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Occupational Risk Assessment in Native Rainforest Management (MIAR^{forest})—Parameters Definition and Validation

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Abstract: Maintaining native rainforests as a sustainable ecosystem and their resilience to external pressures involves their economic profitability as a natural resource of unique and renewable products. For this purpose, new approaches have been developed and refined. This work seeks to contribute in this direction in the context of occupational safety and health (OSH) by presenting a new method for integrated assessment of risks for rainforests (MIAR^{forest}). The MIAR^{forest} is based on the MIAR, a method that has shown promising results in occupational risk assessment in different industrial sectors. Its parameters were discussed and assessed to improve their relevance, wording and risk assessment through the Delphi methodology by a panel of 62 experts in forestry and OSH who responded independently to questionnaires made available through Google Forms. A consensus of over 79% among the experts was reached in two rounds. This result highlights the high objectivity and the low percentage of dubious possible interpretations of the parameters and sub-parameters of this occupational risk assessment method.

Keywords: risk assessment; occupational risk; native forest; forest management; MIAR; Delphi

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1. Introduction

Tropical forests cover more than 9,300,000 km^2, of which the Amazonian forest occupies around 6,700,000 km^2, more than 70% of the total area. This vital forest occupies significant areas of Brazil, Bolivia, Colombia, Ecuador, French Guyana, Guyana, Peru, Venezuela and Suriname.

There are, however, other tropical forests that it is important to list. Of these, the largest is the Congo rainforest, which covers more than 1,800,000 km^2 between Cameroon, the Central African Republic, Congo, the Democratic Republic of Congo, Equatorial Guinea and Gabon. Other smaller but significant rainforests are the Papua New Guinea rainforest of approximately 545,000 km^2, the Borneo rainforest of approximately 290,000 km^2, the Xishuangbanna (China) rainforest of approximately 19,000 km^2 and the Daintree (Australia) rainforest of approximately 1200 km^2.

The sustainable exploitation of native rainforests is necessary for their resilience to external pressures and their maintenance as a unique and necessary ecosystem for the future of humanity [1]. Native rainforest exploitation is distinguished from industrial forest exploitation by its principles of biodiversity maintenance and respect for nature [2].

Sustainable forest management is a holistic approach that aims to ensure the use of planning practices and conservation principles so that a forest can continuously supply a given product or service [3]. It is believed to correspond to the management of the forest for obtaining economic, social and environmental benefits by following planning practices and nature conservation principles that guarantee that the forest is capable of supplying, on an ongoing basis, a specific product or service without jeopardising the sustainability of the ecosystem while being subject to management. The sustainable exploitation of the native rainforest is thus distinguished from industrial forest exploitation by following biodiversity and sustainability principles.

Professionals who carry out their work in forest exploitation are undeniably exposed to the risk of accidents and diseases inherent to the work [4–9]. Occupational risk assessment is a process that allows organisations to implement a proactive management policy in workplaces to prevent the occurrence of occupational accidents and diseases [10–12]. There are several occupational risk analysis techniques and methods for their assessment, from more generalist to more specific. The choice of the method to be used is typically based on its suitability for the activities under analysis and their correlated specificities. However, the use of matrix methods, generally not validated, has a weakness that emerges from its subjectivity. That is, the assessment depends on the experience and perception of the assessor [13,14]. In fact, to date, no well-established methodology in an aggregated form allows for the complete and simultaneous identification of all occupational aspects of a company's activity. Perhaps this is why it is common for organisations to develop their own safety management systems and, therefore, their own methods of occupational risk assessment [15–21].

Different approaches and methods are applied in the particular context of forestry activities. The most widely used are the AHP—analytic hierarchy process [10–21], the MMR—method of the magnitude of risk [22] and the PARCF—process of risk assessment in forest harvesting [23]. However, these methods are not specific to managing activities in native rainforests.

A method that has shown promising results in occupational risk assessment in different industrial sectors is the method for the integrated assessment of risk (MIAR) [24]. The MIAR follows control banding (CB) principles. CB is a risk-management strategy used to control occupational hazard exposure. It is a simplified approach which can be used to identify and implement appropriate control measures based on hazard levels and potential exposure.

Creating a new version of the method, specially developed for the evaluation of occupational risks in the native rainforest, will promote the sustainable use of these forests and thus contribute to their preservation by allowing workers to work with greater safety under the difficult conditions of this working environment.

