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Roll/Tip-Over Risk Analysis of Agricultural Self-Propelled Machines Using Airborne LiDAR Data: GIS-Based Approach

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Abstract: Occupational Health and Safety (OHS) in agriculture is a critical concern worldwide, with self-propelled machinery accidents, particularly tip/roll-overs, being a leading cause of injuries and fatalities. In such a context, while great attention has been paid to machinery safety improvement, a major challenge is the lack of studies addressing the analysis of the work environment to provide farmers with precise information on field slope steepness. This information, merged with an awareness of machinery performance, such as tilt angles, can facilitate farmers in making decisions about machinery operations in hilly and mountainous areas. To address this gap, the Italian Compensation Authority (INAIL) launched a research programme to integrate georeferenced slope data with the tilt angle specifications of common self-propelled machinery, following EN ISO 16231-2:2015 standards. This study presents the first results of this research project, which was focused on vineyards in the alpine region of the Autonomous Province of Trento, where terrestrial LiDAR technology was used to analyze slope steepness. The findings aim to provide practical guidelines for safer machinery operation, benefiting farmers, risk assessors, and manufacturers. By enhancing awareness of tip/roll-over risks and promoting informed decision-making, this research aims to contribute to improving OHS in agriculture, particularly in challenging terrains.

Keywords: roll-over/tip-over risk; self-propelled machines; static stability; digital terrain model (DTM); geographic information system (GIS); farmer behaviour; risk assessment; machinery safety

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1. Introduction

Occupational Health and Safety (OHS) in agriculture represents a significant global concern, despite increasingly stringent regulations in this sector. Notably, the majority of accidents are linked to the use of self-propelled machinery, such as tractors and harvesters. The improper operation of this equipment is responsible for numerous serious and fatal accidents in many countries [1–4]. This is especially relevant regarding the risk of roll-over incidents [5–7].

In Italy, although recent years have seen a decline in accidents, primarily due to reduced operations during the COVID-19 pandemic, the number of injuries and fatalities remains high compared to other sectors [8,9]. According to data collected by the Italian Compensation Authority (INAIL), in the five-year period of 2018–2022, deaths averaged 150 per year, with a peak of 171 in 2019 and a minimum of 137 in 2022, where the leading cause of death was the total or partial loss of control of the means of transport or moving equipment [10]. More specifically, the latter is the cause of more than 50% of fatal accidents

that occurred in 2022 as per the concluded investigations carried out by INAIL. Similar statistical incidences were observed in other countries [11–14], and in the European Union, agriculture represents one of the most impacted economic activities in terms of the number of fatal work accidents [15]. The causes of this phenomenon can be attributed to different roots [16,17]. First of all, the nature of agricultural activities, which are characterized by seasonality, outdoor work, overtime, etc., can be considered a risk factor that distinguishes them from other working contexts [18]. Further, the features of agricultural companies, which, in Italy, are mainly made of small-sized or family enterprises and part-time workers [19,20], should be considered. This aspect can be related to a lower level of safety education and training of farmers, leading to a low-risk perception and the tendency to neglect safety regulations and procedures [21,22]. When it comes to machinery safety, numerous studies have brought to light that all of the above factors contribute to the unsafe use of work equipment and, in particular, to that of self-propelled machinery, such as tractors and harvesters [23,24].

Another aspect that should be considered is related to the morphology of the territory: in Italy, only 23% of the territory is flat, while about 42% of the territory is made up of hills, and the remaining 35% is mountainous [25]. These features have a negative influence on agricultural activities as they make it difficult to use self-propelled equipment for fieldwork and the transport of products, leading to a higher probability of machinery roll-over events [26]. As noted by Facchinetti et al. [16], there is a strict correlation between the cases of tractor roll-over accidents and the territory where they happened: actually, the higher frequency of this type of accident occurred in mountainous and hilly areas, i.e., work environments characterized by slopes. Indeed, the presence of slopes causing an inadequate dynamic stability condition is considered the most significant factor contributing to overturning [27,28]. The majority of interventions aimed at dealing with this problem are focused on passive protection, i.e., the use of roll-over-protective structures (ROPSs), which, depending on the case, can be fixed or foldable/telescopic structures [29–31]. The use of ROPSs (as standalone structures or integrated into the machinery cabin) together with seatbelts can certainly help mitigate the consequences of accidents [32,33], but does not contribute to preventing roll-overs. To reduce the probability of occurrence, recent research has proposed proactive technical solutions, i.e., control systems that alert the driver when he/she is in a dangerous situation leading to the loss of stability or control loss of the vehicle [34]. For example, Casazza et al. [35] proposed a driver-assistance device that can signal critical stability conditions. Similarly, other researchers have developed alert systems in case of a loss of stability [36,37].

