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Agricultural Fatal Accidents Involving Use Of Self Propelled Machineries With Operator On Board: Preliminary Analysis

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Abstract

This paper delves into the analysis of fatal accidents occurring within the agricultural sector, specifically focusing on accidents involving self-propelled machinery with operators on board. Leveraging data sourced from the National Institute for Occupational Safety and Health (NIOSH) fatality investigation report, a comprehensive examination was conducted to discern the primary factors contributing to these accidents. A structured database was developed through a meticulous review of accident reports, comprising two main sections. The first section offers a comprehensive overview of general accident details, including the number of individuals involved, the average age of operators, and the type of machinery involved. The second section, focusing on the taxonomy of factors, categorizes and analyses the primary causal factors contributing to accidents. Through rigorous analysis, significant trends over time and seasonal variations in accident rates were uncovered. Additionally, the investigation identified key causal factors within distinct categories, shedding light on critical areas for intervention. The findings underscore the imperative for targeted preventive strategies aimed at mitigating the inherent risks associated with the utilization of agricultural machinery. The findings from the analysis strongly indicate the necessity for proactive measures to reduce accidents in agriculture. These could include adopting new technologies, assessing the efficacy of interventions, and fostering a safety-conscious culture through training and widespread sharing of knowledge.

Keywords: agricultural accidents, self-propelled machineries, fatal injuries, workplace safety, occupational hazards, NIOSH, NIOSH FACE Program

1. Introduction

The agricultural sector, encompassing half of the world's labour force, stands as a cornerstone of global economies, vital for sustenance and livelihoods. However, it also presents one of the most perilous occupational environments, contributing to approximately 170,000 fatalities annually (International Labour Organization, 2020). According to the 2019 Census of Fatal Occupational Injuries (U.S. Bureau of Labor Statistics, 2019), workers in the agriculture, forestry, and fishing (AFF) sector have a fatal work injury rate of 23.1 per 100,000 full-time equivalent workers and are seven times more likely to die on the job than non-AFF workers.

The prevalence of fatal accidents in agriculture is attributed to a multitude of hazards inherent to farming practices, compounded by factors such as prolonged working hours, heavy reliance on family labour, and frequently, solitary work conditions (Lehtola et al., 2008).

One of the most significant hazards faced by agricultural workers is the operation of machinery, including tractors, combines, and other self-propelled equipment. Despite advancements in technology and increased attention to workplace safety, accidents involving agricultural machinery continue to occur, resulting in severe injuries and fatalities (Arana et al., 2010; Kennedy et al., 2014; Shortall et al., 2019). Understanding the factors contributing to agricultural machinery-related accidents is essential for promoting worker safety, reducing public health burdens, and informing policy development.

This research aims to investigate the dynamics of such accidents, examining their causes, consequences, and potential preventive measures.

The primary aim of the analysis is to delve deeply into the dynamics and factors behind accidents within the agricultural sector. As noted, the substantial involvement of operators underscores the necessity for a comprehensive examination of accident-contributing factors. This enables effective intervention and resolution of lingering issues.

In this paper, we explore the relevance of this research topic, its public health impact, practical applications, policy implications, and interdisciplinary nature. In particular, this paper aims to investigate accidents occurring in the agricultural sector, specifically related to the use of self-propelled agricultural machinery with an operator on board, drawing information from available databases. This investigative activity serves as the starting point to accurately evaluate and identify the primary factors leading to injuries or fatal accidents in the agricultural field, in order to consider and study solutions allowing for a substantial reduction in the number of accidents that still occur despite increasing attention to workplace safety and advancements in regulatory frameworks.

The selected database for analysis is sourced from the Fatality Assessment and Control Evaluation (FACE) Program (NIOSH, 2023). Through this program, the National Institute for Occupational Safety and Health (NIOSH) conducts investigations into fatal occupational injuries, preparing reports with recommendations to prevent similar deaths. Initiated in 1982, the NIOSH FACE Program is a dedicated research initiative aimed at preventing job-related injuries and deaths by investigating selected fatalities, identifying hazards, developing workplace prevention recommendations, and disseminating recommendations to employers, safety professionals, and workers.

