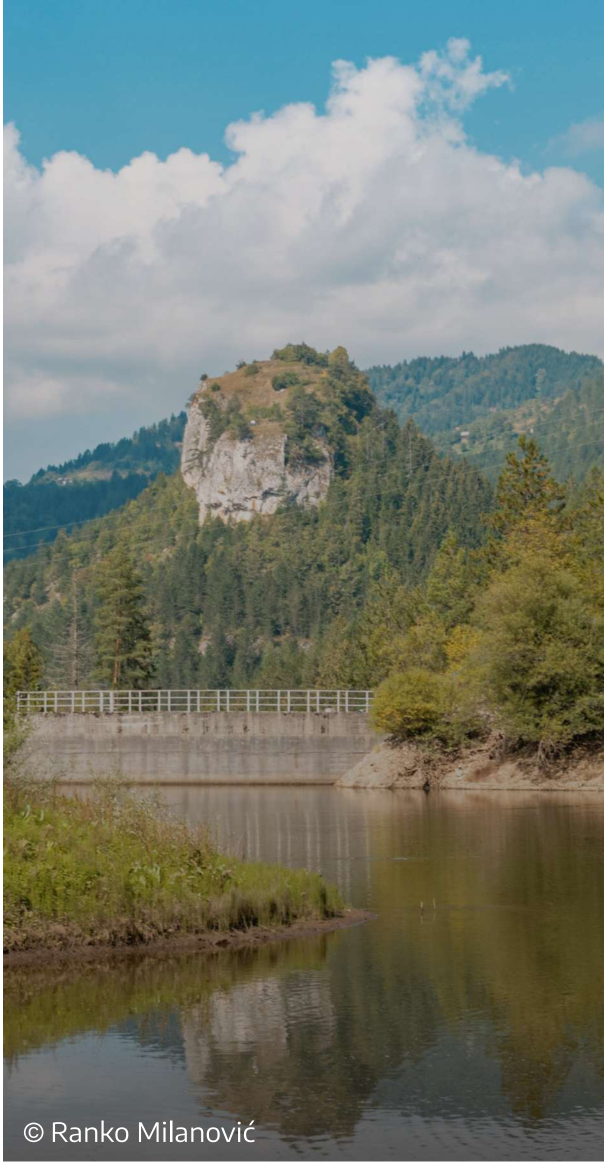
Economy	Serbia	**SERBIA**
IUCN Category	II - National Park	
Area	24,991 ha	
Elevation Range	291-1,591 masl	
Established	1981	
Management Authority	Public Enterprise 'Tara National Park' under Government of Serbia; verseen by Ministry of Environmental Protection	
Management Plan	2020-2030	
2023 Budget	€4,105,389 — despite this budget level, park authorities report limited financial capacity for long-term conservation and ecosystem management	

Ecological and Biodiversity Values

National Park Tara is one of the most significant refuges of Balkan and European flora and fauna. It is home to the globally rare Pančić spruce (Picea omorika), found almost nowhere else in the world, alongside over 1,200 plant species, 68 mammals, and 150 bird species. Notable fauna includes brown bear, wolf, chamois, and various raptors. The park is ~80% forested, with mixed stands of fir, beech, and spruce as the dominant communities.

The Drina River canyon forms the park's natural western boundary and serves as the international border with Bosnia and Herzegovina. The Zaovine and Perućac reservoirs (part of the Bajina Bašta HPP system — Serbia's second-largest) are located within or bordering the park, creating a complex hydrology. These reservoirs have altered the microclimate, submerged entire villages during construction, and changed river regimes — a pre-existing ecological modification now compounded by climate change.

© Marko Janković


© Ranko Milanović

Climate Characteristics and Climate Change Impacts

Historical data from Zlatibor district (1961–1990) records mean January temperatures of −2 °C, July/August averages of ~18 °C, and annual precipitation in a Mediterranean regime (maximum November–January, minimum August). Snow cover normally persists November–March, extending to April above 1,000 m. Tropical days (≥30 °C) average only 1.3 per year — but this baseline is shifting.

BOKU projections for the Tara–Drina corridor indicate warming of +1.8 °C (GWL2.0) to +4.1 °C (GWL4.0); total disappearance of April snow cover possible at GWL4.0; drought intensification up to 5× by GWL4.0 (the strongest in the study); very hot days increasing by up to 20/year in the northern area at GWL4.0; and +8% extreme precipitation intensification. Focus group participants described snowy winters as 'almost gone', rising fire risk, Pančić spruce dieback, new jackal presence, and Zaovine reservoir approaching biological minimum in recent dry summers. Bark beetle outbreaks in spruce and peatbog desiccation at Crveni Potok are documented management concerns.

Accessibility and Population

Access is mainly via Bajina Bašta and Užice, with border crossings at Skelani and Vardište. Tourist centres within the park (Kaluđerske Bare, Mitrovac, Zaovine, Perućac) are connected by poor-quality asphalt roads. Public transport is minimal. The park has a dense forest road network (a legacy of Yugoslav forestry), 300 km of hiking trails (30 marked routes), 3 cycling routes (75 km), 5 educational trails, and 12 equipped lookouts. Perućac Lake supports boat connections to Višegrad (BiH).

Bajina Bašta municipality has 23,533 inhabitants (2022); approximately 740 people live within the park itself. The broader municipality population faces gradual decline and aging. Tourism generates up to 5,000 daily visitors during peak summer and winter seasons, with ~7,000 beds available (mostly private and unregistered). Around 100,000 annual visitors are recorded.

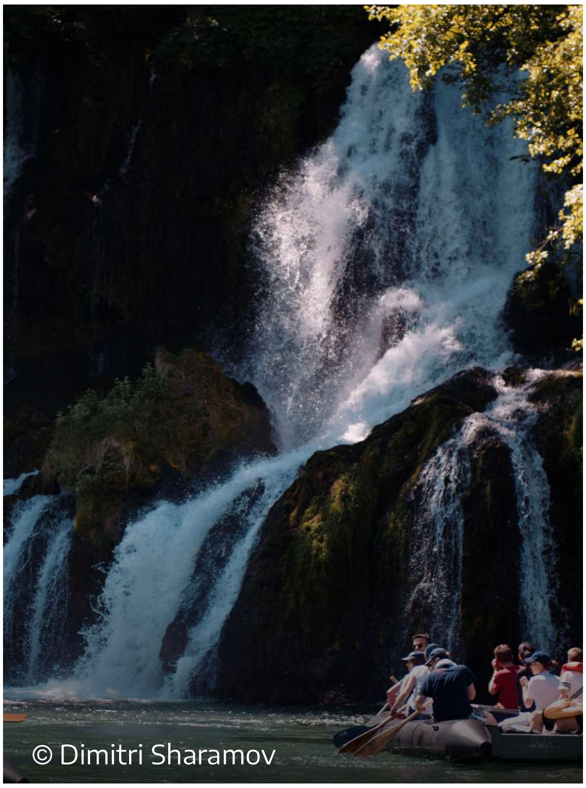
© National Park Tara (Management Authority)

Key Risks and Pressures

- Bark beetle outbreaks (*Ips typographus*) threatening Pančić spruce and forest integrity
- Peatbog desiccation at Crveni Potok: a unique and globally rare habitat type
- Zaovine reservoir approaching biological minimum in dry summers, threatening aquatic ecosystems
- Jackal (*Canis aureus*) expansion as a new species: indicator of habitat change
- Post-COVID surge in illegal construction, ATV use, overcrowding, and forest road expansion
- Inadequate wastewater management: no sewage system in most areas; septic tanks leak on limestone terrain; fecal contamination detected in water tests
- Wildfire risk rising, notably on southern and northwestern slopes
- Drying springs affecting drinking water for Bajina Bašta municipality
- Shorter winter tourism season reducing local income; concentration of summer visitors straining infrastructure

Existing and Planned Infrastructure - Tourism

Planned investments include installation of new trail and tourist signage, reconstruction of visitor centres in Bajina Bašta and Mitrovac, asphalting of the Mitrovac–Banjska Stena road, and preparatory works for a tourist cable car (Perućac–Mitrovac). Revitalisation of camps, ethno-villages, and viewpoints is foreseen. National Park Tara benefits from the highest budget of the 8 parks (€4.1M), enabling relatively stronger management capacity. A significant share of the park's own revenue is generated through forest management activities, alongside tourism services and state support. The Bajina Bašta Municipality Development Plan (2024–2031) identifies Tara as a national eco-tourism hub.


© Dimitri Sharamov

Key Stakeholders - Consultations and Interview Insights

Stakeholder group	Key Representatives	Influence	Climate/ Biodiversity Engagement	Main Concerns Raised
Park Enterprise	PE 'Tara National Park' (4 sectors: planning, land use, legal, economic-financial; ranger service)	High	High	Bark beetle, Pančić spruce conservation, ATV regulation, visitor management
National Oversight	Institute for Nature Conservation Serbia; Directorate for Forests; Ministry of Environmental Protection	High	High	Biodiversity monitoring, forest management, climate adaptation mainstreaming
Energy Utility	EPS AD Belgrade - Division 'Drinsko-Limske HE' Bajina Bašta	High	High	Reservoir management, hydropower operations, downstream flow impact
Local Government	Municipality of Bajina Bašta; Tourism Organisation Tara-Drina	High	Medium	Infrastructure investment, tourism promotion, emergency planning
Hunting Associations	Hunting assocs. 'Soko' and 'Tara'	Medium	Low	Game management, wildlife population
Fishing Society	OSR 'Mladica'	Low	Low	Sport fishing, sustainable water use
Tourism/Adventure	Green Bear, Maple Adventures, Taratours; VU 'Tara' military hotels	Low-Medium	Medium	Trail maintenance, sustainable adventure tourism
Civil Society	Mountaineering Club 'Tara'; BIOS; Tara Ultra; Youth Office Bajina Bašta	Medium	High	Trail stewardship, biodiversity education, youth engagement
Church/Cultural	Eparchy of Žiča - Rača Monastery (1,000 ha forest)	Medium	Low	Cultural heritage, forest management
FGD/KII Insights	Farmers, tourism operators, park staff	Medium	Medium	Shorter winters, tubing replacing sledding, bark beetle, spring failures, 'fire roads' debate

© National Park Drina (Management Authority)

Cluster III

National Park Drina (Bosnia and Herzegovina)

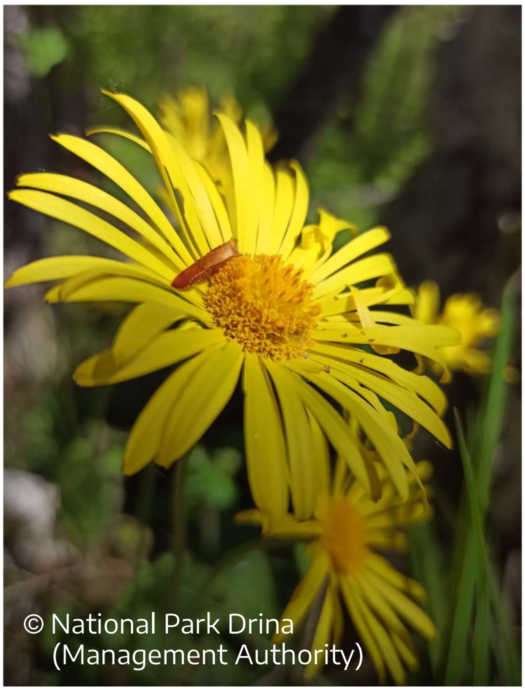
BOSNIA & HERZEGOVINA

Economy	Bosnia and Herzegovina (Republika Srpska)
IUCN Category	II - National Park
Area	6,315 ha
Elevation Range	290–1,265 masl
Established	2017
Management Authority	Public Institution 'Drina NP', Government of Republika Srpska; 12 permanent staff + seasonal
Management Plan	2022-2031
2023 Budget	€190,000

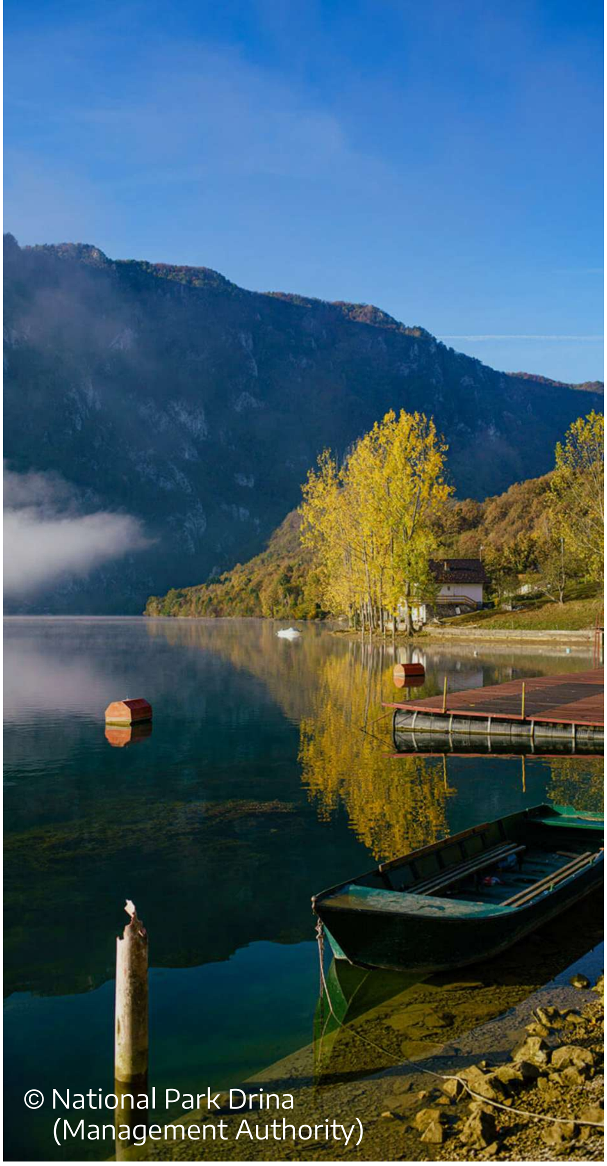
Ecological and Biodiversity Values

National Park Drina protects the middle course of the Drina River canyon in eastern Republika Srpska (Srebrenica municipality). At only 6,315 ha — the smallest of the eight parks in the study — it nonetheless protects limestone canyon habitats with exceptional richness, including over 635 vascular plants and the endemic Derventa knapweed. Fauna includes brown bear, chamois, and golden eagle.

The park sits at the boundary between National Park Tara (Serbia) — sharing the Drina River as a transboundary corridor — and the proposed cross-border Drina UNESCO Biosphere Reserve (joint BiH–Serbia initiative under MAB Programme). Conservation importance is elevated by the canyon's unique microclimate, relict flora, and endemic riparian species including the critically restricted Serbian bittercress (*Cardamine serbica*). The Perućac reservoir (Bajina Bašta HPP, Serbia) spans the park's northern boundary.



© National Park Drina (Management Authority)



© National Park Drina (Management Authority)

Climate Characteristics and Climate Change Impacts

The Management Plan (2022–2031) incorporates climate projections indicating warming trends with hotter summers, milder winters, and more irregular precipitation — wetter winters/autumns and drier summers/springs, increasing flood and drought risks. BOKU projections for the Tara–Drina corridor indicate up to 20 extra very hot days per year at GWL4.0; total snow loss in April possible by GWL4.0; drought intensification up to 5×; and +8% extreme precipitation intensification.

Focus group participants reported summer water restrictions in Srebrenica (3pm–6am daily, June–September), intermittent stream drying (Jadar, Drina tributaries, up to 70% lower flow), recurring landslides, frequent fires in Luka, Klotjevac, Krušev Do, and Šarena Bukva, and declining river fish populations including huchen (Hucho hucho) from combined HPP and climate impacts. Participants noted that local livelihoods for fishers and guides are increasingly unstable.

Accessibility and Population

Road transport dominates. Access relies on regional roads R452 (Milići–Skelani) and R453 (Bratunac–Zeleni Jadar), supplemented by 28 local roads and numerous unclassified routes. The nearest railway is in Zvornik (45 km). Poor regional connectivity and rugged relief restrict mobility. Settlements within the park (Klotjevac, Prohići, Osatica, Radjenovići, and others) are small; average density is 14 inhabitants/km_2, below the Srebrenica municipal average (22/km_2). Srebrenica municipality receives ~150,000 visitors annually, primarily diaspora returning July–August, creating intense but brief seasonal pressure.

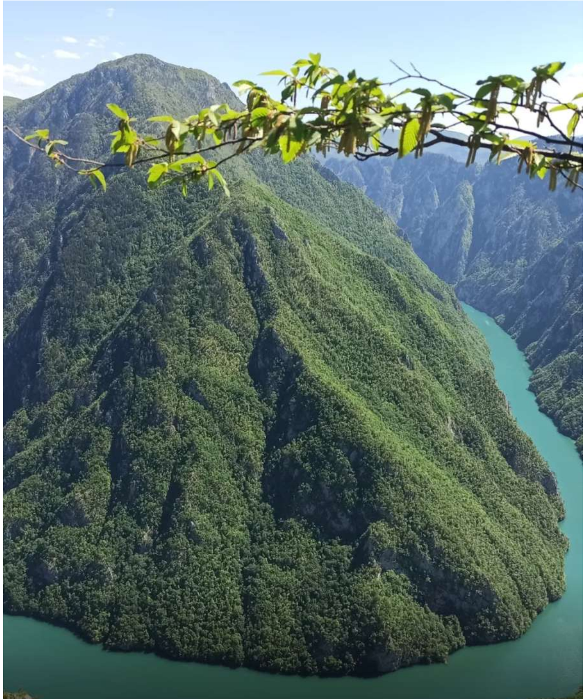
© National Park Drina (Management Authority)

Key Risks and Pressures

- Cross-border floating waste in Perućac Lake: seasonal accumulation arriving from upstream with no bilateral management mechanism
- Illegal shoreline structures and floating houses on the lake and river, degrading habitats
- Open bauxite mining near Milići (Podravno, Palež): air and soil pollution, landscape alteration
- Frequent forest fires: Luka, Klotjevac, Krušev Do, Šarena Bukva zones
- Severe 2014 floods and recurring Sućeska landslides blocking access routes
- Declining huchen (*Hucho hucho*) population from barriers, HPP operations, and climate-driven flow variability
- Invasive pumpkinseed (*Lepomis gibbosus*) spreading
- Limited budget (€190,000) and 12 permanent staff — insufficient for the park's management needs
- No organised wastewater treatment; sewage discharged directly into rivers

Existing and Planned Infrastructure - Tourism

Tourism is at an early stage, with limited guesthouses, rural accommodation, and no large eco-lodges. Hiking and river activities (rafting on Drina, cultural heritage tours) are possible but trail networks and signage are underdeveloped. The Management Plan (2022–2031) prioritises a main visitor centre, thematic trails, and improved river access points. Broader strategies (Srebrenica Development Strategy 2023–2030, cross-border Biosphere Reserve Drina) prioritise eco-friendly accommodation, heritage promotion, and transboundary ecotourism products. Cross-border cooperation with National Park Tara (Serbia) and Mokra Gora aims to develop a joint destination.


