

## OCCUPATIONAL SAFETY IN FORESTRY: CONTEXT AND CHALLENGES

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### REVIEW ARTICLE

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#### Abstract

*Occupational safety in forestry and logging operations represents a complex challenge shaped by the interaction between the natural environment, human factors, and technology. Although the forestry sector has benefited from technological progress, it remains one of the most hazardous industries, with persistently high rates of severe and fatal accidents. The determining factors include unpredictable natural conditions—terrain configuration, vegetation density, unstable soils, and meteorological variability—alongside workers' experience and behavior, as well as technical equipment that is often inadequate or poorly maintained. Accidents arise from a combination of these elements, and a simplistic approach that attributes incidents solely to human error proves insufficient. Safety culture, which reflects the way employees perceive and manage risks, plays a central role in prevention. Its development requires continuous training, active managerial involvement, and open communication at all organizational levels. Preventive measures encompass on-site risk assessments, the use of personal protective equipment, adherence to standardized work procedures, and the integration of modern technologies.*

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#### INTRODUCTION

Forestry and forest harvesting rank among the most complex and hazardous professional activities, both due to the nature of the environments in which they take place and the dynamic character of the operations involved. In the global context of recent decades—marked by increasing pressure on natural resources and a steadily rising demand for wood products—the forestry sector must reconcile its economic objectives with the responsibility to ensure safe working conditions for its workforce. International organizations such as the Food and Agriculture Organization (FAO) and the International Labour Organization (ILO) emphasize that, despite substantial technological advancements, forestry remains one of the most dangerous industries worldwide, displaying a disproportionately high rate of serious and fatal accidents (Poschen, 2011). This situation underscores the necessity for an in-depth examination of occupational risks, the determinants of accidents, and the ways in which safety culture can transform the sector into one that is both sustainable and prevention-oriented.

The significance of such an analysis derives not only from the imperative to protect workers' health and lives, but also from the fact that occupational safety is directly linked to the sector's economic efficiency. A severe accident can produce far-reaching operational consequences, including delays, substantial financial losses, legal liabilities, and a deterioration of worker morale. Over the long term, the absence of a strong safety culture affects the reputation of forestry organizations, their ability to attract qualified personnel, and, consequently, the stability of the market. Therefore, a thorough assessment of risks and the formulation of appropriate preventive measures become not only necessary actions but also essential strategic components for the long-term development of the forestry sector (Garland et al., 2020).

Beyond its economic and ecological significance, the forestry sector constitutes a domain of major interest for interdisciplinary research, positioned at the intersection of environmental sciences, occupational health and safety, engineering, and the social sciences. The forestry work environment combines natural uncertainty with complex interactions between human factors and technology, making

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it particularly relevant for the analysis of systemic risk and for the development of adaptive safety strategies. In this context, occupational risks cannot be understood solely as isolated events, but rather as outcomes of dynamic and interdependent processes.

Despite the existence of well-established legislative frameworks and international guidelines, accident rates in forestry remain high in many regions, indicating a substantial gap between formal regulations and their implementation under real working conditions. This discrepancy highlights the need to move beyond strictly normative approaches and toward analytical models capable of capturing the context-specific nature of risk. Examining how safety measures are implemented, adapted, or disregarded in practice becomes essential for identifying the limitations of conventional prevention systems (Garland et al., 2020).

From a scientific perspective, research on occupational safety in the forestry sector has traditionally focused on individual risk factors or technical failures. However, recent developments in occupational risk theory emphasize the importance of integrated approaches that account for cumulative exposure, behavioral adaptation, and organizational learning processes. In this regard, forestry activities provide a relevant framework for analyzing how risk is negotiated on a daily basis within environments characterized by high variability and limited control.

This study integrates theoretical foundations and internationally established guidelines to provide a comprehensive perspective on the complexity of the forest environment as both a professional setting and a zone of inherent risk. Its objective is to highlight how the interaction between natural, human, and technological factors generates a challenging occupational landscape, while also demonstrating the central role that safety culture plays in mitigating risks and fostering a sustainable long-term working environment.