The choice of this database was motivated by the comprehensive nature of the information available for each accident, facilitating a thorough review of circumstances related to agricultural accidents caused by the use of self-propelled machinery with an operator on board. The methodological approach adopted accident dynamics and the development of effective mitigation strategies.

The subsequent sections of this paper are organized as follows. Section 2 outlines the structured database was developed through a meticulous review of accident reports. In Section 3, a systematic analysis of the factors contributing to accidents is conducted, aiming to comprehensively understand the data and elucidate relationships among the variables under examination. Section 4 presents and delves into the results derived from our comprehensive analysis. Section 5 offers conclusions drawn from our findings and proposes potential avenues for future research in related domains.

2. Methodology

The NIOSH FACE Program provides users with access to the full text of fatality investigation reports a detailed overview of fatal accidents occurring on American soil from 1992 to 2023, comprising a total of 211 recorded events. Each accident is documented through a comprehensive report, encompassing general information such as the age and gender of individuals involved, the day of occurrence, and pertinent details facilitating the reconstruction of the accident's dynamics and causes, including the work environment, type of machinery, and asphalt conditions, among others.

We opted to utilize the NIOSH database due to its comprehensive nature and the wealth of information available in its descriptive reports of fatal accidents. In comparison to other databases we explored, which lacked sufficient content to form a coherent dataset for structured analysis, the NIOSH database clearly stood out as the superior choice. Furthermore, NIOSH's collaboration with government institutions like the United States Department of Labor lends credibility and authority to its data and information on workplace safety and health.

2.1. Database used to conduct the analysis

Subsequent to a meticulous review of the reports pertaining to each accident, a specialized and structured database was developed to compile and emphasize the most pertinent information. The database is comprised of two primary sections, aimed at providing a comprehensive view of the accident's dynamics while accentuating the precipitating causes. The initial segment delineates details pertinent to the operator and the accident in general, as illustrated in Table 1.

Table 1. Excerpt of the database highlighting general factors.

Involved persons	Average Age	Day	Month	Season	Year	Type of contract	Performed Activity	Type of machinery/model
1	56	28/06/2023	June	summer	2020	-	operating a tractor	tractor-1971 harvester 1066 open cab row crop
1	21	19/08/2023	August	summer	2021	-	work as a "sorter"	harvester
1	11	04/08/2023	August	summer	2020	-	cleaning corn off a silo floor	auger
1	22	06/02/2023	February	winter	2021	full time	cleaning and debirs removal	shredder
1	45	-	-	summer	2017	full time	bring the harvesting equipment on the orchard	deutz 3006 farm tractor

This section furnishes an overview of fundamental variables, encompassing elements such as:

- Involved person: the number of individuals implicated in the accident;
- Average Age: the age of the involved operator;
- Day: the day on which the accident transpired;
- Month: the month during which the accident occurred;
- Season: the season in which the accident took place;
- Year: the year in which the accident occurred;
- Type of contract: the nature of the employment contract signed by the operator;
- Performed Activity: the type of activity undertaken by the operator at the time of the accident;
- Type of machinery/model: the category of agricultural machinery utilized and its specific model, etc.

The subsequent section, depicted in Table 2, focalizes on the taxonomy of factors, proffering an analysis of the causes instigating the accident. This segment of the database endeavours to methodically classify and categorize the pivotal factors contributing to the accident, furnishing a structured and detailed elucidation. For clearer classification at a glance, each contributing factor to the accident has been allocated a distinct colour.

Table 2. Excerpt of the database highlighting taxonomy of factors.

