

## Evaluation of risk factors in fatal accidents in agriculture

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### Abstract

Many fatal accidents happen in agriculture and some of them are not officially recorded. The aim of this research was to compare official to real data about fatal accidents in agriculture and to characterize and evaluate the main risk factors associated with them. A comparative study of 388 fatal accidents related to agricultural machinery, occurred in Spain during the last five years, has been conducted. Official records only account for 61.85% of the deaths. Older people are the social group with the highest risk but children and nonfarmers are risk groups too. The main cause of death was the overturn of tractors lacking roll-over protective structures (ROPS) since from 272 fatal overturns detected; only one occurred in tractors equipped with homologated ROPS. Many overturns happened while tractor driving along roads and tracks. Terrain conditions as slopes, ditches and obstacles are also risk factors. A total of eleven risk factors have been characterized but the concurrence of at least two of them is required to cause a fatal accident. Most accidents are caused by the overlapping of three or more risk factors. Therefore, accidents are preventable when trying to circumvent all described risk factors because the probability of concurrence of at least two decreases.

**Additional key words:** age, cause, machinery, overturning, ROPS, tractor.

### Resumen

#### Evaluación de los riesgos de accidente mortal en agricultura

En el ámbito agrario se producen anualmente muchos accidentes mortales, no siendo todos ellos registrados oficialmente como accidentes laborales. El objetivo de esta investigación es comparar los datos reales y oficiales de accidentes agrícolas mortales y caracterizar los principales riesgos asociados a ellos. Un estudio sobre 388 accidentes mortales ocurridos en España con maquinaria agrícola en los últimos cinco años ha mostrado que sólo el 61,85% de ellos ha tenido carácter oficial. Las personas mayores fueron el sector de la población con un mayor riesgo, seguidos de los niños y las personas ajenas al sector agrario. La mayoría de las muertes registradas fueron debidas al vuelco de tractores sin estructuras de protección. De las 272 muertes causadas por accidentes con vuelco del tractor, sólo una sucedió en un tractor con estructura de protección homologada. La mayoría de los vuelcos se produjo en trayectos por carreteras o caminos, aunque las fuertes pendientes y los baches también son un factor de riesgo. Se han caracterizado once factores de riesgo y se ha comprobado que para que ocurra un accidente generalmente es necesario que confluyan, al menos, dos factores de riesgo y que la mayoría de los accidentes son causados por la concurrencia de tres o más de estos factores. Todos los accidentes son evitables porque requieren la coincidencia de más de un factor de riesgo. Si intentamos evitar todos los factores de riesgo, es posible que exista uno de estos factores, pero es muy difícil que concurren dos o más de ellos a la vez.

**Palabras clave adicionales:** causas, edad, maquinaria, ROPS, tractor, vuelco.

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Abbreviations used: ASAE (American Society of Agricultural Engineers), INSL (*Instituto Navarro de Salud Laboral-Occupational Health Navarre Institute*), MARM (*Ministerio de Medio Ambiente y del Medio Rural y Marino-Environment, Rural and Marine Minister*), MTAS (*Ministerio de Trabajo y Asuntos Sociales-Labour and Social Affairs Spanish Minister*), NSC (National Safety Council), ROPS (roll-over protective structures).

## Introduction

According to ASAE (American Society of Agricultural Engineer), «an accident is considered such from the legal point of view when medical care is required, when it causes a permanent disability, or when the victim can not go back to work or do all the normal activities until at least the day following that when the incident happened». In Italy, during 1995-1996, there were more than 6,000 accidents related to the use of self-propelled machines; about 1% of these were fatal (INAIL, 2000) being tractor roll-over the principal cause (Casini-Ropa, 1980). In the USA, agriculture has the highest rate of occupational fatalities of any industry at 24.11 deaths per 100,000 workers per year, which is more than five times the annual rate for all workers at 4.5 deaths per 100,000 workers. Litchfield (1999) identified risks in agriculture work, such as: cuts, bruises, deep wounds, broken limbs, amputations, spinal-marrow injuries, fatal injuries, contact with micro-organisms, contact with pesticides, pain, stress, and injuries resulting from ergonomic problems due to poor working procedures and conditions.

