



Publisher: Scientific-Professional Society for Disaster Risk Management

International Journal of Disaster Risk Management



Review Article

Human Security Implications of Illegal Logging: A Multidimensional Risk Analysis and Contextual Case Study of Serbia

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Received: 15 July 2026; Revised: 24 September 2026; Accepted: 5 October 2026; Published: 27 October 2026.

ABSTRACT

Illegal logging is a pervasive driver of global environmental degradation, state revenue loss, and threats to local communities. Beyond being a crime and causing environmental damage, illegal timber extraction fundamentally undermines key pillars of human security. This study applies the seven-dimensional human security framework defined by the United Nations Development Program (UNDP, 1994)—encompassing environmental, economic, political, health, food, personal, and community security—to examine the structural mechanisms and cascading risks associated with illegal logging. Using an analytical matrix, we synthesize global data and compare them with a case study of the Republic of Serbia. Official statistical data in Serbia show a 12.53 percentage-point increase in forest cover between 1979 and 2023 (representing a growth in reported forest area of approximately 51.5%). However, our analysis shows that this indicator primarily reflects changes in inventory methodology and the mass depopulation of rural areas, not ecological recovery. At the same time, remote sensing data indicate a loss of 74,200 hectares of forest cover between 2001 and 2023, evidencing the qualitative degradation of mature forest communities. This paper presents public policy mechanisms to combat forestry crime, including digital chain-of-custody monitoring, harmonized condition monitoring, and capacity building for judicial authorities.

KEYWORDS

Illegal logging, human security, forest governance, risk analysis, qualitative forest degradation, rural depopulation, Serbia.

1. Introduction

Illegal logging—the harvesting, processing, transportation, purchase, or sale of timber in violation of national and international laws—drives forest degradation worldwide (FAO, 2020). Researchers have traditionally evaluated it through ecological or economic lenses, but illicit forest exploitation creates complex socio-political feedback loops that undermine human well-being and governance stability (Hoare, 2015; INTERPOL, 2019).

To evaluate these systemic impacts, this paper utilizes the human security framework established by the United Nations Development Program (UNDP, 1994). Human security shifts the analytical focus from state-centric territorial defense to “freedom from fear and freedom from want,” encompassing seven interdependent dimensions: environmental, economic, political, health, food, personal, and community security.

This study pursues a twofold objective:

- To construct a multidimensional analytical matrix linking illegal logging mechanisms to the seven human security dimensions based on global empirical literature.
- To apply this framework to a contextual case study of the Republic of Serbia, reconciling national statistical trends with remote-sensing data and socioeconomic dynamics in a Southeast European transition economy.

1.1. Methodological Approach

This review follows a structured integrative synthesis rather than a statistical meta-analysis. The evidence base combines peer-reviewed research with authoritative institutional and national sources addressing illegal logging, forest degradation, human security, governance, livelihoods, health, disaster risk, and remote-sensing-based forest monitoring. We used recent peer-reviewed studies to update or triangulate older institutional estimates, while retaining Serbia-specific administrative and statistical materials where they provide context not available in international datasets.

Sources were considered relevant when they addressed at least one of five analytical domains: 1) drivers or prevalence of illegal logging; 2) environmental and geomorphological consequences of forest disturbance; 3) economic, political, health, food, personal, or community-security implications; 4) monitoring, enforcement, or timber-legality interventions; and 5) evidence specific to Serbia or the Western Balkans. Opinion pieces and media reports are not treated as primary evidence for causal claims; where such sources are retained for local case detail, their evidentiary role is explicitly limited to contextual illustration.

The retained evidence was coded deductively against the seven UNDP human-security dimensions and, where appropriate, against cross-cutting risk mechanisms linking drivers, exposure, vulnerability, institutional capacity, and cascading consequences. The qualitative evidence-strength descriptors in Table 1 are interpretive synthesis categories based on consistency across sources, evidence directness, and geographic breadth; they should not be read as formal certainty grades derived from meta-analytic effect sizes.

Because the underlying datasets differ substantially in spatial scale, time period, operational definitions, and measurement method, the study does not pool them into a single quantitative estimate. The study interprets national forest inventories, satellite-derived tree-cover loss, reported illegal-logging estimates, governance indicators, and violence data as distinct evidence streams. The comparison identifies convergent or divergent patterns, not temporal equivalence or direct causality between indicators collected for different purposes.

1.2. Research Questions and Contribution

The analysis is guided by two research questions: RQ1: Through which mechanisms does illegal logging generate cascading risks across the seven dimensions of human security? RQ2: How does the Serbian case differ from dominant international patterns of deforestation and illegal logging when official inventories, remote-sensing evidence, rural-demographic change, and institutional conditions are considered together? The paper's principal contribution is integrating forest crime, disaster-risk pathways, and human-security consequences into one analytical matrix, while explicitly distinguishing forest-area expansion from improvements in forest quality and legality.