Trigger/blame	Latent factor			Contingent factor	
		Personnel	Working environment	Socio-technical	Environmental
	no ROPS, no seatbelts, lack of periodic maintenance, old equipment	lack of training	no markers on ground,road condition	night shift, lone worker, heavy load	-
		inadequate clothes, communication issues	-	night shift	obstacle
entanglement with active machinery		no lockout-tagout procedure, young worker, inadequate clothes	confined space, inadequate lighting	unguarded active machinery, unsupervised activity	-
entanglement with active machinery	no operator presence operating system (OPPS), lack of safety warnings	lack of training	-	lone worker	-
	lack of periodic maintenance, non-functional emergency brake	lack of training	-	tractor's critical issue, heavy load, lone worker	-
accidental start of operation	old equipment, inadequate equipment, rewired safety devices	no safety procedures	-	lone worker	field conditions,weather issue

Specifically, the ensuing categories of factors impacting the incidence of the accident were identified, each bearing specific relevance within the analytical milieu:

- Trigger/blame. This category epitomizes the precipitating cause, the event directly accountable for the fatal accident. It underscores the pivotal element that initiated the sequence of events culminating in the accident itself.
- Latent factor. Latent factors denote those correlating with the accident, albeit not directly culpable. Within this category, discrete subclasses were identified, inclusive of "Machinery related" (pertaining to the machinery), "Personnel" (pertaining to the individual), and "Working environment" (pertaining to the work milieu). These subclasses proffer a nuanced breakdown of the influences contributing to accidents.

- Contingent factor. Contingent factors hinge upon specific or particular circumstances influencing the likelihood of an event transpiring. Pertaining to this category, subclasses were delineated concerning "Socio-technical factors," encapsulating the interplay between social and technological factors, and "Environmental factors," pertaining to the proximate environment, encompassing terrain and meteorological conditions. This targeted stratification facilitates a detailed and systematic classification of the pivotal factors contributing to accidents, furnishing a comprehensive and structured framework for an exhaustive analysis of the implicated dynamics.

3. Analysis of fatal accidents

Following the creation and compilation of the database, a structured analysis of the accidents factors was conducted to comprehensively understand the data and relationships among the variables under examination. The analysis aimed to:

- Identify trends and patterns. The analysis helps identify any trends, patterns, or significant relationships within the data. This can assist in identifying recurring behaviours or anomalies that may otherwise go unnoticed.
- Describe the data. Descriptive statistics, such as mean, median, standard deviation, etc., provide a clear and concise summary of the fundamental characteristics of the data. This helps gain an overview of the distributions and variations present.
- Assess significance. The analysis can help determine the significance of certain factors or relationships among them. This is particularly important when seeking to understand the impact of specific variables on the situation at hand.
- Support decision-making. The analysis provides an objective framework for making informed decisions. It helps reduce the risk of misinterpretations or decisions based on unverified intuitions.

To conduct a comprehensive analysis of the results, key discriminants were considered to obtain a complete understanding of the dynamics leading to fatal accidents. Firstly, the total number of accidents recorded from 1992 to the current year of 2023 was examined to identify annual trends that may emerge over the years. This approach provided a temporal perspective to evaluate the overall trend of accidents over time. Additionally, seasonality was considered as an important discriminant to identify any repetitions during different seasons (winter, autumn, spring, summer) within a year. This analysis aimed to reveal recurring patterns related to seasonal conditions, thus contributing to a deeper understanding of influencing factors in specific periods. Finally, attention was focused on the causes that have the greatest impact for each defined class of factors. This step allowed for the identification and understanding of key variables contributing to accidents within specific categories, facilitating a targeted strategy for prevention and management.

Through this stratified analysis, it has been possible to extract significant insights that go beyond simple quantification of accidents, offering a deeper understanding of temporal trends, seasonal influences, and predominant causes.