## **FOREST: WORKPLACE AND RISK**

The forest, by definition, represents a living, dynamic, and fundamentally unpredictable ecosystem. In contrast to industries that operate in controlled environments, forestry operations take place in a context where every natural element can influence the level of risk (FAO, 1993). Variable

terrain, soil composition, vegetation density, weather conditions, and the presence of biological factors constitute essential components of an environment that is difficult to standardize. Forestry workers must perform their tasks on steep slopes, unstable areas, wet or frozen soils, amid exposed roots, dense vegetation, and natural obstacles that may impede movement and equipment handling. Unlike other professions, in which risks can be consistently anticipated, forestry work requires repeated assessments, constant adaptation, and a high capacity for rapid decision-making under stressful conditions (FAO, 1993).

Weather conditions represent another major factor affecting worker safety. Strong winds, sudden precipitation, extreme temperatures, or microclimatic variations can radically alter tree stability and the safety level of workers (Garland et al., 2020). For instance, a tree that appears stable under calm conditions can become extremely hazardous during gusty winds. Simultaneously, the presence of soil moisture, combined with leaf litter or snow cover, reduces the traction of work footwear and increases the risk of slips.

A distinct aspect of forestry work is isolation. In many cases, worksites are located at considerable distances from populated areas, limiting rapid access to medical care and emergency teams. In the absence of effective communication systems, even minor accidents can become fatal. Consequently, isolation significantly amplifies worker vulnerability and underscores the importance of well-structured preventive measures, first-aid training, and detailed operational planning.

The human factor plays a central role in risk dynamics. The experience of forestry workers, their ability to assess hazards, their interpretation of natural signals, and their proficiency in handling technical equipment directly contribute to accident prevention. Research indicates that workers at the beginning of their careers are exposed to significantly higher risks, particularly due to lack of experience and practical skills (Poschen, 2011). In many countries, young or seasonal workers are employed without adequate training, which considerably increases the number of severe accidents.

Technology in the forestry sector is constantly evolving. While modern equipment reduces direct exposure to hazards, it introduces new risks, particularly associated with the operation of heavy machinery. Vehicle

overturns, hydraulic system failures, mechanical blockages, or limited visibility can trigger serious accidents (Poschen, 2011). In economically constrained regions, equipment is often outdated, improvised, or inadequately adapted, which significantly intensifies operational hazards.

### **FACTORS INFLUENCING OCCUPATIONAL ACCIDENTS IN THE FORESTRY SECTOR**

Accidents in forestry operations arise from a complex interplay of interdependent factors. FAO analyses emphasize that the majority of severe incidents are not the result of a single element, but rather a combination of factors such as inadequate training, human errors, technical malfunctions, adverse weather conditions, and the absence of proper supervision (FAO, 1993). This reality necessitates a systemic approach to safety, one that goes beyond the simplistic perspective attributing accidents solely to worker mistakes.

Human factors constitute the primary category of accident determinants. Inattention, fatigue, lack of experience, overestimation of personal abilities, and productivity pressures frequently lead to risky decisions. A worker who fells trees without correctly assessing their direction of fall or who operates a chainsaw from an unstable position exposes themselves to immediate hazards. Simultaneously, workers compensated on a piece-rate or quota basis are prone to bypass safety steps in an attempt to increase productivity, a practice that is highly dangerous (Garland et al., 2020).

Faulty or inappropriate technical equipment represents another significant determinant of accidents. Older machinery, lack of regular maintenance, mechanical improvisations, and the absence of specialized equipment are acute problems in many developing countries. Conversely, even modern equipment can become hazardous when operated by untrained personnel.

Organizational and managerial conditions decisively influence the level of risk. Lack of direct supervision, absence or non-enforcement of procedures, economic pressures, and poor communication are factors that increase the likelihood of accidents. In many cases, forestry organizations lack formal risk monitoring systems or do not encourage incident reporting, which limits their capacity for learning and continuous improvement.

An additional factor influencing the occurrence of occupational accidents in the forestry sector is the organization of working time and the management of chronic fatigue. Forestry activities involve intense physical exertion, prolonged periods of concentration, and continuous muscular strain. Extended working hours, insufficient rest breaks, or the absence of task rotation lead to a reduced capacity for reaction and judgment. Accumulated fatigue adversely affects coordination, attention, and risk assessment, thereby increasing the likelihood of errors that, in the forestry environment, may result in severe or fatal consequences.

Another distinct element concerns the contractual structure of the workforce, particularly the frequent use of subcontracting and temporary employment. Workers engaged on short-term contracts or through intermediaries are often insufficiently integrated into organizational occupational health and safety systems, with limited access to information, training, or supervision. This fragmentation of responsibilities undermines the consistent application of safety procedures and creates areas of ambiguity in accountability for accident prevention (Poschen, 2011).