2. Theoretical Framework: The Seven Dimensions of Human Security

The concept of human security provides a comprehensive framework for analyzing multidimensional threats (UNDP, 1994). When a seven-dimensional matrix is applied to natural resource management, it can reveal how environmental violations trigger chain reactions of vulnerability within social structures:

- Environmental security: Protection against short- and long-term environmental degradation, habitat loss, and climate destabilization.
- Economic security: Access to basic income, market stability, and protection against impoverishment or fiscal drain caused by resource exploitation.
- Political security: Protection of human rights and the preservation of the rule of law and institutional integrity against corruption and illicit networks.
- Health security: Preservation of conditions for healthy living, protection against environmental health risks and vector-borne diseases, and access to traditional natural medicine.
- Food security: Guaranteed physical and economic access to basic food supplies and resilient agricultural ecosystems.
- Personal security: Protection of individuals against physical violence, extortion, and harassment by state or non-state actors.
- Community security: Preservation of cultural identity, traditional livelihoods, and social cohesion among the local population.

In this study, risk is not synonymous with forest loss. Instead, illegal logging is conceptualized as a risk-generating process whose consequences depend on how the intensity of forest disturbance interacts with people's and ecosystems' exposure, pre-existing socioeconomic vulnerability, and the capacity of institutions and communities to prevent, absorb, and respond to harm. This framing is useful because similar levels of canopy disturbance can produce very different human-security outcomes depending on governance quality, livelihood dependence, terrain, and access to protective resources.

3. Multidimensional Risk Analysis Framework for Illegal Logging

To move beyond a broad descriptive catalog, this section analyzes how illegal logging interacts with the seven core dimensions of human security. Table 1 synthesizes these linkages, outlining the illicit mechanisms, direct/indirect implications, illustrative indicators, primary data sources, and regional scopes of evidence.

Table 1. Analytical Matrix: Human Security Dimensions and Illegal Logging Linkages

Human Security Dimension	Illegal Logging Mechanism	Direct & Indirect Consequences	Primary Indicators	Principal Data Sources	Geographic Scope & Evidence Strength
Environmental	Canopy clearance, unsustainable timber extraction, habitat fragmentation	Loss of biodiversity, disruption of local hydrological cycles, soil erosion, biomass loss	Gross tree-cover loss (ha), carbon emission estimates, erosion severity indices	Global Forest Watch (GFW), FAO FRA, IPCC reports	Global; Strong empirical evidence
Economic	Tax evasion, tariff avoidance, under-reporting quotas, market distortion	Deprived state revenue, artificially low timber prices, loss of legitimate forestry jobs	Uncollected forestry fees, price variance between legal/illegal timber, market loss (\$)	World Bank, INTERPOL, UNEP, EU FLEGT	Global / Regional (Tropical & Transition zones); High
Political / Governance	Corruption of public officials, illegal concession awards, institutional paralysis	Erosion of state legitimacy, weakening rule of law, mistrust in public authorities	Corruption Perceptions Index (CPI), Rule of Law Index, official inspection records	Transparency International, World Justice Project (WJP), Judicial data	Global; Robust comparative evidence
Health	Deforestation-driven vector habitat shifts, loss of medicinal flora, water pollution	Increased vector-borne disease risks (e.g., malaria dynamics) and reduced access to natural remedies.	Vector incidence rates, water turbidity, availability of local medicinal species	WHO, epidemiological literature, regional field surveys	Regional / Local (e.g., SE Asia, Amazon, Sub-Saharan Africa); Moderate
Food	Soil degradation, microclimate disruption, loss of non-timber forest products (NTFP)	Decreased agricultural yields, reduced availability of forest foods during drought	Local food vulnerability indices, soil fertility indicators, NTFP harvest yields	FAO, IFPRI, local agricultural extension reports	Local / Rural community level; Moderate
Personal	Violence by illegal operators, intimidation of forest guards and local populations	Assaults, extortion, death threats, homicides targeting environmental defenders	Reported killings, physical assaults, harassment incidents against activists/guards	Global Witness, Forest Peoples Program (FPP), police records	High-risk logging zones (e.g., LatAm, SE Asia, Balkans); Strong
Community	Forced displacement, disruption of traditional livelihoods, inter-ethnic tension	Degradation of community resilience, loss of cultural heritage, conflict escalation	Land dispute records, community displacement counts, social cohesion metrics	NGO field reports, ethnographic studies, local governance files	Community level / Indigenous territories; Moderate to Strong

Source: Authors. Evidence-strength labels are qualitative synthesis categories and do not represent formal meta-analytic certainty ratings.

3.1. Environmental Implications of Illegal Logging

Environmental history research shows that irresponsible natural resource exploitation can create environmental conditions inhospitable to community survival. However, evaluating the ecological pathways of illegal logging requires precise biogeochemical framing:

- **Carbon Dynamics:** Carbon storage per cubic meter of wood varies significantly depending on tree species, wood density, moisture content, and forest stand age. Forests represent major terrestrial carbon sinks, interacting alongside soils, peatlands, wetlands, and marine ecosystems in global carbon sequestration. Illegal logging removes mature canopy trees, reducing ongoing sequestration capacity and releasing stored carbon through biomass degradation or burning (Lawrence & Vande-car, 2015). A risk-based interpretation therefore requires attention to degradation within standing

forests, not only to complete land-cover conversion. Large-scale synthesis shows that timber extraction, repeated fire, drought, and edge effects can progressively erode forest structure and ecosystem services even where satellite or administrative classifications continue to identify an area as forest (Lapola et al., 2023). This distinction is central to the Serbian case, where a rise in reported forest area does not by itself establish improvement in stand condition or a decline in unrecorded extraction. The soil dimension is particularly relevant to the transition from environmental degradation to disaster risk. Global evidence based on hundreds of paired observations indicates that forest conversion can reduce soil carbon storage, nutrient cycling, and functional processes while reshaping microbial communities (Qu et al., 2024). These changes can reduce infiltration and soil cohesion, indirectly increasing sensitivity to erosion and hydrological extremes, especially when disturbance coincides with steep terrain or intense precipitation.