© National Park Drina (Management Authority)

Key Stakeholders - Consultations and Interview Insights

Stakeholder group	Key Representatives	Influence	Climate/ Biodiversity Engagement	Main Concerns Raised
Park Authority	Public Institution Drina NP (Management Board, Director, 4 sectors)	High	Medium	Floating waste, illegal construction, fire management, understaffing
Forestry Company	Public Forestry Company 'Forests of RS'; FMU 'Drina' Srebrenica	High	Medium	Sustainable forest use, illegal logging prevention, fire risk
Local Government	Mayor Srebrenica; Depts of Economy, Spatial Planning, Social Affairs	High	Medium	Tourism investment, road infrastructure, environmental compliance
Tourism Organisation	Srebrenica Tourist Organisation	High	Medium	Tourism promotion, Drina NP events, cross-border ecotourism
Hunting / Fishing	Hunting ground 'Javor'; Sports Fishing Societies	Medium	Medium	Fish stock management, wildlife habitat, huchen protection
Civil Society / NGOs	NGO 'Sara'; Beekeepers Association 'Osat'	Low	Low-high	Community heritage, meadow conservation, honey/organic tourism
FGD/KII Insights	Fishers, guides, local residents, municipal staff	Low-Medium	Medium	Water restrictions, flood damage, fire risk, waste, fish decline, diaspora tourism

3. Recommendations

Integrating Ecosystem-Based Adaptation (EbA) and Nature-Based Solutions (NbS) into Protected Area Management

This chapter translates the findings from the climate risk analysis and the protected area profiles into actionable recommendations for integrating ecosystem-based adaptation (EbA) and nature-based solutions (NbS) into the management plans of the three transboundary protected area clusters and their eight national parks. The chapter also identifies the actors and institutions needed to deliver these measures, proposes specific roles for the private sector and tourism operators, and provides guidance on using the Western Balkans Climate Change Proofing Platform (WB-CPP) as a decision-support tool for park managers, municipalities, and national authorities.

Tara-Drina Corridor

The Tara–Drina corridor faces the strongest projected drought intensification in the study (up to 5× by GWL4.0), combined with total April snow loss and rising bark beetle and wildfire risk. Management plans in both parks already acknowledge climate change as a threat, but lack operational EbA measures and coordinated transboundary responses. The recommendations below are designed to be integrated directly into the National Park Tara Management Plan (2020–2030, next revision) and the National Park Drina Management Plan (2022–2031), and into the action framework of the proposed Drina Biosphere Reserve.

Priority **EbA** Measures for Integration into Management Plans

- **Pančić spruce (*Picea omorika*) refuge management:** Designate climate refugia zones at high elevation and moist ravines as strictly protected core areas. Buffer spruce stands against bark beetle through mixed-species enrichment planting (fir, beech, maple) in degraded zones, reducing monoculture vulnerability. Integrate pheromone trap monitoring networks into the annual management programme.

- **Peatbog and spring hydrological restoration:** Rehabilitate Crveni Potok peatbog through ditch-blocking, water table restoration, and exclusion of livestock. Restore springs in small park settlements through micro-retention works and buffer vegetation planting - providing both biodiversity benefit and community water security.

- **Riparian and wetland restoration along Drina tributaries:** Create micro-wetland retention basins along the Jadar River and other Drina tributaries (Štedrić, Sućeska). Restore riparian forest galleries using native species (willows *Salix spp.*, alder *Alnus spp.*, and black poplar *Populus nigra*) to reduce flash-flood impacts, stabilise riverbanks, enhance low-flow conditions, and protect habitats of the endemic Serbian bittercress (*Cardamine serbica*) in the canyon.

- **Slope stabilisation and landslide risk reduction:** Implement mixed-species reforestation on Žlijebac-Sućeska slopes and other identified landslide-prone zones, using deep-rooted native species. Combine with gabion and check-dam structures in the most active torrent channels. Link directly to disaster risk reduction planning in Srebrenica municipality.

- **Wildfire prevention and firebreak management:** Establish a joint Tara-Drina fire management zone covering the northwestern Tara slopes and BiH-side forest ridgelines. Maintain strategic firebreaks through prescribed grazing and selective vegetation management rather than machinery where terrain permits. Invest in shared early-warning infrastructure (automated weather stations, camera monitoring).

- **Open grassland and semi-natural habitat maintenance:** Maintain open grassland habitats in National Park Tara through targeted mechanised management - preventing forest encroachment into biodiversity-rich meadows. Link to agri-environment payment schemes for local farmers who provide grazing services.

- **Cross-border floating waste interception on Perućac Lake:** Design and install floating debris booms at strategic points on the Drina and at the Perućac reservoir inlet. Establish a joint waste collection protocol with EPS (Serbia) and National Park Drina, including seasonal clean-up operations coordinated with upstream municipalities in BiH.

- **Climate-resilient visitor management:** Implement seasonal and spatial visitor flow management using carrying capacity thresholds derived from ecosystem sensitivity mapping. Develop green infrastructure standards for tourist facilities (eco-drainage, composting, rainwater harvesting) - mandatory for any new development permissions in both parks.

Stakeholder Engagement Options

Actor / Stakeholder	Type	Role / Actions
PE Tara National Park / Public Institution Drina NP	Protected Area Authorities	Lead management plan revision; implement EbA pilots; coordinate joint fire management; operate monitoring networks
Ministry of Environmental Protection (Serbia) / RS Ministry of Physical Planning (BiH)	National Authorities	Provide regulatory framework and financing; align management plans with national climate adaptation plans; approve cross-border cooperation protocols
Institute for Nature Conservation of Serbia	Scientific / Technical	Provide species monitoring data; advise on Pančić spruce conservation genetics; evaluate EbA pilot effectiveness
EPS / Division 'Drinsko-Limske HE' Bajina Bašta	Energy Utility	Negotiate minimum environmental flow releases from Zaovine and Perućac; participate in floating waste management protocol; share hydrometeorological data
International Sava River Basin Commission (ISRBC); Drina Task Force	International / Regional Mechanisms	Facilitate cross-border water data sharing; coordinate flood and drought management protocols; provide technical support for biosphere reserve nomination
Srebrenica Municipality / Bajina Bašta Municipality	Local Government	Mainstream climate risk into spatial plans; enforce construction standards; co-finance visitor infrastructure; coordinate disaster preparedness
Srebrenica Tourist Organisation; Tourism Organisation Tara-Drina	Tourism Sector	Develop joint Tara-Drina tourism brand; apply carrying capacity standards; promote off-peak and shoulder-season products
UNDP, UNEP, GEF, GCF	International Finance	Finance EbA pilot projects; provide technical assistance for management plan climate integration
EU IPA III cross-border programme (Serbia-BiH)	EU Funding Mechanism	Finance transboundary water management, flood risk reduction, tourism infrastructure, and shared early-warning systems
IUCN Dinaric Arc Programme; WWF Adria	Conservation NGOs	Technical advisory support; species monitoring; advocacy for Biosphere Reserve designation, huchen recovery
Local farmers, fishers, beekeepers (Osat Association)	Community Actors	Provide agri-environment and fishery management services; participate in community-based monitoring; benefit from NTFP and ecotourism income schemes

Private Sector and Tourism Operator Roles

Tourism operators in the Tara-Drina corridor should be required to adopt and display climate-resilient tourism standards as a condition of licensing. Specific requirements should include: wastewater treatment at all facilities; prohibition of ATV use outside designated tracks; contribution to a visitor infrastructure maintenance fund; and seasonal pricing that deters peak-season overcrowding.

Eco-adventure tourism operators (rafting, kayaking, hiking, trail running) should partner with National Park Tara and National Park Drina to develop jointly certified 'Drina Wild' experience packages that financially support conservation through direct visitor levies. This builds on the existing model of successful eco-tourism products along the Drina and the Tara Canyon.

Hospitality businesses in Bajina Bašta and Srebrenica should be supported to transition from seasonal winter-only to year-round diversified offerings. Climate projections clearly indicate that reliable winter snowpack will be absent at mid-elevation by mid-century; business models built exclusively on ski tourism are stranded assets. The tourism development plans of both municipalities should reflect this trajectory and incentivise investment in spring, autumn, cultural, and slow-adventure tourism products.

Bistra-Korab / Shar Mountain

This cluster hosts the most severe combined drought-wildfire risk in the study area, with BOKU projections showing drought events becoming up to 4× more intense and the water tower function of the Shar massif (supplying Tetovo, Gostivar, Prizren, and Kukës — collectively 350,000+ people) under acute threat. The three parks require both individual management plan revisions and a tri-national coordination mechanism. National Park Shar Mountain's Management Plan (2022–2031) provides the strongest existing framework; National Park Sharri's plan is expired and needs urgent renewal; Korab–Koritnik has no current plan.

Priority **EbA** Measures for Integration into Management Plans

- **Snow and water monitoring network:** Establish a tri-national automated monitoring network for snow depth, soil moisture, spring flow rates, and stream discharge across the Shar massif. Connect existing stations in all three economies through a shared real-time data platform. This is simultaneously a conservation tool (tracking glacial lake decline, peatbog desiccation) and a water security tool (early warning for urban water deficit in Tetovo and Gostivar).
- **Glacial lake and peatbog protection:** Designate the 40 glacial lakes and associated peatbog systems in National Park Shar Mountain as strictly protected climate refugia. Implement hydrological isolation from ATV damage. Develop a long-term surface area and water level monitoring programme as a climate change indicator. Exclude livestock from buffer zones around all peatbog systems.
- **Pasture rehabilitation and invasive species control:** Rehabilitate ATV/snowcat-damaged pastures at Popova Šapka and adjacent zones through exclusion, overseeding with native species, and seasonal patrol enforcement. Implement a tri-national common juniper (*Juniperus communis*) control programme on Bjeshkët e Nemuna slopes and Sharri meadows using targeted mechanical removal and follow-up grazing management.

- **Spring revitalisation and water retention:** Rehabilitate drying springs along the Luma River (Korab-Koritnik), in the Zhupa-Lepenc-Lumbardhi basin (Sharri), and in Tetovo-adjacent catchments. Construct micro-retention ponds and infiltration trenches in degraded upper catchment areas to improve groundwater recharge. Link to municipal water security planning in Tetovo, Gostivar, Prizren, and Kukës.
- **Wildfire risk reduction and firebreak management:** Develop a cross-border fire management plan covering all three parks and the connecting landscape corridors. Establish strategic firebreaks using prescribed grazing (avoiding mechanical methods in ecologically sensitive areas). Install shared automated fire-weather monitoring stations drawing on BOKU FWI projections. Conduct joint annual tabletop exercises with fire services from all three economies.
- **Leshnica River rehabilitation:** Implement comprehensive river renaturalisation of the Leshnica River as the primary water retention and biodiversity restoration investment in National Park Shar Mountain. This includes bank revegetation, removal of artificial channelling, and construction of small check dams - providing flood mitigation, groundwater recharge, and aquatic habitat benefits.
- **Climate-resilient ski resort transition planning:** Commission independent climate scenario assessments (using BOKU GWL2.0 and GWL4.0 snow projections) for all ski infrastructure investment proposals (Popova Šapka cable car, Brezovica expansion). Results should be formally incorporated into environmental impact assessments. Reorient resort investment toward elevation-appropriate infrastructure, year-round mountain sport facilities, and four-season cultural and wellness tourism.
- **NTFP certification and sustainable harvesting zones:** Design and implement a tri-national NTFP certification framework for medicinal plants, blueberries, and other forest products - establishing species-specific collection quotas, seasonal calendars, and benefit-sharing mechanisms for local community collectors. Link to EU organic certification standards to access premium markets.

Stakeholder Engagement Options

Actor / Stakeholder	Type	Role / Actions
NP Shar Mountain Public Institution / NP Sharri Directorate / NAPA Albania (Korab–Koritnik)	Protected Area Authorities	Lead management plan revision and EbA pilot implementation; co-develop tri-national monitoring protocols; enforce ATV and construction regulations
Ministry of Environment and Physical Planning (N. Macedonia) / MESPI/KEPA (Kosovo*) / Ministry of Tourism and Environment (Albania)	National Environment Ministries	Establish tri-national coordination mechanism; align national adaptation plans with park management; fund shared monitoring infrastructure
AD ESM (ELEM) — Sharski Vodi system operator	Energy Utility	Negotiate minimum environmental flow releases from Sharski Vodi diversions; participate in water monitoring data sharing; terminate HPP concession contracts in park (as per Management Plan commitment)
Tetovo, Gostivar, Prizren, Kukës municipalities	Local Government	Mainstream water security risk into local development plans; co-finance spring restoration; support carrying capacity enforcement for ski resorts
Drin Coordinated Action (DCA)	International River Basin Mechanism	Coordinate transboundary water management in the Drin basin; acilitate cross-border data sharing; support climate-proofed hydropower governance

Actor / Stakeholder	Type	Role / Actions
EU IPA III (Albania–Kosovo*; N. Macedonia–Kosovo* cross-border)	EU Funding Mechanism	Finance shared monitoring infrastructure, pasture rehabilitation, spring restoration, and tri-national fire management plan
Ski Centers (Popova Šapka, Brezovica)	Private Sector — Ski Tourism	Conduct and publish independent climate viability assessments; transition investment toward four-season products; contribute to visitor management funds
Municipalities of Dragash, Shtërpce, Prizren; Tetovo; Gostivar	Local Government	Enforce zoning and construction law at Brezovica and Popova Šapka; implement Spatial Plan for NP Shar Mountain buffer zone
Local hunting and fishing associations (all 3 economies)	Community Actors	Participate in wildlife monitoring; support pasture management through sustainable hunting practices; advocate for invasive species control
Women farmers associations; organic producers (Eco-Sharr); CNVP	Civil Society / NGOs	Develop NTFP certification scheme; support community-based monitoring; promote organic and climate-resilient agri-food products

Private Sector and Tourism Operator Roles

Ski resort operators at Popova Šapka and Brezovica must be urgently engaged as partners in climate adaptation rather than treated purely as commercial concessionaires. The 2022-2031 National Park Shar Mountain Management Plan already prohibits further large-scale ski infrastructure within the park proper. This framework should be replicated in the National Park Sharri management plan renewal and in Korab-Koritnik's forthcoming plan.

Tourism operators across all three parks should be incentivised through licensing conditions and tax concessions to develop year-round ecotourism products: wildlife watching (bears, lynx, raptors), medicinal plant and gastronomy trails, cultural tourism in mountain villages, mountain biking, and high-altitude hiking. These products are more resilient to climate variability than ski-dependent winter tourism.

Tour operators offering the High Scardus Trail (495 km) and related cross-border routes should contribute to a shared trail maintenance and climate-proofing fund - maintaining path drainage, slope stabilisation, and signage in a context of increasing extreme rainfall intensity. This creates a direct financial link between tourism revenue and ecosystem resilience.

Albanian Alps – Prokletije – Bjeshkët e Nemuna

This cluster shows the highest extreme precipitation intensification (+14%) and wildfire risk expanding above 2,000 m — a combination that threatens the most biodiverse of the three clusters while simultaneously experiencing the most intense tourism pressure (558,000 visitors to Albanian Alps in 2023). The Peaks of the Balkans trail serves as the primary cross-border tourism and conservation thread. Management plans are at different stages: National Park Albanian Alps is in revision, National Park Prokletije (2021–2025) is due for renewal, and National Park Bjeshkët e Nemuna (2024–2033) is current. All three plans require EbA integration as an explicit management objective.

Priority **EbA** Measures for Integration into Management Plans

- **Multi-lateral wildfire monitoring and response:** Establish a joint automated fire weather monitoring system covering the entire Prokletije massif - a minimum of 8 stations distributed across the three economies at key elevation bands. Use BOKU FWI projections to define seasonal fire danger levels and trigger pre-positioned response resources. Develop joint annual fire management drills with national fire services. This is the single highest-priority transboundary measure for this cluster.
- **Spring restoration and micro-retention:** Restore drying springs in Theth, Valbona, and Vermosh valleys (Albanian Alps) and along the Rugova Gorge (Bjeshkët e Nemuna) through spring-capping protection works, micro-retention basins (50-200 m?), and buffer vegetation planting. Springs are both ecological assets and the primary drinking water source for dispersed mountain communities - their restoration delivers immediate social co-benefits.
- **Bilberry belt and vegetation restoration**: Implement revegetation and erosion control in the degraded 400-800 m elevation bilberry belt above Theth and Valbona valleys, using indigenous shrub and grass species. This zone acts as the primary surface water buffer between high-altitude snowmelt and valley communities - its degradation amplifies flash-flood risk.
- **Juniper control and NTFP management zones:** Establish formally demarcated NTFP collection and management zones in Rugova Gorge and other designated areas of National Park Bjeshkët e Nemuna, incorporating quotas for 20,000 seasonal collectors. Introduce community ranger systems with NTFP-related duties. Implement common juniper (*Juniperus communis*) control through targeted mechanical removal and reseeding with palatable native species.
- **Grazing zone rehabilitation and erosion prevention:** Rehabilitate degraded grazing zones in the Deçan valley (Bjeshkët e Nemuna) and on Prokletije slopes through rotational grazing management, slope stabilisation planting, and check dams in active erosion gullies. Integrate traditional herding knowledge into management plan adaptive measures.
- **Waste and wastewater infrastructure - Peaks of Balkans trail:** Design and implement minimum wastewater treatment and solid waste collection systems at the 12-15 key trail nodes on the Peaks of the Balkans route where overnight accommodation and visitor concentration occurs. Apply a consistent tri-national 'green trail' standard. Finance through visitor fees (€2-5/night at accommodation), national park entrance fees, and EU IPA cross-border support.

- **Landslide and flash flood risk reduction:** Conduct systematic terrain assessment of the highest-risk trail and road corridors in the Albanian Alps (Theth-Valbona route, Grebaja Valley road). Install small-scale engineering measures (slope netting, gabions, drainage improvement) at the most critical failure points. Develop an early-warning SMS system for extreme rainfall events affecting trail access.

- **Riparian restoration along Lumbardhi and Deçanit rivers:** Restore riparian vegetation gallery along the Lumbardhi and Deçanit and Deçanit river corridors, which have been degraded by HPP diversions and channel modification. Restore natural channel morphology where feasible, re-establish native gallery species, and create buffer zones excluding harmful activities for at least 50 m from the river bank.

Stakeholder Engagement Options

Actor / Stakeholder	Type	Role / Actions
NP Albanian Alps (NAPA/RAPA Shkodër) / NP Prokletije (JPNPCG) / NP Bjeshkët e Nemuna (Directorate, KEPA)	Protected Area Authorities	Lead EbA pilot implementation; revise/align management plans with climate projections; jointly operate fire monitoring network; coordinate Peaks of Balkans trail standards
Ministry of Tourism and Environment (Albania) / Ministry of Ecology, Sustainable Development (Montenegro) / MESPI/KEPA (Kosovo*)	National Environment Ministries	Establish tri-national coordination forum; align HPP regulatory framework with conservation law; co-finance monitoring infrastructure; submit coordinated reporting under Kunming-Montreal GBF
Ministry of Infrastructure and Energy (Albania) / national energy regulators (Montenegro, Kosovo*)	Energy/Infrastructure Ministries	Impose and enforce minimum ecological flow requirements on small HPPs within/near all three parks; apply environmental impact re-assessment to Skavica HPP proposal (Albania)
Municipalities of Tropoja, Malësi e Madhe, Shkodër (Albania); Plav, Gusinje (Montenegro); Peja, Deçan, Junik, Gjakova (Kosovo*)	Local Government	Co-fund waste and wastewater infrastructure; enforce construction permits; integrate carrying capacity standards into local spatial plans; co-manage tourism pressure
Peaks of the Balkans Trail Consortium	Regional Tourism Initiative	Establish and implement tri-national 'green trail' standard; collect and distribute visitor maintenance levy; commission annual trail condition and climate risk report
UNDP, UNEP, GEF, Zo? Environment Network, FEA	International Development Partners	Finance EbA pilots; support management plan revision; facilitate tri-national coordination; monitor and evaluate EbA outcomes
EU IPA III Cross-Border Programmes (Albania-Kosovo*; Albania-Montenegro; Montenegro-Kosovo*)	EU Funding	Finance shared fire infrastructure, NTFP certification, spring restoration, ecotourism product development, and institutional capacity building
PONT (Prespa Ohrid Nature Trust); CNVP; Vis Albania	Conservation NGOs / Development Partners	Implement community-based EbA measures; NTFP certification and market linkages; community ranger training; women and youth engagement in eco-tourism
Local herders, farmers, beekeepers, NTFP collectors	Community Actors	Provide grazing management services; participate in community-based monitoring; benefit from NTFP certification and fair value chains; custodians of traditional ecological knowledge
National civil protection agencies (all 3 economies)	Disaster Risk Reduction	Integrate park fire and flash-flood risk into national early warning systems; develop tri-national disaster response protocol for Prokletije massif

Private Sector and Tourism Operator Roles

The Albanian Alps is experiencing the most acute tourism governance crisis in the study - 558,000 visitors in 2023, uncontrolled construction, and a demolition controversy in 2025 that generated community conflict. Tourism operators cannot continue to function in the current unregulated environment, which is simultaneously economically unsustainable and ecologically destructive. A tiered licensing system - with different requirements for different accommodation types and activities - should be developed jointly by NAPA, the relevant municipalities, and the national tourism ministry.

