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Farm machinery safety in Indian agriculture: A comprehensive review

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Abstract
This comprehensive review paper delves into the escalating issue of farm machinery accidents in Indian agriculture, where the widespread adoption of modern farming practices and the mechanization of agriculture have brought about increased risks for farmers and laborers. The paper begins by providing an overview of the prevalence and geographical distribution of these accidents, shedding light on their magnitude and regional disparities. It then delves into a detailed analysis of the multifaceted causes and risk factors contributing to these accidents, including equipment design, operator training, and environmental influences. By scrutinizing the sociodemographic profiles of victims, the study highlights vulnerable groups at higher risk of accidents, emphasizing the need for tailored safety measures and interventions. Moreover, the review explores the economic and social implications of farm machinery accidents on the affected individuals and their communities, shedding light on the broader consequences of these accidents. It critically evaluates the existing safety regulations and policies in India, assessing their effectiveness in mitigating accidents and safeguarding the agricultural workforce. In addition, the paper draws from international best practices and innovative approaches aimed at reducing farm machinery accidents, presenting a range of strategies that have proven successful in other agricultural settings and could be adapted to the Indian context.

Keywords: Farm machinery accidents, Indian agriculture, risk factors, safety regulations, socioeconomic impact etc.

Introduction
Agriculture has long been the backbone of India's economy, employing a significant portion of its population and providing sustenance to millions. With the advancement of technology and the mechanization of farming practices, the sector has witnessed a transformation that has boosted productivity and efficiency. Farm machinery has become an integral part of modern Indian agriculture, enabling farmers to till, sow, harvest, and transport crops more effectively. However, this mechanization has also brought about a growing concern – farm machinery safety. As the use of these powerful tools becomes more prevalent, so does the potential for accidents and injuries. This comprehensive review paper addresses the critical issue of farm machinery safety in Indian agriculture, seeking to shed light on the various aspects of this challenge, including its prevalence, risk factors, existing safety measures, and the socio-economic implications of accidents in this vital sector. By examining these factors, this review aims to provide a comprehensive understanding of the current state of farm machinery safety in India and to offer insights that can guide future policies and practices to protect the well-being of those who labor in the fields and contribute to the nation's food security.

In the Indian agricultural landscape, laborers constitute a pivotal source of farm power, actively engaging with a variety of equipment, including animal-drawn machinery, tractors, power tillers, as well as self-propelled and power-operated devices. Table 1 provides insight into the demographic dynamics of the Indian agricultural workforce, projecting a total population of approximately 242 million agricultural workers by 2020, with females accounting for half of this workforce. This underscores the substantial role played by farm laborers in the nation's agriculture, emphasizing the critical need to prioritize their safety and occupational health concerns. Doing so can result in enhanced productivity, reduced accident rates, and fewer occupational health issues, all of which are integral to the overall success of the agricultural sector.

Table 1: Population dynamics of Indian agricultural workers (No. in million)

S.N.	Particulars	2001	2007	2012	2020
1	Country's population	1029	1130	1210	1330
2	No. of workers as % of population	39	41	42	45
3	Total No. of workers	402	463	508	605
4	% of agricultural workers to total workers	58.2	52.0	47.5	40.0
5	No. of agricultural workers	234	241	241	242
6	% of females in agril. Work force	39	42	45	50
	of male agri cultural workers	143	140	132	121
	No. off male agricultural workers	91	101	109	121

Source (Banthia, 2004; GOI, 2002; GOI, 2006) [1, 5-]

A wealth of research has been dedicated to the study of farm machinery accidents and injuries in the United States and other industrialized nations, as evidenced by studies conducted by Myers *et al*. (2009) [12], HAE (2009), and Mukherjiee and Chang Ping (2008) [11]. Conversely, the body of literature addressing these issues in developing countries is considerably limited. In the context of India, notable studies include those by Verma *et al*. (1978) [18], Tandon *et al*. (1988) [15], Mohan and Patel (1992) [10], Mittal *et al*. (1996) [19], Lakhtakia (2000) [8], Patel *et al*. (2001) [13], and Tiwari *et al*. (2002) [16]; however, their investigations primarily centered on specific problems or regions. In pursuit of comprehensive and representative data regarding agricultural accidents in India, a survey was undertaken in selected villages across four states, namely Madhya Pradesh, Tamil Nadu, Orissa, and Punjab, covering incidents that occurred during the years 1995-1999 (Gite and Kot, 2003) [3]. This survey yielded valuable insights, indicating that fatalities resulting from agricultural accidents amounted to 21.2 per 100,000 workers annually. The primary sources of these accidents were farm machinery, including tractors, threshers, chaff cutters, cane crushers, sprayers, and electric motors. Other contributing factors included snake bites, incidents of drowning in wells or ponds, and lightning strikes.