• **Hydrological and Soil Functions:** Forest canopies and root networks temper soil erosion, regulate microclimates, and facilitate groundwater recharge. While water retention capacity depends heavily on soil texture and organic matter depth, removing forest cover undeniably increases runoff velocity, heightening the risk of flash flooding and landslides during extreme weather events (Reboredo, 2013, pp. 296–298). Land-use and drainage research also shows that land-cover alteration can amplify flood susceptibility (Iftikhar & Iqbal, 2024). The relationship between forest removal and slope instability is also context-dependent rather than deterministic. Global and regional research indicates that reducing deforestation and restoring forest cover can create co-benefits for biodiversity conservation and landslide-risk reduction in vulnerable mountain regions (Li et al., 2022). At the same time, geomorphological studies show that the magnitude and duration of the landslide response depend on slope, regolith properties, rainfall, and landscape history; in one well-studied rift setting, deforestation increased landslide erosion for a limited post-clearing period, but the effect varied with geomorphic context (Depicker et al., 2021).

Historical and contemporary research converges on the conclusion that unsustainable forest exploitation can alter ecological conditions in ways that increase vulnerability to climate-related and hydrological hazards. The key mechanism is not simply tree removal but the cumulative degradation of canopy structure, soils, biodiversity, and ecosystem functions that regulate water, carbon, and local microclimates. For risk analysis, this means that selective or repeated disturbance can be consequential even where land remains formally classified as forest (Lapola et al., 2023; Qu et al., 2024).

Recent evidence reinforces the need to distinguish complete deforestation from forest degradation. In the Amazon, fire, edge effects, timber extraction, and extreme drought can generate carbon emissions comparable to deforestation, while also reducing dry-season evapotranspiration and causing substantial biodiversity losses (Lapola et al., 2023). Although these estimates are region-specific and should not be transferred mechanically to Serbia, they demonstrate why area-based forest statistics alone can underestimate ecological and security-relevant deterioration.

Trees also play a role in the atmospheric water cycle. If illegal deforestation is not prevented or at least mitigated, it can disrupt rainfall cycles in different parts of the world. A 2015 study shows that removing a large forest area in one part of the world can drive climate change across the planet (Lawrence & Wandecar, 2015). For example, some models suggest that deforestation in the Amazon basin could reduce rainfall over the American Midwest and northeastern China while boosting rainfall over eastern Africa and northern Europe. One reason is that forests cool the air and, if they disappear, could disrupt wind patterns and affect global climate conditions. (Lawrence & Vandecar, 2015: 28). In addition, tree canopies conserve soil moisture, thereby protecting it from wildfires and droughts. Canopies also provide shade during the day and heat retention at night, on which wildlife depends to a large extent. As much as 80 percent of plant and animal life lives in forests. (Amadeo, 2021).

Forest conversion and degradation also affect below-ground ecological processes that security assessments often omit. A global paired-site synthesis found that conversion of native forests to managed land uses alters soil microbial communities and reduces functions associated with carbon storage, nutrient cycling, and organic-matter decomposition (Qu et al., 2024). These processes matter for human security because reduced soil functionality can amplify erosion, lower ecosystem productivity, and weaken the regulating services that support agriculture and watershed stability.

In addition, illegal logging is considered a driver of natural disasters such as floods, landslides, and soil erosion. As Fernando Reboredo points out (Reboredo, 2013: 296, 298), such cases have already been observed in China and the Philippines. Namely, in the summer of 1998, the People's Republic of China experienced heavy rainfall that caused certain rivers, such as the Yangtze and Songhua, to overflow. The floods claimed several thousand lives, while 14 million people were left without their homes, with damage estimated at 26 billion dollars. Although heavy rain directly caused the floods, authorities determined that illegal deforestation was "the trigger for such a disaster." In the Philippines, in 2004, a massive landslide killed 1,800 people in Quezon province. Philippine authorities quickly determined that "illegal logging was one of the leading causes of the disaster" and "directed the military and police to crack down on illegal loggers and their financiers" (Reboredo, 2013, p. 298).

3.2. Economic Pathways

Illegal timber trade imposes severe financial burdens on resource-dependent nations. Illegal operators evade taxes, royalties, and export tariffs, placing illegally harvested timber on international markets at prices 7% to 16% below legal market rates (CRS, 2019, p. 1). This price suppression distorts markets and disincentivizes sustainable forest management (Hoare, 2015).