3.1. Total number of fatal accidents from 1992 to 2023

The initial graphical analysis, depicted in Figure 1, focused on studying the trend over the years of the number of recorded accidents. From the analysis of the graph, it is evident that the peak occurred in 1995, with a recorded number of fatal accidents reaching 36. However, from 1992 to 2005, the trend appears rather irregular, showing significant variations before stabilizing from 2005 to the present. Several factors contributed to the significant reduction in agricultural accidents in the USA before 2006:

- Implementation of Safety Regulations. The introduction and enforcement of safety regulations by governmental agencies such as the Occupational Safety and Health Administration (OSHA) played a crucial role. These regulations mandated safety practices, equipment standards, and training requirements for agricultural workers and employers.
- Advancements in Technology. Before 2006, there were notable advancements in agricultural machinery and equipment aimed at improving safety. Innovations such as rollover protection structures (ROPS) on tractors, guards on power take-off (PTO) shafts, and safety features on harvesting equipment helped reduce the risk of accidents.
- Education and Training Programs. Increased awareness of farm safety and the implementation of education and training programs helped farmers and agricultural workers adopt safer practices. These programs provided valuable information on equipment operation, hazard identification, and emergency response, contributing to accident prevention.

- Research and Development. Investment in research and development led to the identification of hazards in agricultural work and the development of solutions to mitigate risks. Research institutions, universities, and agricultural organizations collaborated to study safety issues and develop innovative technologies and practices to address them.
- Industry Initiatives. Agricultural organizations and industry associations initiated campaigns and programs to promote farm safety. These initiatives provided resources, training materials, and support to farmers and farmworkers, encouraging the adoption of safer practices across the industry.
- Public Awareness and Advocacy. Increased public awareness of farm safety issues, fueled by media coverage and advocacy efforts, contributed to a cultural shift towards prioritizing safety in agriculture. Safety advocates, including nonprofit organizations and community groups, raised awareness about the importance of farm safety and lobbied for policy changes to improve

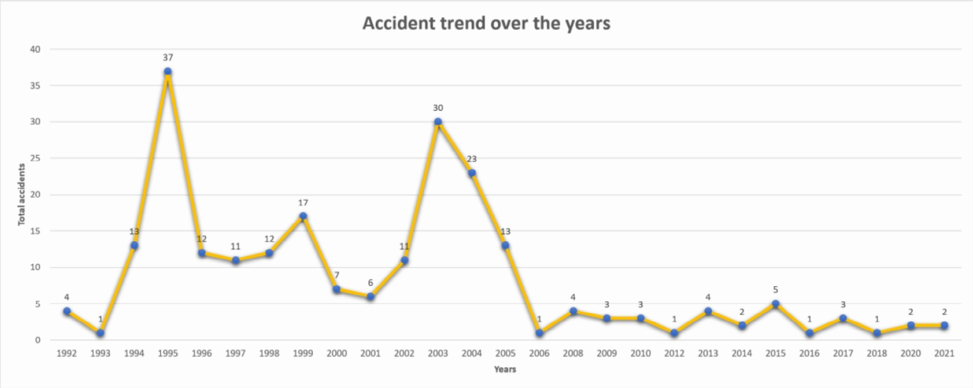

Fig. 1. Accident trend over the years.

The regularity observed in recent years suggests a possible positive impact of these variables, indicating increased awareness and commitment in the agricultural sector to mitigate risks associated with the use of agricultural machinery.

3.2. Seasonality

The analysis of seasonality, as shown in Figures 2 and 3, plays a fundamental role in revealing any anomalies or deviations from usual seasonal patterns. For this reason, the emergence of significant differences in the number of accidents in relation to the different seasons of the year was evaluated graphically. Furthermore, analyzing seasonal variations could also prove useful in developing more targeted preventive strategies and formulating appropriate interventions based on the time of year when accidents are most frequent or critical.

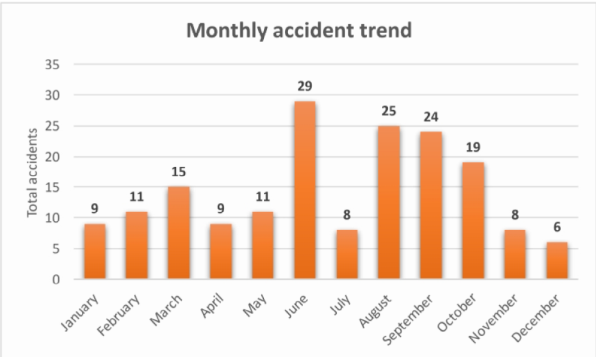

Fig. 2. Monthly accident trend.