Considering the above, it was defined as the objective of this work to identify the parameters and sub-parameters and perform their validation. In this way, we aim to contribute to the development of an occupational risk assessment methodology to support safety management systems in native rainforests by adopting the basic principles of the MIAR.

2. MIAR's Original Version—Short Presentation

The original version of the MIAR was developed to support the integration of management systems and allows the framing of the risk assessment of the environmental and occupational components. Its focus was on industrial activities in the chemical industry, creating synergies between the processes with the NP-EN-ISO 9001:2008—quality management system standard and the HAZOP—hazard and operability study method [24]. In this way, it allows organisations to improve their performance while at the same time being simple to apply and with reproducible and reliable results.

The first version of the MIAR has been investigated and applied in different industrial sectors such as metalworking [25], construction [26], industrial waste sorting [27], mining industry [28,29] and slaughterhouses [30]. These applications of the method always point towards high reproducibility, tending to be above 75%, and towards the reliability of the results, i.e., with the MIAR, the risks are assessed identically by different experts, and the results obtained are congruent with reality.

In the MIAR, the identification of hazards starts by identifying the sequence of industrial processes, sub-processes, activities and tasks, going down to the level considered adequate. It also includes the identification of materials and machinery used in activities, working conditions and constraints, the characteristics of the spaces where the activities occur and the surrounding spaces. Existing accident- and risk-protection equipment, minimisation procedures and potential failures are also checked [31].

In the MIAR, the risk is defined as a measure of the uncertainty of the occurrence of an event in a situation involving exposure to a hazard. The risk level (RL) is obtained as the product of two parameters, severity (S) and likelihood (Li), where Li is the product of the extent of impact (Ei) and the frequency of exposure (Fe) (Equations (1) and (2)). These parameters must be considered independently from each other.

$$\mathrm{Li} = \mathrm{Ei} \times \mathrm{Fe} \tag{1}$$

$$\mathrm{RL} = \mathrm{S} \times \mathrm{Li} \tag{2}$$

where accident severity corresponds to the likeliest consequence should the accident materialise, accident extent refers to the number of workers affected, and the frequency of exposure represents the time a worker is exposed to a given risk.

Within the scope of risk management, the prioritisation of interventions for risk mitigation considers another parameter, risk control (RC), calculated according to the ongoing organisational measures of accident prevention. Thus, after the valuation of the risk level, it is possible to estimate the weighted risk level (WRL) as a result of dividing the risk level by the risk control (Equation (3)):

$$\mathrm{WRL} = \mathrm{RL}/\mathrm{RC}, \tag{3}$$

In other words, WRL assesses the effectiveness of risk control processes (existing or soon to be implemented) according to a control hierarchy.

In all parameters, the valuation of the possible occurrence of an occupational accident is translated into the chromatic scale represented in Table 1.

Table 1. Association between colours and evaluation levels.

Absent/Very Low	Low	Moderate	High	Very High
(green)	(yellow)	(orange)	(red)	(magenta)

3. Materials and Methods

The design of the new version of the MIAR for rainforests—the MIAR^{forest} (method for the integrated assessment of occupational risks in native rainforests)—was based on the MIAR's concepts defined in ISO 31000:2018 [32], namely those related to the three stages of the risk management program (identification, analysis and evaluation) and the concepts of hazard and risk, in accordance with ISO 45001:2018—the occupational health and safety (OHS) management system. Therefore, the MIAR^{forest} uses the equations of the MIAR (Equations (1)–(3)) and follows the principles of control banding (CB) methods, integrating information on potential hazards, levels of exposure and an assessment of occupational health and safety performance management systems. It seeks the latter to prioritise appropriate measures to minimise the impact of workers' exposure to hostile environments such as native rainforests.

To adapt the MIAR to the reality of native rainforest management activity, information was collected face-to-face in the Brazilian federal government forest holdings in the eastern Amazon. This data collection focused on the relevant hazards and risks at different stages of the management process [33]. Subsequently, a first draft of the MIAR^{forest} was developed based on this information and in the reference literature on this topic [7,13,14,34].

The validation process of each of the parameters and sub-parameters regarding their relevance and clarity of wording, as well as the risk-assessment scale considered, followed the premises of the Delphi methodology [35,36]. Therefore, a panel of experts, professionals in the forestry and OHS area, was invited to respond anonymously to the following questionnaire made available through Google Forms:

Do you agree with the proposed parameters and sub-parameters? Do you consider their description sufficiently clear?