A broader institutional perspective helps explain why comparable forest resources can be associated with very different levels of illegal extraction across countries. Bösch's (2021) cross-national analysis found that illegal logging is systematically associated with indicators of economic and institutional development, including rule of law and control of corruption. This implies that forest crime cannot be addressed solely through technical forestry measures; fiscal governance, administrative accountability, and credible enforcement shape the causal environment in which illegal extraction becomes more or less feasible.

The following figures clearly illustrate the extent to which illegal logging has become a serious threat to economic security in recent years. At the beginning of the twenty-first century, illegal deforestation was estimated to cost governments worldwide 10 billion annually (WB, 2004: 12). By 2012, these losses had increased to an estimated USD 30–100 billion (Nellemann, 2012: 13; Amadeo, 2021). More recent INTERPOL estimates put annual economic losses at USD 51–152 billion (CRS, 2019, p. 1; GI, 2018). It should be noted, however, that these estimates do not include the reduction in timber prices caused by the influx of illegally harvested wood into the market, which is estimated at between 7 and 16 percent (CRS, 2019: 1). Nor do they account for the economic value of biodiversity loss, which, according to Amadeo (2021), amounts to an astonishing USD 4.5 trillion.¹

The economic effects of illegal logging extend beyond foregone taxes and royalties. Illegal supply can depress market prices, disadvantage compliant producers, and shift profits toward actors able to exploit weak enforcement or opaque supply chains. Cross-national evidence further suggests that illegal logging is associated with broader economic-institutional conditions, including rule of law, control of corruption, voice and accountability, and trajectories of economic development (Bösch, 2021). These findings support treating economic security and institutional quality as mutually reinforcing components of the same risk pathway rather than as separate consequences.

The profitability of illicit timber markets also creates incentives to persist when the expected benefits of illegal extraction outweigh the perceived probability and cost of detection. This makes enforcement capacity, transparency, and traceability economically relevant risk controls: they increase the likelihood that authorities identify illegal timber before it enters legitimate supply chains and reduce opportunities to launder it through intermediaries or processing facilities (Bösch, 2021; Thompson & Magrath, 2021).

¹ As Amadeo (2021) notes, more than half of all pharmaceutical products are derived from genetic resources.

3.3. Political and Governance Dynamics

Illegal forest exploitation thrives in environments with weak institutional oversight, bribery, and a compromised rule of law (Magrath et al., 2010, p. 15). Corruption and illegal logging reinforce each other: administrative corruption enables fraudulent logging concessions and uninspected transport, while illicit proceeds fund further political influence (Reboredo, 2013, p. 299).

Institutional weakness is not merely a background condition; it can be part of the operating mechanism of forest crime. A comparative cross-national study links the prevalence of illegal logging to governance variables such as voice and accountability, rule of law, and control of corruption (Bösch, 2021). Case evidence likewise shows that when organized criminal groups can combine bribery, intimidation, and impunity, communities and legitimate forest enterprises may lose both economic opportunities and the capacity to contest illegal extraction (García-Jiménez & Vargas-Rodriguez, 2021).

International legality regimes can improve transparency and create new governance structures, but their effects are neither automatic nor uniformly positive. A systematic review of EU FLEGT-related policies found evidence of governance improvements alongside persistent social and economic challenges in timber-supplying countries (Tegegne et al., 2022). Earlier analysis of the emerging transnational timber-legality regime similarly emphasized the value of interacting public regulation, certification, monitoring, and stakeholder participation, while warning that implementation gaps can weaken effectiveness (Overdevest & Zeitlin, 2014).

Illegal logging is driven by heterogeneous motives and opportunity structures, ranging from livelihood-based extraction and agricultural conversion to organized commercial operations and corruption-linked timber laundering. The governance risk becomes especially severe where public officials, criminal groups, and commercial actors interact through bribery, intimidation, fraudulent permits, or selective non-enforcement. Evidence from western Mexico illustrates how organized criminal control, corruption networks, intimidation, and institutional passivity can jointly accelerate forest degradation and weaken community forestry (García-Jiménez & Vargas-Rodriguez, 2021). These patterns align with broader green criminology concerns about environmental harm, unequal exposure, and weak accountability (Ignjatović, 2023).

The global extent of illegal logging remains difficult to quantify precisely because the activity is clandestine, legal definitions vary across jurisdictions, and many estimates combine different reference periods. Accordingly, interpret the percentages in Table 2 as historical, country-level estimates reported by the Congressional Research Service (2019), not as contemporaneous 2025 measurements. Their analytical value lies in illustrating the scale and geographic heterogeneity of reported forest illegality, rather than enabling direct statistical comparison with current governance indicators.