A study carried out by the National Institute for Safety and Hygiene at Work over 175 events of tractor roll over provided the following statistics: 60% of minor accidents, 19% of severe accidents and 21% of deadly accidents. Accidents which involve a roll-over are often fatal for the tractor operator (Jarén *et al.*, 2009). The risk of accident increases with age of tractors and their life span in Spain is longer than in other European countries as Italy (Fenollosa-Ribera *et al.*, 2007). Tractor roll-overs are the leading cause of death related to work in USA, where only about 70% of sold tractors were equipped with ROPS (Freeman, 1999). Each year, about 250 people are killed in tractor accidents in USA (NIOSH, 2004) which constitutes more than one third of all production agriculture-related fatalities (Murphy and Yoder, 1998). The majority of fatal accidents involved tractors without protective structures (Arana *et al.*, 2002). Accidents including a roll over are often fatal for the tractor driver and represent one third of all fatalities in the agricultural sector. From those, 90% referred to lateral roll over, and only a 10% to roll backwards (Mangado *et al.*, 2007). The National Safety Council (NSC) estimated that about 200 deaths resulted from agricultural tractor overturns each year (NSC, 1997). The loss of stability is not only due to the terrain slope but to a multiplicity of causes. More than half of the lateral turnovers are caused by tractor slipping into

ditches or bumping against obstacles (Chisholm, 1972). A roll-over protective structure in combination with a seatbelt can prevent nearly all tractor overturns related to fatalities and serious injuries (MMWR, 1993).

Because of the non-availability of sufficient and reliable data on the aetiology of agricultural accidents, it becomes difficult to plan strategies for minimizing these accidents (Tiwari *et al.*, 2004). Basic information is generally lacking and the number and characteristics of the people injured as well as the causes and consequences of the accidents are essential for designing prevention programs.

The aim of this research was to compare official to real data about fatal accidents in agriculture and to characterize and evaluate the main risk factors associated with them.

## Material and methods

This study examined 388 fatal tractor-related accidents that occurred in Spain between 2004 and 2008, to characterize and evaluate the main risk factors for accidents in agricultural activity.

Official data published by the *Ministerio de Trabajo y Asuntos Sociales* (MTAS, Labour and Social Affairs Spanish Minister) were compared to real data collected by authors. These data were obtained by daily search on local and national newspapers carried out by a group of volunteers spread all over the country. Moreover, Internet searching was performed using the most important search engines (google, yahoo etc.) with the following keywords: fatal accident, dead in tractor accident, crushed by tractor and others. Once a fatal accident was found, main characteristics were gathered and checked with the press agency when possible.

Features as day of week, age of deceased, causes of accident, machinery involved, type of work during the accident, terrain conditions and other circumstances, were considered and studied as risk factors in fatal accidents. That made possible to count the number of them that concurred on each of the studied accidents.

Obviously, more accidents might have occurred since not all of them are published, but those collected may represent a very significant sample.

The statistical analysis includes data from the whole of the fatal accidents happened in Spain from 2004 to 2008. In order to compare the data, the percentage represented by each datum was performed. When there was concurrence of different risk factors, mean, mode

**Table 1.** Number of deaths in the agricultural sector from 2004 to 2008 collected by the Labour and Social Affairs Spanish Minister (MTAS) and by the authors

Year	MTAS	Authors
2004	40	75
2005	58	72
2006	41	70
2007	50	98
2008	51	73
<b>Total</b>	<b>240</b>	<b>388</b>

and range were calculated to show the smallest value, the most often value and the average number of risk factors needed to produce a fatal accident. This analysis has been performed using SPSS v.15 statistical software.

