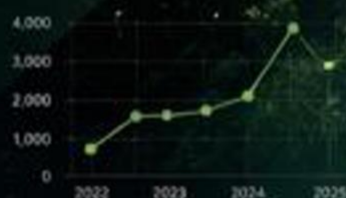


FOREST CANOPY COVER LOSS AND FIRE-INDUCED DEGRADATION IN KOSOVO

A Satellite-Based Assessment
(2022-2025)



SATELLITE EVIDENCE
EFFIS • GEE
EFFIS • GEE

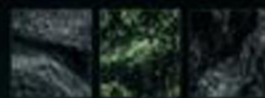


FOREST LOSS [ha]



FIRE EVENTS
(2022-2025)

CHANGE DETECTION



PRISHTINA, 2026

www.sikosova.org

ABSTRACT

This report presents a satellite-based assessment of forest change and fire impacts in Kosovo for the period 2022–2025. Using Global Forest Change v1.12, Copernicus Tree Cover Density (10 m), and data from the European Forest Fire Information System (EFFIS), the analysis provides a standardized, inter-annually comparable evaluation of forest canopy loss, burned areas, and fire-induced forest degradation.

Results indicate that 35,259.65 hectares were affected by fires during the analysed period, of which approximately 17,176 hectares correspond to areas with established tree canopy cover prior to fire events. The years 2024 and 2025 account for more than 84% of the total burned area, highlighting a marked increase in fire intensity and spatial extent in the most recent years. Spatial analysis reveals uneven regional distribution of impacts, with the Prishtina and Mitrovica regions most affected.

The findings confirm that forest canopy loss and fire-related degradation in Kosovo are shaped by a combination of climatic variability, increasing anthropogenic pressure, and institutional capacity constraints. By integrating multi-temporal satellite monitoring with visual validation, the report establishes a robust evidence base for policy development, forest governance reform, and alignment with the Green Agenda for the Western Balkans, the EU Green Deal, and global biodiversity and climate commitments.

EXECUTIVE SUMMARY

This report presents a comprehensive, satellite-based assessment of forest canopy cover loss and fire-induced forest degradation in the Republic of Kosovo for the period 2022–2025.

The analysis is based on harmonised international datasets, including Global Forest Change (GFC) v1.12 (Hansen et al., 2013; Hansen et al., 2024), Copernicus Tree Cover Density (10 m) (Copernicus Land Monitoring Service, 2024), and the European Forest Fire Information System (EFFIS, 2025), combined with multi-temporal visual verification. Together, these provide a robust and inter-annually comparable evidence base for forest monitoring and policy development.

Forest canopy cover loss is assessed for the period 2022–2024, while fire-related impacts extend to 2025 based on European Forest Fire Information System (EFFIS)¹ data availability.

The findings reveal a significant and accelerating pressure on Kosovo’s forest ecosystems. During the analysed period, a total of 35,259 hectares were affected by fire, of which approximately 17,176 hectares correspond to areas with established forest canopy cover prior to fire events. This indicates that nearly half of all burned areas directly impacted forest ecosystems, with substantial implications for biodiversity, carbon sequestration, and ecosystem resilience.

A pronounced escalation of fire activity is observed in the most recent years. 2024 and 2025 account for more than 84% of total burned area, with 2025 representing the most severe year within the analysed period. This pattern reflects the convergence of climatic stressors—particularly prolonged drought and elevated temperatures—with increasing anthropogenic pressures and limitations in early detection and response capacities. The findings indicate systemic vulnerability rather than isolated or episodic events, consistent with broader climate risk trends identified in European and global assessments (IPCC, 2022).

Spatial analysis further demonstrates strong regional concentration of impacts, with the Prishtina and Mitrovica regions accounting for more than half of total burned areas. These patterns highlight the influence of landscape configuration, land-use intensity, accessibility, and climatic exposure, underscoring the need for territorially differentiated risk management and intervention strategies.

In parallel, the analysis identifies 3,976 hectares of tree canopy cover loss for the period 2022–2024, driven by a combination of logging (both legal and illegal), land-use conversion, infrastructure development, agricultural expansion, settlement growth, and fire-related impacts. These drivers are interconnected and mutually reinforcing, contributing to cumulative forest degradation and increased susceptibility to climate-related risks.

¹ European Commission (Copernicus Emergency Management Service) (2025)
European Forest Fire Information System (EFFIS). Available at: <https://effis.emergency.copernicus.eu/>

The methodology applied in this report demonstrates that satellite-based monitoring systems can provide reliable, transparent, and policy-relevant evidence to support forest governance. The integration of GFC, Copernicus, and EFFIS datasets is consistent with Monitoring, Reporting and Verification (MRV) approaches used within the European Union environmental frameworks and aligns with emerging forest monitoring and reporting systems under the EU Forest Strategy for 2030 and the EU LULUCF Regulation².

The findings are directly relevant to Kosovo's alignment with key regional frameworks, including the Green Agenda for the Western Balkans, and global commitments under the Paris Agreement and the Kunming–Montreal Global Biodiversity Framework (CBD, 2022).

Overall, the report highlights the urgent need to transition from reactive forest management toward a systematic, data-driven, and risk-based governance approach. Institutionalising satellite monitoring, strengthening fire prevention systems, and prioritising restoration in high-risk areas will be critical to enhancing forest resilience and supporting Kosovo's climate and biodiversity objectives.

² European Parliament and Council (2018, amended 2023) Regulation (EU) 2018/841 on the inclusion of greenhouse gas emissions and removals from land use, land-use change and forestry (LULUCF) in the 2030 climate and energy framework. Official Journal of the European Union.

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LIST OF ABBREVIATIONS

Abbreviation	Full Term
CART	Classification and Regression Trees
CLMS	Copernicus Land Monitoring Service
CO ₂	Carbon dioxide
EFFIS	European Forest Fire Information System
ETM+	Enhanced Thematic Mapper Plus (Landsat 7 sensor)
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resources Assessment (FAO)
GEE	Google Earth Engine
GFC	Global Forest Change (Hansen et al. dataset)
GFW	Global Forest Watch
GWIS	Global Wildfire Information System
HRL	High Resolution Layer (Copernicus)
IPCC	Intergovernmental Panel on Climate Change
NFI	National Forest Inventory
NASA	National Aeronautics and Space Administration
SDGs	Sustainable Development Goals
TCD	Tree Cover Density
TM	Thematic Mapper (Landsat 5 sensor)
UNEP	United Nations Environment Programme
VIIRS	Visible Infrared Imaging Radiometer Suite
OLI	Operational Land Imager (Landsat 8 sensor)
VCC	Vegetation Continuous Cover

INTRODUCTION

Forests represent one of the most strategic natural assets at global, European, and national levels. They play a critical role in climate regulation, biodiversity conservation, carbon sequestration, soil stabilisation, water regulation, and the provision of livelihoods for more than 1.6 billion people worldwide.

Despite their importance, global forest ecosystems continue to face significant pressure. According to the Food and Agriculture Organization of the United Nations (FAO), approximately 10 million hectares of forest are lost annually, while around 420 million hectares have been converted to other land uses since 1990 (FAO, 2020). These trends have positioned forest governance at the centre of global environmental policy and sustainable development agendas.

Forests are equally central to international climate commitments. The Intergovernmental Panel on Climate Change (IPCC)³ identifies forest ecosystems as one of the most cost-effective natural climate solutions due to their capacity to absorb and store significant amounts of carbon dioxide (CO₂) (IPCC, 2021). Conversely, forest loss and degradation contribute to greenhouse gas emissions, weaken ecosystem resilience, and intensify climate-related risks, including droughts, extreme heat events, wildfires, and land degradation (IPCC, 2022). The protection and restoration of forests are therefore essential not only for mitigation, but also for climate adaptation and long-term ecological stability.

Within the European context, forests are a cornerstone of the European Union's transition towards climate neutrality under the European Green Deal⁴. Key policy frameworks—including the EU Forest Strategy for 2030⁵, the EU Biodiversity Strategy, and the Nature Restoration Law—establish clear objectives to halt forest degradation, restore ecosystems, and strengthen monitoring systems based on harmonised and scientifically robust methodologies. These frameworks are closely linked to EU Monitoring, Reporting and Verification (MRV) requirements, including the LULUCF Regulation and biodiversity targets under the Kunming–Montreal Global Biodiversity Framework (European Commission, 2021; CBD, 2022).

For Western Balkan countries, including Kosovo, forest governance is not only an environmental priority but also a structural component of EU integration under Chapter 27 (Environment and Climate Change). The Green Agenda for the Western Balkans sets out a comprehensive regional framework for aligning environmental policies with EU standards. Its Biodiversity Pillar emphasises the protection and restoration of ecosystems, the expansion

³ The Intergovernmental Panel on Climate Change (IPCC) provides globally recognised scientific assessments on climate change, including evidence on increasing temperatures, drought patterns, and wildfire risk, which are directly relevant to forest degradation dynamics analysed in this report.

⁴ The European Green Deal provides the EU's overarching policy direction for climate neutrality and environmental sustainability, including forest protection, biodiversity restoration, and climate adaptation, which are directly relevant to forest governance and monitoring approaches outlined in this report.

⁵ The EU Forest Strategy for 2030 sets out the European Union's approach to sustainable forest management, forest protection, and restoration, with a focus on enhancing biodiversity, climate resilience, and ecosystem services.

of protected areas, and the development of integrated, data-driven monitoring systems for biodiversity and forest resources (European Commission, 2020).

Transparent, standardised, and inter-annually comparable forest data are therefore essential for policy harmonisation, institutional strengthening, and accession progress.

Kosovo faces increasing pressure on its forest ecosystems due to climate change, land-use conversion, fires, economic exploitation, and governance constraints. These pressures coincide with the country's strategic commitment to align national environmental legislation with EU standards and to implement key frameworks such as the including the Forestry Development Strategy (2023–2032) and national climate change and adaptation policy frameworks. However, achieving these objectives requires reliable, spatially explicit, and scientifically validated evidence to support policy design, enforcement mechanisms, and targeted interventions.

The rapid evolution of Earth observation technologies has significantly strengthened the capacity for such evidence-based governance. Over the past decade, institutions such as FAO, UNEP, NASA, and the European Space Agency (ESA) have developed advanced satellite systems enabling continuous monitoring of forest dynamics. In particular, datasets such as Global Forest Change (GFC), Copernicus Tree Cover Density (TCD), and the European Forest Fire Information System (EFFIS) provide high-resolution, standardised, and policy-relevant data compatible with EU-level methodologies (Hansen et al., 2013; Copernicus Land Monitoring Service, 2024; EFFIS, 2025).

These tools enable early detection of tree canopy cover loss, inter-annual trend analysis, and spatial quantification of burned areas, while also contributing to increased transparency and accountability in environmental governance (Global Forest Watch, 2024). Their integration into national monitoring systems represents a critical step towards strengthening institutional capacity and aligning with European environmental reporting standards.

Sustainability Leadership Kosova has applied these internationally recognised methodologies to the Kosovo context, and this report contributes to strengthening national forest governance, enhancing transparency, and supporting alignment with European environmental frameworks. It provides a scientifically grounded assessment designed to inform decision-making, guide targeted interventions, and support Kosovo's transition towards a more resilient, data-driven, and integrated approach to forest and climate governance.

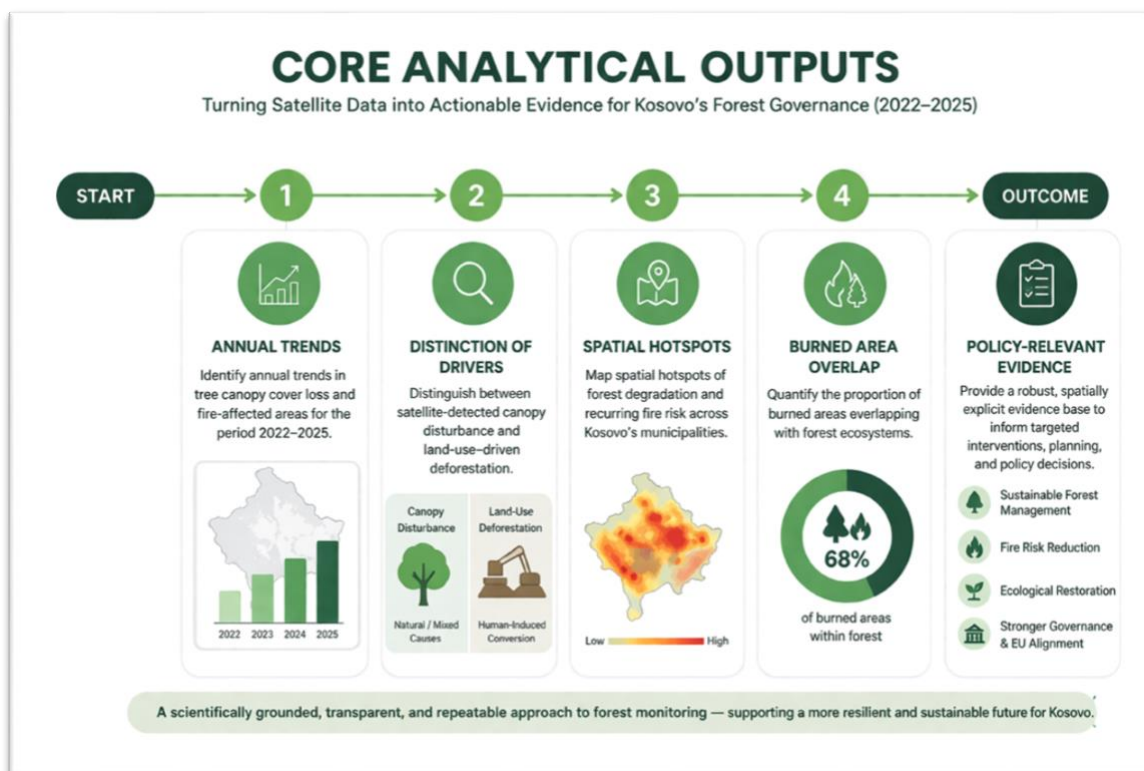
PURPOSE OF THIS REPORT

The purpose of this report is to provide a comprehensive, data-driven assessment of tree canopy cover loss, forest degradation, and fire impacts in the Republic of Kosovo for the period 2022–2025. The analysis integrates advanced satellite-based methodologies with institutional data sources to establish a standardised and replicable framework for forest monitoring.

Building on the broader environmental and policy context outlined in the introduction, the report responds to the need for reliable, spatially explicit, and inter-annually comparable data to support evidence-based decision-making. It applies a multi-temporal analytical approach using Global Forest Change, Copernicus Tree Cover Density, and EFFIS fire datasets, combined with spatial cross-validation, to generate a consistent and policy-relevant evidence base.