Guesthouse operators and trail guides in the Theth-Valbona-Vermosh area should be organised into a formal Ecotourism Operators Association with binding commitments to: waste disposal standards; minimum wastewater treatment; maximum occupancy registration; and contribution to a park protection levy. In exchange, the association should receive official recognition, marketing support through Albania's national tourism platform, and access to public infrastructure (water points, waste collection services).

Adventure and eco-tourism operators across the Peaks of Balkans trail - from Valbona to Grebaja to Rugova - should jointly develop and market a 'Prokletije Wild' certified experience package. This product would bundle accommodation, guiding, and cultural experiences under a single quality and sustainability standard, directing revenues partly to a joint trail and spring maintenance fund.

In Montenegro and Kosovo*, where tourism volumes are lower but growing, operators should be proactively incentivised to develop shoulder-season (April-June, September-October) offerings rather than concentrating demand in July-August. This requires marketing support, seasonal pricing incentives, and investment in spring and autumn trail infrastructure.

3. General and Economy-Specific Recommendations

Cross-Cutting Strategic Recommendations

The following recommendations apply across all three transboundary clusters and all eight protected areas. They address the systemic conditions needed for EbA integration to succeed at the landscape scale:

- Institutionalise climate risk assessments in PA planning: All protected area management plans should systematically include climate vulnerability assessments and EbA response measures based on park-specific climate projections.
- Align national climate adaptation plans with PA management: National Adaptation Plans (NAPs) in all six economies should explicitly cross-reference protected area management plans as key delivery mechanisms for ecosystem-based adaptation commitments - and vice versa. Currently, these planning processes operate in institutional silos.
- Establish a Western Balkans Transboundary Protected Areas Climate Monitoring Network: Create a shared environmental monitoring framework covering all three clusters, tracking: mean and extreme temperature; precipitation and drought indices; snow cover duration and extent; wildfire risk days (FWI); forest health indicators (bark beetle, NDVI, mortality); spring flow rates; and biodiversity sentinel species. Annual reporting against this indicator set should be institutionalised through a joint regional platform, building on UNEP's existing Western Balkans engagement.
- Strengthen PA budgets and staffing for climate functions: The disparity between National Park Tara's budget (€4.1M) and National Park Drina's (€190,000) illustrates a major inequity in management capacity. International climate finance (GEF, GCF, EU IPA) should be targeted at the under-resourced parks - particularly National Park Albanian Alps, National Park Prokletije, Korab-Koritnik, and National Park Drina - to build the institutional capacity needed for EbA implementation.
- Develop a regional EbA learning and exchange programme: Building on the successful workshops in Albania (May 2025) and Kyrgyzstan (July 2025), institutionalise an annual Western Balkans EbA Exchange bringing together park managers, municipal planners, national climate focal points, and community representatives from all six economies. This creates the peer-learning infrastructure that is currently absent.
- Align tourism and infrastructure development with climate and biodiversity objectives: National and municipal authorities should introduce stricter screening of tourism and infrastructure investments within and around protected areas. Climate-incompatible projects - such as ski expansion without snow reliability assessments, uncontrolled resort construction, or river-altering infrastructure - should be avoided. Instead, investments should prioritise green tourism and nature-based economies, including low-impact visitor infrastructure, sustainable mountain agriculture, and ecosystem restoration initiatives that strengthen local livelihoods.

- Tourism planning should also be guided by ecosystem carrying-capacity assessments, defining sustainable visitor thresholds, infrastructure density limits, and service provision levels for sensitive mountain landscapes. These assessments should inform spatial planning, park management plans, and tourism development strategies.

Economy-Specific Recommendations

Economy	**Key EbA/NbS Recommendation**	**Suggested Instrument**
Albania	Adopt EbA as an explicit objective in the revised Albanian Alps NP Draft Management Plan and the forthcoming Korab-Koritnik management plan. Restrict further HPP development within or adjacent to protected areas.	Management plan support by UNEP; Law 81/2017 zoning enforcement; National Tourism Strategy 2025-2030 northern cluster implementation
Montenegro	Integrate BOKU climate projections into the forthcoming NP Prokletije Management Plan revision. Develop a wildfire and early response plan for the Prokletije massif. Apply climate viability criteria to proposed ski resort development in the park area.	NP Prokletije 2026 management plan; Law on Nature Protection; EU IPA cross-border with Albania and Kosovo*
Kosovo*	Renew the expired NP Sharri management plan (2013-2023) with EbA integration. Strengthen enforcement of construction regulations at Brezovica. Develop an NTFP certification.	Kosovo* Climate Change Strategy 2019-2028; EU IPA III; UNDP support to KEPA; Law on Nature Protection (2010)
North Macedonia	Enforce the existing prohibition on new large-scale infrastructure (including HPPs) within NP Shar Mountain. Commission an independent climate viability assessment for the Popova Šapka cable-car investment before funding is committed. Establish the Lesnica River restoration pilot as the flagship national EbA investment.	NP Shar Mountain Management Plan 2022-2031; Climate Change Law (2021); EU Chapter 27 obligations; Flood Risk Management Plan for Upper Vardar
Serbia	Integrate peatbog hydrological restoration and Pančić spruce refugia management as priority measures in the NP Tara Management Plan next revision. Negotiate minimum environmental flow releases from Bajina Bašta HPP. Actively participate in the Drina Biosphere Reserve nomination process as a governance mechanism for cross-border EbA.	NP Tara Management Plan 2020-2030; Law on Climate Change (2021); ISRBC and Drina Task Force frameworks; EU Chapter 27
Bosnia and Herzegovina	Accelerate development of a state-level National Adaptation Plan that explicitly references NP Drina as an EbA delivery mechanism. Resolve the floating waste governance gap on the Drina and Perućac Lake through a bilateral agreement with Serbia. Significantly increase NP Drina's budget (currently only €190,000) to a minimum operationally adequate level.	NP Drina Management Plan 2022-2031; Srebrenica Development Strategy 2023-2030; UNESCO MAB Biosphere Reserve process; EU IPA III (BiH-Serbia cross-border)

ANNEX I Using the WB-CPP Platform to Prepare National Parks for Climate Impacts

The Western Balkans Climate Change Proofing Platform (WB-CPP), accessible at https://wbcpp.neopix.dev, is a free, open-access digital tool developed under the Austrian Development Agency - UNEP project on Climate Proofing for Sustainable Development in the Western Balkans. It provides centralised access to downscaled climate change projections, interactive maps, and scenario-based data for all six Western Balkan economies. The platform requires no registration and operates through any modern web browser. This section provides practical, step-by-step guidance for national park managers, municipal planners, and national authorities on how to use WB-CPP to support climate-resilient protected area management - from management plan revision to day-to-day operational decisions.

WB-CPP Platform: Key Features Relevant to Protected Area Management

Climate Variables Available on the Platform

The WB-CPP provides 16 climate variables across three categories. The variables most directly relevant to mountain protected area management are:

Variable	Category	Definition	Primary PA Relevance
Dry Spells (5 days) and Dry Spells (7 days)	Precipitation	Number of periods with ?5 or ?7 consecutive dry days per year	Wildfire danger season; drought impacts on springs, pastures, and forest health
Hot Days in Dry Spells (5 and 7 days)	Compound	Days with Tmax >30 °C during a dry spell - simultaneous heat and drought	Compound stress on biodiversity, bark beetle risk, soil degradation in semi-arid park zones
Critical Rainfall for Landslides	Precipitation	Rainfall intensity exceeding landslide triggering thresholds (days/year)	Flash flood and landslide risk on steep terrain; trail corridor safety assessment
Precipitation Extremes	Precipitation	Frequency and intensity of extreme daily rainfall events	Flood risk management; torrent system design; trail and road damage risk
Snowfall / Heavy Snowfall	Precipitation	Total snow water equivalent or days of heavy snowfall	Winter tourism viability; spring snowmelt timing; drinking water supply from snowpack
Precipitation Amount	Precipitation	Total accumulated precipitation (seasonal/annual)	River flow and spring recharge; water security for park settlements and downstream municipalities
Mean / Maximum / Minimum Temperature	Temperature	Baseline temperature indices by season	Habitat shift tracking; growing season change; biodiversity impact assessment
Hot Days (30 °C) and Very Hot Days (40 °C)	Temperature	Number of days per year exceeding 30 °C or 40 °C	Visitor safety; heat stress on endemic species; tourism season shifting
Freeze-Thaw Cycles	Temperature	Days cycling above and below 0 °C within a period	Trail and road infrastructure damage assessment; water pipe risk
Days Exceeding Wind Speed Extremes	Compound	Future frequency of extreme wind events	Wildfire spread risk in combination with dry spell projections

Time Periods and Scenarios

All projections are available for three time periods and three climate scenarios, enabling users to understand both near-term committed change and longer-term trajectory under different emission pathways:

Time Period	Description	Recommended use for PA Planning
Historical Baseline (1981-2010)	Reference period representing observed climate	Understand current climate of the park; compare to projected changes
Near Future (2021-2050)	Reflects already committed climate change	Management plan revision horizon; infrastructure investment decisions; EbA pilot design
Far Future (2071-2100)	Long-term projection; most sensitive to emissions scenario choice	Long-term biodiversity and ecosystem strategy; climate refugia designation; stress-testing tourist infrastructure investments

Scenario	Warming Level	Recommended use
RCP 2.6 / SSP1-2.6	~1.5–2 °C by 2100 (strong mitigation)	Best-case planning; Paris Agreement alignment; minimum-risk scenario for nature-based solutions design
RCP 4.5 / SSP2-4.5	~2–3 °C by 2100 (intermediate mitigation)	Central scenario for national adaptation plans and management plan revision; most commonly used for PA planning
RCP 8.5 / SSP5-8.5	~3.5–5 °C by 2100 (business as usual)	Worst-case stress testing; infrastructure design standards; identify non-linear risk thresholds

Step-by-Step Guide for Park Managers

Park managers with no specialist climate background can use the WB-CPP platform in six straightforward steps. The following workflow is recommended for producing a climate evidence base for management plan revisions or EbA pilot design:

Step	Action	Tips for Mountain PA Context
1 Access the Platform →	Open https://wbcpp.neopix.dev No registration needed	The interactive map loads a regional view of all six economies. Use zoom controls to locate your protected area.
2 Select Your Park Area →	Click on the map to select the economy or sub-national region; toggle boundary layers (economy / administrative / river basin) to frame the park area.	Use river basin boundary layer to capture the full catchment relevant to your park's water security context.
3 Choose a Climate Variable →	Open the Variables or Indicators panel; browse by category (Temperature, Precipitation, etc); select your variable. A legend shows the colour scale and units.	Start with Dry Spells (7 days) and Precipitation Amount to understand the overall drought/water signal before adding compound variables.

Step		Action	Tips for Mountain PA Context
4	Select Time Period and Scenario →	In the Scenario panel, choose Historical, Near Future (2021–2050), or Far Future (2071–2100). Select RCP 2.6, 4.5, or 8.5.	First view the Historical baseline, then switch to Near Future under RCP 4.5 (central scenario). Compare to RCP 8.5 Far Future for stress testing.
5	Visualise, Click and Compare →	The map updates to show the spatial distribution as a coloured raster layer. Click any point to see the exact value. Use the Compare function to display two scenarios side by side.	Focus on changes that appear robustly under both RCP 4.5 and RCP 8.5 — these are most reliable for planning. Seasonal breakdowns (summer vs. winter) often tell different stories.
6	Export and Cite Data →	Use the Download/Export button to retrieve data as CSV, GeoTIFF, or map image for use in reports and planning documents.	Note the data source, variable, time period, and scenario in all citations. Include both Near Future and Far Future projections in management plan climate sections.

Priority WB-CPP Applications for the Protected Areas

Based on the climate risk profile of the three transboundary clusters, the following WB-CPP applications are top 5 priorities for park managers:

Step		Action	Tips for Mountain PA Context
Wildfire risk season planning	Dry Spells (7 days); Hot Days in Dry Spells (5 and 7 days); Days Exceeding Wind Speed Extremes	Select the park; compare Dry Spells (7 days) Historical vs. Near Future vs. Far Future under RCP 4.5 and 8.5. Overlay with Hot Days in Dry Spells to identify compound heat-drought risk months.	Use to define a climate-adjusted fire danger season; update fire prevention staffing and pre-positioning plans; share projections with national fire services for joint planning across cluster boundaries.
Water security: springs, rivers, snowmelt	Precipitation Amount (seasonal); Snowfall; Dry Spells (5 days)	Select the relevant sub-catchment; compare seasonal Precipitation Amount under RCP 4.5 vs. baseline; overlay Snowfall projections to assess change in spring snowmelt timing. Use summer-season breakdown.	Identify springs and river sub-basins with greatest projected decline; prioritise micro-retention and spring restoration pilots; provide evidence base for municipal water security planning in Tetovo, Gostivar, Prizren, Bajina Bašta, Kukës.
Flash flood and landslide risk on trails and roads	Critical Rainfall for Landslides; Precipitation Extremes	Select the mountain park; choose Critical Rainfall for Landslides; compare frequency of exceedance events between Historical, Near Future, and Far Future under RCP 8.5. Identify highest-risk terrain zones.	Overlay outputs with slope stability maps; trigger engineering risk assessments; update disaster preparedness protocols; notify civil protection authorities; inform trail infrastructure investment prioritisation.
Winter tourism and ski resort viability	Snowfall; Heavy Snowfall; Mean Temperature; Minimum Temperature	Select the ski resort elevation zone (e.g., Popova Šapka 1,780 m; Brezovica 900-2,500 m); compare snowfall duration and amount under RCP 2.6 (best case) and RCP 8.5 (worst case) for 2021-2050 and 2071-2100.	Provide climate evidence for management plan tourism sections; assess long-term ski infrastructure viability; trigger ski resort operator engagement; support four-season tourism diversification planning and business case development.
Biodiversity and habitat shift tracking	Mean Temperature (seasonal); Maximum Temperature; Precipitation Amount (summer)	Select the area; compare Mean Temperature change by season under RCP 4.5 to map thermal shift magnitude across elevation bands. Combine with summer Precipitation decline to identify thermal-moisture stress zones.	Define climate-sensitive monitoring zones (peatbogs, glacial lakes, subalpine tree line); link projections to species distribution models; identify and map climate refugia for spruce, endemic flora, peatbog habitats.

How Local Municipalities Can Use WB-CPP

Municipalities surrounding the eight protected areas - particularly Tetovo, Gostivar, Prizren, Kukës, Bajina Bašta, Srebrenica, Plav, Gusinje, Tropoja, and Peja - face climate risks that are directly linked to the parks' eco functions. WB-CPP can be used by municipal planners without specialist training across four key areas:

- **Water supply security:** Municipal utilities drawing drinking water from mountain springs or rivers can use WB-CPP Precipitation Amount and Snowfall projections to quantify the magnitude and timing of future water deficits. The platform's seasonal breakdown (summer vs. winter) is particularly important: declining summer precipitation and snowmelt advance will affect source water reliability even before total annual precipitation shows significant decline. This evidence should trigger: investment in alternative or supplementary water sources; reservoir storage capacity upgrades; and municipal demand-management frameworks linked to park management plans.
- **Disaster risk reduction and spatial planning:** Municipal civil protection offices should use WB-CPP's Critical Rainfall for Landslides and Precipitation Extremes variables to map flood and landslide hotspots across their jurisdiction. The platform allows users to compare current-period exceedance frequency to 2021-2050 projections, providing a direct input for updating hazard zones, evacuation route planning, and spatial planning restrictions. Municipalities should share these outputs with national park managers to ensure that trail, road, and visitor infrastructure within parks is consistent with updated risk maps.
- **Tourism and destination investment planning:** Tourism-dependent municipalities should use WB-CPP Hot Days (30 °C and 40 °C) projections to understand shifting visitor comfort thresholds, and Snowfall projections to assess the long-term viability of winter tourism investment (ski resorts, hut refurbishment). The WB-CPP guidance recommends RCP 4.5 as the central scenario for investment planning and RCP 8.5 for stress testing infrastructure proposals with long design lifetimes. This evidence base is directly applicable to municipal development strategy revisions.
- **Agricultural support for park-adjacent communities:** Municipal agricultural extension services can use Dry Spells (5 and 7 days) and Hot Days in Dry Spells projections to advise local farmers on crop variety adaptation, irrigation scheduling, and climate insurance product design. The compound indicator (Hot Days in Dry Spells) is particularly valuable here because it captures simultaneous heat and drought stress - the combination most damaging to mountain agriculture - which single-variable temperature or precipitation indicators would miss.

How National Authorities Can Use WB-CPP

National environment ministries, protected area agencies, and climate focal points in all six economies have four strategic uses for the WB-CPP platform:

- **National Adaptation Plan development and updates:** Environment ministries developing or updating NAPs can use the WB-CPP platform to generate consistent, spatially explicit climate projection data for priority sectors (water, biodiversity, agriculture, disaster risk). The platform's coverage of all six economies on a harmonised technical basis enables cross-border comparison, which is essential for transboundary protected area management and supports reporting under the United Nations Framework Convention on Climate Change (UNFCCC), including Nationally Determined Contributions (NDCs).
- **Protected area management plan climate screening:** National park agencies - NAPA in Albania, JPNPCG in Montenegro, KEPA/Directorates in Kosovo*, Park Public Institutions in North Macedonia, Serbia, and BiH - should formally adopt WB-CPP as the standard evidence platform for the climate change section of all management plan revisions. Using a shared platform ensures cross-park comparability, reduces the data gap currently impeding systematic climate integration, and provides a defensible evidence base for EbA investment prioritisation. The platform's ability to present projections as spatial maps directly supports the spatial zoning components of management plans.
- **EU environmental acquis alignment:** Countries in EU accession negotiations are required to align with the EU Floods Directive, Water Framework Directive, Habitats Directive, and EU Climate Adaptation Strategy. WB-CPP projections for Precipitation Extremes, Critical Rainfall for Landslides, and Precipitation Amount directly support the evidence requirements of Flood Risk Management Plans (Floods Directive), River Basin Management Plans (WFD), and Natura 2000 / Emerald Network site management under the Habitats Directive. Environment ministries should embed WB-CPP into their EU acquis alignment roadmaps as a practical tool that addresses multiple directive requirements simultaneously.
- **Climate-proofing EU IPA and public investment portfolios:** National and regional IPA implementing agencies should require WB-CPP scenario analysis as a standard component of feasibility assessments for EU-funded infrastructure projects, tourism investments, and water management schemes. The WB-CPP guidance recommends that all infrastructure designed for lifetimes of 20+ years should be stress-tested under RCP 8.5 Far Future (2071-2100) conditions. This requirement directly addresses the current gap in climate-proofing of public investment in the Western Balkans protected area sector.

Bundesministerium für Umwelt, Klimaschutz, Naturschutz und nukleare Sicherheit

UN environment programme

Factsheet #0 |
Technical Background

TECHNICAL BACKGROUND

13 CLIMATE ACTION
15 LIFE ON LAND

| OBSERVED CLIMATE DATA

To evaluate the impacts of climate change in a region, it is important to know the climate of the past for a longer term, preferably several decades. Observations are mainly based on weather stations and satellites. For the observed climate dataset, we combined data from WorldClim v2.1, CHELSA v2.1, and CHELSA-W5E5 with the reanalysis dataset ERA5 to fill in gaps and improve accuracy. The resulting data provides observations of important climate parameters in the timeframe 1981 – 2020. Based on those observations, we can characterise the past climate of a region, which also serves as a reference for future changes simulated by climate models.