Table 2. Descriptive Comparison of Historical Illegal-Logging Estimates and 2025 Institutional Governance Indicators (Selected High-Risk Countries)

Country	Estimate of illegal logging relative to total forest logging ¹	Corruption Perceptions Index and Ranking for 2025 ²	Rule of Law Index and Ranking for 2025 ³
Brazil	50%	35 (107)	0,5 (78)
Cameroon	50-65%	26 (142)	0,36 (134)
Democratic Republic of the Congo	90%	20 (163)	0,34 (136)
Ghana	34-70%	43 (76)	0,54 (63)
Indonesia	60-80%	34 (109)	0,52 (69)
Laos	35-80%	34 (109)	/
Malaysia	35%	52 (54)	0,57 (56)

Papua New Guinea	70%	26 (142)	0,41 (117)
Peru	80-90%	30 (130)	0,48 (93)
Russian Federation	10-15% in the Northwest and 50% in the Far East	22 (157)	0,41 (119)

Note: Illegal-logging percentages are historical estimates compiled by the Congressional Research Service (2019) from earlier sources and are not temporally harmonized with the 2025 governance indicators. CPI scores range from 0 (highly corrupt) to 100 (very clean), while Rule of Law Index scores range from 0.00 (weakest) to 1.00 (strongest). The table is descriptive only and is not used for causal or inferential comparison across columns. Sources: ¹ Congressional Research Service; ² Transparency International; ³ World Justice Project: Rule of Law Index.

The European Forest Law Enforcement, Governance and Trade Agency warns that: “Illegal logging has a devastating impact on some of the world’s most valuable remaining forests, as well as on the people who live in them and rely on the resources they provide.” (EU FLEGT, 2020) In order to protect and restore European and global forest wealth in 2021, the following were adopted: The Communication from the European Commission - Towards a Healthy Planet for All, the EU Action Plan: Towards net-zero air, water and soil pollution, and the Communication from the European Commission on a long-term vision for the EU’s rural areas: Towards stronger, connected, resilient and prosperous rural areas by 2040, further emphasizing the importance of Union action to protect and enhance forest resilience. Forest resilience, but also the overall resilience of communities, is clearly at risk - the loss of forests and forest ecosystems is dangerously threatening the well-being of current and future generations, and possibly even the survival of humanity. Resilience extends across multiple dimensions and levels, capturing the adaptive capacities of individuals, groups, and communities (Cvetković, 2023). In contemporary discourse, scholars, policymakers, and governmental and non-governmental organizations widely use resilience to denote the capacities, abilities, skills, and knowledge that enable individuals and communities to respond to and recover from adverse conditions. (Kabir, Hossain, & Haque, 2022) In other words, evidence indicates that illegal logging is included in analyses of a single community’s resilience, as well as as a significant global challenge. Effective implementation of environmental regulation also depends on institutional capacity and governance alignment (Sudar et al., 2024). This multidimensional perspective is consistent with recent conceptual work that treats resilience as dynamic, cross-level, and actor-dependent (Milenković & Cvetković, 2025).

The policy literature suggests that legality assurance works best as a layered system rather than as a single trade restriction. FLEGT-style arrangements, due-diligence requirements, independent monitoring, civil-society participation, and certification can reinforce one another, but only where domestic institutions have sufficient capacity and incentives to act on the information generated (Overdevest & Zeitlin, 2014; Tegegne et al., 2022). For Serbia and neighboring Western Balkan systems, this places equal emphasis on technical traceability and on administrative, judicial, and cross-border enforcement capacity.

Growing recognition of the global ecosystem’s interdependence suggests that no state or economic system should externalize pollution or environmental risks to other regions to preserve the illusion of its own sustainability. Implementing sustainable development principles globally requires commitment from all stakeholders and emphasizes developed countries’ responsibility to help developing nations by facilitating access to advanced technologies. As global society becomes increasingly interconnected, sustainable development can only be achieved by balancing economic growth, environmental protection, and societal needs at the planetary level (Đorđević & Gačić, 2024)/

3.4. Personal, Community, Health, and Food Security Implications

Confrontations between illegal loggers, state rangers, and local environmental defenders frequently trigger violent outcomes. Table 3 presents a non-exhaustive subset of reported fatal attacks against

land and environmental defenders globally in 2016. Violence against environmental and land defenders should be interpreted as a governance and human-security outcome rather than as an isolated criminal-justice issue. Global evidence shows that environmental conflicts frequently involve criminalization, physical violence, and, in the most severe cases, killings of defenders, even where local mobilization contributes to more sustainable environmental outcomes (Scheidel et al., 2020). Research on forest-related violence further indicates that corruption, patrimonial power relations, and distrust of authorities can obstruct access to justice and leave community defenders exposed to recurrent harm (Grant & Le Billon, 2020).

Table 3. Reported Killings of Forest and Environmental Defenders in Selected Countries (2016)

Country	Reported Number of Victims
Brazil	49
Colombia	37
Philippines	28
India	16
Honduras	14
DR Congo	10

Source: Forest Peoples Program

Forest disturbance can alter vector habitats and human exposure in ways that affect disease transmission, but the relationship is strongly context-dependent. In the Brazilian Amazon, a large municipality-level analysis found that deforestation increased malaria incidence and also documented a feedback in which reduced malaria burden reduced subsequent forest clearing (MacDonald & Mordecai, 2019). Evidence from sub-Saharan Africa further shows that the association varies by household wealth and vector biology, with poorer households experiencing greater malaria vulnerability under deforestation exposure (Estifanos et al., 2024). These findings caution against universal causal claims while supporting inclusion of ecosystem change within health-security analysis. The health pathway therefore operates through coupled ecological and social mechanisms: land-cover change modifies breeding environments and human-vector contact, while poverty, housing quality, access to prevention, mobility, and health services condition who is most exposed and least able to cope. This interaction fits a human-security framework because environmental disturbance becomes a health risk only through specific exposure and vulnerability pathways, not through forest loss alone (MacDonald & Mordecai, 2019; Estifanos et al., 2024).