The report is designed to deliver four core analytical outputs: 1) identification of annual trends in tree canopy cover loss and fire-affected areas; 2) differentiation between satellite-detected canopy disturbance and land-use-driven deforestation; 3) spatial mapping of degradation hotspots and recurring fire risk; and 4) quantification of the proportion of burned areas affecting forest ecosystems.

By establishing this analytical foundation, the report supports targeted interventions in forest management, fire risk reduction, ecological restoration, and climate adaptation planning. It is intended to inform national authorities, municipalities, environmental agencies, development partners, and civil society actors engaged in forest governance and climate resilience in Kosovo.



FOREST RESOURCES IN KOSOVO

Forests represent one of Kosovo's most important natural assets, not merely as timber resources but as multifunctional ecosystems of high ecological, climatic, and socio-economic value. They contribute to biodiversity conservation, hydrological regulation, carbon

sequestration, soil stabilization, and the livelihoods of rural communities. A clear understanding of forest extent, ownership, composition, and management structure is essential for assessing forest canopy cover loss, degradation, and land-use change (Republic of Kosovo, 2023).

According to the most recent National Forest Inventory⁶, Kosovo’s total forest area is estimated at approximately 481,000 hectares, accounting for 44.7% of the national territory (Republic of Kosovo, 2023). This relatively high forest cover underscores the strategic importance of forest governance within national environmental, climate, and land-use policies.

Forest ownership is divided between public and private entities: approximately 62% of forests are publicly owned, while 38% are privately owned (Kosovo Forestry Agency, 2021–2022). This dual ownership structure creates institutional and enforcement challenges, particularly regarding sustainable management standards, monitoring consistency, and alignment with EU forestry governance principles.

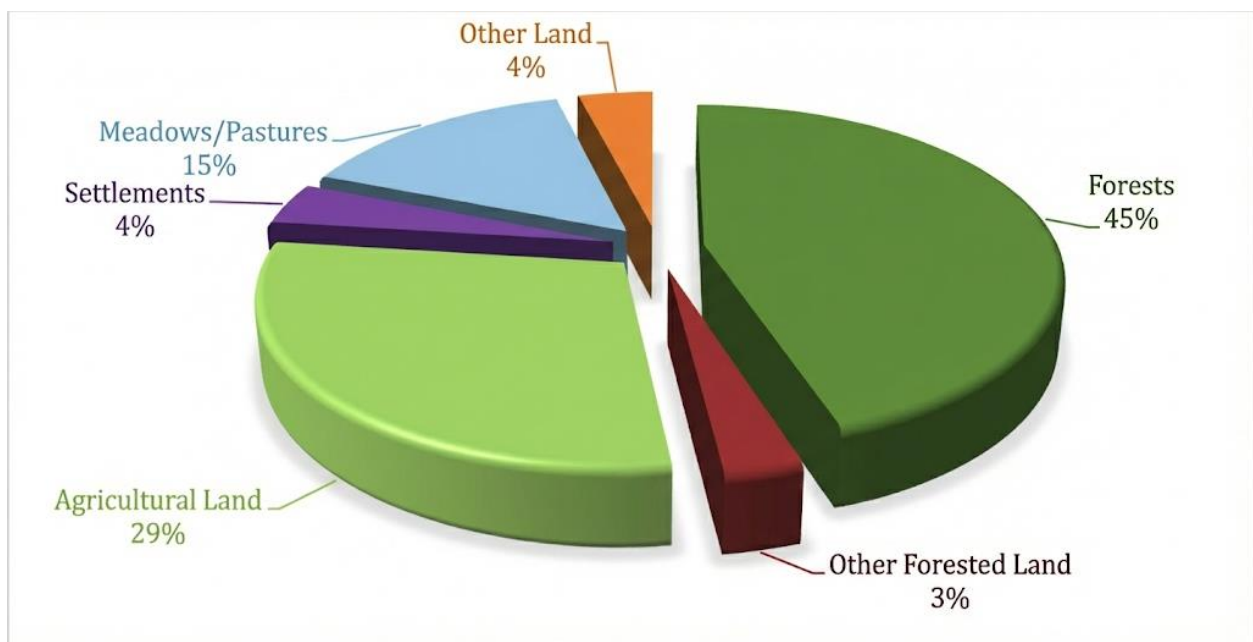


Figure 1. Land use classes in Kosovo (% of total territory area) *Division of Kosovo's territory area by main land use categories. Source: National Forest Inventory (INP), elaborated by the authors.*

FOREST COMPOSITION AND STRUCTURAL CATEGORIES

Kosovo’s forests are predominantly composed of deciduous species. Of the total forest area, approximately 449,400 hectares are covered by deciduous forests, while 23,800 hectares

⁶ Republic of Kosovo (2023) National Forest Inventory – Final Report. Prishtina: Ministry of Agriculture, Forestry and Rural Development.

(about 7%) consist of coniferous forests (National Forest Inventory – INP; Republic of Kosovo, 2023).

This composition has implications for fire behaviour, regeneration potential, biodiversity resilience, and carbon storage dynamics.

From a silvicultural and management perspective, forests are categorized into:

- High forests, representing the most structurally developed and ecologically stable systems;
- Coppice (low) forests, typically subject to short rotation cycles and repeated harvesting;
- Degraded forests, reflecting prolonged pressure from overexploitation, fire, or insufficient regeneration;
- Shrub and transitional woodland areas, often resulting from canopy loss, disturbance, or land-use change.

The high proportion of coppice forests is particularly relevant in the context of this report, as frequent harvesting cycles can increase structural vulnerability and fire susceptibility.

ECOLOGICAL SIGNIFICANCE AND BIODIVERSITY

Kosovo's forests play a central role in maintaining ecological stability. They regulate hydrological cycles, reduce erosion risk, stabilize soils, and protect habitats, particularly in mountainous and hilly regions (Forestry Development Strategy, 2023). Through carbon sequestration and storage, forests contribute to local and regional climate regulation and enhance resilience to extreme climate events.

From a biodiversity perspective, Kosovo's forest ecosystems host numerous species of flora and fauna, including endemic and threatened species, positioning the country within a region of high ecological value in the Balkans (Forestry Development Strategy, 2023). In addition to timber production, forests provide non-timber forest products—such as berries, medicinal and aromatic plants—and ecosystem services linked to recreation, hunting, and nature tourism. These functions support rural livelihoods and contribute to sustainable local development (State of Nature Report, 2017).

POLICIES, MANAGEMENT AND INVENTORY

The Kosovo's official forest definition, used for inventory and reporting, follows internationally recognized criteria: a minimum area of 0.5 hectares, canopy cover above 10%, and the presence of trees capable of reaching a defined minimum height at maturity (Forestry Development Strategy, 2023). These parameters are aligned with FAO and international reporting standards.

National forest inventories have documented structural changes over time, reflecting both natural processes and anthropogenic pressures. Illegal logging, insufficient enforcement, and incomplete management planning remain key challenges. A significant proportion of public forests lack updated management plans, while private forests often show inconsistent implementation of sustainable harvesting standards (Forestry Development Strategy, 2023).

The structural dominance of coppice forests further increases vulnerability to long-term degradation and fire risk due to repeated harvesting cycles and reduced regeneration capacity.

At the institutional level, reforms have been initiated through the Forest Development Strategy (2023–2032), afforestation and reforestation initiatives, and cooperation with international partners aimed at strengthening technical and monitoring capacities.

THE IMPORTANCE OF CONTEXT FOR ANALYSIS

Understanding forest extent, ownership patterns, structural composition, and governance frameworks is critical for interpreting the satellite-based findings presented in this report. Contextual knowledge enables differentiation between:

1. Temporary canopy disturbance and permanent land-use change,
2. Sustainable harvesting and structural degradation,
3. Natural disturbances and anthropogenic pressures.

This contextual framework ensures that satellite-derived canopy cover loss is interpreted accurately within Kosovo's ecological and institutional realities. It also provides the necessary foundation for formulating feasible, evidence-based policy recommendations aimed at strengthening forest governance, enhancing climate resilience, and aligning national practices with EU and global environmental standards.

METHODOLOGICAL FRAMEWORK

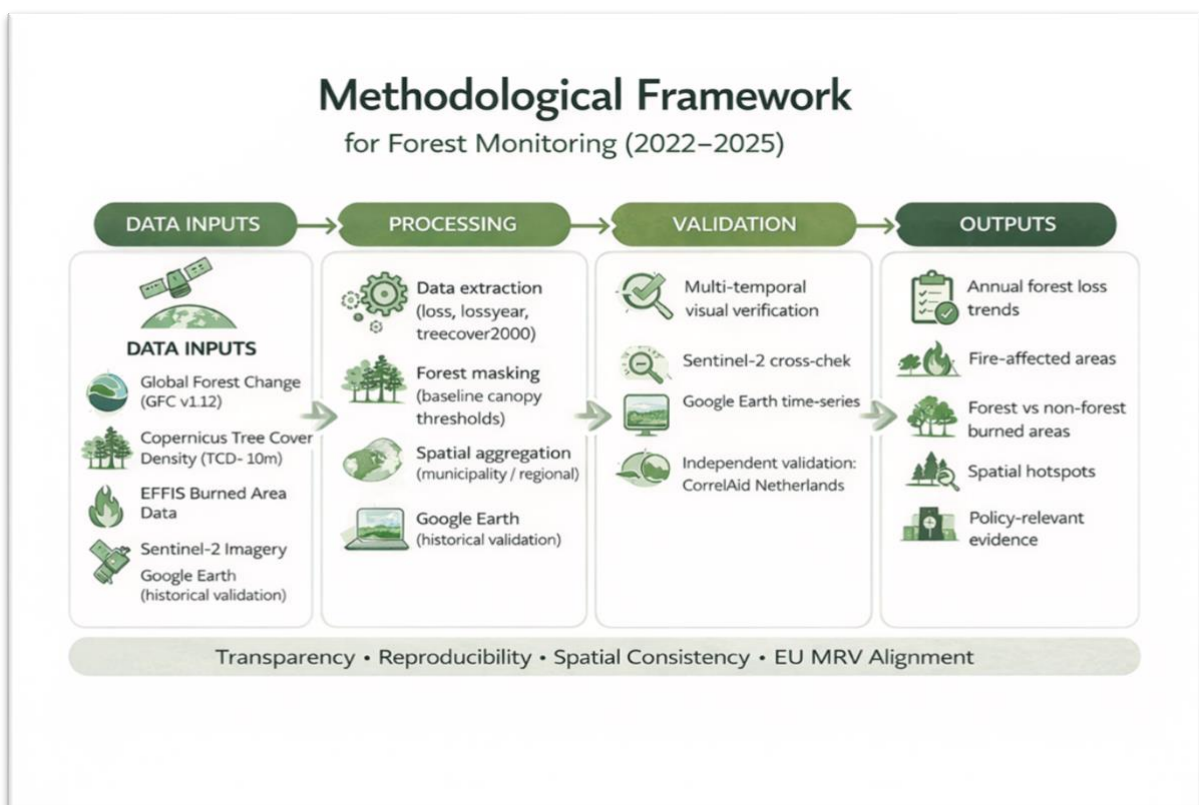
The assessment of forest canopy cover loss and fire-related degradation in Kosovo for the period 2022–2025 is based on the systematic use of satellite-derived datasets processed through a standardized workflow within Google Earth Engine (GEE)⁷. The methodological approach is designed to ensure transparency, reproducibility, spatial consistency, and inter-annual comparability, in line with principles applied within European Union monitoring and reporting systems. The methodological approach ensures transparency, reproducibility, spatial consistency, and inter-annual comparability.

⁷ Google Earth Engine (GEE) is a cloud-based geospatial analysis platform that enables large-scale processing and analysis of satellite imagery and environmental data.

These principles are consistent with monitoring and reporting standards applied within European Union environmental governance frameworks, particularly under MRV-related approaches in forestry and climate policy.

The analytical foundation of the study is the Global Forest Change (GFC) v1.12 dataset (2000–2024), which provides globally harmonized information on tree canopy cover, annual canopy loss, and potential regeneration. This dataset is widely used in scientific research and institutional forest monitoring, and supports approaches consistent with EU Monitoring, Reporting and Verification (MRV) requirements under climate and environmental governance frameworks.

In this report, the term “forest canopy cover loss” is used strictly in its satellite-detected meaning. It does not automatically imply deforestation as defined by FAO, which requires confirmation of permanent land-use change. Satellite-detected canopy reduction may result from harvesting, fires, wind damage, pest outbreaks, or natural dynamics. Maintaining this distinction is essential for methodological integrity and for avoiding misinterpretation in policy discussions.



The analytical workflow involved extraction of the “loss,” “loss year,” and “treecover2000” layers for the years 2022–2024. Pixels with low baseline canopy cover were masked to exclude areas that did not meet minimum forest characteristics at the beginning of the reference period. Processing within Google Earth Engine enabled consistent calculation of annual canopy loss, spatial aggregation by municipalities and regions, and construction of inter-annual change models at national scale.

To increase robustness and reduce classification uncertainty, multi-temporal visual verification was carried out using Sentinel-2 imagery at 10 m resolution, complemented by historical time-series interpretation in Google Earth. This verification step strengthens reliability and aligns the methodology with EU best practices requiring cross-checking of automated outputs with independent visual interpretation.

FIRE-RELATED FOREST DEGRADATION

Forest degradation from fire events was assessed through integration of Copernicus Tree Cover Density (TCD, 10 m resolution) and burned-area polygons provided by the European Forest Fire Information System (EFFIS), part of the Copernicus Emergency Management Service.

EFFIS provides harmonized burned-area delineation across Europe and neighbouring regions, including Kosovo. However, fire perimeters frequently contain both forest and non-forest land cover. For this reason, a spatial intersection analysis was conducted between EFFIS polygons, the TCD dataset, and the forest mask derived from GFC. This step allowed identification of burned areas corresponding specifically to forest canopy cover, thereby increasing precision in estimating fire-induced forest degradation.

This integrated use of Copernicus services and globally harmonized datasets reflects an approach compatible with EU environmental monitoring frameworks and supports Kosovo's gradual alignment with European reporting standards in forestry, climate adaptation, and biodiversity governance.

VALIDATION OF ANALYTICAL APPROACH

To strengthen the reliability and robustness of the analytical results, the data processing and analytical workflow developed by Sustainability Leadership Kosova (SLK) were subject to independent validation in collaboration with CorrelAid Netherlands⁸.

The analysis—including data collection, integration of satellite datasets (Global Forest Change, Tree Cover Density, and EFFIS), spatial processing within Google Earth Engine, and interpretation of results—was carried out by SLK. CorrelAid Netherlands contributed by reviewing the overall analytical framework, verifying the consistency of data processing steps, and cross-checking key outputs against the underlying datasets and methodological assumptions.