Methods and Materials

Data Collection: Considering the gravity of the farm machinery accident situation and the imperative need for a comprehensive dataset, a meticulous survey was conducted across a diverse and extensive geographical spread. This survey was carried out in collaboration with the Indian Agricultural Statistical Research Institute, New Delhi. Seven states, namely Madhya Pradesh, Tamil Nadu, Orissa, Punjab, Rajasthan, Arunachal Pradesh, and West Bengal, were selected as the study's geographical scope. To ensure a representative dataset, a systematic approach was adopted. From each of these states, 20% of the total districts were thoughtfully chosen, with the aim of capturing the diversity of agricultural practices and regional nuances. Within each selected district, a total of 40 villages were randomly chosen for the survey work. This randomized selection process sought to mitigate any potential bias and ensure the inclusivity of various demographic, agricultural, and environmental factors.

Data Collection Period

The data collection phase extended over a significant timeframe to encompass seasonal and yearly variations. Field investigators were assigned to visit the selected villages periodically, covering a period of one year between 2004 and 2007, as specified in Table 2. This extended data collection period aimed to capture the dynamic nature of farm machinery accidents, considering variations in agricultural activities, equipment usage, and environmental conditions over the course of a full year.

Accident Data Gathering

Field investigators were equipped with standardized data collection tools and methodologies to ensure the consistency and reliability of the information gathered. Their visits to the selected villages included interviews with farmers and agricultural workers, as well as inspections of accident reports, hospital records, and any other relevant sources of information. This comprehensive approach aimed to compile accurate and representative data on the occurrence, causes, and outcomes of farm machinery accidents in the selected regions.

Data Compilation and Analysis: The collected data were meticulously compiled and subjected to rigorous analysis. Statistical methods were employed to assess the frequency and severity of accidents, identify common causative factors, and derive meaningful insights into the patterns and trends of farm machinery accidents within the surveyed regions. The statistical analysis was complemented by qualitative assessments of accident reports and interviews, providing a well-rounded perspective on the issue.

Table 2: Details of agricultural accidents data collected by centres of AICRP on ESA in the respective states

State	No. of villages surveyed	Data collection period	No. of accidents reported			
			Farm machinery	Hand tools	Others	Total
Tamil Nadu	240 from	July 04-	116	137	308	561
	6 districts	June 05	(20.7%)	(24.4%)	(54.9%)	(100%)
Orissa	240 from	July 04-	176	262	78	516
	6 districts	June 05	(34.1%)	(50.8%)	(15.1%)	(100%)
Madhya Pradesh	360 from	July 04-	84	38	67	189
	9 districts	June 05	(44.5%)	(20.1%)	(35.4%)	(100%)
Punjab	200 from	Jan 05-	33	0	8	41
	5 districts	Dec 05	(80.5%)	(0%)	(19.5%)	(100%)
Rajasthan	280 from	July 05-	173	52	228	453
	7 districts	June 06	(38.2%)	(11.5%)	(50.3%)	(100%)
Arunachal Pradesh	160 from	July 05-	8	50	27	85
	4 districts	June 06	(9.4%)	(58.8%)	(31.8%)	(100%)
West Bengal	120 from	Sept 06-	108	244	93	445
	3districts	Aug07	(24.3%)	(54.8%)	(20.9%)	(100%)
Total			698	783	809	2290
			(30.5%)	(34.2%)	(35.3%)	(100%)

Ethical Considerations

Ethical guidelines and informed consent procedures were strictly adhered to throughout the data collection process. All participants were provided with information about the survey's objectives, and their participation was entirely voluntary. Confidentiality and privacy were maintained, and no personal or sensitive information was disclosed without explicit consent.

Results and Discussion

Table 2 & 3 give a brief summary of the agricultural accident data collected by ESA centres (CIAE, 2007).