RCP	Description
RCP2.6	International coordination under the Paris Agreement enables strong climate action to limit global warming to 2 °C above pre-industrial levels.
RCP4.5	An intermediate scenario presuming medium climate action. Green house gas emissions start to decline slowly after 2040.
RCP8.5	A high-emissions, low climate actions scenario. Emissions continue to rise throughout the 21st century.

| CLIMATE MODELS

Future climate scenarios are based on different climate models that simulate the Earth's climate system. These models use scenarios called "Representative Concentration Pathways" (RCPs), which describe possible futures based on how much climate-effective greenhouse gases are emitted. RCPs range from strong climate action (like RCP2.6) to high-emission, low-action pathways (like RCP8.5). Since climate models are simplifications of the real-world climate system, they have different strengths and limitations. Therefore, it is highly recommended to always use an ensemble of different models for evaluating climate changes.

| GLOBAL WARMING LEVELS

Climate change impacts in a region can be related to the global climate via global warming levels (GWLs). GWLs refer to how much the Earth's global average temperature has increased compared to pre-industrial times (1850-1900). We use 20-year periods to evaluate the timing of GWLs in each climate model. By sampling model results based on GWL periods, models with different characteristics can be compared.
The global temperature increase reached 1 °C in the period 2001-2020 (GWL1.0). A global warming of 1.5 °C will likely be reached within the 2020s (GWL1.5). Under high emission scenarios, GWL3.0 and GWL4.0 could occur in the second half of the 21st century. The Paris Agreement of 2015 is a global pact to limit global warming to well below 2°C.

GWL	Time period	Description
GWL0.0	1850-1900	The base state of the climate before major human influence.
GWL1.0	2001-2020	Used as the reference for the recent climate.
GWL1.5	Mid/Late 2020s	GWL1.5 is inevitable.
GWL2.0	Around 2040	Ambitious climate action leads to global warming stopping at or below 2.0 °C
GWL3.0	Likely by 2nd half of 21st century	If we continue with current green house gas emissions, the 3-degree warmer world is reached within the 21st century.
GWL4.0	Likely towards the end of 21st century	If emissions continue to rise for the coming decades, GWL4.0 could still occur this century.

Data Sources
WorldClim: https://www.worldclim.org/data/worldclim21.html
CHELSA: https://chelsa-climate.org/
ERA5: https://cds.climate.copernicus.eu/datasets/derived-era5-single-levels-daily-statistics?tab=overview

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer

BOKU Institut für Meteorologie und Klimatologie

Bundesministerium für Umwelt, Klimaschutz, Naturschutz und nukleare Sicherheit

UN environment programme

Factsheet #1 |

Basic Information

| Regional Information

Located along the border of Serbia and Bosnia and Herzegovina, the transboundary protected area Tara-Drina corridor ranges from 300 m to almost 1,600 m in elevation. It spans approximately 310 km^2, including stretches of the Drina river and Zaovine lake. The climate is characterized by moderate seasonal temperature variation and abundant precipitation throughout the year, with snow occurring in the winter months (DJF) at higher elevations.

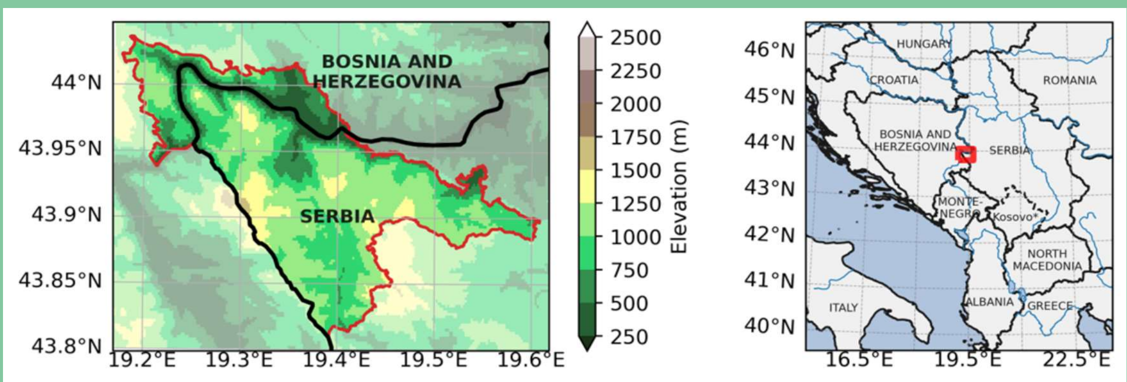


Figure 1:
Left: Borders and topography of the region.
Right: Location of the region (red) within the Western Balkans.

A climate diagram (also Walter/Lieth diagram) shows the most important climatic properties of a location: Sea level, annual and monthly mean temperatures and precipitation sums. This information indicates whether a location is dry or wet, and whether snow occurs over the seasons. Months with over 100 mm precipitation are marked as especially wet, whereas months where the precipitation curve lies below the temperature curve are dry. Months with mean temperature below 0 °C indicate the occurrence of snow or ice.

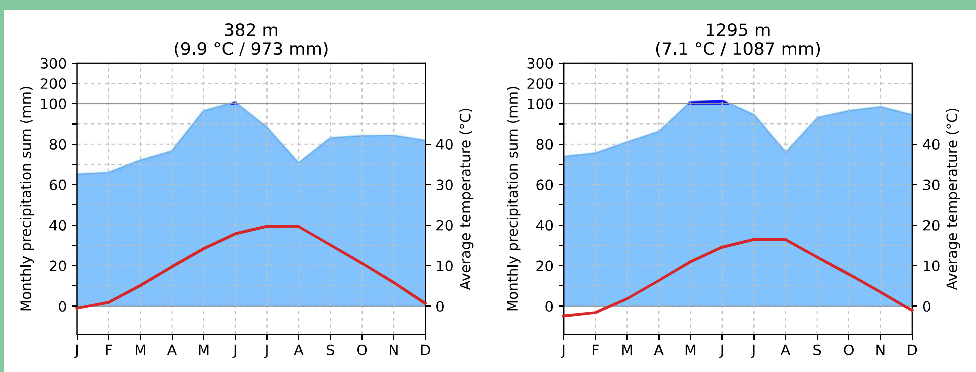


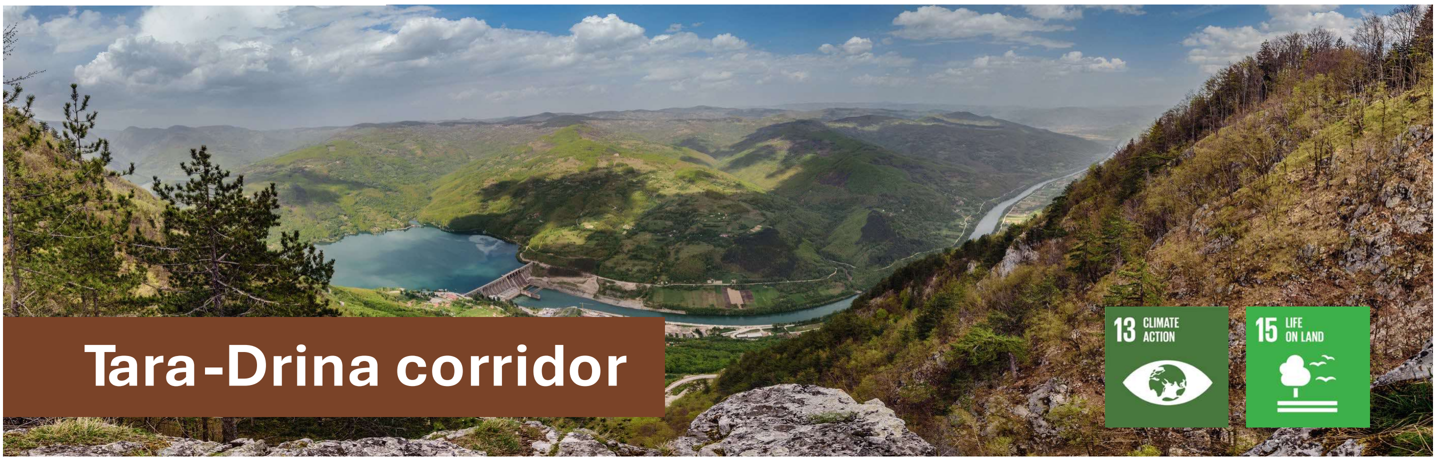
Figure 2: Climate diagrams for the period 1991-2020 of two locations in the region: a valley (left) and a peak (right). The diagrams show the elevation, mean annual temperature and precipitation sum of the location on the top. In the graph, monthly average temperatures (red line, left y-axis) and monthly average precipitation sums (blue area, right y-axis) are plotted.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer

BOKU Institut für Meteorologie und Klimatologie

Factsheet #2 |
Temperature & Heat



Tara-Drina corridor

| Observed and future temperature

First and foremost, climate change concerns average yearly or seasonal temperatures. Weather observations show a significant temperature increase in the region over the past 40 years, both in summer and winter. Climate models simulate further development of average temperatures up to 2100. Figure 1 shows that this development strongly depends on the emissions scenario (RCP). With low-end emissions, temperature rise stops about mid-century, while medium and high scenarios show further increasing temperatures. It depends on our ambitions for climate action whether temperatures continue rising at all, rise by 2 °C or by more than 4° C locally until the end of the century, compared to the period 1981-2010.

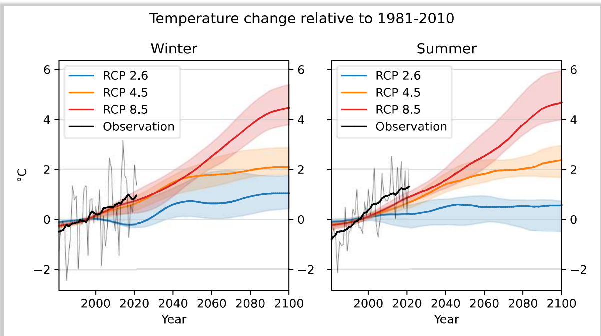


Figure 1: Temperature changes in this region compared to the average of the period 1981–2010.
Left: Winter from December to February.
Right: Summer from June to August.
Black lines represent weather observations: The thin black line shows individual years; the thick black line is smoothed to highlight the trend. Data from climate models is shown in different colours for different emissions scenarios: low (blue), medium (orange) and high (red) emissions. The shaded areas show a range of different climate models.

Rising temperatures have clear indications for the region. In summer, a relatively small temperature increase leads to a sharp rise of hot days and extended heat episodes, leading to heat stress on humans, animals, plants, and impacting water resources. In winter, this could mean the total disappearance of snow on lower elevations, with wide-ranging impacts for water availability in spring. Seasonal warming also means an altered growing season, which impacts the composition of the ecosystem and biodiversity. Although the precipitation regime of the region is wet, increased evaporation could lead to drier periods in summer and autumn, thereby increasing wildfire hazards. The following sections describe a few central indicators for these impacts of climate change.

| Very hot days (above 35 °C)

The number of very hot days indicate extended periods of heat, impacting the health of humans and wildlife and water availability due to higher evaporation. With summers warming faster than the other seasons, the frequency of very hot days will increase. Figure 2 shows the average number of days per year for the region. Like with average regional temperatures, the rise in very hot days strongly depends on the intensity of global climate change. This is indicated by the global warming levels (GWLs).

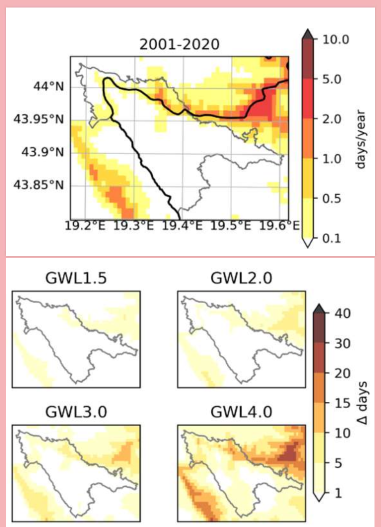


Figure 2: Average number of very hot days per year in the region.
Top: Recent climate (2001-2020).
Bottom: Changes for the GWLs 1.5 °C to 4.0 °C. E.g. light yellow indicates an increase of more than one day per year.

BOKU
Institut für Meteorologie und Klimatologie

| Growing season

Increasing temperatures lead to shorter winters and thus allow for a longer growing season. This means that plants can start growing earlier in the year, increasing seasonal water demand for both natural vegetation and agriculture and thereby intensifying pressure on regional water resources. Through the food chain, the shifted availability of nutrition also affects biodiversity.
Figure 3 shows changes in the duration of the growing season in the region, dependent on the intensity of global warming (GWLs).

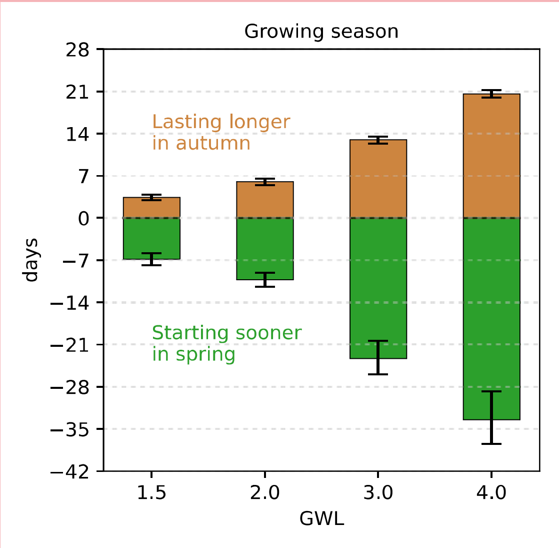


Figure 3: Change of growing season duration in days compared to the recent climate (2001-2020) at four GWLs: 1.5 °C, 2 °C, 3 °C and 4 °C. Brown colours indicate how many days the growing season extends into autumn (positive numbers), green colours show how many days earlier it starts in spring (negative numbers).

The growing season indicator starts on the day of the year when the average temperature first exceeds 5 °C for 5 consecutive days and ends on the day when the temperature is below 5 °C for 5 consecutive days. The bars in the figure indicate both earlier start in spring and later end in autumn. The total increase of the growing season is the sum of both earlier start in spring and later end in autumn. It ranges between 1.5 additional weeks at GWL1.5 and almost 8 additional weeks at GWL4.0.

| Wildfires

Wildfires pose a threat to infrastructure and ecosystems. Vegetation is often severely altered for decades after a wildfire. As both a safety risk and a loss of attraction, this also reduces local tourist activity.
The danger for wildfires increases in hot, dry and windy weather conditions and can be approximated by the Fire Weather Index (FWI). Figure 4 shows the number of days in the region with high FWI, representing high wildfire risk, for the recent climate and the GWLs 1.5 ° C, 2 ° C, 3 °C and 4 °C.

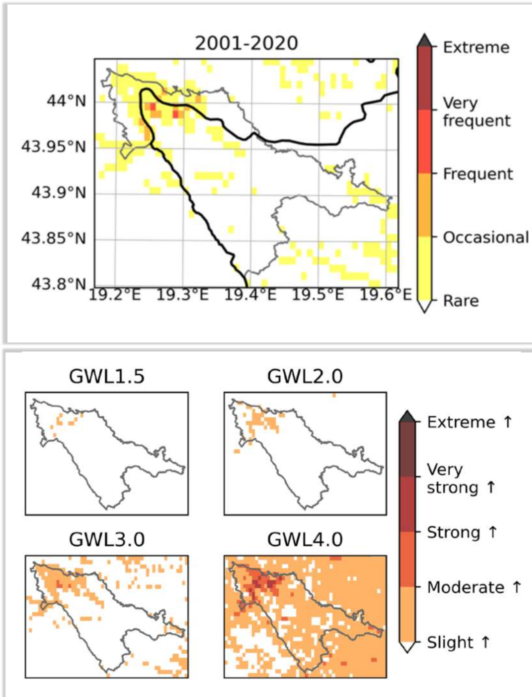


Figure 4: Frequency of days with a high FWI (defined as >38), indicating favourable weather conditions for wildfires.
Top: Recent conditions (2001–2020). 'Rare' indicates fewer than 1 day per year with a high FWI. 'Extreme' refers to more than 30 days per year with a high FWI.
Bottom: Changes in the number of days with a high FWI ranging from slight (less than 1 additional day/year) to extreme (more than 30 additional days/year).

Higher temperatures favour wildfire trigger conditions in all climate scenarios. The increase is most pronounced in the Drina valley in the northwest of the region, where evaporation is higher on steeper, south-facing hillsides than on flat land. The FWI shows optimal weather conditions for wildfires but does not consider whether actual fuel (material for ignition) is available. It also does not consider the spread of fires to other areas. Therefore, even areas with low fire danger can experience wildfires when they are carried in from other regions by strong winds.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © 2021 Aliaksei Kruhlenia | Shutterstock

BOKU Institut für Meteorologie und Klimatologie

Bundesministerium
für Umwelt, Klimaschutz, Naturschutz
und nukleare Sicherheit

UN environment programme

Factsheet #3 |

Water availability, Droughts & Floods

Tara-Drina corridor

| Changes in average precipitation

Whether a region is characterised as wet or dry depends on the average annual and seasonal amount of precipitation (rain and snow) and the corresponding amount of water removal through evaporation or abstraction. The resulting water balance indicates if water resources are abundant or scarce.

Figure 1 shows the change in average precipitation of the region for summer and winter. The general trend is a slight increase of precipitation in winter (left panel). Due to rising temperatures, more precipitation will fall as rain instead of snow, especially in the lowlands.

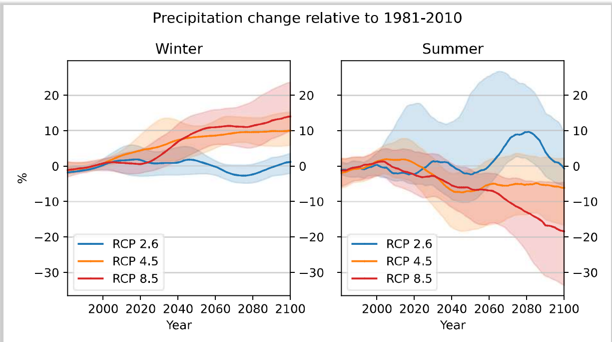


Figure 1: Seasonal precipitation changes in the region. Changes are shown in percent compared to the average of 1981–2010.
Left: Winter (December to February).
Right: Summer (June to August) .
Different emissions scenarios are shown in colours (blue, orange, red), with the shaded area indicating a range of different climate models.

Summer precipitation (right panel) shows a decline, depending more strongly on the emissions scenario. Low emissions result in no definitive change, medium to high emissions could lead to a 5% to more than 20% decrease in precipitation. Combined with rising temperatures, this could intensify dry spells in summer and autumn.

| Snow

In terms of seasonal water availability, snow works as a buffer that saves water in the cold months and releases it into the ecosystems when it gets warmer. Snowmelt in spring is crucial to meet water demand of natural and agricultural vegetation, and to fill up rivers for hydropower generation.

With rising temperatures, snow cover decreases in all elevations and seasons. Figure 2 shows the number of days with a snow cover of more than 10 cm in April. Under recent climate, the region still experiences up to a week of snow cover in large areas. Under future scenarios, snow cover in April might disappear completely.