⁸ CorrelAid Netherlands is a data science for social good organisation that supports non-profit and public sector initiatives through data analysis and methodological validation. Available at: <https://www.correlaid.org/netherlands>

This validation process included a structured review of data integration procedures, spatial intersection methods (particularly between burned area polygons and tree cover density layers), and the interpretation of canopy loss and fire-related degradation. Attention was given to ensuring that distinctions between forest and non-forest areas, as well as between canopy loss and permanent land-use change, were applied consistently and in line with established methodological standards.

In addition, selected outputs were reviewed for logical consistency across temporal and spatial dimensions, including inter-annual comparisons and regional distribution patterns. This helped ensure that the results accurately reflect observed trends and are not influenced by processing inconsistencies or dataset limitations.

The involvement of an independent data science partner provided an additional layer of quality assurance, reinforcing the transparency, credibility, and methodological integrity of the findings. This approach is consistent with good practice in data-driven environmental assessments and strengthens the report's relevance for policy development and institutional use.

LIMITATIONS OF THE ANALYSIS

Despite the robustness of the methodology, several limitations must be acknowledged.

First, satellite-based canopy loss detection does not automatically differentiate between temporary disturbance and permanent deforestation. Without field verification or land-use confirmation, caution is required when interpreting canopy loss as structural forest conversion.

Second, while visual validation improves reliability, systematic nationwide field surveys were not conducted as part of this study. The analysis therefore remains remote sensing based.

Third, temporal coverage differs slightly across datasets. GFC canopy loss data are available until 2024, whereas fire analysis extends into 2025 using EFFIS data. Comparisons involving 2025 should therefore be interpreted carefully.

Finally, although 10 m resolution datasets provide high spatial detail, very small-scale disturbances may remain undetected or aggregated within pixel-level analysis.

Acknowledging these constraints enhances transparency and reinforces the credibility of the findings.

KOSOVO FOREST LOSS ANALYSIS (2022-2025)

Reliable, standardized, and consistently updated spatial data remain a key requirement for effective forest governance and environmental monitoring. The Global Forest Change (GFC)

dataset (Hansen et al., 2013; updated 2024) provides a globally harmonized and methodologically consistent basis for assessing tree canopy cover and its changes over time.

Using GFC v1.12, this analysis examines forest canopy cover loss in Kosovo for the period 2022–2024. The dataset enables annual tracking of canopy disturbance at 30-meter resolution, supporting a consistent assessment of spatial and temporal trends in forest dynamics across the country.

The analysis indicates that forest canopy cover loss during the period 2022–2024 is not uniformly distributed but instead reflects distinct spatial patterns and year-to-year variation in disturbance intensity. Areas of concentrated canopy loss suggest the influence of multiple drivers, including fire events, land-use pressures, and other anthropogenic or natural disturbances. At the same time, the presence of dispersed loss patterns indicates that smaller-scale or localized processes also contribute to overall forest change.

It is important to note that “forest canopy cover loss” as detected by GFC refers to structural changes in tree cover and does not automatically imply permanent deforestation. Observed canopy reduction may result from a range of factors, including harvesting, fire, or natural disturbance, and may in some cases be followed by regeneration. Maintaining this distinction is essential for accurate interpretation and for avoiding misrepresentation in policy and planning contexts.

As illustrated in Figure 2, annual canopy loss varies across the analysed period, reflecting fluctuations in disturbance intensity. Figure 3 further demonstrates that canopy loss is spatially concentrated in specific areas rather than evenly distributed across the territory, indicating localized pressures on forest ecosystems.

Together, these findings provide an evidence-based overview of recent forest canopy dynamics in Kosovo and establish a foundation for further analysis of underlying drivers, including fire-related degradation and broader land-use change processes.

SOURCES AND DATA STRUCTURE

The Global Forest Change dataset is primarily derived from Landsat satellite imagery with a spatial resolution of 30 meters. The time series integrates observations from:

- Landsat 5 TM and Landsat 7 ETM+ (2000–2011)
- Landsat 8 OLI and Landsat 9 (2012 onward, including 2022–2024)

The transition to newer sensors has improved radiometric quality, spectral consistency, and disturbance detection capability. This enhances differentiation between selective logging, stand-replacing canopy loss, burn scars, and short-cycle vegetation dynamics.

Annual cloud-free composite images are generated through advanced cloud masking and spectral normalization procedures. Each pixel in the baseline year (2000) is assigned a tree

canopy cover value ranging from 0–100%. Subsequent annual layers record whether canopy cover loss or gain has occurred during the monitoring period.

CLASSIFICATION METHODOLOGY

Forest canopy cover loss detection in GFC relies on a machine-learning framework combining Classification and Regression Trees (CART) with ensemble bagging techniques. These algorithms classify pixels based on their multi-temporal spectral signatures across the Landsat archive.

The model is trained using globally distributed reference samples derived from Landsat imagery and high-resolution visual interpretation (including Google Earth). Training data encompass diverse land cover types, including dense forests, degraded forests, agricultural lands, shrublands, burned areas, urban surfaces, and plantation systems.

Within this framework, a pixel is classified as experiencing canopy cover loss when a stand-replacement disturbance is detected. Such disturbances reflect substantial reduction in canopy cover and may result from logging, fire events, construction, infrastructure expansion, or severe natural disturbances.

It is important to reiterate that canopy cover loss detected by GFC does not automatically imply permanent deforestation. The dataset captures structural canopy disturbance, regardless of whether regeneration subsequently occurs.

DATASET CONTENTS FOR PERIOD 2022–2024

One of the key advancements of the 2024 version is the inclusion of data up to 2024, making this dataset one of the most up-to-date global sources for monitoring forest change. For the period 2022–2024, the dataset provides detailed information on annual canopy loss (“lossyear”), where each pixel experiencing tree canopy reduction is assigned the corresponding year of disturbance.

It also includes forest gain layers, identifying areas where vegetation has increased and where sustained forest regeneration has occurred over recent years. In addition, updated composite imagery for the most recent year enables visual inspection and comparison with other satellite sources or local orthophotos.

Together, these components allow for direct monitoring of recent trends, supporting the identification of newly affected areas, as well as zones where forest recovery or expansion may be taking place. This temporal depth and spatial consistency make the dataset particularly valuable for detecting emerging patterns, validating analytical outputs, and supporting evidence-based decision-making.

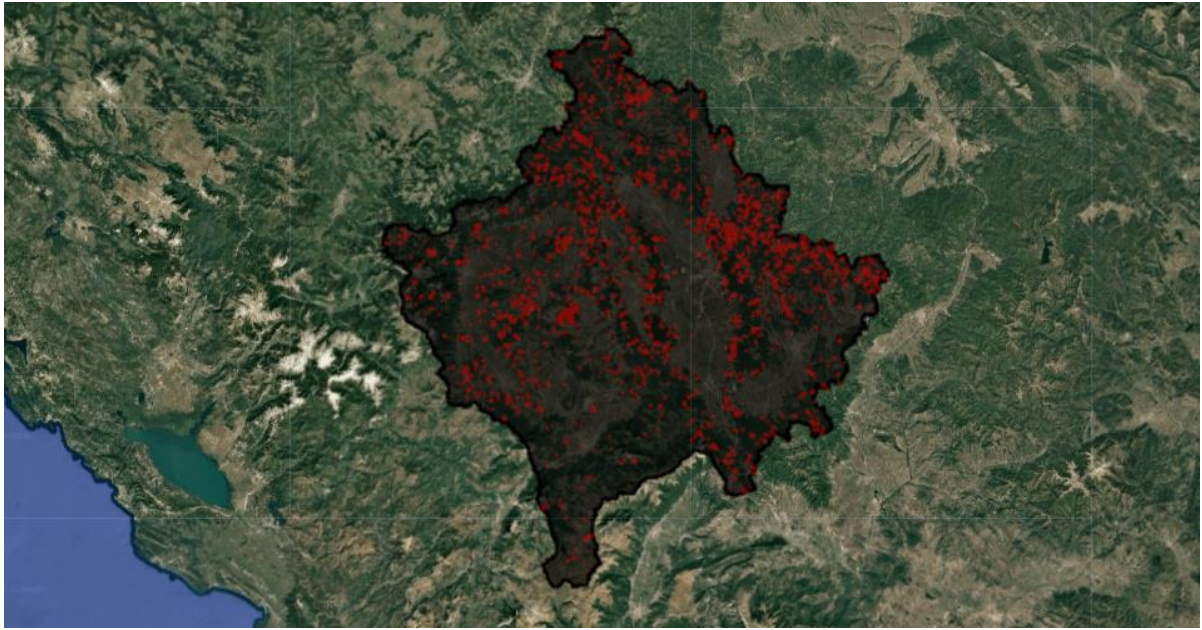


Figure 2. Forest loss areas in Kosovo for the period 2022–2024 – annual forest crown loss expressed in hectares, based on the analysis of satellite data. Global forest change v1.12 (Hansen et al.), edited by the authors.



Figure 3. Spatial distribution of forest loss areas in Kosovo for the period 2022–2024 - Geographical location of pixels with forest crown loss, identified through longitudinal satellite analysis. Global Forest Change v1.12 (Hansen et al.), edited by the authors

INTERPRETATION OF THE RESULTS

The analysis of forest canopy cover loss for the period 2022–2024 identifies a total of 3,976 hectares of canopy disturbance across the territory of the Republic of Kosovo. The annual

distribution and relative contribution of each year are presented in Figure 4 and Figure 5, which together illustrate both the proportional and absolute dynamics of loss.

Figure 4 (percentage distribution) shows a clear peak in 2023, which accounts for 46.41% of total canopy loss during the analysed period. This is visually evident in the chart, where nearly half of all recorded loss is concentrated in a single year.

Figure 5 (hectares by year) confirms this trend quantitatively, indicating:

- 2023: 1,845 ha
- 2024: 1,212 ha
- 2022: 918 ha

The graphical comparison between Figures 4 and 5 demonstrates that the spike observed in 2023 is not merely proportional but also substantial in absolute terms. While 2024 shows a reduction compared to 2023, it remains significantly higher than 2022, suggesting that canopy disturbance levels have not returned to the lower baseline observed at the beginning of the period.

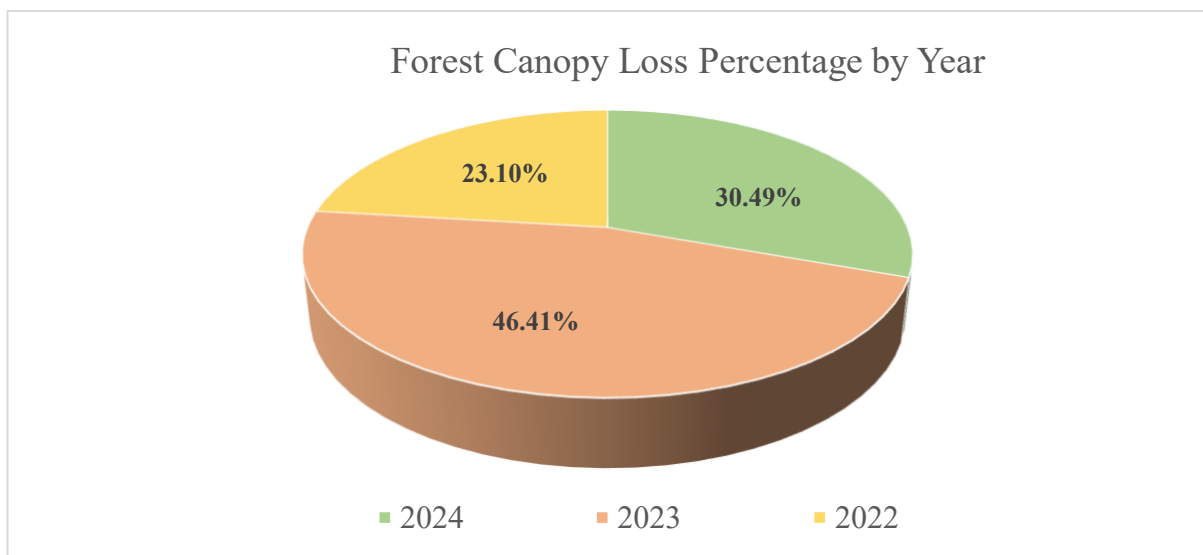


Figure 4. Percentage distribution of forest crown loss by years for the period 2022–2024 - The relative percentage of forest crown loss for each year analysed, in relation to the total period. Global Forest Change v1.12 (Hansen et al.), edited by the authors.

The inter-annual variability shown in these figures indicates that canopy loss is not structurally constant but responds to dynamic pressures. These may include fluctuations in logging intensity, climatic stress events, localized fire outbreaks, infrastructure expansion, and land-use conversion activities.

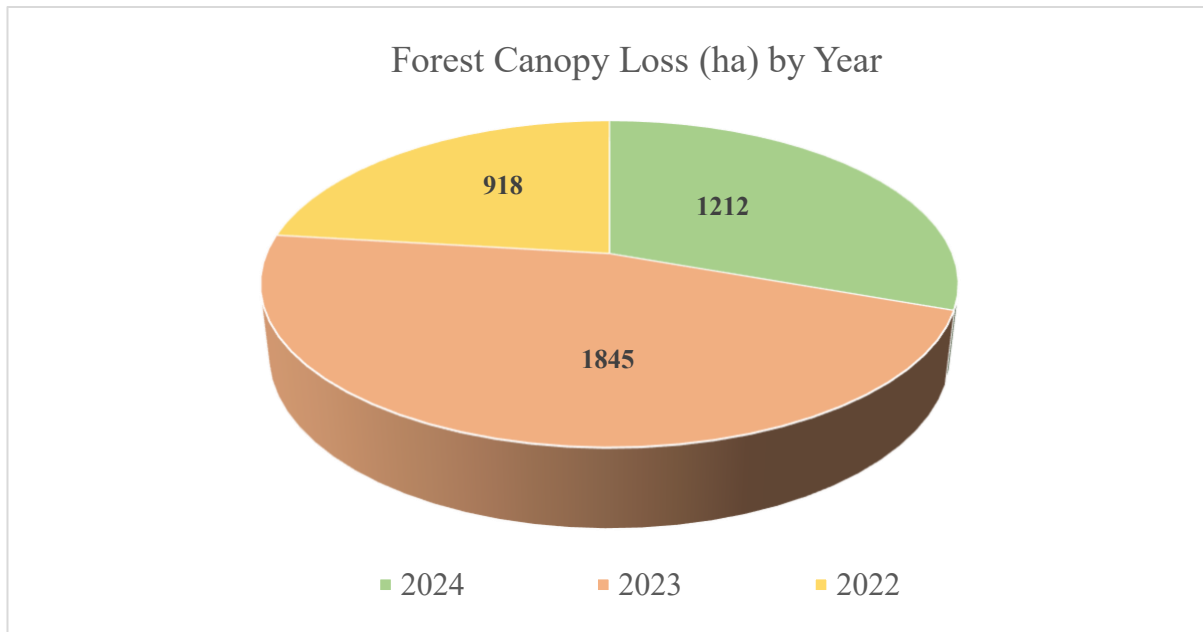


Figure 5. Forest crown loss by years (ha) for the period 2022–2024. Absolute annual forest crown loss expressed in hectares, based on the analysis of satellite forest loss data. Global Forest Change v1.12 (Hansen et al.), edited by the authors.