- If you disagree with the presented proposal, what alternative wording do you propose?
- Do you agree with the assessment levels considered for the proposed parameters and sub-parameters?
- What valuation levels do you propose if you disagree with the proposal that has been made?

Do you consider that other sub-parameters should be added? Which ones and why?

The experts were informed that, when answering the survey, each parameter/sub-parameter should be assessed as if there were no influence on any other and that the chromatic scale used to assess the possibility of the occurrence of an occupational accident was chromatic (Table 1), with numerical assessment being performed at a later stage.

The answers obtained were analysed quantitatively and qualitatively, considering the experts' agreement with the proposals and their comments and suggestions. In accordance with the assumptions of the Delphi methodology, the parameters that did not obtain a consensus of opinions greater than 75% and/or received pertinent criticism regarding their definition were adjusted accordingly. A new proposal for the wording of the parameters and risk assessment was produced and submitted for consideration by the experts. In this new questionnaire, the questions to the experts were created in the same way as in the first round, with not only the new wording of the text to be evaluated being presented with all the changes made duly evidenced but also the version of the first round and the corresponding evaluation results.

This iterative process was stopped once the answers obtained reached a consensus of opinions higher than 75% [35,36]. Ten factors with direct influence on the severity (S) of accidents were identified:

- Two factors with global impact:
  - i. Worker protection (WP): whether the worker is protected by personal protective equipment or by a collective protection system;
  - ii. Forest typology (FT): tree density (in this research, only the ombrophilous forest is considered).
- Two controllable factors:
  - iii. Machine- and tool-handling (MT): the level of protection that machines and tools have and the training that workers must have to use them;
  - iv. Relationship between tasks (RBT): the number of and relationship between tasks being performed simultaneously on the same site.
- Six uncontrollable factors:
  - v. Object fall (OF): the situation of a worker being hit not only by falling broken branches and/or trees but also by other objects such as logs and small tools/utensils that can fall during road and yard operations;
  - vi. Terrain slope (TS): the ability/difficulty of maintaining the balance and the progress of workers both on foot and by vehicle within the forest;
  - vii. Obstacles (Obst): the ability/difficulty of traversing vegetation, rivers and streams, fallen trees and rocks during road and yard operations;
  - viii. Wild animals (WA): the presence of disease vectors, poisonous animals or predators that can cause severe injuries or death.
  - ix. Precipitation intensity (PI): the feasibility of performing/or not performing work in rain;
  - x. Wind intensity (WI): the feasibility of carrying out/or not carrying out work in windy conditions that contribute to the shaking of treetops as well as the falling of branches and objects onto the worker.

The parameters of exposure (E) and frequency (F) were renamed as, respectively, extent of impact (Ei) and frequency of exposure (Fe).

4. Delphi Rounds Results

The validation of the MIAR^{forest} was proposed to a group of 250 experts and was performed according to the Delphi approach. For the first round, 65 experts agreed to respond to the questionnaire; for the second round, there were 62 respondents. Of these professionals in the forestry and/or occupational safety area, 94% had university qualifications, and at least one had a postgraduate degree in occupational safety.

In the first round, the pertinence of the parameters, sub-parameters and respective levels was questioned. Experts' opinions and suggestions for changes were also collected.

The experts' suggestions considered relevant for the second round were introduced for the second version of the method. After this operation, the modified version was sent back to the experts to confirm their opinion on items that lacked consensus and validate the changes made.

The obtained results are shown in Table 2. All items with an approval rate greater than 75% could be considered validated at the end of the first round. However, only the sub-parameters of likelihood (Li)—(extent of impact (Ei) and frequency of exposure (Fe)), as well as the parameter of risk control (RC), were considered closed at the end of the first round and, due their pertinence, some changes suggested by the experts were introduced. The proposed modifications include the introduction of the type of protection for workers (individual PPE or collective cabin) and the subdivision of the sub-parameter "terrain characteristics" (TC) into two, the slope of the terrain (TS) and obstacles (Obst).

Table 2. Percentage of agreement obtained in the rounds.

