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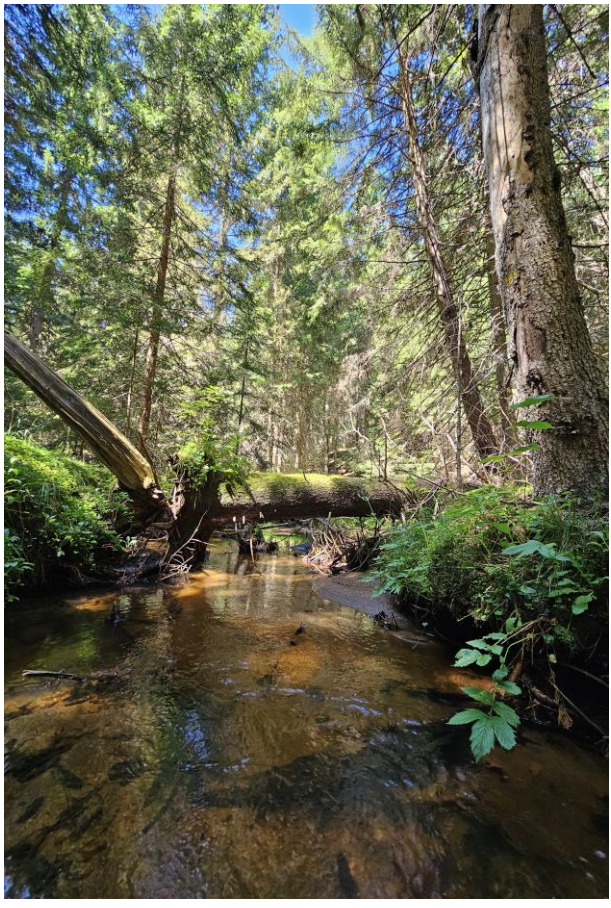

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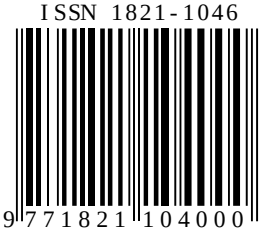

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Professional paper

FOREST FIRES AS A FACTOR OF ECOLOGICAL SAFETY AND THEIR IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

Goran ĐORĐEVIĆ[1], Martina PETKOVIĆ [2], Marko TOMIĆ[3], Andreja MIJATOVIĆ[4]*

Abstract: *Ecological safety represents an important segment of every country, with each nation striving to strengthen it by reducing risks that can compromise it. Forest fires are a significant factor of ecological safety due to their capacity to disrupt ecosystems by generating a range of harmful by-products. By reducing the frequency of forest fires and the resulting damage – both material and environmental – ecological safety can be enhanced. Ecological safety, in turn, contributes significantly to the sustainable development of regions, given the broad impacts of forest fires on natural and human systems.*

Keywords: ecological safety, forest fires, sustainable development.

ŠUMSKI POŽARI KAO FAKTOR EKOLOŠKE BEZBEDNOSTI I UTICAJ NA ODRŽIVI RAZVOJ

Izvod: *Ekološka bezbednost je važan segment svake države, i svaka država se trudi da ekološka bezbednost bude što bolja i rizike koje dovode do narušavanja ekološke bezbednosti smanji na što manju meru. Šumski požari su važan faktor ekološke bezbednosti, jer njihovim nastankom remeti se i ekološka ravnoteža, pojavom niza negativnih produkata. Smanjenjem broja šumskih požara i smanjenjem šteta nastalih šumskim požarima, kako materijalnih, tako i ekoloških, utiče se da ekološka bezbednost bude bolja. Ekološka bezbednost utiče na održivi razvoj svakog regiona, kao i pojava i ispoljavanje šumskih požara u svim segmentima svog ispoljavanja.*

Ključne reči: ekološka bezbednost, šumski požari, održivi razvoj.