It is important to emphasize that the values illustrated in Figures 4 and 5 represent tree canopy cover loss, as detected by the Global Forest Change v1.12 dataset. They do not automatically equate to permanent deforestation (i.e., land-use change). The dataset captures stand-replacement disturbances at pixel level, which may result from selective or complete logging, fire events, storm damage, or other structural canopy interruptions.

MAIN DRIVERS OF FOREST CANOPY LOSS

Based on spatial analysis and data interpretation, several key factors have been identified as contributing to the observed levels of forest canopy loss in Kosovo. These include logging activities (both permitted and illegal), land-use conversion for agriculture and pastures, infrastructure development, expansion of settlements, and fire-related impacts.

These drivers reflect both direct pressures on forest ecosystems and broader underlying dynamics linked to climatic variability, socio-economic conditions, and institutional capacity.

Importantly, these factors do not operate in isolation. They often interact and reinforce one another, resulting in cumulative impacts on forest structure and function. For example, canopy disturbance associated with logging or land-use change may increase vulnerability to fires, while fragmented or degraded forests exhibit reduced resilience to climatic stress.

The following sections provide a detailed analysis of each of these drivers and their spatial manifestations across the territory of Kosovo.

LOGGING (ILLEGAL AND PERMITTED)

Logging constitutes one of the principal drivers of tree canopy cover loss in Kosovo during the analysed period. Canopy disturbance occurs both through illegal extraction and through harvesting authorized under approved forest management plans. Although these activities differ in legal status and procedural oversight, both may generate measurable canopy reduction when regeneration, supervision, and post-harvest monitoring are insufficient.

Illegal logging is typically concentrated in areas with limited institutional control or difficult terrain access. Spatially, such activities often produce irregular canopy openings and dispersed fragmentation patterns rather than systematically planned harvesting blocks. Beyond direct canopy removal, illegal extraction may trigger secondary ecological impacts, including soil compaction, disruption of natural regeneration cycles, and the creation of informal access routes that facilitate further disturbance.

Socio-economic drivers remain significant. High dependence on firewood, particularly in rural areas, combined with limited enforcement capacity, increases the likelihood of recurrent canopy disturbance. Where oversight mechanisms are weak, canopy loss may persist over successive seasons, contributing to cumulative structural degradation.



Forest cover before logging

Forest cover after logging

Figure 6. Tree canopy cover loss associated with logging activities (before–after comparison). Sentinel-2 / Google Earth imagery, elaborated by the authors. Mramor, Prishtine. 42.647188, 21.279402.

Permitted logging, although conducted within the framework of forest management plans, may also lead to substantial canopy cover reduction if regeneration measures are delayed or inadequately implemented. In cases where replanting or assisted natural regeneration does not occur promptly, harvested areas may remain partially exposed for extended

periods. This prolongs canopy discontinuity and increases susceptibility to erosion, invasive species establishment, and elevated fire risk.

The spatial expression of canopy disturbance associated with harvesting activities is illustrated in Figure 6. The multi-temporal satellite comparison shows reduction in crown density and increasing fragmentation patterns consistent with tree felling interventions.

FOREST COVER LOSS RESULTING FROM CONVERSION TO PASTURES

In several areas of Kosovo, tree canopy cover loss is associated with the conversion of forest land into pasture for livestock grazing. Unlike selective harvesting, this process typically involves near-complete canopy removal and subsequent land-use change, resulting in structural transformation of the ecosystem rather than temporary disturbance.

The conversion of forested land into grazing areas often occurs without comprehensive environmental impact assessment or long-term land management planning. From a spatial perspective, satellite imagery reveals abrupt transitions from continuous canopy cover to open grassland, accompanied by clear boundary demarcation and removal of woody vegetation. Such changes are consistent with permanent land-use conversion rather than cyclical forestry operations.

The ecological implications are significant. Removal of tree cover reduces soil stability, increases exposure to erosion processes—particularly on sloped terrain—and disrupts hydrological regulation functions. Forest soils, once cleared, often experience compaction due to grazing pressure, further limiting natural regeneration potential. In many observed cases, post-conversion areas show limited signs of forest recovery, indicating that the disturbance represents long-term canopy loss rather than temporary degradation.



Forest cover before removal

Forest cover after removal

Figure 7. Conversion of forest areas into pasture through tree canopy removal (before–after comparison). Sentinel-2 / Google Earth imagery, elaborated by the authors.

Beyond soil and hydrological impacts, land conversion to pasture fragments forest landscapes and reduces habitat continuity, affecting biodiversity and ecosystem resilience.

The interruption of natural succession processes may result in persistent reduction of carbon sequestration capacity and diminished ecosystem services.

The spatial manifestation of this land-use change is illustrated in Figure 7, which presents a multi-temporal satellite comparison of conditions before and after conversion. The imagery demonstrates the transition from closed forest canopy to open grazing land, highlighting canopy removal, boundary reshaping, and land-use transformation.

FOREST COVER LOSS FOR THE EXPANSION OF AGRICULTURAL AREAS

The expansion of agricultural land represents another identifiable driver of tree canopy cover loss in Kosovo. Unlike selective logging, agricultural conversion typically results in permanent land-use change, characterized by systematic clearing of vegetation and restructuring of parcel boundaries.

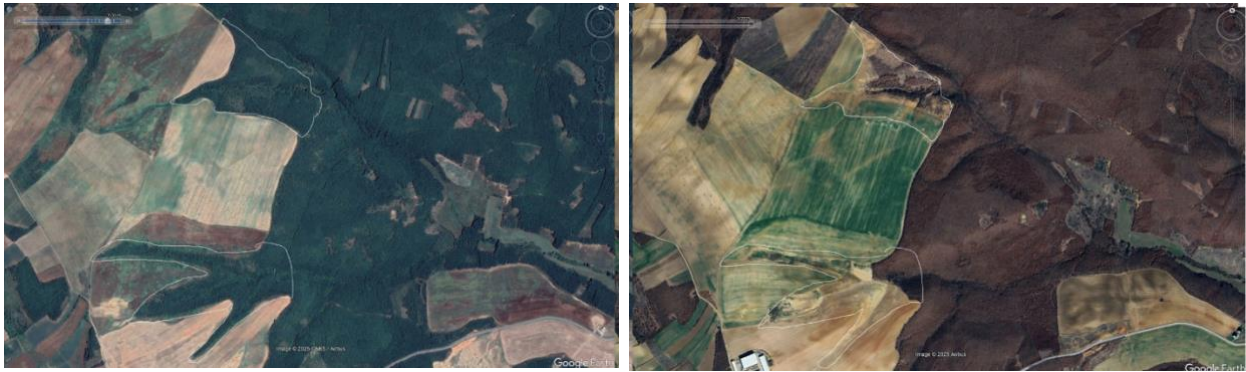
Rising demand for agricultural production and income generation has encouraged the conversion of forested or semi-natural areas into cropland. This process often involves full canopy removal, mechanical land preparation, and establishment of monoculture fields or orchards. From a satellite perspective, such transformations are visible as sharp geometric parcel patterns replacing previously continuous or irregular forest canopy structures.

Multi-temporal satellite comparison clearly demonstrates the progressive transition from forest cover to agricultural plots, including land clearing, boundary realignment, and intensification of cultivation. These spatial signatures indicate structural transformation rather than temporary canopy disturbance.

The ecological implications are substantial. Conversion to agriculture reduces habitat continuity, fragments forest landscapes, and diminishes carbon sequestration capacity. Soil disturbance during clearing increases vulnerability to erosion, particularly in sloped terrain, while repeated cultivation may accelerate nutrient depletion. Without integrated land-use planning and environmental impact assessment, this type of canopy loss frequently results in long-term ecological degradation.

In some cases, short-term agricultural gains are followed by declining productivity due to soil exhaustion, leading to abandoned or degraded land with limited capacity for natural forest regeneration. Such dynamics create a degradation cycle in which the ecological functions of the original forest ecosystem — including biodiversity conservation, hydrological regulation, and climate buffering — are not restored.

The spatial manifestation of this process is illustrated in Figure 8, which presents a before–after satellite comparison of forest areas converted into agricultural land. The imagery highlights canopy removal, parcel restructuring, and land-use transformation consistent with agricultural expansion.



Forest cover before logging

Forest cover after logging

Figure 8. Tree canopy cover loss associated with agricultural expansion (before–after comparison).

Sentinel-2 / Google Earth imagery, elaborated by the authors. Kline, 42.564936, 20.536937.

INFRASTRUCTURE DEVELOPMENT

Infrastructure expansion constitutes a structurally distinct driver of tree canopy cover loss in Kosovo. The construction of roads, transmission lines, pipelines, hydropower facilities, and other public works frequently requires permanent clearing of forested corridors and localized removal of tree cover.

Unlike selective logging, infrastructure-related canopy loss typically appears in linear or geometric spatial patterns, reflecting engineered alignments and access routes. These interventions generate continuous clearings that fragment previously connected forest stands and alter landscape configuration.

From an ecological perspective, linear fragmentation reduces habitat connectivity, disrupts wildlife movement corridors, and increases edge effects. Newly created forest edges are generally more exposed to wind, desiccation, invasive species colonization, and ignition sources. In mountainous and sloped terrain, canopy removal associated with road construction may also increase erosion risk and surface instability. An additional indirect effect relates to accessibility. Newly constructed roads often provide entry into previously less-accessible forest areas, potentially increasing pressure from unauthorized logging, land conversion, or uncontrolled human activity. In this way, infrastructure development may act not only as a direct driver of canopy loss but also as an enabling factor for secondary disturbance.

The spatial signature of infrastructure-induced canopy disturbance is illustrated in Figure 9, which presents a before–after comparison of forest areas affected by linear clearing. The imagery highlights corridor formation, fragmentation patterns, and localized canopy removal consistent with infrastructure expansion.



Forest cover before

Forest cover after

Figure 9. Tree canopy cover loss and forest fragmentation associated with infrastructure development (before–after comparison). Sentinel-2 / Google Earth imagery, elaborated by the authors. Kishnareke, Drenas. 42.555959, 20.861894.

EXPANSION OF NEW SETTLEMENTS

Urban expansion and residential development represent an increasingly visible driver of tree canopy cover loss in Kosovo, particularly in peri-urban zones and municipalities experiencing demographic growth. As built-up areas extend outward, forested land is frequently converted into construction parcels for housing, access roads, parking areas, and associated infrastructure.

Unlike logging or agricultural conversion, settlement expansion typically results in permanent land-use change. Once forest cover is replaced by sealed or semi-sealed surfaces, natural regeneration potential is substantially reduced or eliminated. This transition therefore corresponds not only to canopy disturbance but, in many cases, to functional deforestation.

Spatially, settlement-driven canopy loss often appears as clustered or irregular clearings that progressively expand from existing urban edges. Over time, this pattern contributes to fragmentation of remaining forest patches, loss of ecological continuity, and reduction of ecosystem services.

From a risk perspective, the removal of forest cover in sloped or hydrologically sensitive areas may reduce natural protection against erosion, surface runoff, flooding, and landslides. Forest ecosystems that previously functioned as buffer zones for microclimatic regulation and water retention become increasingly constrained.

The land-cover transformation associated with settlement expansion is illustrated in Figure 10, which presents a before–after comparison of forested areas converted into built-up space. The imagery demonstrates progressive canopy removal and structural land-use transformation consistent with urban development patterns.



Forest cover before cover loss

Forest cover after cover loss

Figure 10. Tree canopy cover loss associated with settlement expansion and urban development (before–after comparison). Sentinel-2 / Google Earth imagery, elaborated by the authors. Batllave, Podujeve. 42.828338, 21.316952.

FIRE-INDUCED FOREST DEGRADATION (2022–2025)

Forest fires represent one of the most significant drivers of forest degradation in Kosovo, with impacts that extend beyond immediate canopy removal. In recent years, both the frequency and spatial extent of fire events have increased, particularly during prolonged drought periods characterized by high seasonal temperatures and reduced soil moisture. These climatic conditions, combined with anthropogenic ignition sources—whether intentional or accidental—have amplified forest vulnerability across several regions.

Fire-related impacts manifest at multiple ecological levels. At the structural level, fires result in partial or complete loss of tree canopy cover, alteration of stand composition, and disruption of forest continuity. However, degradation does not end with the burn event itself. Post-fire processes often include soil exposure, loss of organic matter, reduced infiltration capacity, and increased surface runoff. In sloped terrain, these processes significantly elevate erosion risk and may contribute to long-term land instability.

From a functional perspective, fires reduce forests' capacity for carbon sequestration, temporarily shifting affected areas from carbon sinks to carbon emission sources. Repeated fire exposure further weakens regeneration potential, especially in ecosystems already stressed by drought or previous disturbances. This feedback mechanism reinforces climate-related risks and may lead to structural simplification of forest stands if recovery is insufficient. In ecological terms, severe fire events can disrupt habitat structure, reduce species diversity, and fragment remaining forest patches. The long-term resilience of affected ecosystems depends on fire intensity, recurrence interval, pre-fire stand condition, and post-fire management responses.

The physical manifestation of fire-induced degradation is illustrated in Figure 11 - The imagery demonstrates vegetation loss, exposed soil surfaces, and structural damage consistent with high-intensity burn events.



Figure 11. Forest degradation following fire events – post-burn conditions.

Field photographs documenting vegetation loss, soil exposure, and structural damage after fire events. Photographs processed by the authors. Kqiq i Madh, Mitrovice. 42.878281, 20.917915

EFFIS AND BURNED AREAS

The European Forest Fire Information System (EFFIS) is the European Union’s operational service for monitoring forest fires and assessing fire-related impacts across Europe and neighbouring regions (EFFIS, 2024). It operates under the Copernicus Emergency Management Service (CEMS) and represents one of the core EU instruments for fire-related monitoring, reporting and situational awareness.