Parameter/ Sub-Parameter		1st Round		2nd Round		
		Consideration of the Parameter	Writing of Risk Levels	Parameter/ Sub-Parameter	Consideration of the Parameter	Writing of Risk Levels
S				WP	100.0	100.0
	FT	89.2	83.1			
	MT	89.2	86.2	MT	82.3	82.3
	RBT	89.2	86.2	RBT	82.3	83.9
				OF	88.7	88.7
	TC	93.8	93.8	TS	80.6	80.6
				Obst	83.9	82.3
	WA	95.4	90.8	WA	83.9	83.9
	PI	95.4	89.2	PI	80.6	80.6
	WI	96.9	89.2	WI	80.6	79.0
Li	Ei	89.2	84.6			
	Fe	95.4	89.2			
RC		100.0	95.4			

The introduced changes were presented to the experts in the second round, asking if they preferred the original or the new version with the changes. Most experts opted for the latest version (Table 2). The obtained results were considered sufficient to accept as finalising the process of defining the parameters through the Delphi methodology.

5. MIAR^{forest} in Detail

With a consensus among experts of over 79%, the MIAR^{forest} allows for identifying and assessing occupational risks arising from sustainable exploitation of native rainforests in different stages. In its design, simplicity was sought in the application of the method, associated with the quality of the results obtained from the risk assessment.

In the MIAR^{forest}, the parameters/sub-parameters assessment must be carried out considering the actual situation in which the work is performed. This means the tasks must be classified considering all safety measures already implemented during the evaluation.

The method generates risk assessment based on three groups of parameters corresponding to the severity, likelihood and capacity to control the risk of accident using the occupational health and safety management systems implemented in the organisation.

5.1. Severity

The severity of occupational accidents in rainforests depends on worker protection, which in turn depends on how the work is performed, that is, on whether the worker executes the activity while protected only by personal protective equipment (pedestrian work) or whether the worker executes the tasks while isolated from the environment (the forest) by a collective protection system (such as the cabin of a harvesting machine). These two scenarios will condition the accident's potential severity due to either controllable or uncontrollable factors. In addition, severity is also related to three classes of factors: meteorological, edapho-biological (ground, animals and vegetation) and operational (machinery and tools).

Thus, the MIAR^{forest} considers parameter severity (S) depending on ten sub-parameters and can be computed according to Equation (4). This equation was designed by assuming that all factors ("sub-parameters") significantly influence the severity of occupational accidents in native rainforests, each of them in their own particular way. Therefore, in order to avoid instability in results, the traditional computation using multiplication and sums of parameters was dropped, and a calculation that included a balance between median and maximum values was used instead. This option allows greater stability in the results and emphasises the sub-parameter with the highest potential for harm, whatever it may be.

The parameters used to assess the severity and the correspondent rating are summarised in Table 3.

$$S = WP \times FT \times \text{maximum}\,(MT, RBT, OF, TS, Obst, WA, PI, WI) \times \text{median}\,(MT, RBT, OF, TS, Obst, WA, PI, WI), \quad (4)$$

Table 3. MIAR^{forest} Severity parameters.

Subparameter	Level Description	Rating
Worker protection (WP)	Individual protection	1
	Collective protection	0.25
Forest typology (FT)	Submontane dense ombrophilous forest.	16
	Submontane open ombrophilous forest.	8
	Alluvial dense ombrophilous forest.	4
	Lowland dense ombrophilous forest.	2
	Lowland open ombrophilous forest.	1
Machinery and tools (MT)	Forest harvesting machine with a manual device, e.g., steel cable.	16
	Forest harvesting machine with a hydraulic device, e.g., grapple, blade.	8
	Portable forest harvesting machine, e.g., chainsaw.	4
	Hand tool, e.g., machete, wedge, sledgehammer.	2
	No use of tool or machine—situation without injury or damage.	1
Relationship between tasks (RBT)	>3 different tasks running simultaneously.	8
	Three different tasks running simultaneously.	4
	Two distinct and dependent tasks running simultaneously but lagged.	2
	Two separate and independent tasks running simultaneously.	1
	One task.	0.5
Precipitation intensity (PI)	Precipitation intensity > 0.5 mm/h.	256
	0 mm/h < precipitation intensity ≤ 0.5 mm/h.	2
	Without precipitation, precipitation probability—60% < pp ≤ 100%.	1
	Without precipitation, precipitation probability—0% < pp ≤ 60%.	0.5
	No precipitation, precipitation probability 0%.	0.25