The quality of information flow and operational planning constitutes another significant determinant of risk. Incomplete or delayed communication regarding changes in field conditions, work sequencing, or the presence of other teams can generate hazardous situations, including interactions between workers and machinery. The absence of clearly structured work plans, regularly adjusted to actual site conditions, increases uncertainty and exposure to uncontrolled risks (Garland, 2018).

In the current context, climate change has emerged as a factor that directly influences occupational safety in the forestry sector. The increasing frequency of extreme events—such as storms, strong winds, intense precipitation, or prolonged droughts—affects tree stability and the predictability of tree behavior during harvesting operations (Odenthal-Kahabka, 2005). Trees subjected to hydric stress, diseases, or pest infestations often exhibit unpredictable fracture patterns, complicating risk assessment and necessitating the continuous adaptation of operational procedures.

### **VULNERABLE GROUPS IN THE**

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## FORESTRY SECTOR

In numerous countries, children and adolescents are involved in forestry activities, particularly in rural communities that depend on natural resources (Garland et al., 2020). This involvement is extremely hazardous, as they often lack the physical strength, attention, cognitive maturity, and experience required to identify and avoid hazards. Activities may include the collection of non-timber forest products, work in nurseries, tree planting, or plantation maintenance. In many cases, they may also be exposed to chemicals or physical tasks that exceed age-appropriate limits.

Child labor is closely linked to poverty and social inequalities and can have negative consequences on education, health, and physical and psychological development (FAO, 2015). Individuals under 18 years of age should not engage in hazardous tasks, and light work must be strictly regulated and supervised. The use of children in dangerous activities violates fundamental child rights and represents a significant occupational safety and health concern (ILO, 2017). Protecting children and youth in the forestry sector requires prohibiting hazardous work, regulating light activities, ensuring adequate supervision, complying with national legislation, and implementing social measures for families economically dependent on child labor.

Women constitute another particularly vulnerable group in the forestry sector, engaging in activities such as collecting non-timber forest products, working in nurseries, planting and maintaining plantations, or operating light machinery (Poschen, 2011). Personal protective equipment is often designed for male anatomy, reducing effectiveness and increasing ergonomic risks (Garland et al., 2020). Additionally, physically demanding tasks, heavy material handling, and exposure to chemicals can lead to musculoskeletal disorders, reproductive system impairments, and other health problems. Studies indicate that women generally have lower work capacity than men and face weight limits for lifting that are often exceeded, increasing the likelihood of accidents and health issues (Poschen, 2011).

Socially and organizationally, women face limited access to professional training, technical information, and decision-making participation, frequently being involved in the informal economy or underrepresented in professional

organizations and unions. The work environment may be hostile, including harassment or gender discrimination, which affects safety behaviors and increases accident risks. Additional family responsibilities contribute to work-family conflicts and stress.

To mitigate these vulnerabilities, it is essential to provide tailored professional and safety training, appropriate personal protective equipment, and active involvement of women in safety-related decision-making. Integrating gender perspectives into occupational health and safety policies aims to create a fair and safe working environment for all employees, rather than offering special treatment.

## BUILDING A SAFETY CULTURE IN FORESTRY

Safety culture constitutes a fundamental element in preventing accidents and promoting occupational health within the forestry sector, a field characterized by high levels of risk and exposure to multiple hazards. It goes beyond mere compliance with formal regulations and reflects the way employees perceive risks, adhere to protective procedures, and assume responsibility for their own safety as well as that of their colleagues (Garland et al., 2020). Developing a robust safety culture is a gradual process that requires the ongoing commitment of all organizational levels and the facilitation of open dialogue between management and workers, enabling the identification and reporting of hazardous situations without constraints and with the aim of implementing effective solutions (Cooper, 2016).

Leadership plays a decisive role in reinforcing this culture. When managers and supervisors rigorously adhere to safety standards, actively participate in prevention programs, and consistently identify and mitigate risks, employee behavior naturally aligns with safety norms (Ek et al., 2014; Tobisch et al., 2005). In this context, continuous training and practical instruction are fundamental components. Employees must be consistently informed about the specific risks associated with forestry activities, receive detailed guidance on the use of personal protective equipment, and participate in practical exercises that develop emergency response skills. This training not only enhances individual competencies but also strengthens team cohesion and collective responsibility for maintaining a safe working environment (McLean & Rickards, 1998).