[1] Academy of Technical Studies, Polytechnic, Belgrade,
[2] Academy of Kosovo and Metohija, Department of Zvečan
[3] Tara National Park Public Enterprise, Bajina Bašta
[4] Ministry of Internal Affairs, Republic of Serbia, Sector for Emergency Situations, Belgrade, Požarevac Department
*Corresponding author. E-mail: goranzop@gmail.com

1. INTRODUCTION

Unregulated and uncontrolled exploitation of natural resources, including forests, and their endangerment through various harmful influences and processes lead to severe disruptions in fundamental ecological processes, endangering the quality and survival of essential natural substrates, including plant and animal life.

Forests play a crucial ecological role, providing health benefits, recreational opportunities, aesthetic value, material goods and a food supply. Consequently, any threat to forest resources can be considered a threat to ecological safety.

In general terms, an ecologically safe state can be defined as one where no environmental threats are present or active, nor is there any risk of their development. Based on these environmental characteristics and factors, ecological safety signifies the absence of elements that might disturb balanced and harmonious natural processes and relationships. However, this is often unattainable in practice, as the primary threats today stem from human activities (anthropogenic factors), influenced by work practices, and daily activities and habits. The anthropogenic impact on forests and the broader environment disrupts natural processes, depletes natural resources, and diminishes environmental quality, issues in which forests play a significant role.

1.1. The Concepts of Safety, Ecological Safety, and Environmental Crime

Unregulated and uncontrolled exploitation of natural resources, along with their endangerment through harmful processes and activities, disrupts fundamental natural processes and jeopardises essential ecological principles. This degradation endangers the quality and survival of specific natural entities, ultimately threatening the broader environment.

A lack of awareness and concern for the surrounding environment, along with deliberate harm to it, are primary causes of environmental violations. These offenses include prohibited and punishable actions by individuals or groups that aim to derive benefits or engage in practices harmful to the environment, endangering both public health and safety.

An ecologically safe state, in its broadest sense, can be defined as one in which there are no active environmental threats or risks of their development.

Most factors that jeopardise the environment, including forest resources, originate from human activities, both occupational and lifestyle-related.

These harmful effects give rise to further disruptions that, directly or indirectly, impact the quality of life and public health, while also degrading the environment. Such impacts include loss of arable land, reduction of forested areas, damage to the recreational and health-supporting roles of forests, air and water pollution, habitat destruction, and decline of plant and animal species. These environmental degradations lead to critical issues such as reduced drinking water supplies, lower food availability, the effects of global warming, increased frequency of extreme weather events, and rising disease rates.

The complexity and severity of these issues significantly impact economic and social stability and, consequently, overall safety.

When safety is viewed as a core responsibility of the state toward its citizens, primary tasks for achieving and maintaining ecological safety include identifying, understanding, and addressing the causes and manifestations of environmental threats. Preventive measures— enforced through legal instruments, education, monitoring, and repressive measures, such as detecting and penalizing ecological offenders, enable the state to safeguard citizens' rights to a healthy and sustainable environment.

The various unlawful acts committed by individuals, social groups, or business entities that endanger the environment, threaten human health and safety, and destroy material assets are collectively called **environmental offenses**.

Environmental crime is a relatively new concept, encompassing a category of offenses that has grown significantly in recent years. This type of crime involves a wide range of actions and consequences that impose serious harm on both the environment and public well-being, thereby threatening the ecological safety of both the state and society. The drivers of environmental crime vary and may involve actions by individuals, groups, or organisations, with harmful activities conducted either out of ignorance or deliberately. In essence, the various forms of environmental crime can generally be understood as stemming from either negligence or purposeful, intentional actions.

The primary challenges in identifying, preventing, and combating environmental offenses and environmental crime include:

- clear definition of environmental offenses: A precise and comprehensive definition of environmental offenses is essential to establish which behaviours are considered undesirable and dangerous.
- legal regulation of environmental crime: This requires formal integration of environmental offenses into environmental and criminal law frameworks.
- inadequate and lenient penalties for environmental offenders.
- limited personnel and technical resources: Insufficient resources impede the thorough investigation of environmental offenses, identification of offenders, and analysis of causes and consequences.