Table 3: Category wise and severity wise distribution of agricultural accidents

Sl. No.	Source	No. of accidents			% of total accident
		Fatal	Non-fatal	Total	
1	Farm machinery	39	659	698	30.5
2	Hand tools	1	782	783	34.2
3	Other sources (snake bites, animal bites, fallin well/pond, lightening, heat stroke etc.)	84	725	809	35.3
	Total	124	2166	2290	100

Analysis of the complete dataset reveals that the distribution of accidents presents a notable breakdown: 30.5% were attributed to farm machinery, 34.2% to hand tools, and 35.3% originated from other sources, including snake bites, animal bites, falls in wells, lightning strikes, heat stroke, and various other factors. In terms of the severity of these accidents, 5.6% were classified as fatal, whereas the remaining 94.4% were classified as non-fatal incidents. Calculating the overall accident incidence rate, it was found that there were 333 accidents per 100,000 workers annually, while the fatality rate was 18.3 per 100,000 workers per year. These statistics provide a comprehensive overview of the types, severity, and rates of farm machinery accidents within the surveyed regions.

Comparison of agricultural fatalities data with other countries

Unal *et al*. (2008) [17] reported an agricultural fatality rate of 16 per 100,000 workers annually in Turkey, while Myers *et al*. (2008) indicated a U.S. agricultural fatality rate of 25.4 per 100,000 workers per year. It is worth noting that Western countries typically exhibit a higher degree of mechanization in their agricultural practices, with significantly greater power availability per hectare, approximately 13.0 kW, in contrast to the 1.5 kW observed in India. To meet the ambitious goal of doubling food grain production by 2020, it is imperative to increase power availability in India to 3.5 kW. Neglecting this crucial aspect could lead to a potential rise in the agricultural fatality rate, resulting in significant societal and individual losses among agricultural workers.

Accidents Involving Agricultural Machinery

In this survey, a total of 698 farm machinery accidents were analyzed, revealing that 5.6% of these incidents were fatal, while the remaining 94.4% were non-fatal in nature. Notably, tractor and tractor-operated implements accounted for the highest number of accidents, representing 31% of the total incidents, followed by animal-drawn implements (22%), threshers (14%), electric motors/pump sets (12%), chaff cutters (9%), power tillers (6%), sprayers (4%), and other machines (2%). Furthermore, an examination of the fatalities caused by farm machinery demonstrated that tractors and tractor-operated implements were responsible for 44% of the total fatalities, with electric motors/pump sets, sprayers, power tillers, and threshers contributing to 31%, 13%, 10%, and 2% of fatalities, respectively. The fatality rate due to farm machinery accidents was calculated at 5.7 per 100,000 workers annually, while the non-fatal injury rate stood at 95.7 per 100,000 workers per year. These findings underscore the urgency of prioritizing safety measures for tractors and tractor-operated implements, electric motors/pump sets, sprayers, power tillers, and threshers within the agricultural sector.

Table 4: Source wise and severity wise distribution of farm machinery accidents

Sl. No.	Source	No. of accidents			%of total accident
		Fatal	Non-fatal	Total	
1	Tractor & tractor operated implements	17	196	213	31
2	Threshers(Including winnowers)	1	96	97	14
3	Chaff cutters (Manual+ power operated)	0	65	65	9
4	Sprayers (Manual +power sprayers)	5	25	30	4
5	Cane crushers	0	6	6	1
6	Electric motors/pump sets	12	74	86	12
7	Power tillers	4	34	38	6
8	Animal drawn equipment	0	156	156	22
9	Other equipment	0	7	7	1
	Total	39 (5.6%)	659 (94.4%)	698 (100%)	100

Table 5: Type-wise percentage of accidents

Sl. No.	Type	Percentage of total accidents
1	Collision	2.8
2	Overturning	2.9
3	Cut slip	45.0
4	Crushing	3.4
5	Swallowing	0.0
6	Sucking	1.1
7	Shock	3.5
8	Burns	1.1
9	Hit	11.4
10	Falls	11.5
11	Snakebites	11.4
12	Drowning	0.0
13	Thunder/sunstroke	0.0
14	Anyother	5.9
	Total	100

Table 6: Cause-wise percentage of accidents

Sl. No.	Cause	Percentage of total accidents
1	Tiredness	9.5
2	Over speed	10.2
3	Busy in smoking, etc.	2.9
4	Drinks	1.2
5	Poor light	2.8
6	Machine defect	3.4
7	Slippery ground	5.7
8	Sloppy surface	2.6
9	Abnormal crop	7.2
10	Overloading	5.8
11	Loose garments	5.1
12	Lack of protective covers	1.2
13	Lack of safety devices	4.3
14	Ignorance	25.5
15	Any other	12.6
	Total	100