Within the European monitoring architecture, EFFIS contributes to harmonised fire statistics, post-fire damage assessment, and cross-border comparability of wildfire impacts. Its products are increasingly used in support of climate risk assessment, forest resilience monitoring, and reporting obligations under EU environmental and climate frameworks.

BURNED AREA DETECTION AND PROCESSING

EFFIS burned area products are generated through a combination of automated satellite processing and expert validation. In the Rapid Damage Assessment (RDA) workflow, burned area polygons are extracted from medium-resolution satellite imagery using spectral indices sensitive to fire disturbance, including changes in infrared reflectance and vegetation indices.

Historically, EFFIS has integrated data from multiple sensors, including MODIS and VIIRS, and in recent years increasingly relies on higher-resolution imagery such as Sentinel-2. For complex or large-scale events, automated outputs are supplemented by manual interpretation and validation by national focal points and fire monitoring experts. This hybrid approach improves positional accuracy and thematic reliability.

The output consists of georeferenced burned area polygons, which represent the spatial extent of fire-affected zones. These polygons may include multiple land-cover categories within a single fire perimeter.

INTERPRETATION AND LAND-COVER DIFFERENTIATION

EFFIS burned area polygons represent the total affected footprint of a fire event. However, they do not inherently distinguish between forest and non-forest land within that perimeter. For analytical purposes, a secondary spatial intersection with land-cover datasets is required.

In this report, EFFIS polygons were intersected with:

- Tree Cover Density (TCD) data (10 m resolution)
- Forest cover layers derived from Global Forest Change (GFC)

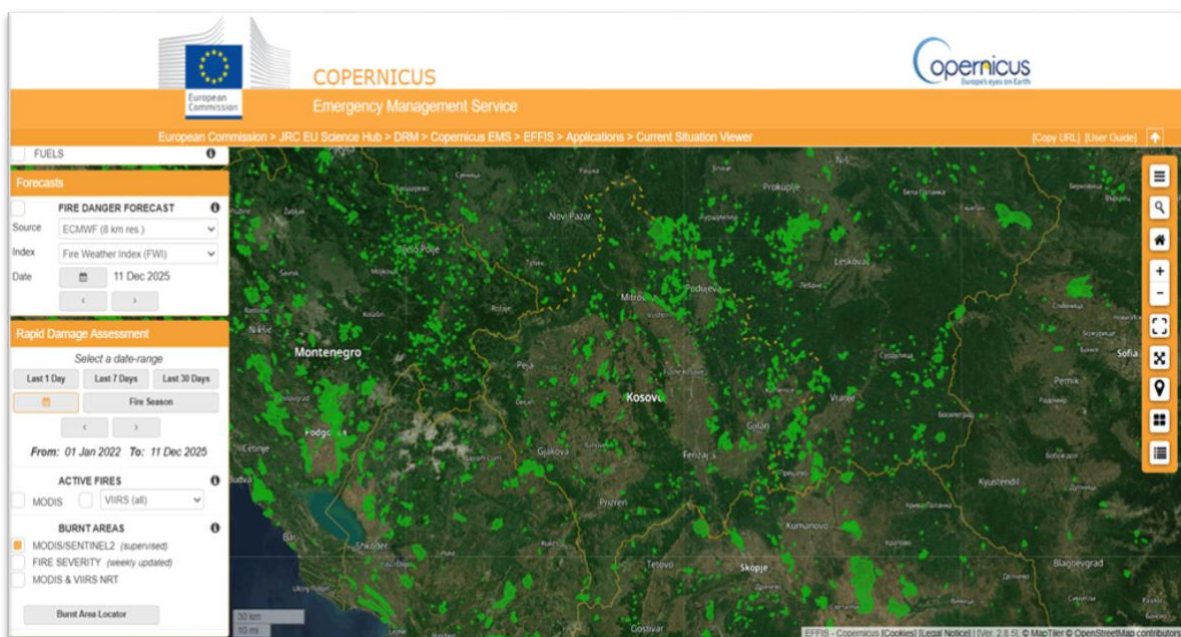
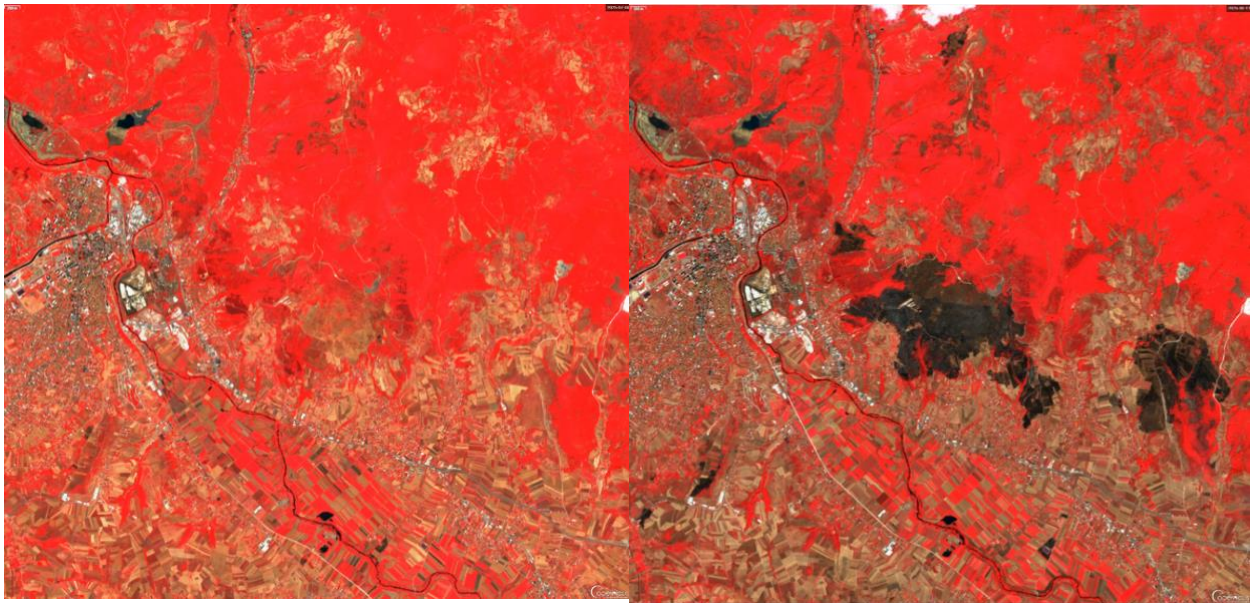


Figure 12. Copernicus Sentinel-2 / EFFIS burned area identification. Copernicus Sentinel-2 imagery, elaborated by the authors.

This additional step enables the isolation of burned areas that correspond specifically to forested land, excluding agricultural fields, pastures, shrublands or artificial surfaces located within the same fire boundary. This methodological refinement significantly increases the accuracy of forest degradation assessment. Examples of burned area identification using

Sentinel-2 imagery are presented in, which illustrate spectral differences before and after fire events, particularly in the near-infrared bands, where vegetation loss and soil exposure become clearly detectable.



Before fire events

After fire events

Figure 13. Infrared comparison before and after fire events. Sentinel-2 multi-temporal imagery, processed by the authors. Coordinates of the location: 42.878281, 20.917915.

ACCURACY CONSIDERATIONS AND DATASET LIMITATIONS

Spatial resolution plays a critical role in burned area estimation. Lower-resolution products (e.g., MODIS-based datasets) tend to underestimate small or fragmented burned surfaces and may exhibit positional uncertainty along fire boundaries. Higher-resolution datasets such as Sentinel-2 (10 m) provide improved delineation of fire perimeters and better identification of mixed land-cover impacts.

EFFIS data, while robust at continental scale, are optimized for operational monitoring rather than fine-scale ecological assessment. Therefore, integrating EFFIS with high-resolution land-cover datasets (such as TCD) enhances analytical reliability, especially when distinguishing between general burned surfaces and fire-induced forest degradation.

RELEVANCE FOR KOSOVO

Although Kosovo is not an EU Member State, EFFIS products include Kosovo within regional fire monitoring and reporting outputs, including annual reports and

GWIS/EFFIS statistics. In years with significant fire activity, land-cover category breakdowns (Forest/Other Wooded Land, Other Natural Land, Agriculture, Artificial Surfaces) are available, enabling a more detailed understanding of fire impacts across different land-use types.

These harmonised datasets provide a valuable foundation for aligning Kosovo's fire monitoring practices with European standards, particularly those applied under the Copernicus Emergency Management Service and broader EU environmental monitoring frameworks. They also support the development of evidence-based forest and climate policies by providing consistent, comparable, and spatially explicit data on fire occurrence and impact.

From a policy perspective, the use of EFFIS contributes to strengthening Kosovo's reporting capacity under regional and international environmental frameworks, including the Green Agenda for the Western Balkans (GAWB), which emphasises improved monitoring of natural resources, enhanced fire management, and alignment with EU climate and biodiversity objectives. In addition, the integration of EFFIS-based analysis supports future alignment with EU Monitoring, Reporting and Verification (MRV) approaches relevant to forest governance, climate adaptation, and land-use reporting.

The integration of EFFIS data with Global Forest Change (GFC) and Tree Cover Density (TCD) datasets in this report ensures methodological coherence with European fire monitoring systems and enhances the comparability of results within a broader regional context. This integrated approach strengthens the analytical basis for climate risk assessment, ecosystem resilience planning, and evidence-based decision-making in Kosovo's forest and environmental governance.

TREE COVER DENSITY (TCD)

To differentiate between general burned surfaces and fire-induced forest degradation, this analysis applies the Copernicus Land Monitoring Service (CLMS) High Resolution Layer – Tree Cover Density (TCD). Specifically, the HRL VCC Tree Cover Density 2021 product (CLMS_HRLVLCC_TCD_S2021_R10m_E51N21_03035_V01_R00), published on 31 March 2024, was used as the reference layer for pre-fire canopy conditions.

The TCD dataset provides a quantitative estimate of tree canopy cover percentage for each 10-meter pixel across Europe. Unlike binary forest/non-forest classifications, TCD is a continuous dataset with values ranging from 0% to 100%, representing the proportional coverage of tree crowns within each pixel. This continuous structure allows for a more nuanced and ecologically meaningful interpretation of canopy condition.

This methodological characteristic is particularly important in degradation analysis. Forest disturbance does not always result in complete canopy removal; it often manifests as partial reduction in crown density, structural thinning, or mosaic fragmentation. TCD enables the identification of:

- Fully forested stands,
- Partially degraded areas,
- Transitional vegetation zones, and
- Structurally weakened forest surfaces.

By capturing gradients of canopy density rather than binary categories, the dataset supports a more refined assessment consistent with EU forest monitoring principles and Copernicus land-cover harmonisation standards.

Within this report, TCD was spatially intersected with EFFIS burned area polygons to determine which portion of the fire footprint corresponded to pre-existing forest cover. This spatial overlay procedure allowed:

- The isolation of burned pixels with significant pre-fire canopy density,
- The exclusion of non-forest land cover types (e.g., pastures, agricultural land, shrublands, bare soil), and
- The quantification of actual forest degradation attributable to fire events.

The 10-meter spatial resolution of TCD aligns directly with Sentinel-2 imagery, ensuring high positional consistency across datasets and reducing uncertainty typically associated with lower-resolution fire products. This harmonised spatial framework enhances analytical reliability and supports methodological coherence with Copernicus-based monitoring systems.

As presented in Figure 14, the regional distribution of burned areas (2022–2025) reflects the spatial outcome of this integrated assessment approach, combining EFFIS fire perimeters with canopy density thresholds to quantify fire-induced forest degradation.

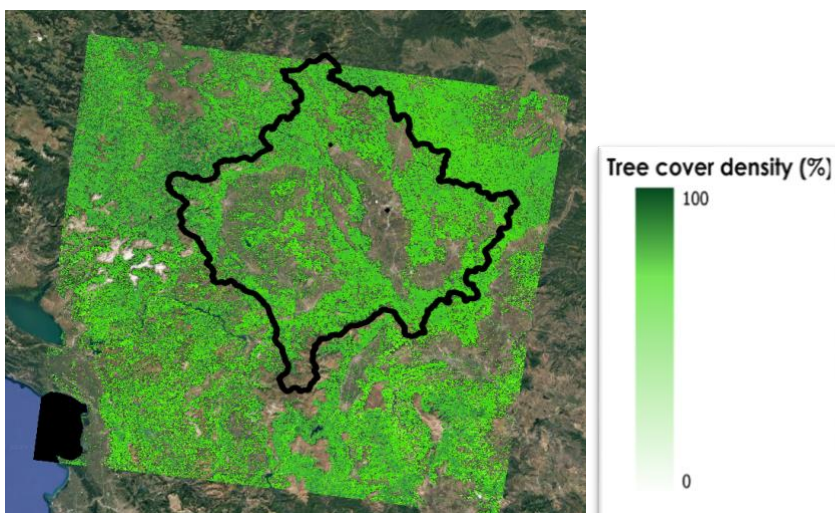


Figure 14. Distribution of burned areas by regions in Kosovo (2022–2025).

Regional breakdown of fire-affected surfaces following spatial intersection of EFFIS burned area polygons with Tree Cover Density (10 m). Source: Copernicus Land Monitoring Service (TCD) and EFFIS, elaborated by the authors.

KEY FEATURES OF THE DATASET

The Tree Cover Density (TCD) dataset used in this analysis is not a binary forest/non-forest product. Instead, it represents a continuous model of canopy density, where each 10-meter pixel contains a value ranging from 0% to 100%, indicating the proportion of ground area covered by tree crowns.

This continuous structure enables a significantly more precise and ecologically meaningful assessment of forest conditions compared to traditional threshold-based classifications. Rather than imposing an artificial cut-off (e.g., defining forest only above a fixed canopy percentage), TCD captures the full gradient of forest density across the landscape.

Such an approach is particularly important in the context of forest degradation assessment. Forest ecosystems rarely shift abruptly from “forest” to “non-forest.” Instead, disturbance often manifests progressively through:

- Thinning of canopy cover,
- Fragmentation of previously continuous stands,
- Emergence of vegetation mosaics,
- Transition zones between forest and agricultural or shrubland areas, and
- Partial structural damage caused by fires, logging or other pressures.

By capturing these gradients, TCD allows detection not only of complete canopy removal, but also of partial crown reduction and structural weakening. This makes it especially suitable for distinguishing between total forest loss and varying degrees of degradation — a distinction that is central to accurate environmental monitoring and reporting.