Key data regarding the characteristics, state and quality of environmental conditions – both before and after an offense occurs—can be obtained through an effective monitoring system. Tracking the frequency and patterns of certain occurrences enables the monitoring system to capture the dynamic characteristics of particular areas and processes.

A system essential for improving ecological safety is risk management, which should aim to reduce incidents that endanger ecological stability, address risks leading to environmental harm, and enable prompt and effective responses to hazardous events that negatively impact the environment. Data that reflect both the character of natural processes and the consequences of harmful actions toward nature can significantly aid in risk assessment and forecasting potential outcomes. Ultimately, this supports more effective environmental protection and stronger ecological safety, which can be achieved through an efficient risk management system.

Ecological safety can be understood not only as the sustainable use and protection of nature but also as the minimisation of risks or the likelihood of

experiencing adverse effects from ecological changes and threats. It represents the absence or minimal presence of endangering factors, which must be achieved through effective risk management.

1.2. Ecological Safety Factors

Ecological safety factors can be broadly categorised into two types: those that enhance safety and those that pose threats. Both types are interconnected to varying degrees, collectively shaping a particular state of ecological safety that ultimately impacts the environment itself. Depending on their characteristics and behaviours, certain factors may serve as stabilising elements that improve ecological safety or as destabilising forces that jeopardise it. For example, human actions can positively contribute to ecological safety through responsible behaviour; however, irresponsible or careless actions can disrupt ecological safety and pose risks to the environment.

When it comes to forest fires as a key aspect of ecological safety, climate serves as a prime example. Rainy periods within a climate cycle reduce the likelihood of forest fires, strengthening ecological safety. Conversely, droughts and high temperatures create conditions conducive to fires, thereby weakening ecological safety.

Factors that support ecological safety include:

- policy instruments for environmental protection,
- public awareness,
- relevant government authorities,
- social groups and organisations,
- international and other organisations.

Factors that may pose risks to ecological safety include:

- natural environmental hazards,
- states,
- economic and other entities,
- technical and technological factors,
- human activities.

1.3. Forest Fires and Ecological Safety

Forests have always been regarded as a national treasure, contributing not only to the preservation of vital ecological cycles but also providing economic, tourism, recreational, and health benefits. Due to their essential role in sustaining life, humans have historically sought to protect, nurture, and restore forests. In the past, forests covered a much larger portion of the Earth than they do today. In the Republic of Serbia, forest cover currently spans around 27% of the land, or about 2.3 million hectares, with roughly 50% in private ownership. Serbia's forest and forestland consist of 50% high forests, 28% coppice forests, and 22% barren land suitable for afforestation.

Forests face a variety of adverse factors, from tree diseases and forest pests, over weather extremes, droughts, floods and erosion to human-induced damage.

However, none of these factors can be as destructive as forest fires. The rising frequency and severity of forest fires, which often reach catastrophic proportions, not only devastate forests but also damage agricultural crops, threaten settlements, and endanger human lives. This growing threat underscores the need for organised, strategic monitoring of fire-risk factors and the establishment of preventive and suppressive protection measures.

Frequent fires and large burned areas result in substantial material losses and numerous other adverse effects, both direct and indirect. In Serbia and worldwide, both the number of forest fires and the total burned area have risen annually. Over the past decade in Serbia, hundreds of significant fires have affected large forested areas. Between 1997 and 2009, 1,442 forest fires were recorded in Serbia, burning a total of 57,884 hectares.

Countries aiming to effectively protect their forests face the challenge of organising and preparing for fire prevention, ensuring better coordination and functioning of activities and measures to prevent forest fires, and implementing meaningful short- and long-term measures to benefit nature and preserve forest wealth. To develop an effective forest fire management system, it is crucial to implement proactive measures addressing fire risk factors and establish a coordinated structure that ensures optimal functioning of forest protection—even in case of a fire. Such a system can be achieved through systematic forest fire risk management, which significantly enhances ecological safety.