Economic loss

Accurate data regarding the costs incurred as a result of accidents are of paramount importance for planners, administrators, and policy makers, as they serve as the foundation for the development and implementation of effective accident prevention programs. To assess the cost of fatal injuries, we applied the YPLL (years of productive life lost) method, as outlined by Lehtola *et al.* (1994) [9]. The valuation of one human life was established at 11 lakh. Similarly, the cost associated with non-fatal injuries was meticulously computed, considering factors such as medical expenses, downtime, and repair costs. Based on the comprehensive survey data, it is estimated that each year, approximately 45,000 fatalities and 7,55,000 non-fatal injuries occur. The average cost per non-fatal injury was determined to be Rs. 5,700. Consequently, the total cost attributed to these accidents was found to amount to Rs. 5,400 crore per year. This data serves as a crucial foundation for informed decision-making in accident prevention and resource allocation.

Reducing Farm Machinery Accidents: Strategies for Safety Enhancement

The rapid development of newer agricultural equipment in the country, coupled with farmers and workers using an array of tools and machinery with which they are often unaccustomed, has become a common occurrence. Additionally, the pursuit of heightened production and productivity often compels individuals to work in adverse conditions, including scorching sunlight, heavy rains, and even during the night. This confluence of factors, encompassing the use of unsafe machinery, a lack of knowledge and skill, hazardous working conditions, and inclement weather, collectively contributes to the rising number of agricultural accidents. It is important to recognize that many agricultural workers belong to the unorganized sector, wherein accident and safety concerns frequently take a backseat, both at the farm level and in governmental considerations. In this context, where securing employment takes precedence, workers often find themselves with limited choices regarding safety aspects. They are compelled to perform activities or operate equipment as directed or provided to them. However, it is the moral responsibility of the nation to protect its agricultural workers, who are the cornerstone of the Indian economy, by implementing comprehensive measures encompassing engineering, enforcement, and education. Drawing from the data and insights gathered during the survey, specific attention is warranted for the enhancement of safety measures for tractors, threshers, chaff cutters, electric motors/pump sets, power tillers, and animal-drawn equipment. In light of these considerations, a series of recommendations are provided herein to address and minimize the incidence of accidents in Indian agriculture, ensuring the well-being of the agricultural workforce and the sustainability of the nation's agricultural sector.

Recommendations related to Engineering aspects of farm machines

- Implementing rollover protective structures (ROPS) on tractors is imperative to mitigate fatalities resulting from tractor accidents, particularly those involving overturning incidents that crush operators.
- Enhance tractor-trailer safety by equipping them with turning indicators and rear lights for improved visibility.
- Ensure that every tractor-trailer is equipped with a slow-moving vehicle (SMV) emblem featuring a fluorescent color at the rear to enhance visibility and safety on the road.
- Prioritize the development of ergonomic layouts for tractor operators' workplaces to enhance comfort and safety during their tasks.
- Consider the principles of stability when designing tractor-trailers to minimize the risk of accidents.
- Enact design modifications for tractors and other farm equipment that facilitate safe and straightforward hitching of equipment with tractors.
- Install fuel meters on all tractors to improve fuel management and efficiency, akin to other vehicles.
- Incorporate built-in safe feeding devices for chaff cutters to ensure the safety of operators during use.
- Equip cane crushers with proper safety devices and feeding systems to reduce the risk of accidents.
- Enhance safety by fitting rotating parts of various prime movers and farm equipment with suitable guards to prevent accidents.
- Develop, evaluate, and promote the use of suitable personal protective equipment such as aprons, goggles, and face masks among farmers during spraying operations.
- Ensure the proper installation of electric motors and pump sets to prevent electrocution accidents by adhering to safe installation procedures.

Enhancing Education and Training for Farmers and Agricultural Workers: Recommendations

- Increase awareness among farmers and workers about the hazards associated with overloading tractor trailers with agricultural materials to prevent accidents.
- Promote the proper construction of farm wells and ponds, which are vital sources of irrigation, to minimize accidents resulting from falls into these water bodies.
- Organize training courses for tractor operators at the block level to ensure they are well-versed in the proper and safe operation of tractors and tractor-operated equipment.
- Conduct periodic training sessions on the safe operation of sprayers and dusters, and include programs on the correct and safe use of various agricultural machines in farmers' meetings at the village, block, or district level.
- Advocate for the use of personal protective equipment during spraying operations to prevent accidents.
- Develop and widely distribute extension leaflets and publicity materials that provide guidance on the proper and safe use of various agricultural machines.