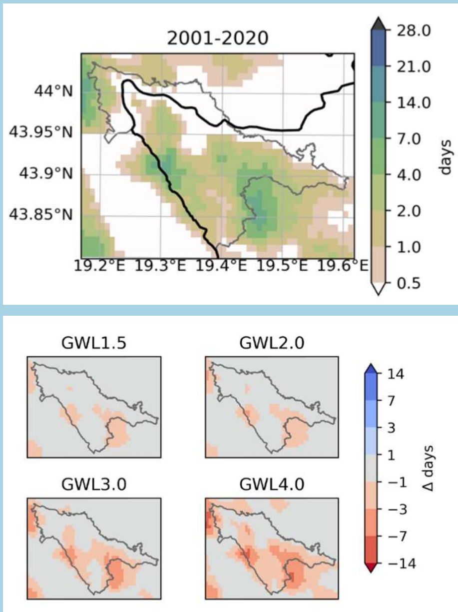


Figure 2: Number of days with a snow cover of more than 10 cm in April.
Top: Recent climate (2001-2020).
Bottom: Changes in the number of days from GWL 1.5 °C up to GWL 4.0 °C.

Shorter duration of snow cover reduces the buffer function of snow and thereby water availability at a critical period in spring, when the growing season starts. Together with reductions in seasonal precipitation in summer, this can lead to more intense periods of droughts.

BOKU
Institut für Meteorologie und Klimatologie

| Meteorological droughts

Meteorological droughts are caused by a lack of precipitation in combination with high evaporation. Evaporation increases with rising temperatures, solar radiation and wind speed.
The Standardized Precipitation Evapotranspiration Index (SPEI) takes all these factors into account. Figure 3 shows monthly changes in SPEI of the region for different climate scenarios (GWLs). Negative numbers indicate drier conditions compared to the recent climate. An SPEI value of –1.5 is considered a severe drought. Dry spells in summer and autumn will become slightly to moderately more intense under all climate scenarios, depending on the intensity of global warming.

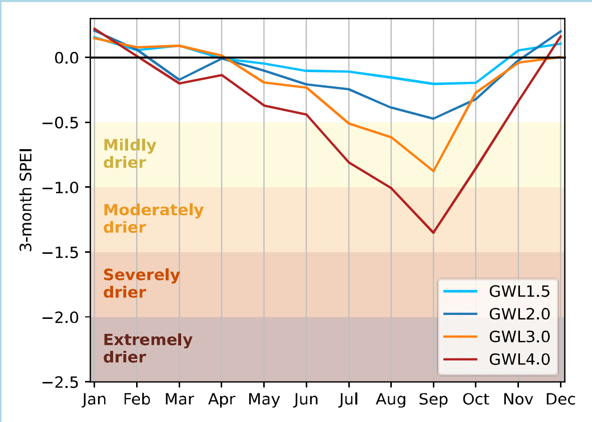


Figure 3: Change of Standardized Precipitation Evapotranspiration Index (SPEI) compared to the recent climate (2001-2020). Negative values represent drought conditions. Coloured lines show the SPEI derived from climate models for the GWLs 1.5 °C, 2 °C, 3 °C and 4 °C.

| Extremes in daily precipitation

Rising temperatures lead to increased drought conditions and more intense heavy precipitation. Both can be true at the same time, even without major changes in average precipitation. The process responsible for increased heavy precipitation is outlined in Figure 4. The atmosphere's moisture-holding capacity increases with temperature, typically at a rate of about 7% per 1 °C. Therefore, with higher temperatures more water is available for precipitation.
This effect is also visible, at least in part, in climate models. Figure 5 shows the change in extreme daily precipitation amounts for the wettest day of the year in the region. The higher the temperature (indicated by the GWL), the more intense the highest daily precipitation in a year.

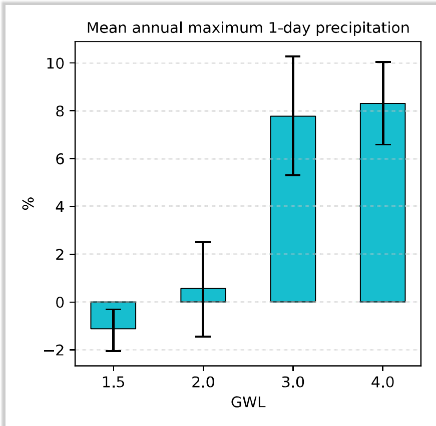


Figure 5: Relative change of precipitation on the wettest day of the year compared to 2001-2020. The error bars show the range within the region.

More heavy daily precipitation increases flood hazards, especially in larger catchments. Also, the high water content in the soil during such events increases the risk of landslides.

| Extremes in short-term precipitation

The effect of rising temperatures on heavy precipitation is even stronger for short-term precipitation events lasting minutes to a few hours. The increase in short-term precipitation extremes can be much stronger than the increase in daily precipitation extremes shown in Figure 5, but climate models do not yet provide robust data on precipitation extremes below the daily timescale.
Given a realistically possible average warming of 4 °C in the Western Balkans, this relation suggests an increase in short-term extreme precipitation intensities by almost a third, meaning a short-term event with 60 mm of precipitation can increase to nearly 80 mm.

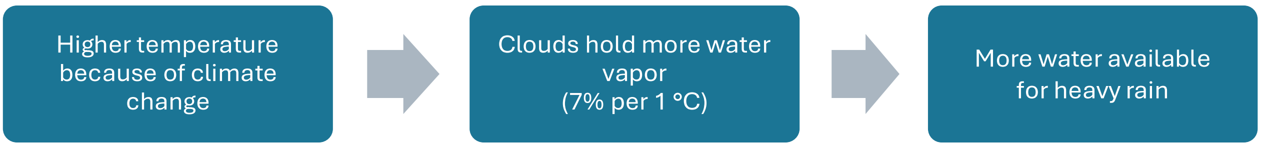


Figure 4: Illustration of the process that links rising temperatures to increased heavy precipitation.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © 2021 Aliaksei Kruhlenia | Shutterstock

BOKU Institut für Meteorologie und Klimatologie

Bundesministerium
für Umwelt, Klimaschutz, Naturschutz
und nukleare Sicherheit

UN environment programme

Factsheet #4 |

Key messages

Tara-Drina corridor

The elevation of the Tara-Drina corridor ranges from around 300 m to almost 1, 600 m. The climate is characterized by moderate seasonal temperature variation and abundant precipitation throughout the year, with snowfall occurring in the winter months (DJF) at higher elevations. The general trend with precipitation is a slight increase in winter. Due to rising temperatures, more precipitation will fall as rain instead of snow, especially in the lowlands. Small changes in average temperature leverage large negative impacts.

Local observations:

"Seasonality has almost disappeared here — winters are now shorter and milder with little or no snow, while summers are increasingly hot and dry. Springs on Tara and tributaries around the Drina often dry up in summer, and temperatures above 30 °C are now common even at higher altitudes. These conditions heighten the risk of forest fires and contribute to the drying of iconic species such as Pančić's spruce (Picea omorika) and the loss of rare plants like Cardamine serbica."

The example is Zaovine Lake that has remained near the biological minimum in recent years due to reduced snowfall and rainfall.
High summer temperatures and prolonged dry periods have significantly increased forest fire risk, with repeated fires recorded in Luka, Klotjevac, and Biljeg, including a large fire in Luka in 2024 that required helicopter intervention. In 2022, around 6, 000 hectares burned in NP Drina, causing major forest degradation and biodiversity loss.
These environmental changes have severe consequences for biodiversity. Early development of crops followed by frost damage has been reported, while changes in flowering times and longer vegetation periods have contributed to reduced yields and lower productivity. Brown bears are entering hibernation later or not at all due to warmer early winters, and jackals are now expanding into wolf habitats.

| Key messages

- **Until the end of the century, average temperatures in the region increase by 1-4 °C in summer and by 1-6 °C in winter compared to 1981 -2010. The actual development depends strongly on human climate action.**
- **In a 4°C warmer world, the region experiences less than half of the current period of snow cover in high elevations. In spring, this leads to less water supply from snowmelt. It is already noticed that snow cover lasts well shorter, and prolonged periods with snow are rare even at the highest altitudes.**
- **Droughts will be more frequent in all seasons but winter due to less precipitation and higher evaporation. What is now a drought that occurs every 15 years in summer could occur every second year in a 4°C world. Springs and tributaries in the Tara and Drina canyon often dry up during summer, while Zaovine Lake has remained near the biological minimum in recent years due to reduced snowfall and rainfall.**
- **The growing season is extended by up to eight weeks in a 4°C warmer world. The shifts in the growing season affects many organisms through the food chain.**
- **Severe wildfire danger increases due to extended dry periods and higher temperatures, with repeated fires recorded in Luka, Klotjevac and Biljeg.**
- **Extreme precipitation events intensify by approx. 7% per 1 °C of warming, increasing the risk of flash floods and landslides. After long dry periods, heavy rainfall now occurs in short, intense bursts, triggering flash floods and landslides. In 2014, floods caused massive landslides in Sućeska that blocked roads for two years, while torrents in Žlijebac destroyed water supply infrastructure.**
- **The recorded and rising socio-economic risks include increasing forest-fire danger, springs and peatlands drying up, water scarcity, and declining aquatic ecosystems.**

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology
Authors & Layout: Ajla Dorfer, Belma Nahić, Fabian Lehner, Benedikt Becsi, Mimi Amaichigh, Herbert Formayer
Photo (Header): © 2021 Aliaksei Kruhlenia | Shutterstock
Photo: National Park Tara (Management Authority)

BOKU Institut für Meteorologie und Klimatologie

Bundesministerium für Umwelt, Klimaschutz, Naturschutz und nukleare Sicherheit

UN environment programme

Factsheet #1 |

Basic Information

Sharr/Sharri/Korab Koritnik

| Regional Information

Located in the southern Western Balkans along the border of Albania, North Macedonia and Kosovo*, the transboundary protected area of Sharr Mountain ranges from 400 m up to 2,700 m in elevation at its highest peaks. It spans approximately 1,500 km^2, including stretches of the Prizren Bistrica and Mazdraca rivers and the Brezovica ski resort. The climate is characterized by abundant precipitation at higher elevations, especially in October and November, with snow on the peaks, and with a drier period in summer. In those months, valleys are susceptible to droughts.

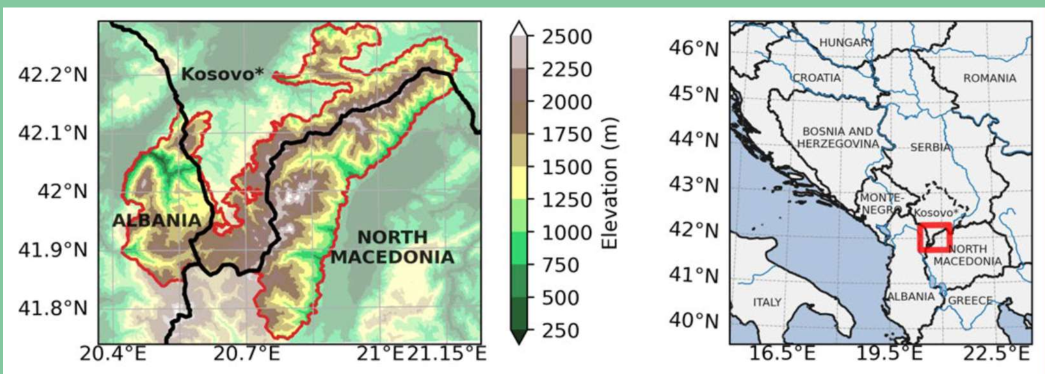


Figure 1:
Left: Borders and topography of the region.
Right: Location of the region (red) within the Western Balkans.

* under UNSCR 1244/99

A climate diagram (also Walter/Lieth diagram) shows the most important climatic properties of a location: Sea level, annual and monthly mean temperatures and precipitation sums. This information indicates whether a location is dry or wet, and whether snow occurs over the seasons. Months with over 100 mm precipitation are marked as especially wet, whereas months where the precipitation curve lies below the temperature curve are dry. Months with mean temperature below 0 °C indicate the occurrence of snow or ice.

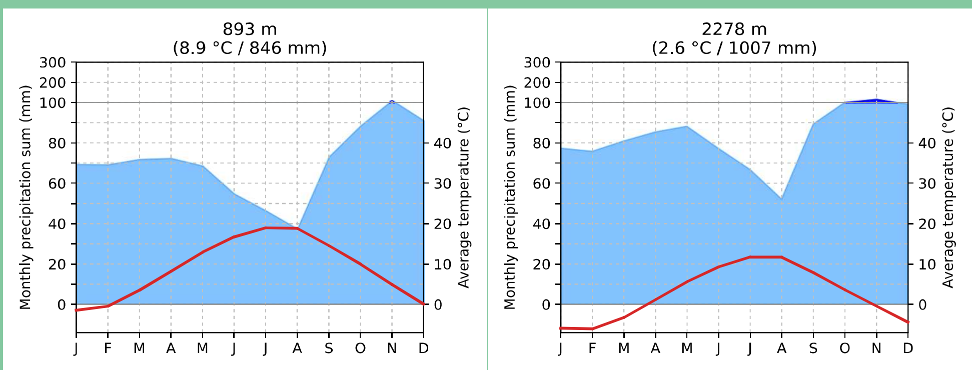


Figure 2: Climate diagrams for the period 1991-2020 of two locations in the region: a valley (left) and a peak (right). The diagrams show the elevation, mean annual temperature and precipitation sum of the location on the top. In the graph, monthly average temperatures (red line, left y-axis) and monthly average precipitation sums (blue area, right y-axis) are plotted.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Anela-Stavrevska-Panajotova

BOKU Institut für Meteorologie und Klimatologie

Bundesministerium für Umwelt, Klimaschutz, Naturschutz und nukleare Sicherheit

UN environment programme

Factsheet #2 |
Temperature & Heat

Sharr/Sharri/Korab Koritnik

13 CLIMATE ACTION

15 LIFE ON LAND

| Observed and future temperature

First and foremost, climate change concerns average yearly or seasonal temperatures. Weather observations show a significant temperature increase in the region over the past 40 years, both in summer and winter. Climate models simulate further development of average temperatures up to 2100. Figure 1 shows that this development strongly depends on the emissions scenario (RCP). With low-end emissions, temperature rise stops about mid-century, while medium and high scenarios show further increasing temperatures. It depends on our ambitions for climate action whether temperatures continue rising at all, rise by 2 °C or by more than 4° C locally until the end of the century, compared to the period 1981-2010.

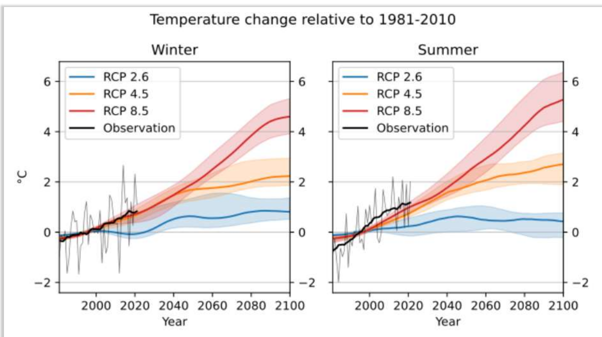


Figure 1: Temperature changes in this region compared to the average of the period 1981–2010.
Left: Winter from December to February.
Right: Summer from June to August.
Black lines represent weather observations: The thin black line shows individual years; the thick black line is smoothed to highlight the trend. Data from climate models is shown in different colours for different emissions scenarios: low (blue), medium (orange) and high (red) emissions. The shaded areas show a range of different climate models.

Rising temperatures have clear indications for the region. In summer, a relatively small temperature increase leads to a sharp rise of hot days and extended heat episodes, leading to heat stress on humans, animals, plants, and impacting water resources. In winter, this could mean the total disappearance of snow on lower elevations, with wide-ranging impacts for water availability in spring. Seasonal warming also means an altered growing season, which impacts the composition of the ecosystem and biodiversity. Missing snow and earlier vegetation could lead to extended periods of drought in spring and summer, thereby increasing wildfire hazards. The following sections describe a few central indicators for these impacts of climate change.

| Very hot days (above 35 °C)

The number of very hot days indicate extended periods of heat, impacting the health of humans and wildlife and water availability due to higher evaporation. With summers warming faster than the other seasons, the frequency of very hot days will increase. Figure 2 shows the average number of days per year for the region. Like with average regional temperatures, the rise in very hot days strongly depends on the intensity of global climate change. This is indicated by the global warming levels (GWLs).

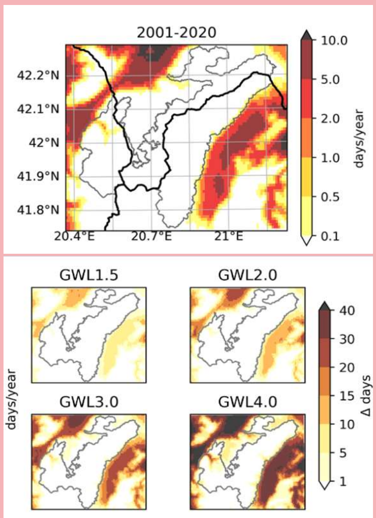


Figure 2: Average number of very hot days per year in the region.
Top: Recent climate (2001-2020).
Bottom: Changes for the GWLs 1.5 °C to 4.0 °C. E.g. light yellow indicates an increase of more than one day per year.

BOKU Institut für Meteorologie und Klimatologie

| Growing season

Increasing temperatures lead to shorter winters and thus allow for a longer growing season. This means that plants can start growing earlier in the year, increasing seasonal water demand for both natural vegetation and agriculture and thereby intensifying pressure on regional water resources. Through the food chain, the shifted availability of nutrition also affects biodiversity.
Figure 3 shows changes in the duration of the growing season in the region, dependent on the intensity of global warming (GWLs).

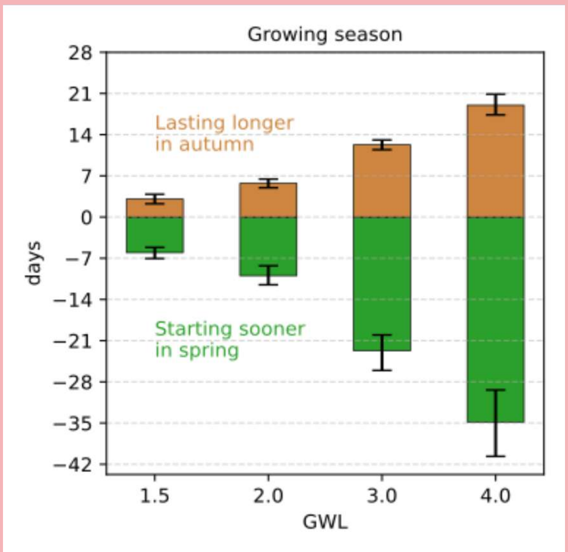


Figure 3: Change of growing season duration in days compared to the recent climate (2001-2020) at four GWLs: 1.5 °C, 2 °C, 3 °C and 4 °C. Brown colours indicate how many days the growing season extends into autumn (positive numbers), green colours show how many days earlier it starts in spring (negative numbers).

The growing season indicator starts on the day of the year when the average temperature first exceeds 5 °C for 5 consecutive days and ends on the day when the temperature is below 5 °C for 5 consecutive days. The bars in the figure indicate both earlier start in spring and later end in autumn. The total increase of the growing season is the sum of both earlier start in spring and later end in autumn. It ranges between nearly 1.5 additional weeks at GWL1.5 and almost 8 additional weeks at GWL4.0.

| Wildfires

Wildfires pose a threat to infrastructure and ecosystems. Vegetation is often severely altered for decades after a wildfire. As both a safety risk and a loss of attraction, this also reduces local tourist activity.
The danger for wildfires increases in hot, dry and windy weather conditions and can be approximated by the Fire Weather Index (FWI). Figure 4 shows the number of days in the region with high FWI, representing high wildfire risk, for the recent climate and the GWLs 1.5 ° C, 2 ° C, 3 °C and 4 °C.