Ecological safety concerning forest resources and fire occurrence entails the absence or minimisation of fire hazards, preventing forest fires or ensuring rapid containment and recovery. Given that forests are complex systems vulnerable to both biological and human-induced threats, the methods for protecting them are diverse and essential for safeguarding these valuable resources.

The main factors influencing forest fire risk, and therefore ecological safety, include:

- vegetation and available combustible material,
- natural phenomena,
- human influence (anthropogenic factors),
- climate and climatic factors,
- bedrock and soil type,
- orography,
- forest management,
- fire history.

Monitoring of forest fires in the Braničevo District from 1998 to 2008 revealed that the most common fires involved fine combustible materials, such as grass and small shrubs (Table 1).

Table 1. *Total Number of Fires by Vegetation Type in Braničevo District (1998-2008)*

Number of fires	Deciduous forest	Coniferous forest	Mixed forest	Grass and low vegetation
2220	124	45	24	2027
% 100	5.59	2.02	1.09	91.30

Table 1 shows that, in addition to grass and low vegetation (91.3%), the most frequent fires occurred in deciduous forests (5.59%), followed by coniferous forests (2.02%) and mixed forests (1.09%). From an ecological safety perspective, this data is crucial for implementing preventive measures focused on vegetation types most susceptible to ignition.

Forest fires are classified into the following types:

- underground fires
- low or surface fires
- high or crown fires

Table 2 shows the number of fires by type in the Braničevo District from 1998 to 2008.

Table 2. *Fires by Type in Braničevo District (1998-2008)*

Total number of fires	High (Crown) fires	Low (Surface) fires	Underground fires
2220	193	2027	0
% 100	8.7	91.3	0

From the perspective of vulnerability and ecological safety, high or crown fires are particularly significant, as they are generally the most challenging to extinguish and can cause substantial material and ecological damage.

Table 3. *Number of Crown Fires and Area Affected by Fires in Braničevo District (1998-2008)*

Vegetation type affected by fire (crown fires)	Number of fires	Average area affected (ha)	Average duration of fire (h)
Deciduoud forest	124	9.8	2.5
Coniferous forest	45	13.6	3.1
Mixed forest	24	5.2	1.2

Table 3 illustrates that, relative to the number of fires, the average area affected is largest in coniferous forests, followed by deciduous forests—both characterised by a uniform composition (single-species stands). In contrast, mixed forests have the smallest average affected area due to their diverse composition and varying tree flammability. Fires also tend to last longer in coniferous forests, owing to the chemical composition of these trees and the greater difficulty of extinguishing them, while mixed forests have the shortest fire duration due to slower fire spread and easier containment.

From an ecological safety standpoint, these findings are essential as they highlight the areas where forest fire prevention efforts should be concentrated to enhance ecological safety.

The main causes of fires are typically:

– natural phenomena
– anthropogenic factors (human activity)

Table 4 provides an overview of the frequency and percentage of fires caused by natural events in the Braničevo District from 1998 to 2008.

Table 4. *Number of Fires Caused by Natural Phenomena in Braničevo District (1998-2008)*

Total number of fires	Number of fires caused by natural phenomena	Number of fires caused by atmospheric discharge	Number of fires caused by solar heat
2220	28	24	4
100%	1.26%	1.08%	0.18%

Table 4 shows that fires resulting from natural phenomena in the Braničevo District accounted for 1.26% of all fires from 1998 to 2008. Lightning strikes and atmospheric discharges were responsible for the majority of these, at approximately 1.08%. However, this figure may be underestimated, as some fires with unknown causes likely stem from natural phenomena as well.

Human activities have a substantial impact on forest fire occurrence. Statistical data indicate that approximately 98% of forest fires are either directly or indirectly linked to human activity.

Table 5 provides the number of fires attributed to human causes in the Braničevo District during the 1998-2008 period.