Table 3. *Cont.*

Subparameter	Level Description	Rating
Wind intensity (WI)	Wind intensity > 40 km/h.	256
	20 km/h < wind intensity ≤ 40 km/h.	2
	10 km/h < wind intensity ≤ 20 km/h.	1
	0 km/h < wind intensity ≤ 10 km/h.	0.5
	No wind.	0.25
Object fall * (OF)	Fall of an object with sufficient energy to cause death or total permanent disability.	48
	Fall from an object with sufficient energy to cause severe injury with total temporary incapacity or partial but low-percentage permanent incapacity.	24
	Fall of an object with sufficient energy to cause minor injuries with partial temporary incapacity but low severity.	8
	Fall of an object with sufficient energy to cause minor injuries without any form of disability.	6
	Fall of an object without sufficient energy to cause injury to the worker.	3
Terrain slope (TS)	Strongly sloping surface (30–45%).	4
	Moderate sloping surface (8–30%).	2
	Smoothly sloping surface (3–8%).	1
	Flat surface (0–3%).	0.5
	Flat surface 0%.	0.25
Obstacles Obst	Surface with obstacles that are impossible to cross on foot.	4
	Surface with obstacles that are difficult to cross.	2
	Surface with obstacles that are easy to cross and/or remove.	1
	Surface with obstacles that are very easy to cross.	0.5
	Unobstructed surface.	0.25
Wild animals (WA)	Contact resulting in injury or damage by large mammals (e.g., *Panthera onca*), snakes with high venom inoculation (e.g., *Micrurus altirostris*), venomous spiders (e.g., *Loxosceles amazonica*) and swarms of bees.	4
	Contact resulting in injury or damage by mid-sized mammals in flocks (e.g., *Pecari tajacu*), snakes with moderate venom inoculation (e.g., *Bothrops jararaca* or *Lachesis muta*) and scorpions.	2
	Contact resulting in injury or damage by small mammals, snakes with low venom inoculation (e.g., *Helicops angulatus*).	1
	Contact resulting in injury or damage by isolated insects (e.g., *Paraponera clavata*).	0.5
	There is no contact with animals.	0.25

* not submitted for validation.

5.1.1. Forest Typology (FT)

The severity (S) of occupational accidents in a native rainforest depends on the characteristics of the forest where the worker carries out the activity. It was decided that S is higher if the activity is carried out in a forest with a high density of trees and other plants and at altitude. Since in the MIAR^{forest} only ombrophilous forest, characteristic of the Atlantic forest and Amazon biomes, is currently considered, the severity levels were defined based on the different characteristics that this type of forest may possess, depending on the altitude at which they are located [37,38].

5.1.2. Worker Protection (WP)

Only two basic situations in which work is executed in forestry operations will be considered for the work protection parameter. The first is pedestrian work, where the worker is equipped with personal protective equipment (PPE). The second refers to work inside a machine cabin. In addition to PPE, the worker can rely on the protection of the cabin itself, which functions as collective protection equipment against hazards existing in the surrounding environment.

5.1.3. Machines and Tools Handling (MT)

Regarding the use of machines and tools, the MIAR^{forest} states that the severity depends on the type of machine or tool the worker uses when carrying out the activity. The severity levels were defined according to the bibliography on this subject specifically applied to native forest exploitation [4,8,39–47]. In the valuation of this parameter, it was decided that the severity is higher if the activity is carried out with forestry machines such as, for example, a loader, a forest tractor, a tracked tractor or a logging truck. These machines may have steel cables, hydraulic clamps or other accessories attached. Only the chainsaw was considered a portable forest-harvesting machine, and manual tools without a motor, such as a machete, wedge or sledgehammer, were considered. The severity levels of occupational accident occurrence according to the type of machine or tool used and/or situations arising from their use were defined according to Roloff [48].

5.1.4. Relationship between Tasks of the Same Activity

In the MIAR^{forest}, the severity depends on the number of tasks that need to be performed as part of the same activity and their degree of dependence. An illustrative example of an activity with more than three distinct tasks running simultaneously is the activity of cubage, which the following professionals traditionally perform: note taker, chainsaw operator, loader operator, measurer and painter/planker. An illustrative example of an activity with only one task is the felling activity, traditionally performed by the following professionals: chainsaw operator and helper. The five levels of severity of occupational accident occurrence as a function of the number of tasks involved in the same activity were defined according to [33] and EMBRAPA guidelines [49].

5.1.5. Meteorological Conditions—Precipitation and Wind Intensity

In the MIAR^{forest}, two sub-parameters related to meteorology are considered—precipit ation intensity (PI) and wind intensity (WI). For each of these sub-parameters, five severity levels were defined in accordance with the World Meteorological Organization (WMO) [50], the Beaufort wind scale [51], the specifications officially established by Brazilian Civil Defense [52] and the recommendations of the Tropical Forestry Institute on this subject [53].