Decision-making regarding risk acceptance or mitigation in the forestry sector is influenced by a range of psychosocial and organizational factors, including professional experience, task familiarity, perception of potential consequences, and behaviors modeled by colleagues or supervisors. Productivity pressures, economic incentives, and confidence in equipment can increase vulnerability to accidents, which is why safety programs must integrate these dimensions, promoting a preventive approach and awareness of human factors.

Active employee involvement in all stages of implementing safety policies represents another essential element. Participation in hazard identification, priority setting, procedure development, and outcome monitoring fosters a genuine sense of responsibility and strengthens preventive behaviors. Even in small organizations, where responsibility may fall on the manager or owner, employees must be trained to recognize hazards and act knowledgeably, thereby contributing to the establishment of a sustainable and participatory organizational culture.

International experiences demonstrate that a mature safety culture is not an obstacle to productivity but is a crucial factor for sustainable sector development. Documented examples, such as those from Chile and South Africa, show that investments in employee professionalization, equipment modernization, continuous training, and the implementation of effective reporting and monitoring systems simultaneously reduce accidents and enhance organizational performance (Garland et al., 2020).

Under these conditions, safety culture in the forestry sector represents a complex system requiring responsible leadership, ongoing training, active employee involvement, careful assessment of risk tolerance, and the adaptation of procedures to real working conditions (Fennell, 2015). Only through an integrated and sustained approach can values regarding occupational safety and health be transformed into concrete practices, ensuring a protected, responsible, and accident-preventive working environment.

## **RISK MANAGEMENT AND PREVENTION**

Risk management in the forestry sector involves the identification, assessment, and

mitigation of hazards before they materialize. A critical stage in this process is the on-site risk assessment, during which supervisors analyze the terrain, weather conditions, vegetation type, tree stability, and the availability of resources (Sarri, 2011). Based on this evaluation, clear operational strategies can be developed, restricted zones can be established, and strict procedures for movement, tree felling, and equipment handling can be implemented.

Personal protective equipment (PPE) constitutes a vital component of prevention. Helmets, face shields, hearing protection, cut-resistant trousers, gloves, and boots with slip-resistant soles significantly reduce the severity of accidents. However, PPE cannot replace technical and organizational measures—it functions as the last line of defense rather than as a primary solution.

Worker training represents another critical element. Training programs must integrate both theoretical components (legislation, procedures, organizational aspects) and practical elements, such as simulations, demonstrations, and applied exercises. These activities are designed to reinforce correct tree-felling techniques, proper machinery operation, effective communication in the field, and emergency response protocols.

A complementary component of risk management consists of the use of prospective assessments aimed at anticipating hazardous situations that may arise as working conditions change. The analysis of potential scenarios, including atypical or rare events, enables the identification of latent risks that are not always evident during routine operations. This approach enhances organizational preventive capacity and reduces vulnerability to unforeseen events.

At the same time, the effectiveness of preventive measures depends significantly on the integration of risk management into daily decision-making processes. When operational planning, resource allocation, and production targets are established without explicit consideration of acceptable risk levels, safety measures tend to become reactive. By embedding safety criteria into decision-making at all organizational levels, accident prevention becomes a continuous and proactive process adapted to field realities (Luria et al., 2008).

The use of modern technologies significantly contributes to accident prevention. Stability sensors, telemetry systems, protective cabins, and automatic shutdown devices are

tools that can substantially reduce operational risks. Their effectiveness, however, depends on proper personnel training and rigorous maintenance.

## CONCLUSIONS

Occupational safety in the forestry sector represents a multidimensional challenge that requires systemic interventions, continuous training, and a mature organizational culture. Analyses based on FAO documents highlight the complexity of interactions between the natural environment, human factors, and technology (FAO, 2013; FAO, 2015). In the absence of an integrated approach, the specific risks associated with forestry activities inevitably manifest, keeping accident rates at a high level.

Through the implementation of a robust safety culture, technological modernization, appropriate training, and the development of effective risk management systems, the forestry sector can progress toward a sustainable and safe model. International evidence demonstrates that change is feasible, with benefits that are both human and economic. The future of forest operations depends on the ability of organizations to embed safety as a core value and to create a working environment in which the life of the worker is the highest priority.

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