## Results and discussion

Large differences between official data and our data collected from other sources were found. Table 1 shows the number of dead people in agricultural accidents from 2004 to 2008, according to MTAS and to the reported research.

Only 61.85% of the deaths in the agricultural sector were officially recorded. Therefore, many of the accidents were not officially counted which could mask the high risk condition of this occupation. There is a need to review criteria and methods of official data collection for statistics in order to avoid differences as shown. With regard to tendency, it is clear that the number of deaths is not decreasing.

The number and percentage of fatalities that occurred on each week day is presented in Table 2. On working days, quite a regular distribution was found. However, on Saturday the number of fatal accidents was remarkably similar to working days whereas on Sunday acci-

dents accounted for more than one-half of those on working days. It is probably due to the large number of nonfarmers who perform farm works on weekends often without an adequate preparation.

Tractor related deaths occurred throughout the year. The highest number of fatalities took place in June, which is in agreement with the results from Bernhardt and Langley (1999). Summer was the season with the highest number of fatal accidents closely followed by spring. Table 3 shows that November and December were the months with the lowest number of fatalities. On the other hand, deaths in January and February were high considering that tractor activity during these months is less than in March or October.

The age distribution of deceased people is presented in Table 4. As shown, 44.59% of the deceased people exceeded their age of retirement. This evidenced the problem that is the weakest people who suffered fatal injuries, likely because they drive too old tractors lacking ROPS. One might consider that the trend of the past four years is a decline in fatalities for old people, but it seems to be very soft. Moreover, it was found that the higher the age of operators, the greater the risk of death. This tendency only changed in the case of children. Time and again, it was found that the weakest people have the greatest risk of fatalities. Considering 55 years as the average age for farmers, we found 65.47% of deaths above this age. Maybe some of the older people could have survived if they had been younger, because they have lower tissue resistance to energy exchanges and, therefore, are more likely to die than younger people with the same injury (Osler *et al.*, 1988).

Our results are in agreement with those obtained by the West Virginia University, reported by the Institute for Safety and Health Training, who stated that tractor operators under 15 and over 64 suffer from seven to ten times more accidents per hour of machine than

**Table 2.** Decease distribution according to the week day

	2004		2005		2006		2007		2008		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Monday	14	18.67	10	13.89	8	11.43	11	11.22	9	12.33	<b>52</b>	<b>13.40</b>
Tuesday	14	18.67	15	20.83	10	14.28	14	14.28	11	15.06	<b>64</b>	<b>16.49</b>
Wednesday	9	12.00	14	19.44	14	20.00	15	15.31	9	12.33	<b>61</b>	<b>15.72</b>
Thursday	10	13.33	10	13.89	9	12.86	16	16.33	12	16.44	<b>57</b>	<b>14.70</b>
Friday	9	12.00	14	19.44	9	12.86	13	13.27	10	13.70	<b>55</b>	<b>14.17</b>
Saturday	12	16.00	5	6.95	14	20.00	15	15.31	14	19.18	<b>60</b>	<b>15.47</b>
Sunday	7	9.33	4	5.56	6	8.57	14	14.28	8	10.96	<b>39</b>	<b>10.05</b>

**Table 3.** Decease distribution throughout the year

Month	2004	2005	2006	2007	2008	Total
January	8	6	7	10	2	<b>33</b>
February	2	7	5	8	7	<b>29</b>
March	6	5	2	7	10	<b>30</b>
April	7	11	10	4	5	<b>37</b>
May	8	12	7	14	4	<b>45</b>
June	14	6	3	17	9	<b>49</b>
July	9	8	4	9	11	<b>41</b>
August	12	6	4	4	7	<b>33</b>
September	5	3	6	9	6	<b>29</b>
October	2	3	9	9	7	<b>30</b>
November	1	2	8	3	3	<b>17</b>
December	1	3	5	4	2	<b>15</b>
<b>Total</b>	<b>75</b>	<b>72</b>	<b>70</b>	<b>98</b>	<b>73</b>	<b>388</b>

operators in the 25-64 group. However, they are more negative for older people than those obtained by Bernhardt *et al.* (1999) who reported a 38% of fatal injuries in the group of 65 and older but less negative results for young people. Callejón Ferre *et al.* (2009) concluded that more information on work risks would be helpful.