In addition to the above references, in defining the severity levels, the opinion of experts in occupational safety in logging operations in native rainforests was also considered. According to the experience of these experts, activities should be wholly suspended during precipitation greater than 0.5 mm/h, as terrain and road conditions, if unpaved, become impractical for working safely. The same experts also stated the importance of considering wind when assessing safety conditions. However, the wind speed value at which safety conditions are compromised did not reach consensus (values ranged from 19 to 44 km/h). Thus, a 30 km/h speed was defined as the value at which the activities should be suspended. It was decided that above this value, the larger branches of trees become very agitated, and this agitation or resulting falls can cause severe accidents. The same can occur when the wind changes direction.

5.1.6. Object Fall (OF)

Occupational accident severity depends on the forest's characteristics where the worker carries out the activity. As the MIAR^{forest} considers ombrophilous forest with incidence of lianas or woody vines, this parameter is related to the movement of vegetation or parts of it (branch, trunk, etc.) and situations resulting from its movement in this forest typology, distinguishing situations that may eventually cause death, disability or superficial injury.

5.1.7. Site Characteristics—Terrain Slope (TS) and Obstacles (Obst)

The MIAR^{forest} states that severity is higher when work is carried out along a path with irregular terrain with a slope and obstacles to overcome and lower if the activity is carried out along a path on regular terrain with no slope and no obstacles to overcome. The severity levels of the occupational accident according to the characteristics of the path were defined according to specific bibliography on this topic, adapted to native forestry [8,39–46]. In the valuation of this parameter, small bridges, such as a bush or a *penguela*, were considered obstacles of difficult transposition. Trails constructed on waterlogged and unstable ground were also considered with the same severity level as trails with difficult obstacles. On the opposite side and with the lowest valuation are obstacles such as rocky outcrops of small size and/or fallen trunks/vegetation that can be easily transferred to another location, clearing the path.

The sub-parameter terrain slope (TS) definition met the experts' suggestions and the New Brazilian Forest Code, Law 12.651, of 25 May 2012, which defines 45° as the maximum slope limit allowed to operate in permanent preservation areas.

It was also decided that the severity is more significant in the case of the activity being developed with obstacles to overcome and lower otherwise, so large rocky outcrops were designated as obstacles of very complex transposition and occasionally requiring the use of external supports to overcome them, small bridges, such as a culvert or a footbridge, as obstacles of difficult transposition, small rocky outcrops and fallen trunks/vegetation which can easily be transferred to another location, clearing the path, as obstacles of easy transposition or removal and the paths performed on waterlogged and unstable ground as obstacles of very easy transposition.

5.1.8. Wild Animals

Regarding the presence (or not) of wild animals (WA) in the forest where the worker carries out the activity, it was decided that the severity is more significant if the activity is carried out within the presence of animals that are large and/or have a high potential for toxicity by bite or sting. The severity levels of the occurrence of occupational accidents due to the presence of wild animals was defined according to support from the SINAN—Sistema de Informação de Agravos de Notificação [54] and information from health professionals. The possibility of the occupational accident occurring not only by contact with venomous animals but also with other animals, such as mammals or birds, was considered.

5.1.9. Severity Bands

Severity is classified into five bands, as shown in Table 4. These bands comprise the values obtained according to Equation (3) and the values in the scores column in Table 4.

Table 4. MIAR^{forest} Severity bands.

Severity	Bands
Extreme	$S \geq 192$
High	$96 \leq S < 192$
Medium-high	$48 \leq S < 96$
Medium-low	$24 \leq S < 48$
Low	$S < 24$

To determine the limit of the bands, it was decided that all parameters would maintain the second lowest level of their scales, varying only the most harmful factor, falling objects.

1. Upper limit for "low severity" (<24)—all sub-parameters at the 2nd level of the respective scale;
2. Upper limit for "medium-low severity" (<48)—sub-parameter "object fall" at the 3rd level of the respective scale and the remaining parameters at the 2nd level of the respective scale;
3. Upper limit for "medium-high severity" (<96)—sub-parameter "object fall" at the 4th level of the respective scale and the remaining parameters at the 2nd level of the respective scale;
4. Upper limit for "high severity" (<192)—sub-parameter "object fall" at the 5th level of the respective scale and the remaining parameters at the 2nd level of the respective scale;
5. Lower limit for "extreme severity" (≥192)—sub-parameter "object fall" at the 5th level of respective scale and remaining parameters at the 2nd level of respective hierarchy.