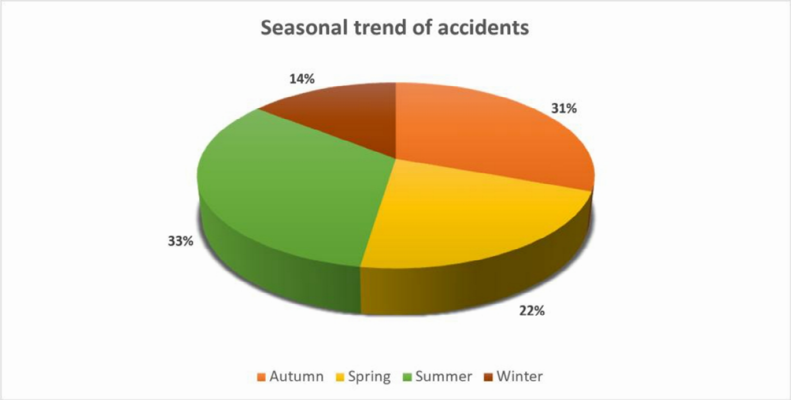

Fig. 3. Seasonal trend of accidents.

From the analysis of the first graph shown in Figure 2, it is immediately apparent that the month of June records the highest number of fatalities. This data can be rationalized by considering that June represents the period dedicated to the harvesting of most summer fruits and vegetables, followed, in order, by the months of August and September. Dividing the year into two semesters, from January to June and from July to December, it is observed that in the first semester, June continues to hold the record for the highest number of fatalities. In the second semester, however, a bimodal distribution emerges, with August and September competing for the month with the highest number of fatalities. On the other hand, December stands out as the month with the lowest number of fatalities, totaling only 6 accidents. The graph shown in Figure 3 confirms and emphasizes what has already been highlighted by the graph just analyzed.

In conclusion, it is plausible to state that summer and autumn represent the seasons with the highest number of fatalities, contributing respectively to 41% and 33% of the total accidents. These periods are critical from various perspectives: sowing and harvesting activities inherently present criticalities, long working days can generate stress and fatigue factors, and it should be noted that in some regions agriculture involves seasonal workers, often with limited experience and, in most cases, poor knowledge of the language. Understanding these seasonal patterns and accompanying factors can provide an essential basis for the development of preventive strategies and interventions aimed at improving safety in the agricultural sector.

3.3. Main causes per factor class

In this analysis, for each category of factors, the most accident causes within each subclass were identified, graphing both in absolute and percentage terms the incidence of each factor in relation to the belonging class. This analysis was conducted to delve into a greater level of detail and appreciate the actual triggering causes of the accident. Regarding the graphs, it is necessary to consider that the individual factors pertaining to the belonging class have not been reported, but it was chosen to report those whose percentage incidence was not less than 2%.

3.3.1. Latent factors

a) *Machinery related*. Referring to the graph in Figure 4, it can be affirmed that, concerning factors related to the machine, the accident-triggering causes occupying 50% cumulated on the total percentage include:

- Inadequate equipment;
- No ROPS (Roll-Over Protective Structure): absence of roll-over protective structure;
- No seatbelt: Absence of seatbelt;
- Lack of periodic maintenance.