A third proposal to deal with this problem is related to farmers' information and training initiatives. This preventive approach was investigated, mainly focusing on two different issues. On the one hand, campaigns were promoted to spread the proper use of ROPSs (and seatbelts) and their use in old machinery (i.e., retrofitting initiatives) [38,39]. On the other hand, the proper use of machinery and the comprehension of safety instructions were also investigated to reduce farmers' risk-taking behaviour and attitudes [40]. As observed by O' Connor et al. [20], the lack of safety information is particularly significant for small-sized companies, which pose a regulatory challenge because assessing their occupational safety and health (OSH) standards on a regular basis demands significant resources. Moreover, it must be noted that although environmental factors affecting tractor safety (e.g., slopes, poor ground conditions, wet surfaces, and obstacles) increase the risk of roll-overs, most farmers tend to underestimate the risks posed by slopes, often believing their tractors can handle them [41]. This suggests a lack of awareness or a wrong perception that the risks are minimal, based on poor information and training [42]. To improve this situation, Qi et al. [43] underlined that it is crucial to develop and enhance

national and community information systems to inform farmers about natural hazards, with the goal of anticipating potential risks in farming activities. More specifically, safety information should be designed for specific areas to enhance awareness of potential risks in agriculture [44]. However, a few studies addressed this issue. Vigoroso et al. [45] examined the understanding of signals indicating hazardous slopes. Their study revealed that while farmers adopt protective behaviours when properly informed, they often struggle to process the information provided in machinery user manuals and road signs in practice.

In particular, to the authors' knowledge, there is a scarcity of research merging information on the slope steepness of fields with the characteristics of self-propelled machinery, i.e., the maximum slope angle at which the machinery can be used safely. Actually, different from the roads where signals can indicate the steepness, farmers have no precise information on the field slopes (e.g., a vineyard) where they have to carry out field works. Therefore, although they should be aware of the maximum operating angle of their machinery as specified by the manufacturer, they lack practical reference information when working in mountainous or hilly terrain. As stressed by Görücü et al. [46], farmers must accurately perceive tilt angles to prevent overturns, but research shows they struggle due to the complexity of factors involved and the lack of information provided. Recognizing potential instability is crucial for corrective action, yet sensing roll-over risk is challenging, especially with attached implements [47].

Following these research hints, the Italian Compensation Authority (INAIL) promoted a research programme aimed at providing specific information and thus training material on the characteristics of the slope steepness of agricultural fields in mountainous and hilly areas in Italy. These data were merged with information related to tilt angles provided by manufacturers of the most common self-propelled machinery, which is defined in accordance with the EN ISO 16231-2:2015 standard [48]. The final goal of this analysis is to provide practical guidelines for the safe use of self-propelled machinery for each specific area of a certain territory and made at the disposal of farmers operating in that area. This allows farmers to recognize the risks associated with the field's slope steepness, enabling them to make informed decisions about which equipment can be used safely and which should be avoided. It also helps them determine the appropriate maneuvers to perform and those that should be avoided to prevent roll-overs.

The current study presents the first phase of this project, which regarded the alpine region of the Autonomous Province of Trento (PAT) in the northern part of Italy, where vineyard cultivations were investigated and data provided by terrestrial LiDAR technology [49] allowed for 3D georeferencing and slope steepness definition for cultivated areas. Accordingly, this study addresses the absence of technical references to slope steepness for field works in mountainous and hilly areas, offering guidance not only to users and entrepreneurs conducting risk assessments of their equipment, but also to machinery manufacturers, which can provide more specific equipment. Occupational health and safety (OHS) considerations must be approached from both perspectives, focusing on developing effective strategies and tools to minimize accidents and injuries related to hazardous machinery. This aligns with Kogler et al. [6], who emphasized the importance of providing informational resources, such as guidelines, to enhance farmers' safety. Consequently, the research presented in this paper can contribute to expanding knowledge on the safe selection and use of self-propelled machinery in mountainous and hilly areas. The remainder of the paper is organized as follows: in the next sections, the research approach is described. Section 3 proposes the outcomes of the case study, while in Section 4, the achieved results are discussed. Section 5 concludes this paper by addressing further work.