5.2. Likelihood

The exposure value results from the association of two sub-parameters, the Extent of impact (Ei) and the Frequency of exposure (Fe), each with five bands (Table 5).

Table 5. MIAR^{forest} likelihood.

	Exposure—Ex—(Description)	Score
Extent of Impact Ei	>5 workers.	5
	4 workers.	4.9
	3 workers.	4.7
	2 workers.	4.4
	1 worker.	4
Frequency of Exposure Fe	Continuous (every day of the week).	5
	Usual (≥3 days/week).	4.5
	Partial (<3 days/week).	4
	Sporadic (≤1 day/week).	3.5
	Punctual (≤1 h/week).	3

The likelihood value is obtained by Equation (1) and is classified into five bands, as shown in Table 6.

Table 6. Likelihood bands.

Likelihood	Bands
Extreme	$E > 22$
High	$19.8 < E \leq 22$
Medium-high	$17.6 < E \leq 19.8$
Medium-low	$15.4 < E \leq 17.6$
Low	$E \leq 15.4$

5.2.1. Extent of Impact

The extent of impact is directly related to the number of workers that may be affected by the same occurrence during the activity(ies) they are performing. In this sub-parameter, five levels have been defined according to the number of workers potentially affected by an accident [33].

5.2.2. Frequency of Exposure

This sub-parameter is related to the length of time the worker is exposed to the risk of an occupational accident. Thus, allowing that the probability of an occupational accident increases with the time of exposure to the hazard [55], the five bands were defined considering different exposure periods in a continuous sequence. The attribution of the exposure time should be performed by attending to the following criteria:

- Continuous—the same activity is performed continuously and daily throughout the week;
- Usual—the same activity is performed for a period equal to or greater than half of the worker's weekly working hours;
- Partial—the same activity is performed during a period equal to or less than half of the worker's weekly working hours;
- Sporadic—the same activity is performed for a period equal to or less than one day during the working week;
- Occasional—the same activity is performed during a period equal to or less than one hour during the working week.

This classification is only valid for routine activities. Activities which are not included in the worker's weekly routine must be assessed separately.

5.2.3. Likelihood Bands Explanation

The likelihood bounds were calculated considering a task performed by a maximum of two workers for different exposure times, as explained below:

1. Upper limit for low likelihood—two workers exposed on an occasional basis (<1 h/week);
2. Upper limit for medium-low likelihood—two workers exposed on a sporadic basis ($\leq$1 day/week);
3. Upper limit for medium-high likelihood—two workers exposed about half of the working week (<3 days/week);
4. Upper limit for high likelihood—two workers exposed about half of the working week ($\geq$3 days/week);
5. Lower limit for extreme likelihood—two workers exposed continuously (every day of the week).

5.3. Risk Control

The risk to which workers are exposed when performing a task is not necessarily the same whether the task is performed in a company with an efficient risk management and control system or in a company without any risk control system. Therefore the MIAR and the MIAR$^{\text{forest}}$ take this into consideration when assessing risk. The MIAR$^{\text{forest}}$ considers various levels of implementation of risk management systems (Table 7) that should be included in the risk level assessment.

Table 7. Risk Control—Performance of prevention systems.

Performance of Prevention Systems (Description)	Score
There is no occupational health and safety management system or any control of occupational health and safety.	0.50
There is no occupational health and safety management system in place, and there is an occupational health and safety control system with visible flaws in its operation.	0.75
There is no occupational health and safety management system in place, but there is an occupational health and safety control system with evidence of operational practices.	1.00
There is an occupational health and safety management system, but there is no objective evidence of a continuous improvement culture.	1.50
There is a continuous improvement culture linked to an occupational health and safety management system with evidence of its functionality.	2.00

5.4. Risk Level

The MIAR$^{\text{forest}}$ states that the risk level (RL) is based on severity and likelihood. However, it also states that the resulting value must be weighted by the performance of the prevention systems existing in the organisation. Thus, the weighted risk level is determined according to Equation (5).

$$\text{WRL} = \frac{\text{S} \times \text{Li}}{\text{RC}}, \tag{5}$$

The rationale for determining each of the different risk bands is based on the fact that in native rainforest management operations, the vast majority of tasks are performed by three or fewer workers on a non-continuous basis. Starting from this reality, risk level band limits were calculated for these operational conditions of likelihood (maximum value—19.8) combined with the band limits already defined for severity. For all the levels of risk, the existence of an occupational health and safety control system, with evidence of operational practices (score 1—Table 7) is considered.