Forest degradation can affect food security through soil erosion, rainfall and microclimate changes, and reduced access to wild foods and non-timber forest products. Evidence from forest-dependent rural households shows that NTFPs can serve as primary, supplementary, and emergency income sources and can materially contribute to household resilience (Mukul et al., 2015). Their loss therefore represents more than a biodiversity impact: it can remove an informal safety net that households use to absorb income shocks, seasonal shortages, and livelihood disruptions. This livelihood function is especially important when evaluating community security. Dependence on forest products is unevenly distributed, and households with fewer alternative income sources may experience a larger welfare loss from restrictions, degradation, or enclosure of forest resources. Consequently, policies against illegal logging should distinguish organized commercial extraction from subsistence dependence and should combine enforcement with legitimate livelihood options, community participation, and access to legal forest benefits (Mukul et al., 2015).

4. Contextual Case Study: Illegal Logging and Forest Governance in Serbia

The Republic of Serbia provides an illustrative case study of a Southeast European transit and transition economy where historical socioeconomic shocks, rural depopulation, and institutional shifts complicate forest resource monitoring. To accurately evaluate forest cover trends, official statisti-

cal inventories must be carefully distinguished from remote-sensing indicators and reconciled with qualitative shifts in forest stand structure. Integrating multi-source GIS and remote sensing is particularly useful for distinguishing spatial risk patterns and land-cover-related processes (Rebouh et al., 2024).

4.1. Re-evaluating Official Forest Area Statistics

Official statistical yearbooks published by the Statistical Office of the Republic of Serbia (SORS) record a notable expansion of land classified as forest over recent decades (Table 4).

Table 4. Reported Forest Land Area (ha) in the Republic of Serbia (1979–2023)

Region	1979 ¹	2011 ²	2023 ³
Belgrade Region	N/A	37.886	53.851
Vojvodina Region	N/A	117.091	171.746
Šumadija and Western Serbia Region	N/A	899.480	1.271.245
Southern and Eastern Serbia Region	N/A	907.878	1.358.114
Total*	1 884 000 (24.32%)	1.962.335 (25.33%)	2.854.956 (36.85%)**

* Notes: Territorial coverage excludes the Autonomous Province of Kosovo and Metohija. Percentages reflect the proportion of national land territory classified as forest land. Sources: ¹ Federal Statistical Office of SFRY (1988); ² Statistical Office of the Republic of Serbia (2012); ³ Statistical Office of the Republic of Serbia (2024).

A mathematical examination of the reported figures indicates that the share of land classified as forest increased by 12.53 percentage points between 1979 and 2023 (from 24.32% to 36.85%). In relative terms, the reported physical forest area expanded by approximately 51.5% over these 44 years. Focusing on the more recent interval between 2011 and 2023, the reported share increased by 11.52 percentage points, representing an approximate 45.5% expansion in reported forest area.

However, interpreting these quantitative increases as unambiguous ecological recovery or as evidence of declining illegal logging would be methodologically unsafe. At least two processes may explain the divergence between reported forest area and forest condition: changes in inventory and land-cover classification practices, and ecological succession on abandoned agricultural land. The available evidence supports treating these as plausible explanatory mechanisms that require triangulation with stand-level inventory, field, and remote-sensing data rather than as single proven causes of the national trend.

- Methodological and classification effects: Long-term comparisons can be affected by changes in forest definitions, inventory design, mapping resolution, and the treatment of scrub or other woody land. For this reason, compare historical and contemporary national totals cautiously, paying close attention to metadata and classification rules, rather than assuming every reported hectare represents an ecologically equivalent forest stand.
- Land abandonment dynamics: Rural depopulation and agricultural abandonment are well documented across European mountain and marginal areas and can promote spontaneous woody succession on formerly cultivated land (Lasanta et al., 2017). Serbia also faces persistent rural abandonment and demographic decline in many settlements (Živanović et al., 2021). These processes can expand woody cover while creating stands that differ substantially from mature managed forests in age, structure, species composition, and ecosystem-service profile.

European evidence shows that land abandonment is spatially selective and especially important in mountain and marginal agricultural areas where demographic decline, accessibility constraints, and low profitability interact (Lasanta et al., 2017). In Serbia, documented rural abandonment provides

a credible demographic mechanism for localized spontaneous revegetation (Živanović et al., 2021). Nevertheless, attributing the national increase in reported forest area quantitatively to depopulation would require spatially explicit land-transition analysis; the present study therefore treats this mechanism as a supported interpretation rather than a measured national causal share.