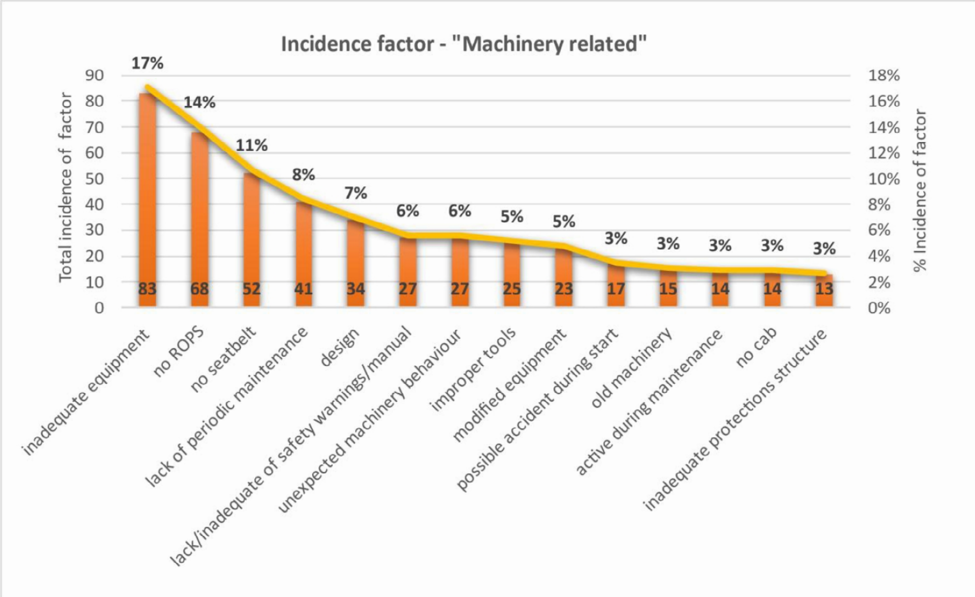

Fig. 4. Incidence of Factors - Machinery Related.

b) *Personnel*. Referring to the graph in Figure 5, it can be affirmed that, concerning factors related to the individual, the main triggering cause, with an incidence of 63% of the total, pertains to "Inadequate Procedure," i.e., the execution of procedures incorrectly by the worker.

c) *Working environment*. Referring to the graph in Figure 6, it can be affirmed that, concerning factors related to the working environment, the main triggering cause, with an incidence of 90% of the total, pertains to "Adverse Ground/Improper Work Area," i.e., ground criticalities and inadequate work areas.

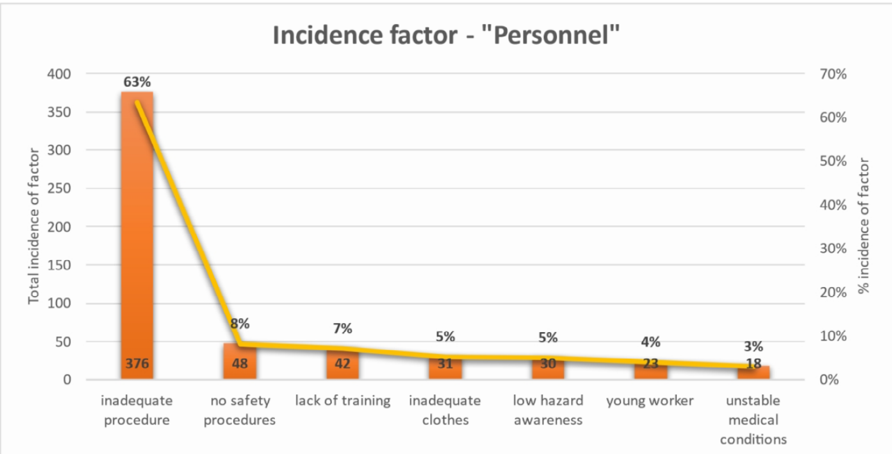

Fig. 5. Incidence of Factors - Personnel.

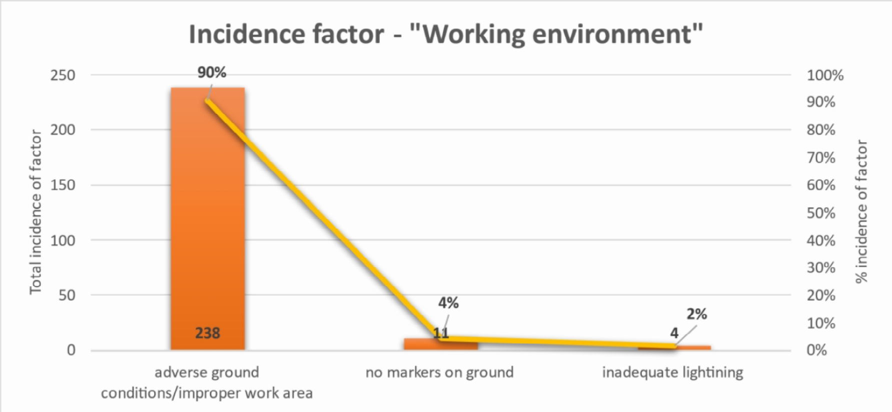

Fig. 6. Incidence of Factors - Working environment.