Table 5 displays the causes of the 388 fatal accidents investigated in this research. It is shown that most of the studied fatal accidents were related to tractor. The main cause of death was tractor overturning in 70.10% of the events. This percentage was higher than that obtained by Murphy and Yoder (1998) because they estimated that deaths from tractor overturn accounted for more than one-third of all production agriculture-related fatalities in the United States. The average value

**Table 4.** Fatalities distribution according to age of dead people

Age (year)	2004		2005		2006		2007		2008		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
< 16	1	1.33	1	1.39	1	1.43	5	5.10	1	1.37	<b>9</b>	<b>2.32</b>
16-19	1	1.33	2	2.77	1	1.43	1	1.02	1	1.37	<b>6</b>	<b>1.54</b>
20-24	2	2.67	1	1.39	1	1.43	0	0.00	2	2.74	<b>6</b>	<b>1.54</b>
25-34	5	6.67	3	4.17	5	7.14	4	4.08	5	6.85	<b>22</b>	<b>5.67</b>
35-44	8	10.67	6	8.33	3	4.29	7	7.15	9	12.33	<b>33</b>	<b>8.51</b>
45-54	12	16.00	6	8.33	15	21.43	14	14.28	11	15.07	<b>58</b>	<b>14.95</b>
55-64	15	20.00	13	18.06	11	15.71	28	28.57	14	19.18	<b>81</b>	<b>20.88</b>
≥ 65	31	41.33	40	55.56	33	47.14	39	39.80	30	41.09	<b>173</b>	<b>44.59</b>

**Table 5.** Causes of fatal accidents occurred between 2004 and 2008

Accident causes	2004		2005		2006		2007		2008		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Overturning in												
Track/Road	11	14.66	23	31.94	20	28.57	37	37.76	22	30.13	<b>113</b>	<b>29.89</b>
Work	7	9.33	16	22.22	20	28.57	11	11.22	14	19.18	<b>68</b>	<b>17.53</b>
Slope	7	9.33	10	13.89	6	8.57	12	12.24	7	9.59	<b>42</b>	<b>10.57</b>
Ditches, obstacles	5	6.67	6	8.33	4	5.71	5	5.10	10	13.70	<b>30</b>	<b>7.73</b>
Unknown	10	13.33	0	0	0	0	5	5.10	4	5.48	<b>19</b>	<b>4.38</b>
Overturning	<b>40</b>	<b>53.32</b>	<b>55</b>	<b>76.38</b>	<b>50</b>	<b>71.42</b>	<b>70</b>	<b>71.42</b>	<b>57</b>	<b>78.08</b>	<b>272</b>	<b>70.10</b>
Hitting/manoeuvres	9	12.00	6	8.33	8	11.43	12	12.24	7	9.59	<b>42</b>	<b>10.82</b>
Traffic accident	11	14.67	3	4.17	3	4.29	7	7.14	5	6.85	<b>29</b>	<b>7.47</b>
Walking tractor	5	6.67	2	2.78	2	2.86	3	3.06	3	4.11	<b>15</b>	<b>3.87</b>
Trailer	6	8.00	4	5.56	2	2.86	2	2.05	0	0	<b>14</b>	<b>3.61</b>
Repairs	1	1.34	1	1.39	5	7.14	1	1.02	0	0	<b>8</b>	<b>2.06</b>
Falls	3	4.00	0	0	0	0	1	1.02	1	1.37	<b>5</b>	<b>1.29</b>
Power take-off	0	0	1	1.39	0	0	2	2.05	0	0	<b>3</b>	<b>0.78</b>
<b>Total</b>	<b>75</b>	<b>100</b>	<b>72</b>	<b>100</b>	<b>70</b>	<b>100</b>	<b>98</b>	<b>100</b>	<b>73</b>	<b>100</b>	<b>388</b>	<b>100</b>