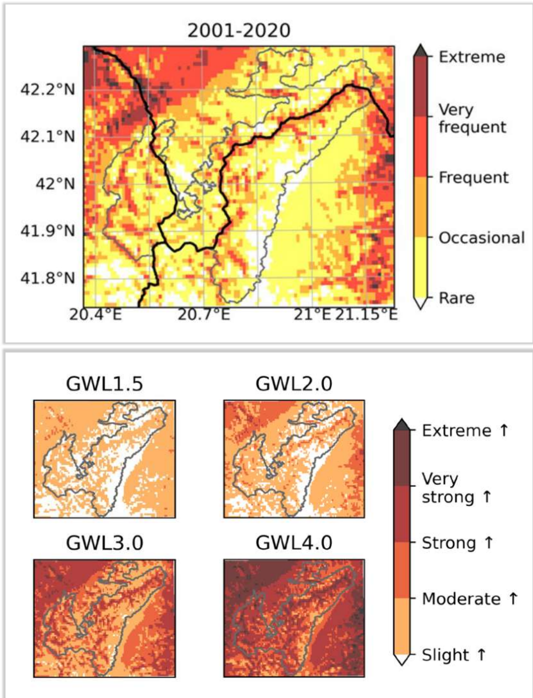


Figure 4: Frequency of days with a high FWI (defined as >38), indicating favourable weather conditions for wildfires.
Top: Recent conditions (2001–2020). 'Rare' indicates fewer than 1 day per year with a high FWI. 'Extreme' refers to more than 30 days per year with a high FWI.
Bottom: Changes in the number of days with a high FWI ranging from slight (less than 1 additional day/year) to extreme (more than 30 additional days/year).

Higher temperatures favour wildfire trigger conditions in all climate scenarios. The increase affects the entire region. The FWI shows optimal weather conditions for wildfires but does not consider whether actual fuel (material for ignition) is available. It also does not consider the spread of fires to other areas. Therefore, even areas with low fire danger can experience wildfires when they are carried in from other regions by strong winds or burn uphill to higher elevations.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Anela-Stavrevska-Panajotova

BOKU Institut für Meteorologie und Klimatologie

Factsheet #3 |

Water availability, Droughts & Floods

Sharr/Sharri/Korab Koritnik

| Changes in average precipitation

Whether a region is characterised as wet or dry depends on the average annual and seasonal amount of precipitation (rain and snow) and the corresponding amount of water removal through evaporation or abstraction. The resulting water balance indicates if water resources are abundant or scarce.
Figure 1 shows the change in average precipitation of the region for summer and winter. The general trend is a slight increase of precipitation in winter (left panel). Due to rising temperatures, more precipitation will fall as rain instead of snow, especially in the lowlands.

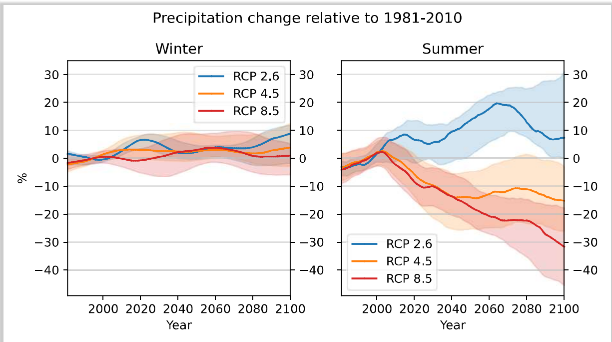


Figure 1: Seasonal precipitation changes in the region. Changes are shown in percent compared to the average of 1981–2010.
Left: Winter (December to February).
Right: Summer (June to August) .
Different emissions scenarios are shown in colours (blue, orange, red), with the shaded area indicating a range of different climate models.

Summer precipitation (right panel) generally shows a decline, depending more strongly on the emissions scenario. Low emissions result in a slight increase, medium to high emissions could lead to a 15% to 30% decrease in precipitation. Combined with rising temperatures, this poses a major challenge for water availability in the summer months.

| Snow

The start and duration of the snow cover plays a crucial role for winter tourism in the region. In terms of seasonal water availability, snow works as a buffer that saves water in the cold months and releases it into the ecosystems when it gets warmer. Snowmelt in spring is crucial to meet water demand of natural and agricultural vegetation, and to fill up rivers for hydropower generation.
With rising temperatures, snow cover decreases in all elevations and seasons. Figure 2 shows the number of days with a snow cover of more than 10 cm in April. Under recent climate, the mountain ridges are covered with snow for the entire month. Under future scenarios, days with snow cover will decrease considerably.

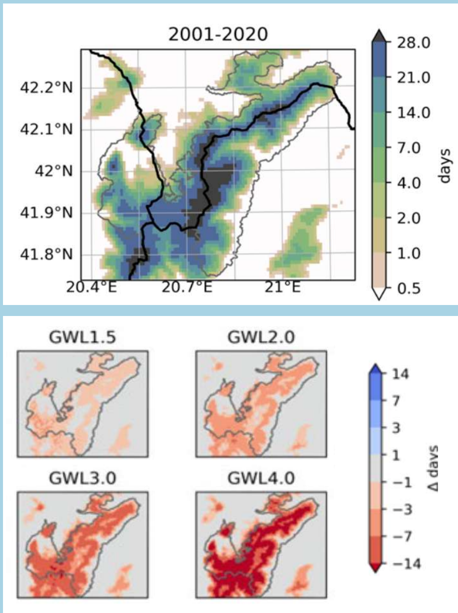


Figure 2: Number of days with a snow cover of more than 10 cm in April.
Top: Recent climate (2001-2020).
Bottom: Changes in the number of days from GWL 1.5 °C up to GWL 4.0 °C.

Shorter duration of snow cover will affect the active season for winter tourism. It also impacts the buffer function of snow and thereby water availability at a critical period in spring, when the growing season starts. Together with reductions in seasonal precipitation in summer, this can lead to extended periods of drought.

| Meteorological droughts

Meteorological droughts are caused by a lack of precipitation in combination with high evaporation. Evaporation increases with rising temperatures, solar radiation and wind speed.
The Standardized Precipitation Evapotranspiration Index (SPEI) takes all these factors into account. Figure 3 shows monthly changes in SPEI of the region for different climate scenarios (GWLs). Negative numbers indicate drier conditions compared to the recent climate. An SPEI value of –1.5 is considered a severe drought. Seasonal droughts in the summer months will become more frequent under all climate scenarios, although the intensity of the drought conditions depends strongly on the intensity of global warming.

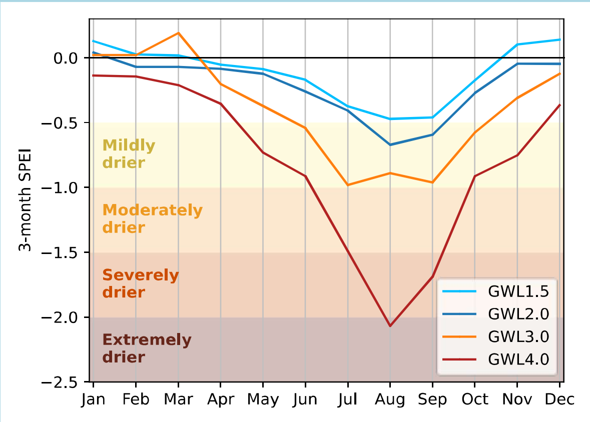


Figure 3: Change of Standardized Precipitation Evapotranspiration Index (SPEI) compared to the recent climate (2001-2020). Negative values represent drought conditions. Coloured lines show the SPEI derived from climate models for the GWLs 1.5 °C, 2 °C, 3 °C and 4 °C.

| Extremes in daily precipitation

Rising temperatures lead to increased drought conditions and more intense heavy precipitation. Both can be true at the same time, even without major changes in average precipitation. The process responsible for increased heavy precipitation is outlined in Figure 4. The atmosphere's moisture-holding capacity increases with temperature, typically at a rate of about 7% per 1 °C. Therefore, with higher temperatures more water is available for precipitation.
This effect is also visible, at least in part, in climate models. Figure 5 shows the change in extreme daily precipitation amounts for the wettest day of the year in the region. The higher the temperature (indicated by the GWL), the more intense the highest daily precipitation in a year.

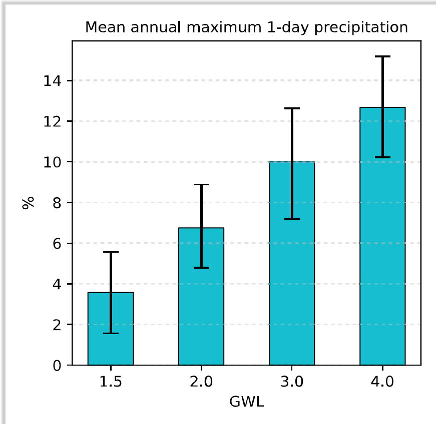


Figure 5: Relative change of precipitation on the wettest day of the year compared to 2001-2020. The error bars show the range within the region.

More heavy daily precipitation increases flood hazards, especially in larger catchments. Also, the high water content in the soil during such events increases the risk of landslides.

| Extremes in short-term precipitation

The effect of rising temperatures on heavy precipitation is even stronger for short-term precipitation events lasting minutes to a few hours. The increase in short-term precipitation extremes can be much stronger than the increase in daily precipitation extremes shown in Figure 5, but climate models do not yet provide robust data on precipitation extremes below the daily timescale.
Given a realistically possible average warming of 4 °C in the Western Balkans, this relation suggests an increase in short-term extreme precipitation intensities by almost a third, meaning a short-term event with 60 mm of precipitation can increase to nearly 80 mm.

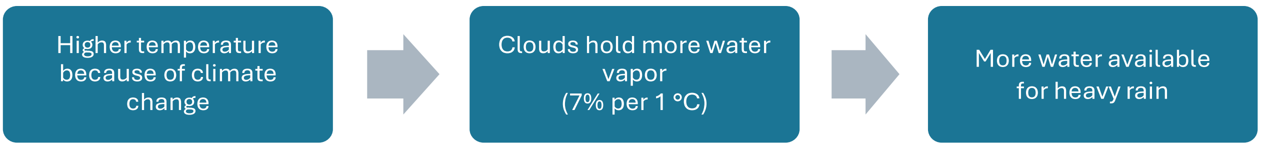


Figure 4: Illustration of the process that links rising temperatures to increased heavy precipitation.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Anela-Stavrevska-Panajotova

Bundesministerium
für Umwelt, Klimaschutz, Naturschutz
und nukleare Sicherheit

UN environment programme

Factsheet #4 |
Key messages

Sharr/Sharri/Korab Koritnik

The elevation of this Transboundary Protected Area (TBPA) ranges from 400 m to 2, 700 m at its highest peaks. The climate is characterized by abundant precipitation at higher elevations, particularly in October and November, with snow covering the peaks, while summers are generally drier. The average temperature development depends strongly on the emissions scenario, meaning that the level of ambition for climate action has direct consequences for the region. Under recent climate, the mountain ridges are covered with snow for the entire month. Under future scenarios, days with snow cover will decrease considerably. For the tourism sector it was noted that with the late arrival of winter, the season for activities such as skiing is shortened, leading to a decrease in tour sales and income. Also, the summer season now begins earlier, which shortens the main tourist period as many visitors avoid traveling during periods of high temperatures. With rising temperatures, droughts and heavy precipitation may increase at the same time, leading to addition flood and landslide risk.

Local observations:

“There is noticeably less snow in winter, and the ski season has become shorter, which directly impacts local communities. Places like Popova Shapka, Brod, and Brezovica depend on winter tourism, from hotels and restaurants to ski centers, so less snow means fewer visitors, reduced income, and fewer jobs for local people.“

These environmental changes have also consequences for biodiversity. It was reported that wild boars are increasingly suffering from heat-related diseases, certain tree species are dying due to lack of rainfall, and flowers are blooming at different times of the year. It was also noted that brown bears enter hibernation later as winters become warmer, while bee colonies are collapsing and honey production has halved.

| Key messages

- **Until the end of the century, average temperatures in the region increase by 1-4 °C in summer and by 1-6 °C in winter compared to 1981 -2010. The actual development depends strongly on human climate action.**
- **In a 4°C warmer world, the region experiences less than half of the current period of snow cover in high elevations. In spring, this leads to less water supply from snowmelt. Communities confirm that snow lasts for a much shorter period than before, and the ski season in areas such as Brod, Brezovica, and Popova Shapka is now significantly shorter, threatening winter tourism and reducing local income.**
- **Droughts will be more frequent all seasons but winter due to less precipitation and higher evaporation. What is now a drought that occurs every 15 years in summer could occur every second year in a 4°C warmer world.**
- **The growing season is extended by up to eight weeks in a 4 degrees warmer world. The shifts in the growing season affects many organisms through the food chain.**
- **Severe wildfire danger increases due to extended dry periods and higher temperatures. Forest fires may reach into higher regions. Migration and land abandonment have also led to the conversion of former farmland into unmanaged forest, further increasing fire risk.**
- **Extreme precipitation events intensify by approx. 7% per 1 °C of warming, increasing the risk of flash floods and landslides. Landslides are also intensified by deforestation have been reported in several administrative units in Kukes, including Zapod, Shishtavec, GrykëÇ aje and others.**
- **Socio-economic risks such as reduced tourism revenue, summer water rationing in Tetovo area, and declining yields, are increasing migration rural vulnerability.**

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology
Authors & Layout: Ajla Dorfer, Belma Nahić, Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Anela-Stavrevska-Panajotova
Photo: © National Park Sharr Mountain (Management Authority)

BOKU Institut für Meteorologie und Klimatologie

Albanian Alps

| Regional Information

Located in Albania, bordering Kosovo* and Montenegro, the transboundary protected area Tara-Drina ranges from 500 m to over 2,500 m in elevation at its highest peaks. It spans approximately 830 km^2, including stretches of the rivers Cem, Lim/Vermosh, Valbona and Gashi. The climate is characterized by abundant precipitation at the peaks, especially in November, with snow at higher elevations, and with a drier period in summer. In those months, valleys are susceptible to droughts.

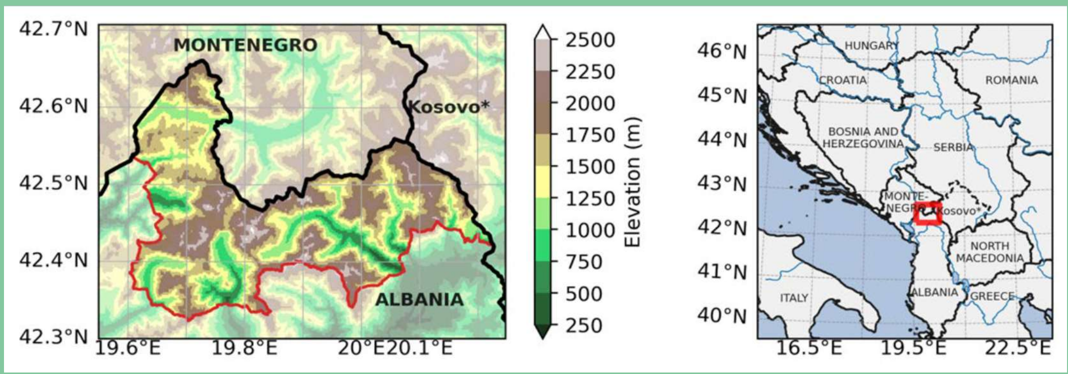


Figure 1:
Left: Borders and topography of the region.
Right: Location of the region (red) within the Western Balkans.

* under UNSCR 1244/99

A climate diagram (also Walter/Lieth diagram) shows the most important climatic properties of a location: Sea level, annual and monthly mean temperatures and precipitation sums. This information indicates whether a location is dry or wet, and whether snow occurs over the seasons. Months with over 100 mm precipitation are marked as especially wet, whereas months where the precipitation curve lies below the temperature curve are dry. Months with mean temperature below 0 °C indicate the occurrence of snow or ice.

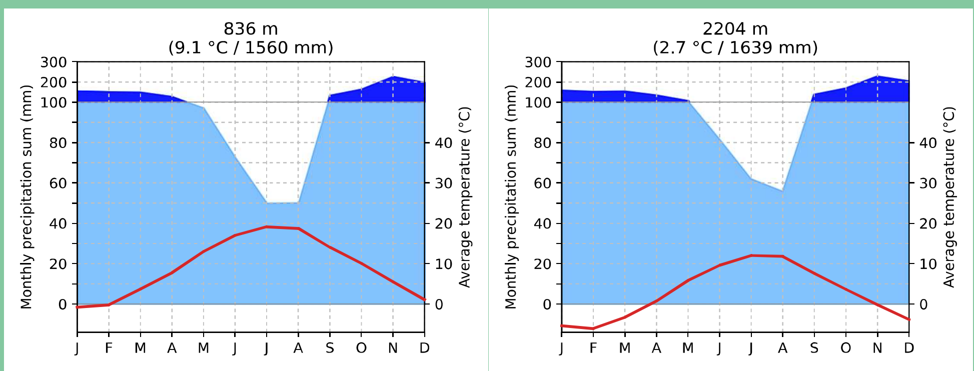


Figure 2: Climate diagrams for the period 1991-2020 of two locations in the region: a valley (left) and a peak (right). The diagrams show the elevation, mean annual temperature and precipitation sum of the location on the top. In the graph, monthly average temperatures (red line, left y-axis) and monthly average precipitation sums (blue area, right y-axis) are plotted.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Mladen Janic | pexels

Albanian Alps

| Observed and future temperature

First and foremost, climate change concerns average yearly or seasonal temperatures. Weather observations show a significant temperature increase in the region over the past 40 years, both in summer and winter. Climate models simulate further development of average temperatures up to 2100. Figure 1 shows that this development strongly depends on the emissions scenario (RCP). With low-end emissions, temperature rise stops about mid-century, while medium and high scenarios show further increasing temperatures. It depends on our ambitions for climate action whether temperatures continue rising at all, rise by 2 °C or by more than 4° C locally until the end of the century, compared to the period 1981-2010.

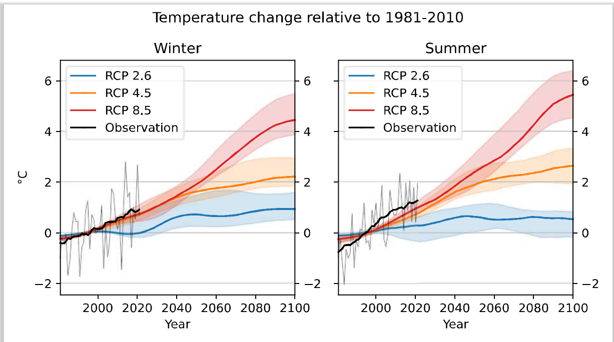


Figure 1: Temperature changes in this region compared to the average of the period 1981–2010.
Left: Winter from December to February.
Right: Summer from June to August.
Black lines represent weather observations: The thin black line shows individual years; the thick black line is smoothed to highlight the trend. Data from climate models is shown in different colours for different emissions scenarios: low (blue), medium (orange) and high (red) emissions. The shaded areas show a range of different climate models.

Rising temperatures have clear indications for the region. In summer, a relatively small temperature increase leads to a sharp rise of hot days and extended heat episodes, leading to heat stress on humans, animals, plants, and impacting water resources. In winter, this could mean the total disappearance of snow on lower elevations, with wide-ranging impacts for water availability in spring. Seasonal warming also means an altered growing season, which impacts the composition of the ecosystem and biodiversity. Missing snow and earlier vegetation could lead to extended periods of drought in spring and summer, thereby increasing wildfire hazards. The following sections describe a few central indicators for these impacts of climate change.

| Very hot days (above 35 °C)

The number of very hot days indicate extended periods of heat, impacting the health of humans and wildlife and water availability due to higher evaporation. With summers warming faster than the other seasons, the frequency of very hot days will increase. Figure 2 shows the average number of days per year for the region. Like with average regional temperatures, the rise in very hot days strongly depends on the intensity of global climate change. This is indicated by the global warming levels (GWLs).