3.3.2. Contingent factors

a) *Socio-technical*. Referring to the graph in Figure 7, it can be affirmed that, concerning socio-technical factors, the conditions in which the worker is alone ("Lone Worker") and the need to handle heavy loads ("Heavy Load") are the most significant.

b) *Environmental*. Referring to the graph in Figure 8, it can be affirmed that, concerning environmental factors, the conditions of the field ("Field Conditions") and the presence of obstacles ("Obstacles") significantly contribute to the cause of accidents.

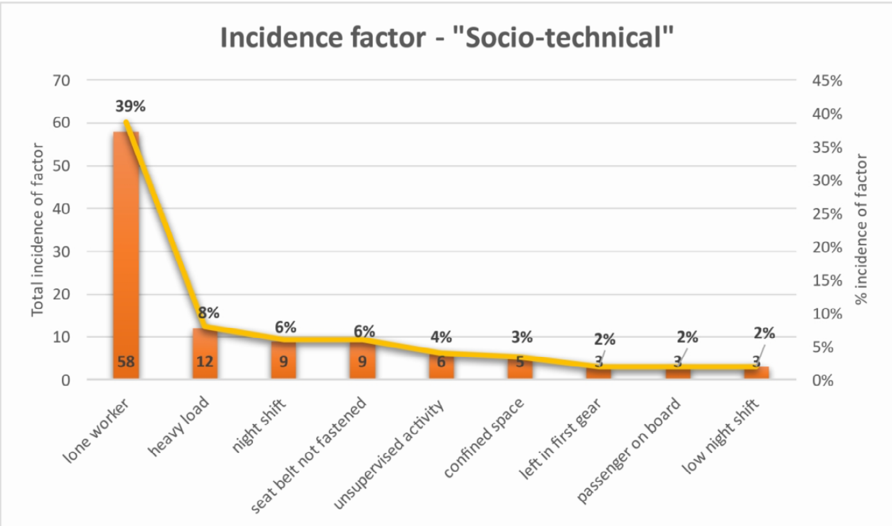

Fig. 7. Incidence of Factors – Socio-technical.

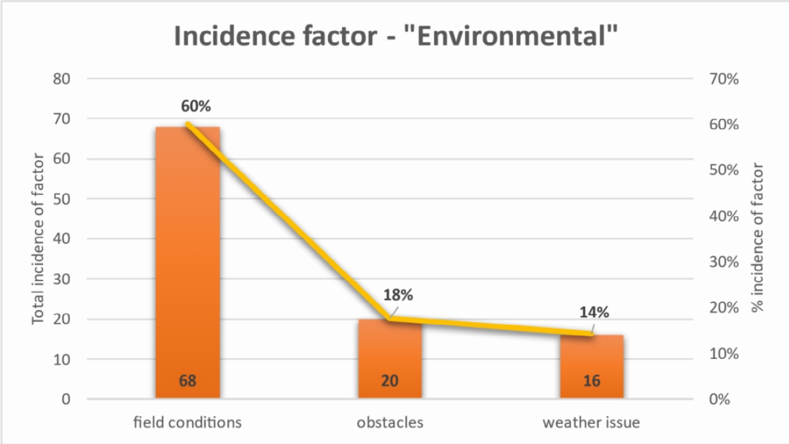

Fig. 8. Incidence of Factors - Environmental.