Figure 15 illustrates the spatial classification of canopy density across Kosovo, highlighting areas of high, medium, and low crown cover. The variation visible in the map demonstrates how canopy density is distributed heterogeneously, reflecting differences in forest structure, management history, and disturbance intensity. The TCD dataset is derived from 10-meter resolution Sentinel-2 imagery, processed through advanced algorithms for canopy detection and spectral modelling. The high spatial resolution ensures strong positional alignment with other Copernicus products and Sentinel-2-based analyses used in this report. This spatial

consistency enhances analytical reliability, particularly when intersecting TCD with EFFIS fire polygons or performing multi-temporal change assessments.



Figure 15. Classification of forest cover density by Tree Cover Density (TCD). Spatial distribution of tree crown density (%), based on the Copernicus Tree Cover Density product (10 m resolution). Source: Copernicus Land Monitoring Service (CLMS), elaborated by the authors.

From a regulatory perspective, the use of the Copernicus Tree Cover Density dataset ensures methodological compatibility with European forest monitoring and reporting systems. As part of the Copernicus Land Monitoring Service (CLMS), TCD is aligned with EU-wide geospatial standards and supports Monitoring, Reporting and Verification (MRV) requirements under evolving European frameworks related to climate mitigation, LULUCF accounting, biodiversity strategy implementation, and the forthcoming EU Forest Monitoring Law. The use of harmonized, high-resolution Copernicus products strengthens the comparability of Kosovo's forest assessments with EU Member State methodologies and facilitates future alignment with EU environmental acquis and reporting obligations.

INTERPRETATIONS OF THE RESULTS

The data for the period 2022–2025 reveal an unusually pronounced and structurally significant fire dynamic across Kosovo, resulting in a total of 35,259 hectares affected by fire. What is immediately evident is the highly uneven temporal distribution of burned areas across the four-year interval.

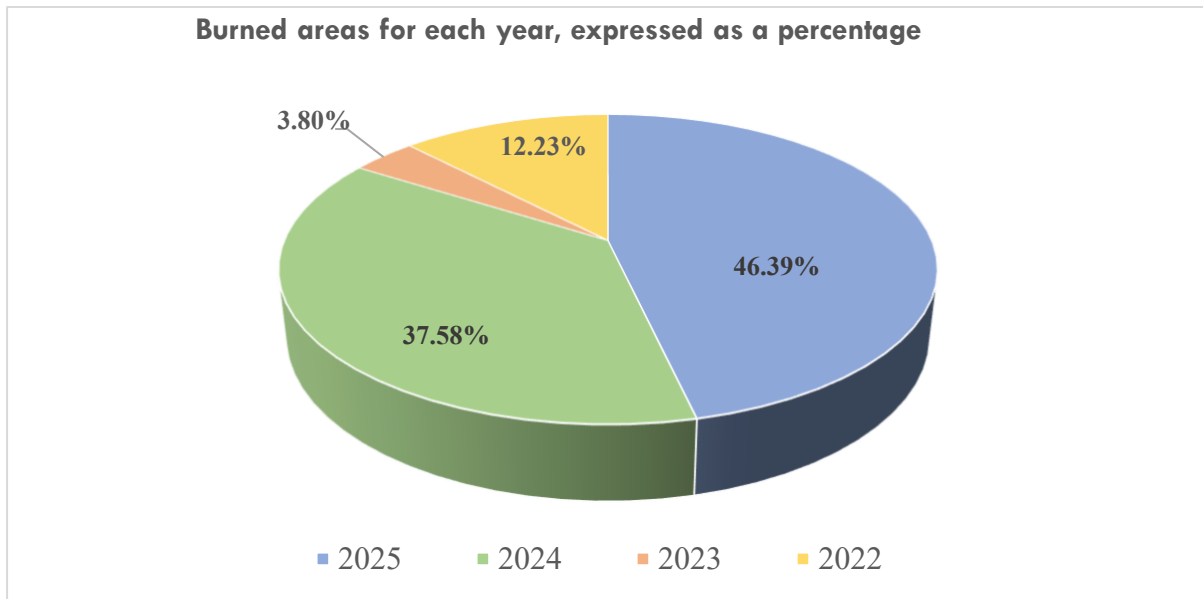


Figure 16. Burned areas for each year (2022–2025),

As illustrated in Figure 16, nearly half of the total burned areas occurred in 2025 alone, which accounts for 46.39% (16,358 ha) of the total area affected during the period. This concentration represents a record level within the analysed timeframe and strongly suggests the convergence of multiple reinforcing drivers: extreme climatic stress (prolonged drought, high summer temperatures), increased anthropogenic ignition sources, and possible constraints in early detection and rapid response mechanisms.

The situation in 2024 also reflects significant escalation, with 13,249 ha burned (37.58%). Together, 2024 and 2025 account for more than 84% of the total burned area, clearly identifying this two-year phase as the most critical fire period within the 2022–2025 interval.

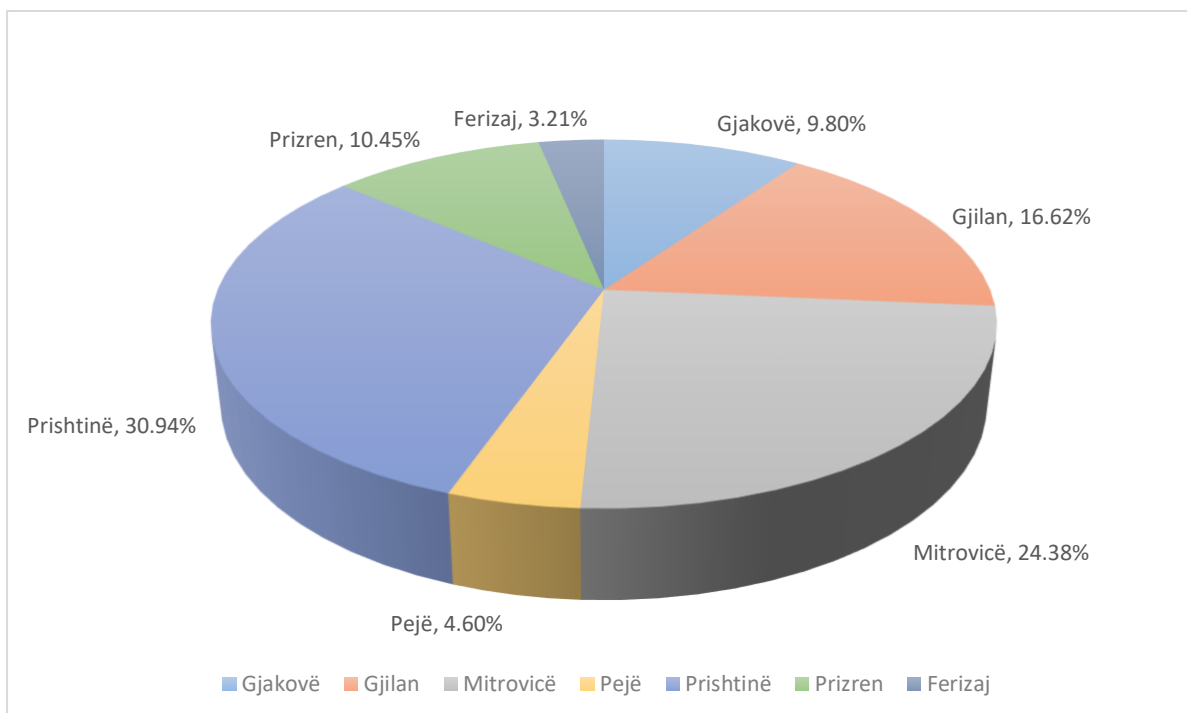


Figure 17.-Distribution of burned areas by municipality for the period 2022-2025

This confirms that this spike is not merely proportional but structurally substantial in absolute land impact. In contrast, 2022 (4,311.45 ha; 12.23%) and 2023 (1,340.71 ha; 3.80%) present significantly lower values. The pronounced inter-annual variation indicates that fire intensity in Kosovo is not constant but responds to fluctuating climatic conditions, land management practices, and patterns of human activity.

Overall, the temporal trend demonstrates a sharp escalation in fire risk in the final two years of the period, underscoring the need for strengthened prevention, monitoring systems, and adaptive response capacities.

REGIONAL DISTRIBUTION OF BURNED AREAS

Burned areas are not spatially uniform across Kosovo. The spatial distribution reveals clear geographic concentration patterns, suggesting differentiated ecological vulnerability and exposure to anthropogenic pressures. Figure 17 illustrates that fire impacts are not spatially uniform. Instead, they exhibit distinct geographic clustering patterns. Burned areas are concentrated in specific corridors and landscape units rather than dispersed evenly across the territory. These patterns suggest that fire occurrence is strongly influenced by a combination of forest structure, terrain morphology, exposure to prevailing winds, seasonal dryness, and human accessibility.

Regions characterized by continuous forest stands, fragmented peri-urban interfaces, or increased road access appear particularly vulnerable. In addition, slope orientation and elevation gradients may influence fire spread dynamics, especially in areas exposed to prolonged summer drought conditions.

The regional breakdown shows:

- Prishtina: 10,909 ha (30.94%)
- Mitrovica: 8,595 ha (24.38%)
- Gjilan: 5,860 ha (16.62%)
- Prizren: 3,686 ha (10.45%)
- Gjakova: 3,454 ha (9.80%)
- Peja: 1,621 (4.60%)
- Ferizaj: 1,131 (3.21%)

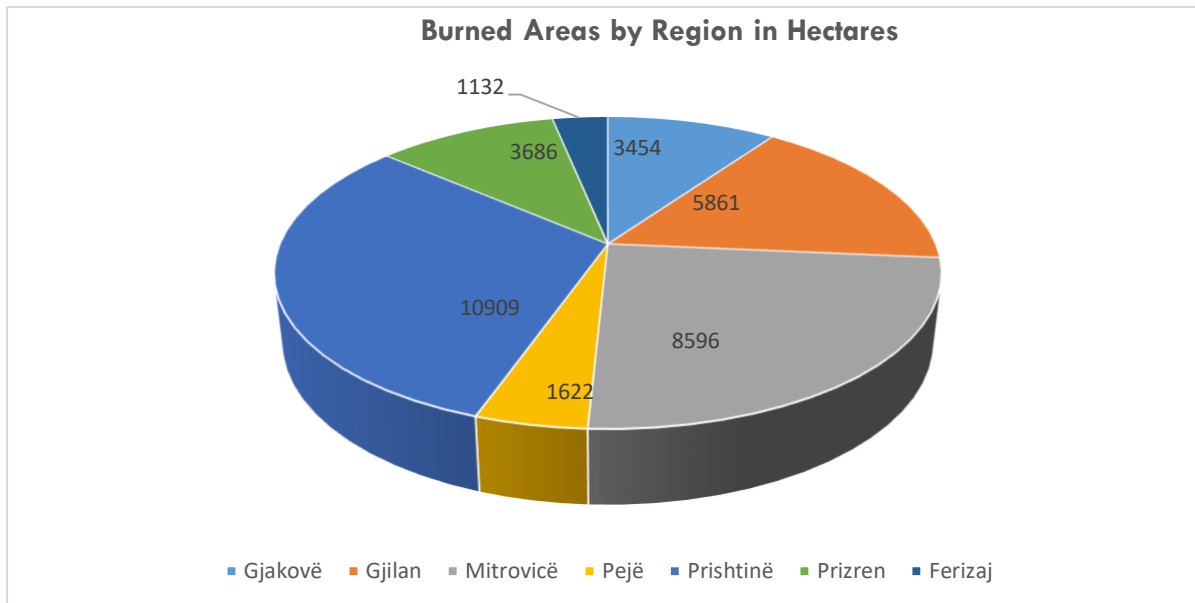


Figure 18. Burned areas by regions in Hectares (2022–2025)

Prishtina emerges as the most affected region, accounting for nearly one-third of the national burned area. This may reflect the interaction between dense forested zones, expanding peri-urban development, recreational pressures, and high levels of human mobility. Increased accessibility can elevate ignition probability, whether accidental or intentional.

Mitrovica ranks second, with nearly a quarter of the total burned surface. The region’s combination of forest cover continuity and dry seasonal conditions may create landscapes that are particularly susceptible to rapid fire spread once ignition occurs.

Together, Prishtina and Mitrovica account for more than half of the national burned area, indicating a pronounced spatial concentration of fire risk. This clustering highlights the importance of regionally differentiated fire prevention and response strategies rather than uniform national approaches.

Gjilan and Prizren represent intermediate levels of impact, while Gjakova, Peja, and Ferizaj show lower absolute values. However, absolute burned hectares must be interpreted relative to each region’s total forest extent, forest density, and ecological sensitivity. In smaller or more fragmented forest systems, even moderate fire events may have disproportionately high ecological consequences.

Overall, the regional distribution suggests that fire occurrence in Kosovo is not random but structurally conditioned by landscape configuration, climatic exposure, and land-use intensity. This reinforces the need for spatially targeted prevention policies, improved early-warning systems, and region-specific forest management interventions aligned with adaptive risk mapping frameworks.

From a climate governance perspective, these spatial patterns are highly relevant for adaptation planning and risk management alignment with European frameworks. Under the

EU Climate Adaptation Strategy, the EU Civil Protection Mechanism, and Copernicus-based risk monitoring systems, member and candidate countries are expected to develop territorially differentiated risk assessments and early-warning capacities. The concentration of fire impacts in specific regions of Kosovo underscores the need for regionally calibrated climate adaptation measures, integrated fire-risk mapping, and strengthened Monitoring, Reporting and Verification (MRV) systems. Embedding spatial fire-risk analysis into national climate adaptation strategies would enhance policy coherence, improve preparedness, and support gradual alignment with EU disaster risk governance standards.

FOREST VS. NON-FOREST FIRE IMPACT (TCD–EFFIS INTERSECTION)

To determine how much of the burned surface affected forest ecosystems (rather than mixed land covers inside broader fire perimeters), a spatial intersection was conducted between EFFIS burned area polygons and the Copernicus Tree Cover Density (TCD) dataset. This step is methodologically important because EFFIS polygons delineate burned perimeters that often include heterogeneous land cover types (e.g., forests, shrublands, pastures, agricultural land, and artificial surfaces). Without intersecting with an independent canopy-density dataset such as TCD, burned area totals could be misinterpreted as forest damage.

The analysis indicates that out of 35,259.65 ha affected by fire during 2022–2025, approximately 17,176 ha correspond to areas that had significant tree canopy cover prior to the fire event, based on TCD values. In practical terms, this means that roughly half of all burned surfaces intersected with canopy-bearing areas — representing direct impacts on forest structure and function, and therefore higher ecological and climate significance than burns occurring in non-forest land categories.

Building on this intersection result, the report then derives the spatial footprint of forest degradation from fires, isolating the burned forest component (rather than total burned land).