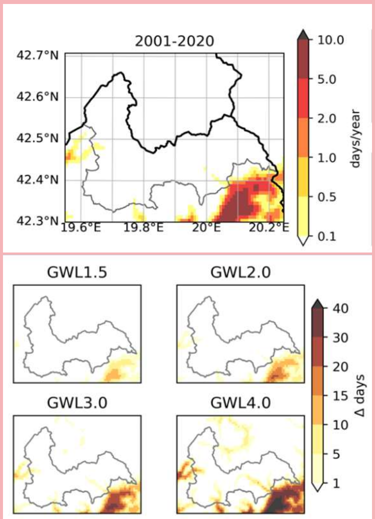


Figure 2: Average number of very hot days per year in the region.
Top: Recent climate (2001-2020).
Bottom: Changes for the GWLs 1.5 °C to 4.0 °C. E.g. light yellow indicates an increase of more than one day per year.

BOKU Institut für Meteorologie und Klimatologie

| Growing season

Increasing temperatures lead to shorter winters and thus allow for a longer growing season. This means that plants can start growing earlier in the year, increasing seasonal water demand for both natural vegetation and agriculture and thereby intensifying pressure on regional water resources. Through the food chain, the shifted availability of nutrition also affects biodiversity.
Figure 3 shows changes in the duration of the growing season in the region, dependent on the intensity of global warming (GWLs).

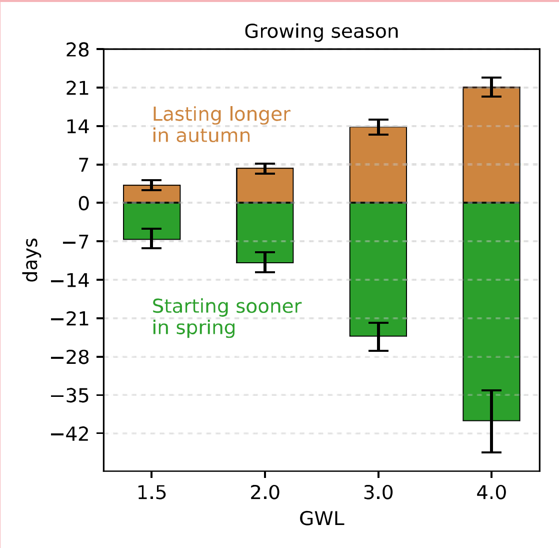


Figure 3: Change of growing season duration in days compared to the recent climate (2001-2020) at four GWLs: 1.5 °C, 2 °C, 3 °C and 4 °C. Brown colours indicate how many days the growing season extends into autumn (positive numbers), green colours show how many days earlier it starts in spring (negative numbers).

The growing season indicator starts on the day of the year when the average temperature first exceeds 5 °C for 5 consecutive days and ends on the day when the temperature is below 5 °C for 5 consecutive days. The bars in the figure indicate both earlier start in spring and later end in autumn. The total increase of the growing season is the sum of both earlier start in spring and later end in autumn. It ranges between 1.5 additional weeks at GWL1.5 and more than 8 additional weeks at GWL4.0.

| Wildfires

Wildfires pose a threat to infrastructure and ecosystems. Vegetation is often severely altered for decades after a wildfire. As both a safety risk and a loss of attraction, this also reduces local tourist activity.
The danger for wildfires increases in hot, dry and windy weather conditions and can be approximated by the Fire Weather Index (FWI). Figure 4 shows the number of days in the region with high FWI, representing high wildfire risk, for the recent climate and the GWLs 1.5 ° C, 2 ° C, 3 °C and 4 °C.

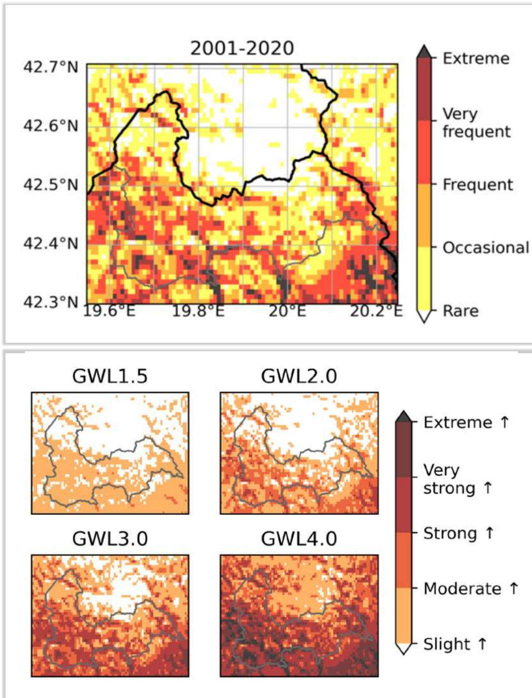


Figure 4: Frequency of days with a high FWI (defined as >38), indicating favourable weather conditions for wildfires.
Top: Recent conditions (2001–2020). 'Rare' indicates fewer than 1 day per year with a high FWI. 'Extreme' refers to more than 30 days per year with a high FWI.
Bottom: Changes in the number of days with a high FWI ranging from slight (less than 1 additional day/year) to extreme (more than 30 additional days/year).

Higher temperatures favour wildfire trigger conditions in all climate scenarios. The increase is affecting the entire region. The FWI shows optimal weather conditions for wildfires but does not consider whether actual fuel (material for ignition) is available. It also does not consider the spread of fires to other areas. Therefore, even areas with low fire danger can experience wildfires when they are carried in from other regions by strong winds or burn uphill to higher elevations.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Mladen Janic | pexels

BOKU Institut für Meteorologie und Klimatologie

Factsheet #3 |

Water availability, Droughts & Floods

Albanian Alps

13 CLIMATE ACTION

15 LIFE ON LAND

| Changes in average precipitation

Whether a region is characterised as wet or dry depends on the average annual and seasonal amount of precipitation (rain and snow) and the corresponding amount of water removal through evaporation or abstraction. The resulting water balance indicates if water resources are abundant or scarce.

Figure 1 shows the change in average precipitation of the region for summer and winter. The general trend is a slight increase of precipitation in winter (left panel). Due to rising temperatures, more precipitation will fall as rain instead of snow, especially in the lowlands.

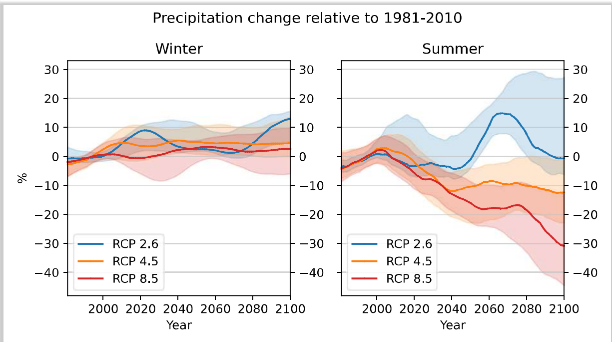


Figure 1: Seasonal precipitation changes in the region. Changes are shown in percent compared to the average of 1981–2010.
Left: Winter (December to February).
Right: Summer (June to August) .
Different emissions scenarios are shown in colours (blue, orange, red), with the shaded area indicating a range of different climate models.

Summer precipitation (right panel) shows a decline, depending more strongly on the emissions scenario. Low emissions result in no definitive change, medium to high emissions could lead to a 10% to 30% decrease in precipitation. Combined with rising temperatures, this poses a major challenge for water availability in the summer months.

| Snow

In terms of seasonal water availability, snow works as a buffer that saves water in the cold months and releases it into the ecosystems when it gets warmer. Snowmelt in spring is crucial to meet water demand of natural and agricultural vegetation, and to fill up rivers for hydropower generation.

With rising temperatures, snow cover decreases in all elevations and seasons. Figure 2 shows the number of days with a snow cover of more than 10 cm in April. Under recent climate, the mountain ridges are covered with snow for the entire month. Under future scenarios, days with snow cover will decrease considerably.

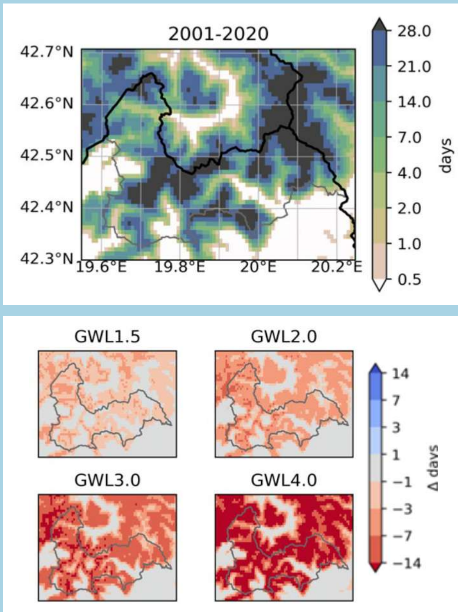


Figure 2: Number of days with a snow cover of more than 10 cm in April.
Top: Recent climate (2001-2020).
Bottom: Changes in the number of days from GWL 1.5 °C up to GWL 4.0 °C.

Shorter duration of snow cover reduces the buffer function of snow and thereby water availability at a critical period in spring, when the growing season starts. Together with reductions in seasonal precipitation in summer, this can lead to extended periods of drought.

| Meteorological droughts

Meteorological droughts are caused by a lack of precipitation in combination with high evaporation. Evaporation increases with rising temperatures, solar radiation and wind speed.
The Standardized Precipitation Evapotranspiration Index (SPEI) takes all these factors into account. Figure 3 shows monthly changes in SPEI of the region for different climate scenarios (GWLs). Negative numbers indicate drier conditions compared to the recent climate. An SPEI value of –1.5 is considered a severe drought. Seasonal droughts in the summer months will become more frequent under all climate scenarios, although the intensity of the drought conditions depends strongly on the intensity of global warming.

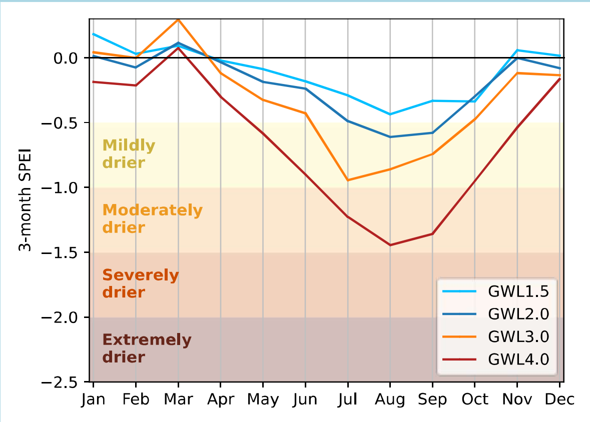


Figure 3: Change of Standardized Precipitation Evapotranspiration Index (SPEI) compared to the recent climate (2001-2020). Negative values represent drought conditions. Coloured lines show the SPEI derived from climate models for the GWLs 1.5 °C, 2 °C, 3 °C and 4 °C.

| Extremes in daily precipitation

Rising temperatures lead to increased drought conditions and more intense heavy precipitation. Both can be true at the same time, even without major changes in average precipitation. The process responsible for increased heavy precipitation is outlined in Figure 4. The atmosphere's moisture-holding capacity increases with temperature, typically at a rate of about 7% per 1 °C. Therefore, with higher temperatures more water is available for precipitation.
This effect is also visible, at least in part, in climate models. Figure 5 shows the change in extreme daily precipitation amounts for the wettest day of the year in the region. The higher the temperature (indicated by the GWL), the more intense the highest daily precipitation in a year.

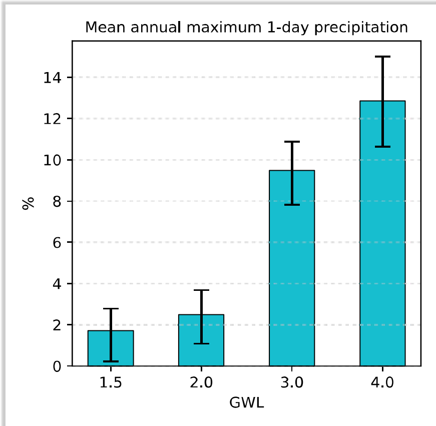


Figure 5: Relative change of precipitation on the wettest day of the year compared to 2001-2020. The error bars show the range within the region.

More heavy daily precipitation increases flood hazards, especially in larger catchments. Also, the high water content in the soil during such events increases the risk of landslides.

| Extremes in short-term precipitation

The effect of rising temperatures on heavy precipitation is even stronger for short-term precipitation events lasting minutes to a few hours. The increase in short-term precipitation extremes can be much stronger than the increase in daily precipitation extremes shown in Figure 5, but climate models do not yet provide robust data on precipitation extremes below the daily timescale.
Given a realistically possible average warming of 4 °C in the Western Balkans, this relation suggests an increase in short-term extreme precipitation intensities by almost a third, meaning a short-term event with 60 mm of precipitation can increase to nearly 80 mm.

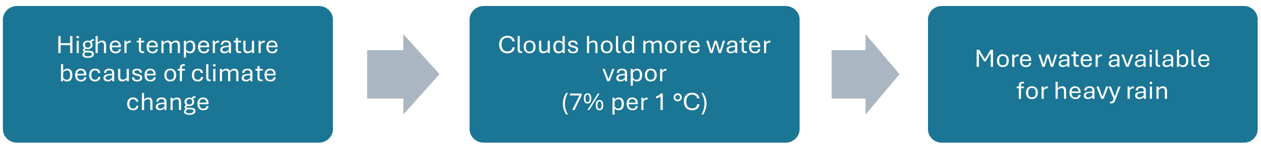


Figure 4: Illustration of the process that links rising temperatures to increased heavy precipitation.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Mladen Janic | pexels

BOKU Institut für Meteorologie und Klimatologie

Albanian Alps

The climate of the Albanian Alps is characterized by abundant precipitation at the peaks, especially in November, with snow at higher elevations, and with a drier period in summer. In those months, valleys are susceptible to droughts. Weather observations show a significant temperature increase in the region over the past 40 years, both in summer and winter. It depends on the ambitions for climate action whether temperatures continue rising at all, rise by 2 °C or by more than 4° C locally until the end of the century, compared to the period 1981-2010. Changes in average temperature can exacerbate existing dry spells in

Local observations:

“There is a drastic decline in chestnut harvests, from about 250 kg per family just a few years ago to only around 50 kg today, and almost no bilberry yield, driven mainly by frost during flowering and sometimes rapid temperature increases.“

summer, leading to extended heat and drought periods with stress on human, animal and plant health as well as water resources. The danger of forest fires increases, even in higher altitudes because of spread through wind or uphill burning. With rising temperatures, droughts and heavy precipitation may increase at the same time, leading to addition flood and landslide risk.
These environmental changes have severe consequences for biodiversity. Several endangered species depend on the water cycle and vegetation in the region. They are mainly affected by temporal shifts in the growing season and upwards spatial shifts of the habitats due to rising temperatures. New pests and diseases are appearing at higher elevations. For instance, vines that once required no fertilization now face pest pressures, and plum viruses and apple and chestnut diseases have been observed since 2018.

| Key messages

- **Until the end of the century, average temperatures in the region increase by 1-4 °C in summer and by 1-6 °C in winter compared to 1981-2010. The actual development depends strongly on human climate action.**
- **In a 4°C warmer world, the region experiences less than half of the current period of snow cover in high elevations. In spring, this leads to less water supply from snowmelt. Impact on the water resources is already evident in villages such as Gashi.**
- **Droughts will be more frequent all seasons but winter due to less precipitation and higher evaporation. What is now a drought that occurs every 15 years in summer could occur every second year in a 4 °C warmer world.**
- **The growing season is extended by up to eight weeks in a 4°C warmer world. This shift is already reflected in longer vegetation periods, blurred seasonal transitions, and altered flowering patterns that reduce yields of products like chestnuts and bilberries.**
- **Severe wildfire danger increases due to extended dry periods and higher temperatures. Forest fires may reach into higher regions.**
- **Extreme precipitation events intensify by approx. 7% per 1 °C of warming, increasing the risk of flash floods and landslides.**
- **Socio-economic pressure is seen through rapid tourism expansion (over tenfold growth), together with unregulated construction and unmanaged waste.**

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology
Authors & Layout: Ajla Dorfer, Belma Nahić, Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Mladen Janic | pexels
Photo: © National Park Albanian Alps (Management Authority)

BOKU Institut für Meteorologie und Klimatologie

Factsheet #1 |
Basic Information

Prokletije/Bjeshkët e Nemuna

| Regional Information

Located in the southwestern Balkans at the borders of Montenegro, Albania and Kosovo*, the transboundary protected area Prokletije ranges from 500 m to over 2,500 m in elevation at its highest peaks. It spans approximately 1,600 km^2, including stretches of the rivers Cem and Vermosh/Lim. The climate is characterized by abundant precipitation, especially in winter, with snow at higher elevations, and with a drier period in summer. In those months, valleys are susceptible to droughts.

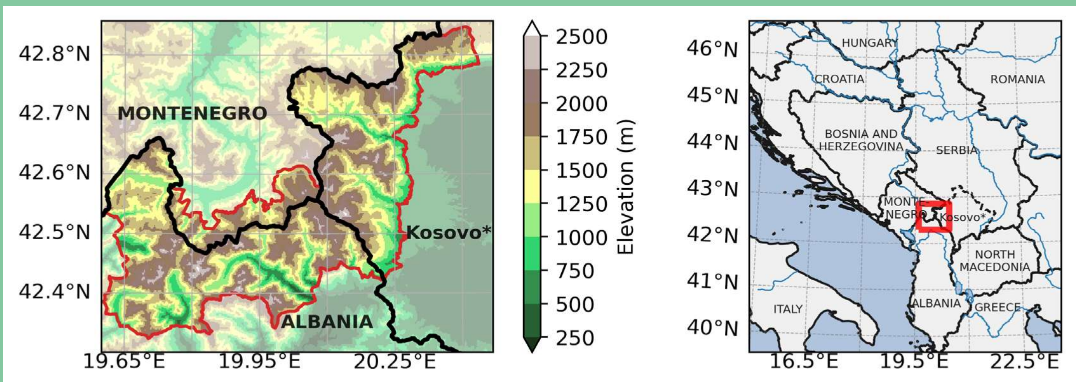


Figure 1:
Left: Borders and topography of the region.
Right: Location of the region (red) within the Western Balkans.

* under UNSCR 1244/99

A climate diagram (also Walter/Lieth diagram) shows the most important climatic properties of a location: Sea level, annual and monthly mean temperatures and precipitation sums. This information indicates whether a location is dry or wet, and whether snow occurs over the seasons. Months with over 100 mm precipitation are marked as especially wet, whereas months where the precipitation curve lies below the temperature curve are dry. Months with mean temperature below 0 °C indicate the occurrence of snow or ice.

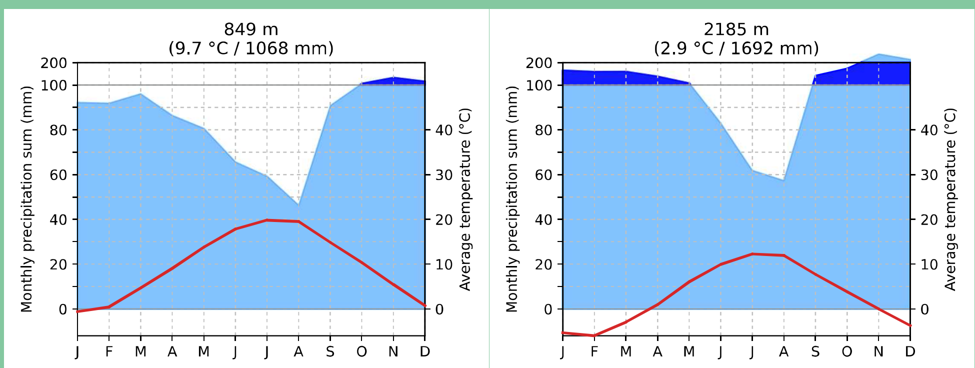


Figure 2: Climate diagrams for the period 1991-2020 of two locations in the region: a valley (left) and a peak (right). The diagrams show the elevation, mean annual temperature and precipitation sum of the location on the top. In the graph, monthly average temperatures (red line, left y-axis) and monthly average precipitation sums (blue area, right y-axis) are plotted.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Ermal Hasimja, 2014

BOKU Institut für Meteorologie und Klimatologie

Bundesministerium
für Umwelt, Klimaschutz, Naturschutz
und nukleare Sicherheit

UN environment programme

Factsheet #2 |
Temperature & Heat

Prokletije/Bjeshkët e Nemuna

| Observed and future temperature

First and foremost, climate change concerns average yearly or seasonal temperatures. Weather observations show a significant temperature increase in the region over the past 40 years, both in summer and winter. Climate models simulate further development of average temperatures up to 2100. Figure 1 shows that this development strongly depends on the emissions scenario (RCP). With low-end emissions, temperature rise stops about mid-century, while medium and high scenarios show further increasing temperatures. It depends on our ambitions for climate action whether temperatures continue rising at all, rise by 2 °C or by more than 4° C locally until the end of the century, compared to the period 1981-2010.