of total number of deaths caused by tractor overturns was 54 deaths each year, which is a high number, because the number of fatalities caused by tractor overturns per year in the United States was approximately 132 according to Myers and Snyder (1993) and about 200 according to NSC (1997). It is worth mentioning that both population and the number of tractors in the United States are much greater than in Spain. With regard to tractor-related accidents, including overturning, traffic accidents, hitting/manoeuvres and power take-off, the average value per year is 69 fatalities, which is also a high one because according to the National Institute for Occupation Safety and Health (NIOSH, 2004), about 250 people are killed each year in tractor accidents. Comparing our results with those obtained by Tiwari *et al.* (2004), the tractor-related fatalities happened each year in Spain were calculated as about 12% of the ones occurred in Central India. These authors had estimated the number of fatalities related to tractor accidents in nearly 550 per year. Therefore, the tractor roll-over safety level in Spain is lower than in the United States, but higher than in India.

With regard to causes of roll-over, Table 5 shows that almost half of overturns happened in tracks and roads but a similar number of overturns is found when adding those caused by the normal work in the farm the ground slope, and ditches or obstacles. The high number of tractor overturns caused by ditches, obstacles or parcel edges are in agreement with the conclusions from Chisholm (1972) who reported that more than a half of lateral turnovers are caused by tractor slipping into ditches or bumping against obstacles. From the 272 fatal overturns studied, only one of them involved tractors equipped with homologated roll over protective structures (ROPS) and this result is in agreement with Jarén *et al.* (2009) who reported that the tests used to homologate tractors and ROPS provided enough safety in most of the cases. Therefore, the main cause of death in agricultural activity is the overturn of tractors lacking ROPS which makes necessary either the replacement of tractors lacking ROPS, as promoted by the Spanish RENOVE Plan, or the installation of ROPS in tractors lacking (Mangado *et al.*, 2006).

The risk factors for tractor overturning are driving along tracks and roads, the ground slope and the presence of ditches and obstacles. However, the risk factor that leads fatal consequences is the lack of ROPS.

Table 5 shows that only 3.87% of fatal accidents were caused by walking tractors, a seldom used machine. On the other side, the rest of agricultural machinery

caused few deaths. Hence, most agricultural machines can be considered safe, except the walking tractor.

After overturning the second cause of fatal accidents was tractor hitting that usually happened during the manoeuvres and accounted for 10.82% of the fatalities. It evidenced the need of careful manoeuvring, looking for driver safety as well as security of all who operate near the tractor. Traffic was another risk factor but the percentage of deaths caused was 7.47%, not very high when compared to overturning or manoeuvres. The use of a trailer was identified as a risk factor too, especially if it was heavily weighed and there were steep slopes. The deaths involving trailer use were 3.61%, just half of those produced by traffic. Repairs, associated to inadequate working of the hydraulic system in most cases, were defined as a new risk factor since 2.06% of the fatalities happened during repairs made in farms. It is interesting to underline that farms are not adequate places to repair tractors and usually the oldest tractors are those repaired in farms, their hydraulic systems do not work correctly and the farming implements can fall over the farmers. Accidents caused by the power take-off were quite frequent but usually did not have fatal consequences. Only 3 out of the 388 fatalities studied (0.78%) were caused by power take-off, but a noteworthy fact was that in all three accidents the power take-off lacked an adequate protection. The dead operators were between 35 and 45 years old, who were not in the risk ages mentioned before. In addition, five people died because of falls.