1. Risk Level 1 (RL1)—the band's upper limit represents the combination with a medium-low severity level (maximum value—24). To the result of this combination (475.2), the decimal digits have been truncated (475). Values lower than 475 obtained with other configurations are also included in this band.
2. Risk Level 2 (RL2)—the upper limit of the band is the combination of the defined likelihood ratio with a medium-low severity level (maximum value 48). To the result

of this combination (950.4), the decimal digits have been truncated (950). Scores of 950 or lower obtained with other configurations are also accepted.

3. Risk Level 3 (RL3)—the upper limit of the band is the combination of the defined likelihood ratio with a medium-high severity level (maximum value—96). To the result of this combination (1900.8), the decimal digits have been truncated (1900). Values lower than 1900 obtained with other configurations are also included in this band.
4. Risk Level 4 (RL4)—the band's upper limit is the combination of the defined likelihood ratio with a high level of severity (maximum value—192). The result of this combination (3801.6) has been rounded to 3800. Values lower than 3800 obtained with other configurations are also accepted in this band.
5. Risk Level 5 (RL5)—This band represents the maximum level of risk and includes all values above 3800.

The risk level bands and the respective assigned scores are presented in Table 8.

Table 8. MIAR^{forest} Risk level.

Risk Level 5 (RL5)	RL5 > 3800
Risk Level 4 (RL4)	1900 < RL4 ≤ 3800
Risk Level 3 (RL3)	950 < RL3 ≤ 1900
Risk Level 2 (RL2)	475 < RL2 ≤ 950
Risk Level 1 (RL1)	RL1 ≤ 475

5.5. Prioritisation of Control Measures

The prioritisation of control measures proceeds from risk level. That is, the highest risk level is the primary priority, and lower risk levels correspond to lower priority, as shown in Table 9.

Table 9. Prioritisation of control measures.

Priority	Risk Level	Description
V	RL5 > 3800	Unacceptable conditions. The activity/task should be suspended immediately. The activity/task should only be restarted after a detailed risk assessment and the definition and implementation of corrective actions and control measures.
IV	1900 < RL4 ≤ 3800	Critical conditions which require urgent correction. A detailed risk assessment and the short-term definition and implementation of corrective actions and control measures are required.
III	950 < RL3 ≤ 1900	Conditions to improve. Preventive and control measures should be taken/revised.
II	475 < RL2 ≤ 950	Conditions subject to surveillance. Possible improvements should be considered.
I	RL1 ≤ 475	Conditions in which no immediate intervention is required.

5.6. Control Measures

Mitigation and control of occupational risks resulting from native forest management activities shall incorporate good occupational health and safety practices. The implementation of control measures shall be in accordance with the following hierarchy:

1. Application of administrative controls, including worker procedures and training, emergency management and medical monitoring;
2. Implementation of missing personal protective equipment (PPE) as a complement to other control measures;
3. Modification of the process or process conditions, where possible, to enclose or isolate the worker from the environment to prevent exposure;
4. Implementation of engineering controls and external advice;
5. Elimination of the specific risks of a particular activity by avoiding carrying it out or replacing it with one of lower risk.

6. Conclusions

The process of timber forest management involves various risks related to the safety and health of the worker, which is known to result in a high number of accidents, generally serious ones. Workers' physical safety and health can be safeguarded by complying with legislation on health and safety at work and by implementing mechanisms for monitoring the forest management activity itself.

Assessing occupational risks allows employers to effectively protect workers from work accidents and occupational diseases. The MIAR^{forest} permits the assessment of occupational risk associated with the process of timber forest management in native rainforests in an appropriate way as it includes, among other aspects, the assurance that all relevant risks are taken into account and verifies the effectiveness of the safety measures adopted.

According to the results, the MIAR^{forest} seems to be a promising method for occupational risk assessment with the potential to be implemented strategically and systematically by the native rainforest industry.

The main added value of this method is that it is relatively simple to apply and allows reliable conclusions to be drawn. However, the MIAR^{forest} is not a closed method. Therefore, a website is being designed with two objectives, dissemination of the method and collection of suggestions for change in order to achieve a continuous improvement of the method.

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