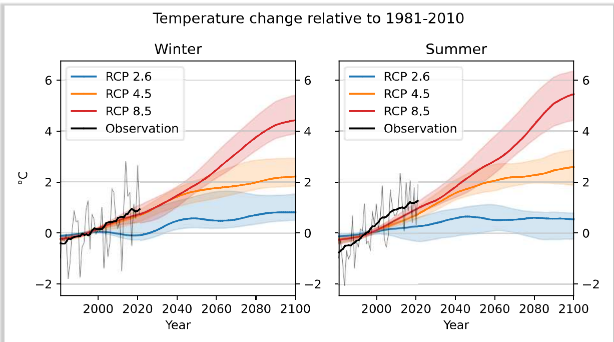


Figure 1: Temperature changes in the region compared to the average of the period 1981–2010.
Left: Winter from December to February.
Right: Summer from June to August.
Black lines represent weather observations: The thin black line shows individual years; the thick black line is smoothed to highlight the trend. Data from climate models is shown in different colours for different emissions scenarios: low (blue), medium (orange) and high (red) emissions. The shaded areas show a range of different climate models.

Rising temperatures have clear indications for the region. In summer, a relatively small temperature increase leads to a sharp rise of hot days and extended heat episodes, leading to heat stress on humans, animals, plants, and impacting water resources. In winter, this could mean the total disappearance of snow on lower elevations, with wide-ranging impacts for water availability in spring. Seasonal warming also means an altered growing season, which impacts the composition of the ecosystem and biodiversity. Missing snow and earlier vegetation could lead to extended periods of drought in spring and summer, thereby increasing wildfire hazards. The following sections describe a few central indicators for these impacts of climate change.

| Very hot days (above 35 °C)

The number of very hot days indicate extended periods of heat, impacting the health of humans and wildlife and water availability due to higher evaporation. With summers warming faster than the other seasons, the frequency of very hot days will increase. Figure 2 shows the average number of days per year for the region. Like with average regional temperatures, the rise in very hot days strongly depends on the intensity of global climate change. This is indicated by the global warming levels (GWLs).

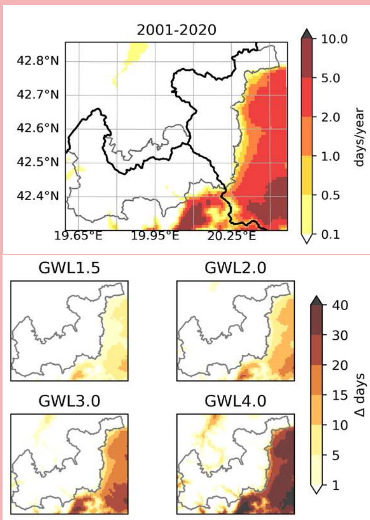


Figure 2: Average number of very hot days per year in the region.
Top: Recent climate (2001-2020).
Bottom: Changes for the GWLs 1.5 °C to 4.0 °C. E.g. light yellow indicates an increase of more than one day per year.

BOKU
Institut für Meteorologie und Klimatologie

| Growing season

Increasing temperatures lead to shorter winters and thus allow for a longer growing season. This means that plants can start growing earlier in the year, increasing seasonal water demand for both natural vegetation and agriculture and thereby intensifying pressure on regional water resources. Through the food chain, the shifted availability of nutrition also affects biodiversity.
Figure 3 shows changes in the duration of the growing season in the region, dependent on the intensity of global warming (GWLs).

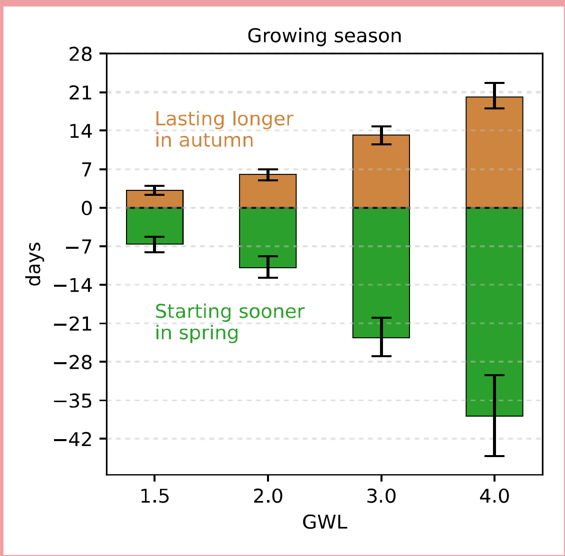


Figure 3: Change of growing season duration in days compared to the recent climate (2001-2020) at four GWLs: 1.5 °C, 2 °C, 3 °C and 4 °C. Brown colours indicate how many days the growing season extends into autumn (positive numbers), green colours show how many days earlier it starts in spring (negative numbers).

The growing season indicator starts on the day of the year when the average temperature first exceeds 5 °C for 5 consecutive days and ends on the day when the temperature is below 5 °C for 5 consecutive days. The bars in the figure indicate both earlier start in spring and later end in autumn. The total increase of the growing season is the sum of both earlier start in spring and later end in autumn. It ranges between 1.5 additional weeks at GWL1.5 and more than 8 additional weeks at GWL4.0.

| Wildfires

Wildfires pose a threat to infrastructure and ecosystems. Vegetation is often severely altered for decades after a wildfire. As both a safety risk and a loss of attraction, this also reduces local tourist activity.
The danger for wildfires increases in hot, dry and windy weather conditions and can be approximated by the Fire Weather Index (FWI). Figure 4 shows the number of days in the region with high FWI, representing high wildfire risk, for the recent climate and the GWLs 1.5 ° C, 2 ° C, 3 °C and 4 °C.

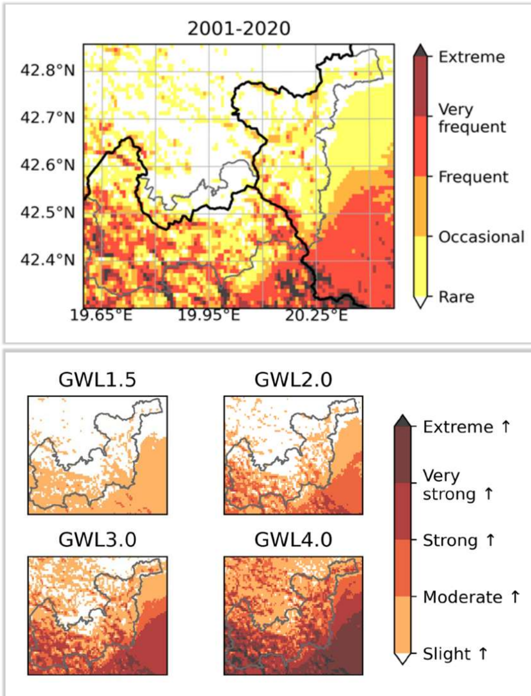


Figure 4: Frequency of days with a high FWI (defined as >38), indicating favourable weather conditions for wildfires.
Top: Recent conditions (2001–2020). 'Rare' indicates fewer than 1 day per year with a high FWI. 'Extreme' refers to more than 30 days per year with a high FWI.
Bottom: Changes in the number of days with a high FWI ranging from slight (less than 1 additional day/year) to extreme (more than 30 additional days/year).

Higher temperatures favour wildfire trigger conditions in all climate scenarios. The increase is most pronounced in the southern region. The FWI shows optimal weather conditions for wildfires but does not consider whether actual fuel (material for ignition) is available. It also does not consider the spread of fires to other areas. Therefore, even areas with low fire danger can experience wildfires when they are carried in from other regions by strong winds or burn uphill to higher elevations.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Ermal Hasimja, 2014

BOKU Institut für Meteorologie und Klimatologie

Bundesministerium
für Umwelt, Klimaschutz, Naturschutz
und nukleare Sicherheit

UN environment programme

Factsheet #3 |

Water availability, Droughts & Floods

Prokletije/Bjeshkët e Nemuna

| Changes in average precipitation

Whether a region is characterised as wet or dry depends on the average annual and seasonal amount of precipitation (rain and snow) and the corresponding amount of water removal through evaporation or abstraction. The resulting water balance indicates if water resources are abundant or scarce.
Figure 1 shows the change in average precipitation of the region for summer and winter. The general trend is a slight increase of precipitation in winter (left panel). Due to rising temperatures, more precipitation will fall as rain instead of snow, especially in the lowlands.

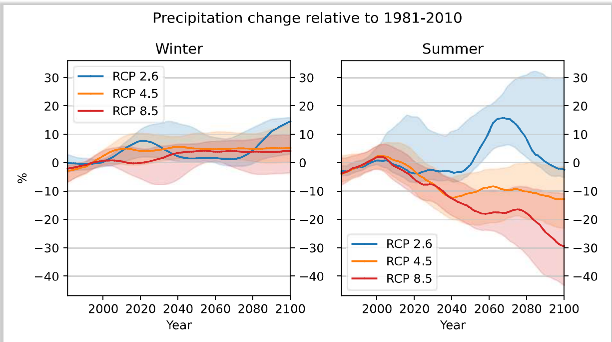


Figure 1: Seasonal precipitation changes in the region. Changes are shown in percent compared to the average of 1981–2010.
Left: Winter (December to February).
Right: Summer (June to August) .
Different emissions scenarios are shown in colours (blue, orange, red), with the shaded area indicating a range of different climate models.

Summer precipitation (right panel) shows a decline, depending more strongly on the emissions scenario. Low emissions result in no definitive change, medium to high emissions could lead to a 10% to 30% decrease in precipitation. Combined with rising temperatures, this poses a major challenge for water availability in the summer months.

| Snow

In terms of seasonal water availability, snow works as a buffer that saves water in the cold months and releases it into the ecosystems when it gets warmer. Snowmelt in spring is crucial to meet water demand of natural and agricultural vegetation, and to fill up rivers for hydropower generation.
With rising temperatures, snow cover decreases in all elevations and seasons. Figure 2 shows the number of days with a snow cover of more than 10 cm in April. Under recent climate, the mountain ridges are covered with snow for the entire month. Under future scenarios, days with snow cover will decrease considerably.

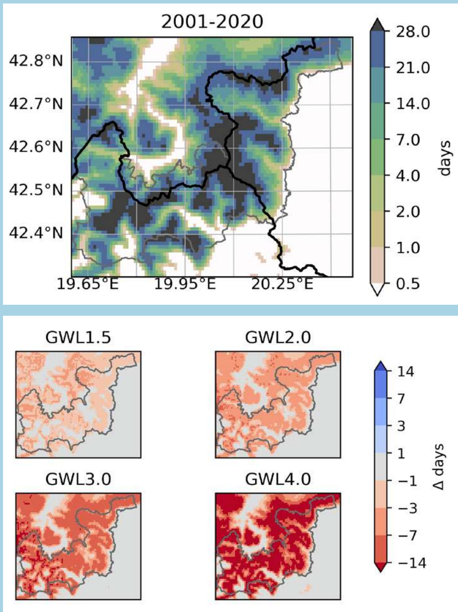


Figure 2: Number of days with a snow cover of more than 10 cm in April.
Top: Recent climate (2001-2020).
Bottom: Changes in the number of days from GWL 1.5 °C up to GWL 4.0 °C.

Shorter duration of snow cover reduces the buffer function of snow and thereby water availability at a critical period in spring, when the growing season starts. Together with reductions in seasonal precipitation in summer, this can lead to extended periods of drought.

BOKU Institut für Meteorologie und Klimatologie

| Meteorological droughts

Meteorological droughts are caused by a lack of precipitation in combination with high evaporation. Evaporation increases with rising temperatures, solar radiation and wind speed.
The Standardized Precipitation Evapotranspiration Index (SPEI) takes all these factors into account. Figure 3 shows monthly changes in SPEI of the region for different climate scenarios (GWLs). Negative numbers indicate drier conditions compared to the recent climate. An SPEI value of –1.5 is considered a severe drought. Seasonal droughts in the summer months will become more frequent under all climate scenarios, although the intensity of the drought conditions depends strongly on the intensity of global warming.

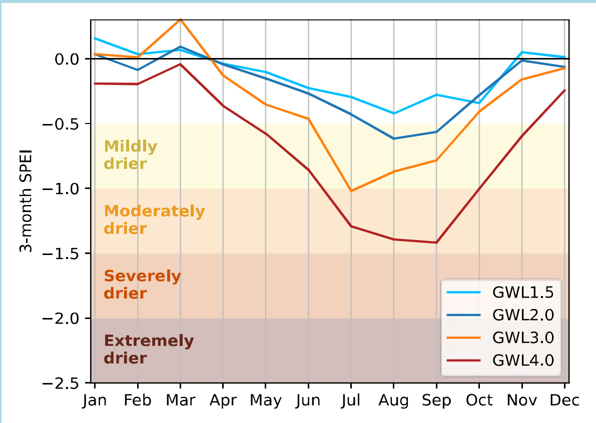


Figure 3: Change of Standardized Precipitation Evapotranspiration Index (SPEI) compared to the recent climate (2001-2020). Negative values represent drought conditions. Coloured lines show the SPEI derived from climate models for the GWLs 1.5 °C, 2 °C, 3 °C and 4 °C.

| Extremes in daily precipitation

Rising temperatures lead to increased drought conditions and more intense heavy precipitation. Both can be true at the same time, even without major changes in average precipitation. The process responsible for increased heavy precipitation is outlined in Figure 4. The atmosphere's moisture-holding capacity increases with temperature, typically at a rate of about 7% per 1 °C. Therefore, with higher temperatures more water is available for precipitation.
This effect is also visible, at least in part, in climate models. Figure 5 shows the change in extreme daily precipitation amounts for the wettest day of the year in the region. The higher the temperature (indicated by the GWL), the more intense the highest daily precipitation in a year.

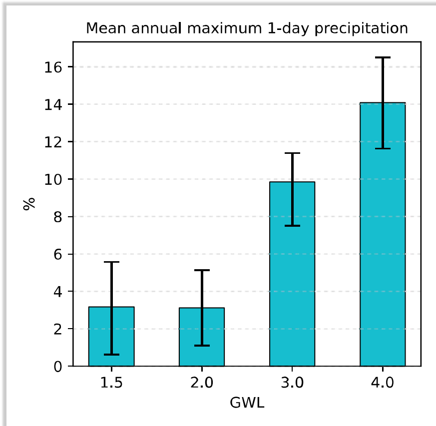


Figure 5: Relative change of precipitation on the wettest day of the year compared to 2001-2020. The error bars show the range within the region.

More heavy daily precipitation increases flood hazards, especially in larger catchments. Also, the high water content in the soil during such events increases the risk of landslides.

| Extremes in short-term precipitation

The effect of rising temperatures on heavy precipitation is even stronger for short-term precipitation events lasting minutes to a few hours. The increase in short-term precipitation extremes can be much stronger than the increase in daily precipitation extremes shown in Figure 5, but climate models do not yet provide robust data on precipitation extremes below the daily timescale.
Given a realistically possible average warming of 4 °C in the Western Balkans, this relation suggests an increase in short-term extreme precipitation intensities by almost a third, meaning a short-term event with 60 mm of precipitation can increase to nearly 80 mm.

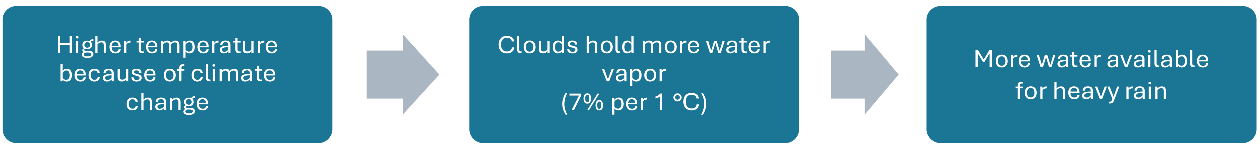


Figure 4: Illustration of the process that links rising temperatures to increased heavy precipitation.

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology

Authors & Layout: Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Ermal Hasimja, 2014

BOKU Institut für Meteorologie und Klimatologie

Prokletije/Bjeshkët e Nemuna

The climate of this Transboundary Protected Area (TBPA) is characterized by abundant precipitation, especially in winter, and by a consistent snow cover from November until April in elevations above 2. 000 m. Weather observations show a significant temperature increase in the region over the past 40 years, both in summer and winter. It depends on the ambitions for climate action whether temperatures continue rising at all, rise by 2 °C or by more than 4° C locally until the end of the century, compared to the period 1981-2010. Small changes in average temperature leverage large negative impacts. They can exacerbate existing dry spells in summer, leading to extended heat and drought periods with stress on human, animal and plant health as well as water resources. Invasive species such as bark beetle, prolonged droughts and the lack of timely sanitation interventions has resulted in widespread tree drying in some forest areas, representing a significant ecological and management challenge. The danger of forest fires increases, even in higher altitudes because of spread through wind or uphill burning. With rising temperatures, droughts and heavy precipitation may increase at the same time, leading to addition flood and landslide risk.

These environmental changes have severe consequences for biodiversity. Several endangered species depend on the water cycle and vegetation in the region. They are mainly affected by temporal shifts in the growing season and upwards spatial shifts of the habitats due to rising temperatures.

Local observations:

"Winters are milder with little snow, while summers are hotter, drier, and marked by intense but brief rainfall. Extended summer dry spells have degraded pastures and lowered crop productivity, while several once- reliable water sources now show reduced flow or dry up completely during the summer. Local communities are increasingly voicing their concerns about how these shifts threaten traditional livelihoods and the region's ecosystems."

| Key messages

- **Until the end of the century, average temperatures in the region increase by 1-4 °C in summer and by 1-6 °C in winter compared to 1981 -2010. The actual development depends strongly on human climate ambitions.**
- **In a 4°C warmer world, the region experiences less than half of the current period of snow cover in high elevations. In spring, this leads to less water supply from snowmelt.**
- **Droughts will be more frequent all seasons but winter due to less precipitation and higher evaporation. What is now a drought that occurs every 15 years in summer could occur every second year in a 4 degrees warmer world. Extended dry spells in summer have already been observed, degrading pastures and lowering crop yields.**
- **The growing season is extended by up to eight weeks in a 4°C warmer world. The shifts in the growing season affects many organisms through the food chain. Chestnut production in Deçan has dropped significantly, and beekeepers report reduced honey yields due to less flowering and limited forage for bees.**
- **Severe wildfire danger increases due to extended dry periods and higher temperatures. Forest fires may reach into higher regions.**
- **Extreme precipitation events intensify by approx. 7% per 1 °C of warming, increasing the risk of flash floods and landslides.**
- **The socio-economic risks already observed in the area include increasing forest fires with associated habitat loss, shifting tourism seasons and income instability.**

Imprint
BOKU University, 2025
Institute of Meteorology & Climatology
Authors & Layout: Ajla Dorfer, Belma Nahić, Fabian Lehner, Mimi Amaichigh, Benedikt Becsi, Herbert Formayer
Photo (Header): © Ermal Hasimja, 2014
Photo: © National Park Prokletije (Management Authority)

BOKU Institut für Meteorologie und Klimatologie

When mountain ecosystems fail, the systems that depend on them — water, forests, and livelihoods — fail as well.

© Sonja Gebert