2. Materials and Methods

The study aimed at combining data from the LiDAR system owned by the Autonomous Province of Trento (PAT) [49] and those related to tilt angles for self-propelled machinery provided by the EN ISO 16231-2 standard [48] in order to classify and categorize cultivated areas based on roll-over risk. Moreover, details of the scheme followed are illustrated in Figure 1.

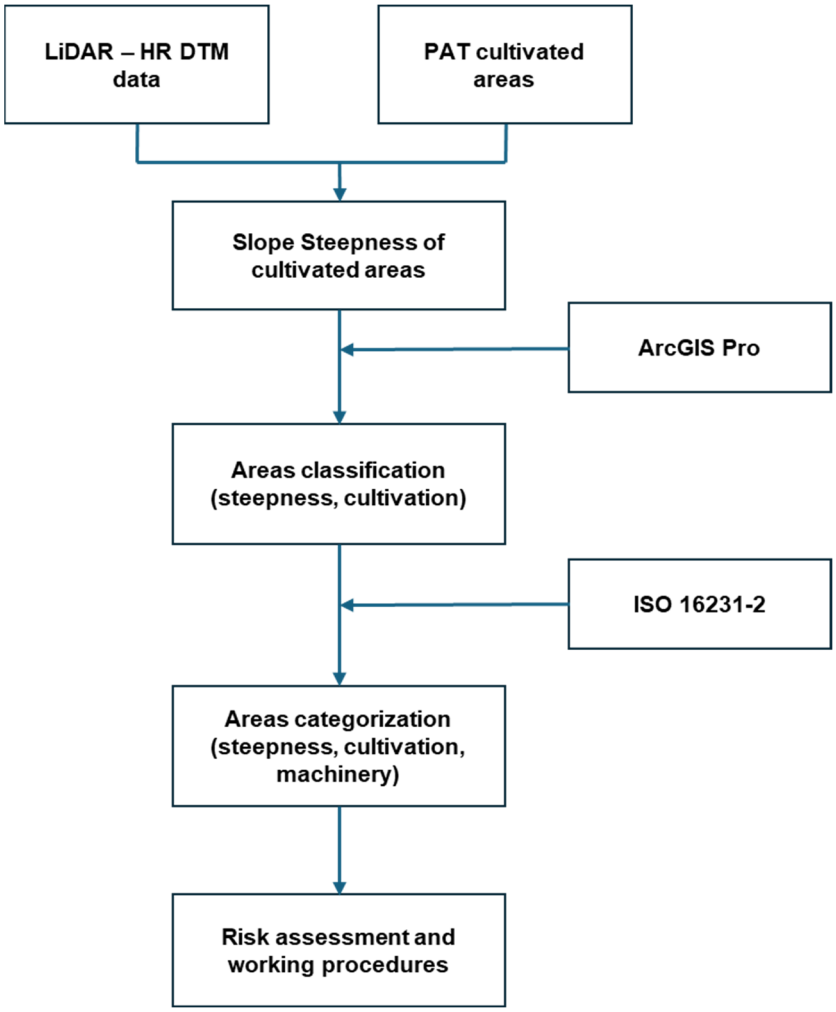


Figure 1. Scheme of the proposed approach.

The sample area is located in the northern part of Italy: as illustrated in Figure 2, the Autonomous Province of Trento (PAT) is an alpine region covering an area of 6210 km^2. The region's morphology features a diverse landscape, with approximately 70% of the total area situated above 1000 m above sea level (a.s.l.) and an average elevation of 1400 m a.s.l. The land use in the region reflects a typical mountain landscape, with forests—predominantly coniferous stands—covering approximately 70% of the total area. Rocky outcrops and bare ground account for 11.5% of the territory, while urbanized and agricultural areas are primarily concentrated in the valley floors, occupying around 19% of the province. Table 1 summarizes main agricultural activities in terms of: (1) utilized agricultural area (UAA), which takes into account the sum of the farm areas intended for agricultural production; (2) the number of enterprises involved in agricultural activities (including forestry), which are mainly small-sized and family-run companies [50].