Table 5. *Number of Fires Caused by Human Activity in Braničevo District (1998-2008)*

Total number of forest fires	Number of forest fires caused by human activity	Number of forest fires caused by human activity with open flames	Number of forest fires caused by other human activities	Number of fires with undetermined cause
2220	2087	2066	21	89
100%	94.01	93.06	0.95	4.01

Table 5 clearly indicates that over 94% of all fires occurring during the observed period can be attributed to human activity. Furthermore, the number of unidentified causes of forest fires can also be linked to human actions, raising this percentage to over 98%. The majority of forest fires caused by humans (93.06%) originate from open flames, while 0.95% result from other activities, such as work on electrical lines, operations at outdoor shooting ranges, and welding or cutting tasks conducted in open areas. The threat to forests from human activity increases significantly when these activities involve fire, such as burning stubble and other organic waste or using fire for various purposes.

From the perspective of ecological safety, this information is vital, as measures to prevent forest fires must primarily target human behaviour, which is the most common driver forcause of these incidents.

Table 6 illustrates the number of fires and their percentage contribution resulting from human activity via open flames, categorised by activity and location in the Braničevo District for the period from 1998 to 2008.

Table 6. *Number of Fires and Percentage Contribution Attributed to Human Activity by Type in Braničevo District (1998-2008)*

Number of forest fires caused by human open flames	Near settlements	Near recreational areas	In tourist areas	During agricultural activities	While gathering forest products	Hunters and fishers	Intentional
2066	212	28	9	1748	16	22	31
100%	10.26%	1.35%	0.43%	84.62%	0.77%	1.06%	1.51%

Table 6 shows that the highest number of forest fires was caused by open flames during agricultural activities, primarily due to the burning of organic material during field clearing, accounting for 84.62%. This is followed by fires near settlements at 10.26% and intentionally set fires at 1.51%.

The occurrence of human-caused fires, which represents the majority of cases, is influenced by several key factors, including:

The proximity of rural and urban settlements and tourist facilities, as well as the network of roads through or near forests increases public access to these areas. As more people frequent forests, the risk of fire incidents rises significantly.

Stationary tourism, drawn by the favourable forest and mountain environmental conditions, is steadily increasing. Tourist facilities are occupied throughout the fire season, with visitors often spending entire days in forested areas, where even a small lapse, like a poorly extinguished cigarette or match, can start a fire.

Picnic tourism with a great number of picnic areas and extensive road networks through forests presents an added fire hazard. Such locations attract large crowds, and these visitors, who often venture deeper into the forest, increase the risk by lighting fires for cooking and using cigarettes or matches, all of which contribute to the potential for wildfires.

Agricultural and field workers represent one of the leading causes of forest fires, often working on land adjacent to or within forest boundaries. Clearing fields by burning organic waste and weed is one of the primary sources of these fires.

Forest fruit harvesters visiting the forest during fire season can be a potential cause of fires. The large number of people in the forest during this time may accidentally or carelessly ignite a forest fire by lighting fires or discarding cigarette butts.

Hunters and fishermen, too, are known fire risks, often using open flames for heating and food preparation and sometimes discarding cigarette butts or matches carelessly.

Intentional fires in forests or grasslands represent a significant portion of human-caused fires. Reasons for setting such fires include the destruction of forested areas for later logging, revenge, or burning grass to promote greener growth for grazing. This type of fire incident has been on the rise year after year. They are usually set at dusk or during the night, when there are few or no people in the forest,

and in secluded areas, delaying discovery and intervention efforts. These fires are often started in areas with abundant fuel, which accelerates the rate of spread.

From an ecological safety standpoint, these data are essential for organisations responsible for forest protection and safety, providing guidance on preventative measures to mitigate fire risks effectively.

2. CONCLUSION

While environmental security implies protection against ecological degradation, ecological safety involves creating conditions in which the physical environment supports community needs without depleting natural resources. Sustainable development is central to promoting ecological safety, as it enables current generations to meet the needs of the present without undermining resources for future generations. Forest resources are a vital component of sustainable development due to their numerous benefits, making their protection essential. Effective fire management systems greatly enhance ecological safety, and if the state fulfills its responsibilities within this system, both ecological and other forms of safety will be elevated.

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