Figure 20 visualizes the geographic distribution and extent of forest areas identified as degraded by fire during the analysed period. The map reinforces that fire impacts on forests are not only substantial in magnitude, but also spatially concentrated, which has implications for targeting prevention measures, restoration planning, and prioritisation of monitoring resources.

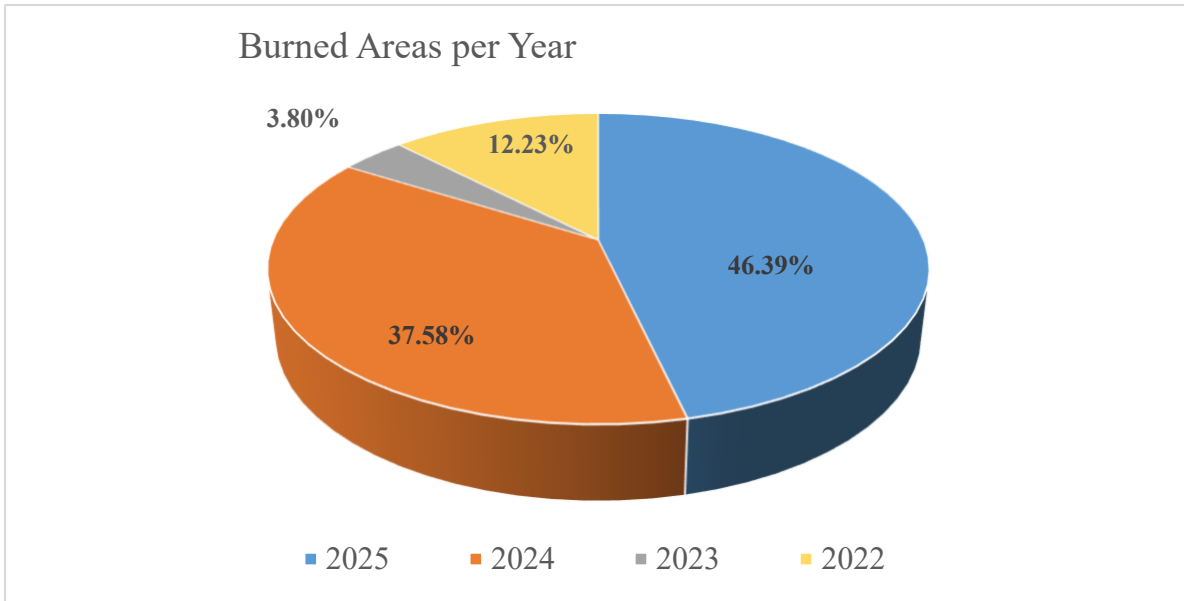


Figure 19. Overlapping EFFIS Polygons with Tree Cover Density (TCD)

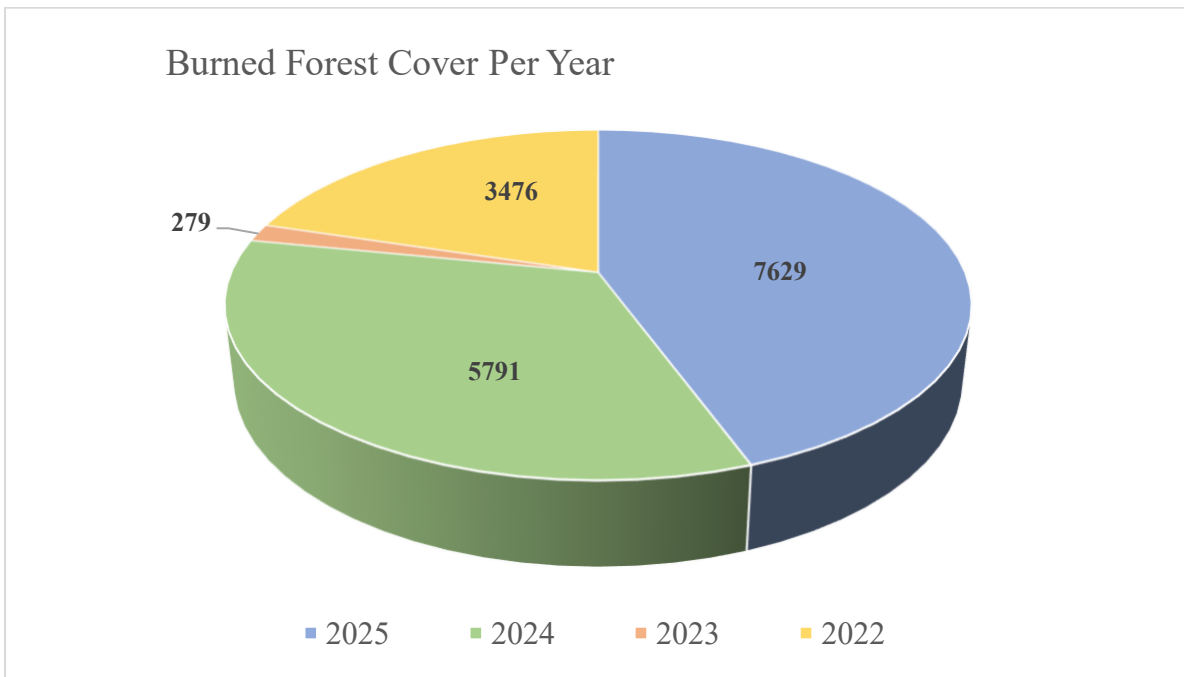


Figure 20. Degraded forests because of fires in the period 2022–2025

To understand how this forest degradation evolves over time, the inter-annual distribution of degraded forest area is analysed as a share of the total.

Figure 21 shows that 2024 and 2025 dominate forest degradation, mirroring the overall burned-area pattern but expressing it specifically for forest ecosystems. This is a critical distinction: even when total burned area fluctuates, what matters most for forest policy and climate resilience is the proportion and scale of damage occurring in canopy-dense forest landscapes.

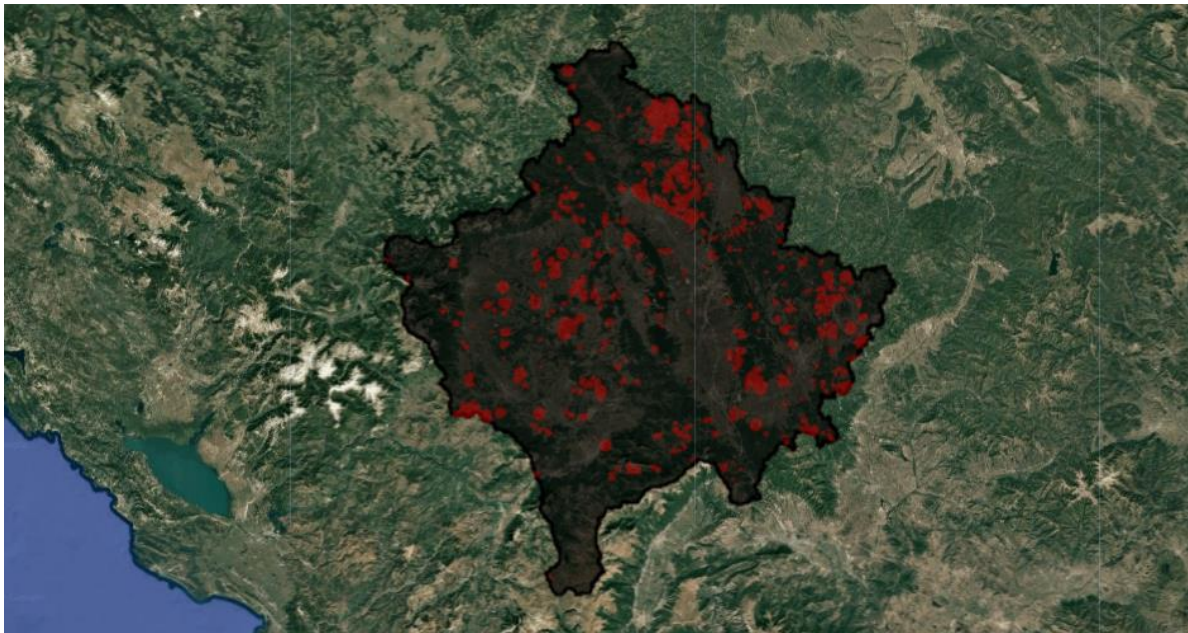


Figure 21. Inter-year distribution of forest degradation from fires (%)

Only after establishing (i) *how much burned area is forest* (Figure 20), and (ii) *where and when forests were degraded* (Figures 21 and 22), the analysis presents the aggregated forest vs. non-forest share of total burned land.

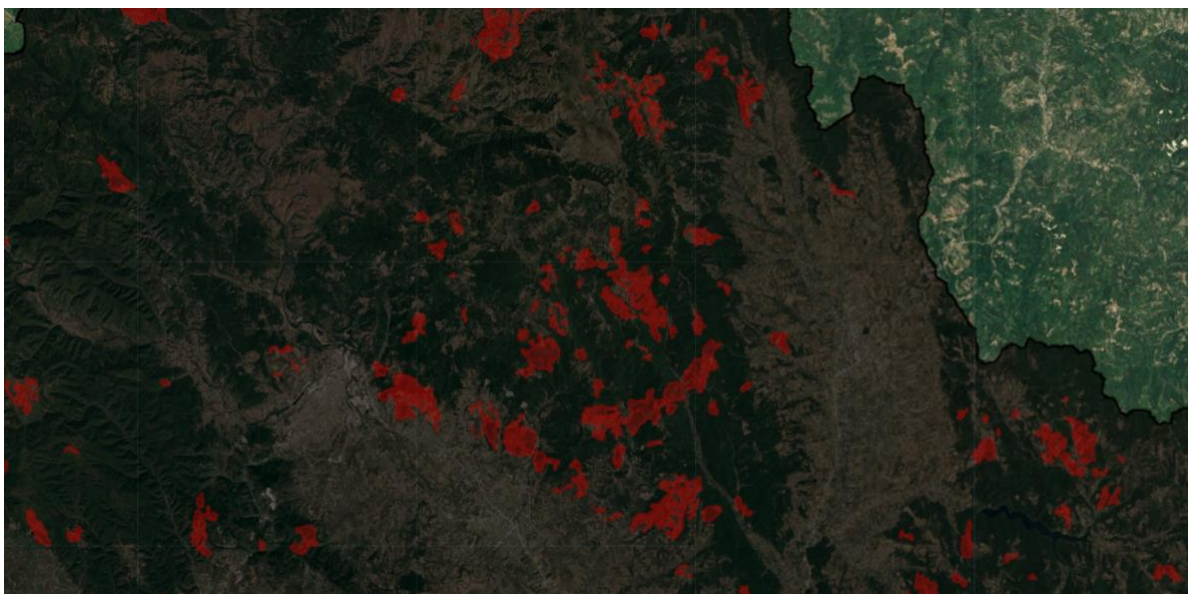


Figure 22. Ratio between forest and non-forest burned areas (2022–2025)

Figure 22 indicates that approximately 49% of total burned area was forested prior to burning, while 51% corresponds to non-forest categories (pastures, shrublands, agricultural lands, bare land, and artificial surfaces). This ratio is policy-relevant: while all burned land experiences ecological disturbance, forest degradation carries disproportionately higher implications for carbon sequestration capacity, biodiversity integrity, hydrological stability, and soil protection, and therefore requires differentiated prevention and recovery strategies.

To consolidate the key quantitative findings presented above, Table 1 provides an integrated summary of total burned areas, forest-specific impacts, and inter-annual distribution for the period 2022–2025.

Year	Total Fire-Affected Area (ha)	Share of Total Fire-Affected Area (%)	Forest Area Affected (ha)*	Share of Forest Impact (%)
2022	4,311	12.23%	3,476	20.24%
2023	1,340	3.80%	279	1.63%
2024	13,249	37.58%	5,791	33.72%
2025	16,358	46.39%	7,629	44.42%
Total	35,259	100%	17,176.	100%

Methodological Note: Burned area figures are derived from EFFIS fire perimeters. Forest-specific impacts are calculated through spatial intersection with Copernicus Tree Cover Density (10 m resolution) to isolate areas with significant pre-fire canopy cover. Percentages reflect proportional distribution within the 2022–2025 observation period.

SYNTHESIS OF KEY FINDINGS

The analysis of fire-affected areas and forest ecosystem impacts for the period 2022–2025 reveals a clear structural escalation of fire risk in Kosovo, particularly during the 2024–2025 period. The concentration of more than 84% of total burned surfaces within two consecutive years indicates not a random fluctuation, but a systemic vulnerability linked to climatic stress, land-use pressures, and institutional response capacity.

Spatial analysis confirms that fire impacts are regionally asymmetric, with strong concentration in Prishtina and Mitrovica. This pattern reflects the interaction between ecological exposure (forest continuity, terrain, dryness) and anthropogenic drivers (accessibility, land-use intensity, settlement expansion). The uneven distribution suggests that national fire risk is shaped by territorial dynamics rather than uniform climatic drivers alone.

The intersection between EFFIS burned polygons and Tree Cover Density (TCD) data demonstrates that nearly half (49%) of all fire-affected areas correspond to actual forest ecosystems. This finding is methodologically significant, as it differentiates between general burned land and true forest degradation. Approximately 17,176 hectares of forest ecosystems experienced canopy-impacting fire disturbance during the analyzed period.

The temporal distribution of degraded forest areas closely mirrors the pattern of total burned surfaces, with 2025 representing the most severe year in both absolute and proportional terms. This confirms that recent fire events have had not only spatial magnitude but also structural ecological consequences.

Taken together, the findings indicate that forest fire impacts in Kosovo during 2022–2025 are not episodic anomalies but reflect increasing systemic exposure. Without strengthened prevention, early detection, territorial risk planning, and ecosystem-based management, such patterns may intensify under projected climate scenarios.

CONCLUSION

The analysis for the period 2022–2025 clearly demonstrates the real scale of fire impact and tree canopy cover loss in Kosovo. During this period, a total of 35,259.65 hectares were identified as burned surfaces, of which approximately 17,176 hectares (around 49%) correspond to areas that had significant forest canopy cover prior to fire events. This finding confirms that nearly half of all recorded fire damage directly affected forest ecosystems, with substantial implications for biodiversity integrity, carbon sequestration capacity, and hydrological stability.

The inter-annual distribution of damage shows a marked escalation of risk, with 2025 emerging as the most critical year of the analysed period. The exceptionally high intensity of fires in 2024–2025 reflects a convergence of climatic stressors (prolonged drought and extreme temperatures), anthropogenic pressures, and limitations in early detection and rapid response systems. These dynamic underscores the need to integrate wildfire management more systematically into national climate adaptation policies, in line with the EU Strategy on Adaptation to Climate Change and evidence-based risk governance principles.