The Republic of Serbia has no systematic record of illegal logging. The only official document offering a partial picture is a report by the State Audit Institution, which states that between 2017 and 2019, out of 87,735 m³ of timber illegally felled in state forests, 55,000 m³ resulted from illegal logging along the administrative line with the Autonomous Province of Kosovo and Metohija (DRI, pp. 7, 64). The same report notes that between 1999 and 2018, illegal logging occurred in the Ground Safety Zone across 8,852.36 hectares, involving the felling of 623,407.67 m³ of timber (DRI, p. 66).

4.2. Differentiating Satellite Disturbance Data from Illegal Deforestation

Complementary spatial data from Global Forest Watch (GFW, 2024) indicates that Serbia experienced approximately 74,200 hectares of gross tree-cover loss between 2001 and 2023, with peak annual canopy disturbances recorded in 2023 (approx. 7,900 ha).

In accordance with remote-sensing conventions, this figure measures gross tree-cover loss—defined as the removal or mortality of canopy structure exceeding 5 meters in height at a specified density threshold. Do not interpret it as equivalent to net deforestation or illegal logging. Gross tree-cover loss includes planned commercial timber harvesting, sanitary fellings, forest fires, windthrow damage, pest infestations, and unrecorded illegal extraction.

The coexistence of satellite-detected canopy loss and expanding official forest area highlights the difference between land-cover classification and forest condition. Satellite-detected disturbance can identify where canopy change has occurred. However, it cannot by itself determine whether the cause was legal harvest, sanitary cutting, fire, windthrow, pests, or illegal extraction. The Serbian case therefore requires integrating remote-sensing signals with forest-management records, inspection data, ownership information, and field verification before inferring legality or stand quality.

This interpretive caution is consistent with the remote-sensing literature. Reviews of forest-degradation monitoring emphasize that degradation is harder to detect than complete deforestation because it may leave the area classified as forest while altering biomass, structure, composition, and function (Gao et al., 2020). No single sensor or method is sufficient across all disturbance types; operational monitoring increasingly relies on combinations of optical imagery, radar, LiDAR, time-series analysis, and disturbance-specific validation (Mitchell et al., 2017).

4.3. Institutional Vulnerabilities and Security Implications

Historical socioeconomic stress and post-socialist institutional change provide important context for interpreting forest governance in Serbia. However, national evidence remains insufficient to quantify the full scale or organization of illegal logging over time. Available audit, journalistic, and administrative records indicate episodes of unrecorded extraction and enforcement difficulties, while broader Western Balkan research points to continuing challenges in public forest administration and especially weaker performance in private-forest governance (Stevanov et al., 2018). These sources support concern about institutional vulnerability but do not justify assuming that all unrecorded canopy loss is the product of organized forest crime.

Recent stakeholder evidence adds a contemporary regional perspective. A 2025 comparative study covering Finland, Lithuania, Romania, Serbia, and Greece identified illegal logging as one of the forest threats stakeholders reported in Serbia. They emphasized the importance of active management, stakeholder engagement, and policy reform (Khanam et al., 2025). Combined with earlier Western Balkan governance research, this suggests that Serbia's forest-security agenda should focus not only

on detecting unlawful cutting but also on strengthening administrative coordination, private-forest oversight, stakeholder trust, and adaptive management capacity (Stevanov et al., 2018; Khanam et al., 2025).

The security implications of illegal logging in Serbia manifest across several human security dimensions:

- **Governance and State Authority:** In vulnerable border regions and along administrative boundary lines, unmonitored timber extraction breeds localized security friction and violent confrontations, occasionally requiring intervention by national law enforcement units.
- **Environmental Security:** Uncontrolled timber extraction on steep slopes destabilizes local soil hydrology. In watersheds such as the Bojatinska River, canopy removal and soil compaction from unapproved logging machinery impair groundwater recharge, exacerbating seasonal water shortages and increasing vulnerability to flash torrents during heavy precipitation events (Milivojević & Vučković, 2019; Cvetković et al., 2024).

5. Discussion

The multidimensional analysis demonstrates that illegal logging operates as a systemic threat that simultaneously undermines multiple interconnected dimensions of human security (UNDP, 1994). These effects are also differentially distributed because exposure, vulnerability, and coping capacity vary across populations, livelihoods, and ecosystems (Canete & Biñas, 2025).

5.1. *The Interconnected Cascade of Security Risks*

The primary value of applying the human security framework to illegal logging lies in revealing the cascading linkages between governance failures and localized vulnerabilities:

- **Political-Economic Drivers:** Weak institutional enforcement, lower risk of detection, and political corruption enable illegal concession awards and market distortions. Lower illicit market prices suppress legitimate forestry revenues and deprive states of critical tax income.
- **Socio-Environmental Impact:** Illicit canopy removal and unmonitored heavy machinery cause localized soil compaction, disruption of hydrological recharge, and habitat loss. This ecological degradation directly compromises community food and water security during extreme weather events.
- **Personal and Health Insecurities:** Where enforcement is compromised, local populations and forest defenders face physical violence and extortion. At the same time, ecological modification alters disease vector dynamics and degrades the availability of local medicinal forest resources.