4. Results and discussion

The analysis of fatal incidents spanning over three decades, from 1992 to 2023, provides valuable insights into the dynamics of agricultural safety. A pronounced peak in incidents was observed in 1995, followed by irregular fluctuations until stabilization around 2005. Subsequent years demonstrated a consistent trend, suggesting potential positive impacts stemming from legislative reforms and heightened safety awareness initiatives within the agricultural sector.

Seasonal analysis revealed summer and autumn as pivotal periods, with the majority of incidents occurring during these times. Intensive harvesting activities, prolonged working hours, and the employment of seasonal labourers were identified as key contributors to heightened risks during these seasons. Furthermore, a detailed examination of causal factors within machinery-related, personnel, and environmental categories elucidated critical underlying issues. Inadequate equipment maintenance, improper operational procedures, and adverse working conditions emerged as predominant factors precipitating fatal incidents..

Beyond mere observation, the findings prompt a deeper discourse on the systemic challenges underlying agricultural safety. Structural issues such as resource constraints, cultural attitudes towards risk, and gaps in regulatory enforcement warrant concerted attention. Furthermore, the integration of technological solutions, including advanced safety features and real-time monitoring systems, presents promising avenues for enhancing workplace safety in agricultural settings. For stakeholders, including policymakers, industry representatives, and agricultural workers, several actionable insights emerge:

- Invest in Training Programs. Allocate resources towards comprehensive safety training programs that educate agricultural workers on hazard identification, safe equipment operation, and emergency response protocols.
- Implement Technological Solutions. Embrace innovative safety technologies such as sensors, automation, and wearable devices to mitigate risks and enhance worker safety on farms.
- Strengthen Regulatory Frameworks. Enact and enforce robust safety regulations tailored to the unique challenges of the agricultural sector, ensuring compliance through regular inspections and penalties for non-compliance.
- Foster Collaboration. Facilitate collaborative efforts between stakeholders to share best practices, lessons learned, and resources, fostering a collective commitment to improving safety standards.
- Prioritize Research and Development. Support research initiatives aimed at identifying emerging safety risks, evaluating intervention effectiveness, and developing practical solutions to enhance workplace safety in agriculture

5. Conclusions

This study delves into the intricate dynamics of fatal accidents within the agricultural domain, serving as a catalyst for proactive safety measures. By analysing trends over time and identifying underlying causes, it lays a solid groundwork for targeted risk reduction strategies. However, the successful implementation of these strategies hinges on collaborative efforts across a spectrum of stakeholders, including policymakers, industry representatives, and agricultural workers.

Looking ahead, stakeholders in agriculture should prioritize certain key actions to bolster safety practices. Firstly, there's a pressing need to enhance training programs for agricultural workers. These programs should go beyond basic safety protocols to address the specific hazards inherent in various agricultural tasks and environments. Additionally, fostering collaboration among stakeholders is paramount. By sharing best practices, resources, and lessons learned, the industry can collectively work towards improved safety outcomes.

Moreover, the integration of innovative safety technologies holds promise. Sensors, drones, and wearable devices offer real-time monitoring and hazard detection capabilities, potentially revolutionizing safety practices in agriculture. However, regulatory frameworks must also be strengthened to ensure the effective implementation of safety measures. Advocating for robust regulations tailored to agricultural contexts is essential for mitigating risks effectively.

Furthermore, promoting a culture of safety consciousness is crucial. Encouraging open communication, recognizing and rewarding safe behaviours, and involving workers in safety decision-making processes can foster a collective commitment to safety excellence.

In terms of future research, evaluating the effectiveness of safety interventions and developing tailored technologies are key priorities. Longitudinal studies tracking the outcomes of safety initiatives and assessing their scalability and adaptability across diverse agricultural settings will provide invaluable insights for evidence-based practices.

Ultimately, by embracing evidence-backed approaches and leveraging technological advancements, the agricultural sector can chart a course towards a safer, more resilient future. Through sustained dedication and collaborative action, stakeholders can collectively safeguard the well-being of agricultural workers and instil a culture of safety excellence within the industry.

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