Government's role in accident minimization programmes

Agriculture in India falls under the jurisdiction of state governance, where the central government plays a role in providing guidance and support to the states. The responsibility for implementing any program rests with the state governments. Both the central and state levels maintain a Directorate of Labour Safety; however, this directorate primarily addresses issues related to laborers in the organized sector, such as industrial workers. Given that a significant portion of agricultural activities occurs within the unorganized sector, the safety and health of agricultural workers are not within the purview of this Directorate. A notable discrepancy exists in the allocation of government resources, with over Rs. 3,000 million annually spent on the well-being of 41 million workers in the organized sector, while the budget designated for the safety and health of 241 million agricultural workers is considerably less, amounting to less than 100 million. The All India Coordinated Research Project on Ergonomics and Safety in Agriculture (AICRP on ESA) has initiated dialogue and collaboration with both the Central and State Governments to address this issue, and initial interactions have yielded promising results.

Dangerous Machine (Regulation) Act 1983

In 1983, the Parliament passed an act to provide for the regulation of trade and commerce in production, supply, distribution and use of the threshers with a view to securing the welfare of labour operating any such machines and for payment of compensation for the death or bodily injury suffered by any labourers while operating any such machine, and for matters connected therewith or incidental thereto. In spite of passing of more than 20 years, this Act has been adopted by some states only. As agriculture is a state subject, the implementation of any such act is the prerogative of the state Govt. In Madhya Pradesh this act was adopted in 1989. However, the agricultural machinery manufacturers called it as the cruel act and demanded repeal of the same. To collect the more information on adoption of DMRA 1983 in various states and problems if any in adoption of this act and also to give suggestions for modification for better adoption, correspondence was made with the Secretary (Agriculture) and Director (Agriculture) of various states. A proposal for revision of DMRA 1983 was prepared and sent to Deptt. of Agriculture & Cooperation, Govt. of India for need ful (Giteetal, 2006) [6].

Compensation provisions for farm machinery accident victims

Ensuring the minimization of occupational health and safety issues within agriculture and providing adequate compensation to agricultural workers in the event of accidents is of utmost importance. As part of these efforts, the All India Coordinated Research Project on Ergonomics and Safety in Agriculture (AICRP on ESA) engaged in collaborative discussions with various State Governments to gather information regarding existing provisions for compensating agricultural accident victims. Remarkably, five states, namely Punjab, Haryana, Rajasthan, Gujarat, and Uttar Pradesh, have instituted schemes to offer assistance to accident victims and their families. Building upon this valuable information, a model proposal has been developed to facilitate financial aid to such victims. The proposal outlines a framework for the State Agricultural Marketing Board to establish an insurance scheme in partnership with an insurance company, with the annual premium funded by the Agricultural Marketing Board's revenue. This proposal has been shared with all state governments, with a request for its adoption within their respective states. Additionally, a copy of the proposal has been forwarded to the Secretary of the Department of Agriculture and Cooperation, Government of India, for their consideration. It is heartening to note that, as a result of our advocacy and engagement, numerous State Governments have initiated schemes to provide social security to agricultural workers. The compensation norms presented in the model proposal are detailed in Table 5 for reference and implementation.

Table 5: Proposed compensation norms for victims of agricultural accidents

Sl. No.	Details of accidents	Compensation proposed
1	In case of death	Rs. 1,00,000/-
2	Amputation of one body part/one body part rendered useless *viz*. hand, arm, leg, eye, foot/any other serious injury	Rs. 30,000/-
3	Amputation two body parts/two body parts rendered useless *viz*. hand, arm, leg, eye, foot etc./any other serious injury	Rs. 45,000/-
4	Amputation of finger, finger parts will be equivalent to amputation of complete finger	Rs. 7,500/-
5	Amputation of two fingers	Rs. 15,000/-
6	Amputation of three fingers	Rs. 22,500/-
7	Amputation of four fingers/amputation of one body part	Rs. 30,000/-

Conclusion

This paper provides an overview of the prevailing agricultural accident landscape in India, with a specific focus on farm machinery accidents. Drawing from collected data, this paper presents recommended solutions to mitigate such accidents. Giving due consideration to these aspects within the

agricultural sector not only enhances the safety and well-being of farmers and workers but also contributes to the nation's well-being by curtailing the financial losses incurred as a result of these accidents.

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