The resulting cascade is best understood as a network of feedbacks rather than a one-way sequence. Weak governance can enable illegal extraction; ecological degradation can increase livelihood and hazard vulnerability; declining livelihood security can in turn increase dependence on informal or illegal resource use; and health or violence impacts can further reduce community capacity to monitor and protect forests. Empirical studies in different contexts demonstrate several components of these feedbacks, including institutional determinants of illegal logging (Bösch, 2021), forest-degradation impacts on ecosystem functions (Lapola et al., 2023), and bidirectional relationships between land-use change and health burdens (MacDonald & Mordecai, 2019). This supports the paper's use of cascading risk as an analytical concept rather than a simple list of independent impacts.

5.2. *Serbia in the Global Context: Qualitative Degradation vs. Area Expansion*

Comparing international evidence with the Serbian case study highlights critical nuances in how forest threats manifest across different geographical and socioeconomic settings.

While tropical regions often experience acute, large-scale deforestation driven by agricultural expansion and commercial timber extraction, the challenge in transition economies like Serbia is characterized by qualitative forest degradation:

- Aggregate quantitative metrics (such as SORS reports showing a 12.53 percentage point increase in reported forest land share from 1979 to 2023) mask underlying stand degradation.
- Much of the recorded statistical gain stems from rural depopulation and secondary ecological succession on abandoned agricultural land, producing unmanaged scrubland with lower timber value, reduced canopy interception, and weaker biodiversity density.
- Meanwhile, mature, high-value broadleaf stands (such as beech and oak) face persistent selective illegal logging, creating localized hydrological and governance vulnerabilities.

5.3. Policy Implications

To address the systemic challenges identified in this study, forest management and security frameworks must adopt integrated policy interventions. These interventions are stronger when institutional measures combine community participation, capacity building, and sustained stakeholder partnerships (Cvetković et al., 2025).

- **Digital Timber Tracking and Transparency:** Implementing end-to-end chain-of-custody tracking systems (e.g., timber marking, digital transport permits, and public logging databases) to minimize document fraud and timber laundering at private sawmills.

Digital traceability can strengthen this intervention, but technology should not replace governance. Reviews of wood supply chains identify blockchain and related digital systems as potentially useful for creating tamper-resistant provenance records, improving chain-of-custody transparency, and supporting certification, while also noting challenges related to data quality, stakeholder participation, and the reliability of information entered into the system (Stopfer et al., 2024). Crime-prevention research likewise supports combining wood tracking and remote sensing with physical access controls, checkpoints, independent certification, and active participation by forest managers, law enforcement, and local communities (Thompson & Magrath, 2021).

- **Harmonized National Monitoring:** Aligning forest inventory definitions with standardized remote-sensing protocols to clearly differentiate high-canopy mature forests from secondary scrubland, ensuring spatial data accurately reflects qualitative stand health.
- **Strengthening Inspection and Judicial Capacity:** Enhancing the technical equipment, field mobility, and legal mandate of forest inspectors, accompanied by specialized judicial training to secure effective prosecution of forestry offenses.
- **Cross-Border Governance:** Intensifying regional cooperation and intelligence sharing among neighboring Balkan states to curb illicit timber transport across state and administrative boundaries.

5.4. Research Limitations

This study acknowledges several analytical and methodological limitations. Data heterogeneity and unrecorded offenses are major constraints, as illicit activities are inherently hidden, creating significant variation in global and national estimates. Available data sources often rely on proxy indicators, judicial records, and NGO field assessments, which may vary considerably in standardization across jurisdictions. Methodological variations in remote sensing also require careful consideration,

since global satellite platforms, such as Global Forest Watch, measure gross canopy cover loss rather than net deforestation. Consequently, these data require careful contextual interpretation alongside local field evidence in order to avoid overestimating the direct impact of illegal logging. Additional limitations include potential selection bias, because the underlying literature is unevenly distributed across regions and research traditions. At the same time, the Serbian case relies on relatively sparse published evidence on illegal extraction. Temporal non-equivalence is another important limitation, as governance indices, historical illegal-logging estimates, national forest inventories, and satellite products often cover different years and therefore cannot be treated as synchronized observations. The research design supports mechanism identification and structured comparison. However, it does not support causal attribution of specific Serbian canopy-loss events to illegal logging or statistical generalization from Serbia to other transition economies. Future research should therefore combine repeated forest-inventory measurements, high-resolution disturbance mapping, geolocated inspection and court data, and interviews with forest owners, inspectors, police officers, prosecutors, and local communities.

6. Conclusion

Illegal logging poses a multifaceted threat that extends far beyond natural resource depletion, intersecting directly with political stability, economic sustainability, and community well-being. Using the UNDP's seven-dimensional human security framework, this paper maps the complex pathways through which forest criminality operates—from macro-level governance paralysis and revenue loss to micro-level hydrological disruption and physical violence against local communities. The contextual examination of the Republic of Serbia underscores the importance of analytical precision when interpreting forest indicators. While national statistical registries record a substantial expansion in total land classified as forest—driven by inventory redefinitions and rural land abandonment—this quantitative increase coexists with localized qualitative degradation caused by unrecorded timber extraction in mature stands. Bridging this gap requires transparent monitoring tools, institutional accountability, and policies that recognize mature forest ecosystems as fundamental pillars of human and environmental security.

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