Results from Table 5 present the incidence and importance of the main risk factors in fatal farm accidents. It is clear that besides the lack of ROPS and older people which were characterized as risk factors, there were several risk factors which caused most of the fatal accidents analyzed. By considering that a circumstance becomes a risk factor when it is the cause of at least 1% of deaths, risk factors for farm fatal accidents were listed in Table 6. Taking into account Table 5, eleven main risk factors were described. Other risk factors as working alone, excessive load or excessive blood alcohol concentration, were allowed. Table 6 shows the incidence of different risk factors on fatal accidents in agriculture.

It was possible to study whether fatal accidents happened when there was a single risk factor or when several risk factors occurred simultaneously. It was very difficult to find out all risk factors that overlapped in a given accident but, from the results of this research, we observed that no accident included one

**Table 6.** Risk factors

Risk factor	Fatal accident number
Lack of ROPS <sup>1</sup>	271
Elderly	186
Working alone	178
Track/Road	159
Slope	41
Ditches, obstacles	30
tractor hitting/ manoeuvres	52
Traffic	31
Walking tractor	15
Trailer	14
Repairs	8
Excessive load	8
Falls	5
Excessive blood alcohol concentration	4

<sup>1</sup> ROPS: roll-over protective structure.

single risk factor. The mean value of risk factors found in the fatal accidents analyzed was 3.75 and the mode value was 3. Hence, to cause a fatal accident at least two risk factors were required although most accidents were caused by the overlapping of three or more risk factors. Due to the above mentioned difficulty to find out all risk factors involved in accidents, their real number could probably have been higher than reported.

Therefore, accidents are preventable when trying to circumvent all described risk factors because the probability of concurrence of at least two decreases.

Therefore, all accidents are preventable, because they require the coincidence of more than one risk factor and because the main risk factors happen in many of the fatal accidents. It is not easy to avoid risk factors, but trying to circumvent all of them makes more difficult to find two or more at the same time.

The most frequent fatal accidents are those that involve lack of ROPS, driving along tracks and roads and older people. Furthermore, the combination of lack of ROPS and ground slope or ditches as well as the combination of manoeuvres, older people and repairs resulted also dangerous. The latter caused a lot of deaths due to tractor hitting or crushing bellow the farm implements.

## Conclusions

The need to improve the method of official data collection has been highlighted in this research since

only 61.85% of the deaths in agricultural occupation have been officially recorded. The number of fatal accidents did not decreased during the last five years. Summer was the most dangerous season. On Saturdays there were same numbers of fatal accidents than during working days, probably due to the large number of nonfarmers who perform farm works on weekends. The older the operators the higher the risk of death was, although children had a high risk of fatal accidents.

Most deaths involved tractors and 70.10% were caused by tractor overturning. The main cause of death in agricultural activity was the overturn of tractors lacking ROPS because from 272 fatal overturns reported, only one included tractors equipped with homologated ROPS. The main risk factors for overturning were driving along tracks and roads, ground slope and the existence of ditches and obstacles. Other risk factors were the use of walking tractors and highly weighed trailers, manoeuvres, and repairs in farm. The power take-off was dangerous but hardly caused fatal accidents.

Eleven risk factors have been characterized and evaluated and led us to conclude that at least two risk factors must concur to cause a fatal accident, even though most accidents were caused by the overlapping of three or more risk factors. The most frequent fatal accidents were those that involve tractors lacking ROPS, driving along tracks and roads and older drivers. The combination of ROPS lacking and ground slope or ditches was another dangerous circumstance as well as the combination of manoeuvres, older people and repairs in farm. All accidents are preventable, because they require the coincidence of more than one risk factor and because the main risk factors happen time and again.

This work provides a description of characteristics and causes of fatal farm accidents that could be useful to develop safety standards that should include replacement of tractors lacking ROPS or their installation, careful driving along roads and tracks or when there are ground slopes, ditches or obstacles. In addition, it is necessary to teach tractor operators that it is dangerous to work alone, to instruct old people they are more prone to have fatal accidents so they have to be extremely cautious and to show nonfarmers that an adequate training is essential to work safely in the farm.

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