The results further indicate that tree canopy cover loss is not an isolated or sporadic phenomenon, but part of a broader pattern of pressure on forest resources. Logging (both legal and illegal), land-use expansion, demand for fuelwood, urbanisation, agricultural conversion, and fires have collectively generated structurally degraded forest landscapes. These developments stand in tension with the objectives of the EU Forest Strategy for 2030, which emphasises resilience, sustainable forest management, and strengthened monitoring systems grounded in scientific data.

The report demonstrates that satellite-based monitoring (Global Forest Change, Tree Cover Density, EFFIS), combined with multi-temporal visual verification (Sentinel-2 and Google Earth), provides a robust foundation for Monitoring, Reporting and Verification (MRV) systems. This approach aligns with the EU LULUCF Regulation requirements and broader climate transparency obligations under the Paris Agreement. It strengthens institutional capacity for harmonised environmental reporting under the Green Agenda for the Western Balkans and supports progressive alignment with the EU environmental acquis.

The fact that approximately 49% of burned areas were forested prior to fire events highlights the urgency of restoration measures consistent with the objectives of the EU Nature Restoration Law and the Kunming–Montreal Global Biodiversity Framework. Forest

ecosystems represent not only natural capital, but critical green infrastructure for flood mitigation, slope stabilisation, biodiversity conservation, and long-term climate resilience.

Beyond environmental considerations, the findings also reveal a socio-economic dimension of forest pressure. Dependence on biomass for heating, management gaps in private forest ownership, and enforcement constraints contribute to cumulative degradation risks. Strengthening forest governance, integrating continuous remote sensing into decision-making processes, and improving regeneration monitoring are therefore essential to balance economic development with ecosystem protection.

In conclusion, the findings position forest management as a strategic national priority with both climate and European integration relevance. Kosovo's forests remain a key asset for climate resilience, biodiversity protection, and emissions mitigation. Achieving these objectives requires an integrated, data-driven, and institutionally coordinated approach aligned with European and global environmental governance frameworks.

RECOMMENDATIONS

The recommendations presented below are grounded in the empirical findings of the 2022–2025 forest loss and fire impact analysis. They are aligned with Kosovo's Forestry Sector Strategy (2022–2030), the Law on Forests, and the country's progressive alignment with the European Union environmental acquis. This includes the EU Forest Strategy for 2030, the European Green Deal, the EU Climate Adaptation Strategy, and the EU Nature Restoration Law, as well as relevant global biodiversity and climate frameworks.

The evidence generated through this analysis demonstrates that Kosovo now possesses a sufficiently robust analytical foundation to transition from predominantly reactive forest management toward a systematic, data-driven and risk-based governance model. The recommendations therefore focus on strengthening institutional capacity, improving spatial prioritisation, enhancing enforcement mechanisms, and aligning forest governance with climate resilience and biodiversity objectives under the Green Agenda for the Western Balkans.

1. INSTITUTIONALISATION OF SATELLITE MONITORING AS A PERMANENT GOVERNANCE TOOL

The analysis confirms that satellite-based datasets provide reliable, spatially explicit and inter-annually comparable evidence of forest canopy cover loss and fire-related degradation. Despite their demonstrated value, the use of such datasets in Kosovo remains largely project-based and externally driven.

It is therefore recommended that satellite-based monitoring be formally institutionalised within the national forest governance framework. The systematic integration of datasets such as Global Forest Change, Copernicus Tree Cover Density and EFFIS into annual reporting

processes would significantly strengthen transparency, accountability and performance monitoring across the forestry sector.

Institutionalising these tools would also enable the development of structured Monitoring, Reporting and Verification (MRV) systems aligned with EU LULUCF reporting requirements and broader climate transparency frameworks. Importantly, embedding satellite data into decision-making processes would allow public institutions to directly link observed forest loss to inspection priorities, budget allocation and restoration planning.

This shift from ad hoc analysis to continuous monitoring represents a critical step toward evidence-based governance, improving policy coherence and enabling measurable environmental outcomes.

2. RISK-BASED SPATIAL PRIORITISATION OF INTERVENTION AREAS

The spatial analysis identifies clear and recurring hotspots of forest canopy loss and fire impact across the analysed period. These patterns indicate that forest degradation in Kosovo is not random but concentrated in structurally vulnerable areas exposed to persistent ecological and socio-economic pressures.

These areas should therefore be recognised as priority intervention zones within national and municipal planning frameworks. Moving from a reactive to a risk-based spatial planning approach would enable institutions to target restoration, fire prevention and enforcement measures where impacts are most significant and where intervention yields the highest ecological and climate return.

Integrating hotspot mapping into spatial planning instruments—including forest management plans, municipal development plans and land-use zoning frameworks—would improve the efficiency and effectiveness of public investments. It would also support a more strategic allocation of limited financial and institutional resources, ensuring that interventions are aligned with ecosystem vulnerability, biodiversity value and climate risk.

3. STRENGTHENING GOVERNANCE OF PRIVATE FORESTS AND REDUCING INFORMAL PRESSURE

Given that a significant proportion of Kosovo's forest area is privately owned, sustainable forest governance cannot be achieved without addressing the management and oversight of private forests. The findings of this analysis indicate that privately owned forest areas are particularly vulnerable to gradual canopy loss and degradation, often driven by a combination of weak supervision, limited technical capacity and sustained socio-economic pressures.

In particular, the continued reliance on firewood for heating, alongside land-use pressures, contributes to incremental and often unregulated extraction. These dynamics highlight the

need to move beyond regulatory frameworks alone and toward a more integrated governance approach that combines oversight, support and incentives.

Strengthening private forest governance requires the clarification and enforcement of management obligations, supported by targeted technical assistance for forest owners. In parallel, the development of incentive-based mechanisms—such as support for sustainable harvesting practices, reforestation, and alternative energy solutions—would help reduce informal extraction pressures while promoting long-term ecosystem resilience.

Better integration of forest policy with rural development and energy transition strategies will be critical to addressing the underlying drivers of degradation. This approach aligns with the objectives of the European Green Deal and reflects principles embedded in the EU Common Agricultural Policy related to sustainable land stewardship and multifunctional land use.

Addressing private forest governance is therefore not only a regulatory issue, but a systemic one, requiring coordinated action across forestry, energy and rural development sectors to achieve durable and measurable outcomes.

4. DEVELOPMENT OF AN INTEGRATED WILDFIRE PREVENTION AND RISK MANAGEMENT SYSTEM

The analysis identifies wildfires as the most significant driver of ecosystem degradation during the 2022–2025 period. The concentration of burned areas, particularly in the later years of the analysis, suggests an increasing interaction between climate variability and human-induced pressures, resulting in heightened systemic risk.

This trend underscores the need to move beyond reactive fire response toward a comprehensive and integrated wildfire risk management approach. Such a system should combine early detection, risk modelling, prevention, response coordination and post-fire ecological assessment within a unified institutional framework.

Satellite-based services, including EFFIS and Sentinel-2, provide a strong foundation for early detection and real-time monitoring. These tools should be complemented by strengthened field-based surveillance, improved data sharing across institutions, and the development of predictive risk models that incorporate climatic, topographic and land-use variables.

Institutional coordination between forestry agencies, emergency services and municipal authorities must be reinforced to reduce response times and improve preparedness. In parallel, post-fire assessments using datasets such as Tree Cover Density should be systematically integrated into recovery and restoration planning to ensure that ecological impacts are properly quantified and addressed.

This integrated approach aligns with the EU Climate Adaptation Strategy and the Sendai Framework for Disaster Risk Reduction, supporting a shift toward proactive risk management and enhanced climate resilience. It also contributes directly to the Biodiversity Pillar of the

Green Agenda for the Western Balkans by strengthening ecosystem resilience and reducing the long-term impacts of disturbance.

5. INTEGRATION OF SATELLITE EVIDENCE INTO INSPECTION AND LEGAL ENFORCEMENT

The analysis demonstrates that satellite-derived data provide clear, spatially explicit evidence of forest canopy loss, including both authorised activities and potential unauthorised disturbances. However, the systematic use of such data within inspection and enforcement processes in Kosovo remains limited.

It is therefore recommended that geospatial analysis be formally integrated into environmental inspection and compliance systems. The routine use of satellite-based evidence would enable institutions to identify and prioritise areas of concern, including suspected illegal logging, unregulated land-use change, and non-compliance with forest management obligations.

Integrating these tools into inspection workflows would significantly enhance transparency, consistency and efficiency. It would allow for more targeted field inspections, reduce reliance on ad hoc reporting, and improve the ability of institutions to detect patterns of repeated or cumulative violations over time.

In addition, satellite monitoring can support the verification of compliance with legal obligations, including regeneration requirements following authorised harvesting, and environmental conditions linked to infrastructure or land-use permits. This creates a more robust evidence base for enforcement actions and reduces the scope for informal practices to go undetected.

Strengthening inspection systems using geospatial data aligns Kosovo with the EU Environmental Compliance Assurance Framework, which emphasises risk-based inspections, transparency and evidence-driven enforcement. It also supports broader governance objectives under the Biodiversity Pillar of the Green Agenda for the Western Balkans by reinforcing institutional accountability and reducing pressures on forest ecosystems.

6. EVIDENCE-BASED REFORESTATION AND RESTORATION PLANNING

The analysis highlights clear spatial patterns of forest canopy loss and fire-related degradation, providing a strong basis for more targeted and effective restoration efforts. Current reforestation initiatives, while valuable, are often implemented in a dispersed and non-prioritised manner, limiting their long-term ecological impact.

It is therefore recommended that reforestation and restoration planning be directly informed by spatial analysis of degradation and regeneration capacity. Priority should be given to areas exhibiting sustained canopy loss, high fire recurrence, and limited natural regeneration

potential, where intervention is most needed and most likely to generate measurable ecological benefits.

Restoration strategies should prioritise the use of native and climate-adaptive species, supported by site-specific ecological assessments. Integrating spatial risk data into species selection, planting design and timing will improve survival rates, enhance ecosystem resilience and reduce the likelihood of repeated degradation.

This approach represents a shift from activity-based reforestation toward outcome-based ecosystem restoration. It aligns with the EU Nature Restoration Law and the objectives of the UN Decade on Ecosystem Restoration, which emphasise measurable recovery of ecosystem structure and function.

Data-driven restoration models—such as those demonstrated through the Green Wings programme—illustrate how combining spatial analysis, innovative delivery methods and community engagement can significantly increase both ecological effectiveness and social impact.

Embedding such approaches within national and municipal restoration frameworks will be critical to ensuring that reforestation contributes meaningfully to climate adaptation, biodiversity recovery and long-term landscape resilience.

7. STRENGTHENING COMMUNITY ENGAGEMENT AND SOCIAL RESILIENCE

The analysis indicates that pressures on forest ecosystems are closely linked to underlying socio-economic dynamics, including energy dependency, land-use practices and local livelihoods. As such, sustainable forest governance cannot be achieved through technical and institutional measures alone but requires structured and sustained engagement with local communities.

It is therefore recommended that community engagement be integrated as a core component of forest governance, rather than treated as a supplementary activity. This includes the development of targeted educational programmes, participatory fire prevention initiatives, and community-based restoration efforts that actively involve local stakeholders in the protection and management of forest ecosystems.

Strengthening community engagement can contribute to reducing informal extraction pressures, improving early detection of fire risks, and fostering a sense of shared responsibility for natural resource stewardship. Importantly, such approaches support behavioural change over the long term, which is critical for the durability of policy and restoration outcomes.

Linking forest governance with social resilience strategies—particularly in relation to energy transition, rural development and climate adaptation—will further enhance the effectiveness of interventions. Empowered and informed communities are better positioned to adapt to

environmental changes, reduce dependency on unsustainable practices, and contribute to ecosystem recovery.

This integrated socio-ecological approach aligns with the Biodiversity Pillar of the Green Agenda for the Western Balkans and contributes to the achievement of Sustainable Development Goals 13 (Climate Action) and 15 (Life on Land). It also reinforces the principle that long-term environmental sustainability depends on the alignment of ecological objectives with social and economic realities

Area of Intervention	Concrete Action (GAWB-Aligned)	Kosovo Context / Gap	GAWB Biodiversity Pillar Alignment
Forest Monitoring	Establish a national biodiversity and forest monitoring system integrating satellite data (GFC, TCD, EFFIS) into a formal MRV framework with annual reporting obligations	Monitoring remains fragmented and project-based	Aligns with Biodiversity Monitoring & Evaluation Framework (MEF) and regional data harmonisation
Spatial Planning & Risk Mapping	Develop national forest risk maps (fire, degradation, biodiversity value) and integrate them into spatial and municipal planning instruments	No operational risk-based planning system	Supports evidence-based biodiversity planning and integration into sectoral policies
Private Forest Management	Introduce sustainable forest management schemes for private owners, including incentives, technical guidance, and compliance monitoring	Weak oversight and high informal pressure	Aligns with mainstreaming biodiversity into land-use and rural policy frameworks
Fire Prevention & Risk Management	Develop a national wildfire prevention system combining early warning (EFFIS), risk modelling, and coordinated response protocols	Reactive fire response, limited prevention capacity	Supports ecosystem resilience and climate–biodiversity integration
Law Enforcement & Compliance	Integrate geospatial evidence into inspection systems, enabling detection of illegal logging and enforcement tracking	Enforcement relies heavily on field inspection	Aligns with strengthened governance, compliance, and accountability mechanisms
Ecosystem Restoration	Implement targeted restoration programmes in degraded forest hotspots using native species and climate-adaptive approaches	Restoration is scattered and not prioritised	Directly aligned with ecosystem restoration targets (GBF / GAWB)
Green Infrastructure & Connectivity	Identify and restore ecological corridors and degraded landscapes to	No systematic approach to landscape connectivity	Aligns with development of green infrastructure and

	improve habitat connectivity and ecosystem services		Natura 2000-type connectivity
Biodiversity Data & Information Systems	Develop a centralised biodiversity data platform linking forest monitoring, fire data, and ecosystem indicators	Data is fragmented across institutions	Aligns with Western Balkans Biodiversity Information Hub and data sharing systems
Strategic Planning & Policy Integration	Align national forest and biodiversity policies with a long-term biodiversity strategy with measurable indicators and targets	Policies exist but lack measurable implementation frameworks	Aligns with WB Biodiversity Strategic Plan (BSP)
Community Engagement & Stewardship	Establish community-based forest stewardship programmes, including fire prevention, restoration, and education	Engagement is fragmented and short-term	Aligns with stakeholder engagement and participatory biodiversity governance

Methodological note: Alignment references reflect monitoring, reporting and verification (MRV)-relevant frameworks and regulatory directions applicable to EU approximation processes and international climate and biodiversity commitments.

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