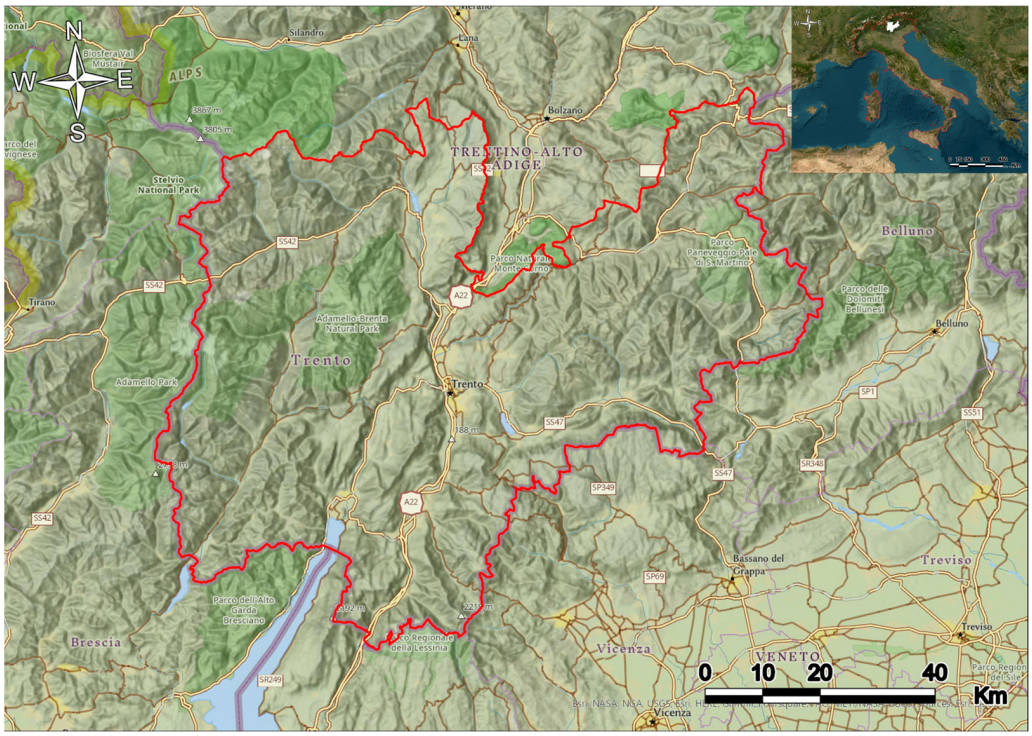


Figure 2. Study area—the Autonomous Province of Trento.

Table 1. Most relevant agricultural activities in the Autonomous Province of Trento (PAT).

Type of Activity	Utilized Agricultural Area (%)	Number of Companies (%)
Viticulture	5.8	36.3
Apple	8.1	28.0
Pasture	56.2	8.7

Due to the relevance of viticulture, this study focused on the characterization of vineyards.

2.1. Slope Steepness of Cultivated Areas

LiDAR data show great potential for agricultural applications, as demonstrated in the literature [51–53].

The Autonomous Province of Trento is covered by an HR-DTM (High-Resolution Digital Terrain Model) derived from airborne LiDAR (Light or Laser Detection and Ranging) data, which is freely available for download [49]. LIDAR is an active remote sensing technique used for topographic surveys by equipping an aerial vehicle with a laser scanner that captures data at extremely high speeds and resolutions. This system generates digital terrain models (DTMs) and digital surface models (DSMs) with a geometric resolution of 1×1 m. Specifically, the mapping process of the entire PAT was performed over different flights that occurred from 2013 to 2015, and subsequently in 2018, to remedy the lack of ground points in the most vegetated areas, and 46 flights were carried out. The 0.5 m $\times$ 0.5 m mesh grating was derived by the interpolation of the original data detected using the sensor (first pulse only), and is available in ASC and XYZ formats. The processed survey points have an altimetric accuracy corresponding to $+/-25$ cm with a confidence level of 95% (2 sigma) and a planimetric accuracy of $+/-50$ cm. The HR-DTM is composed of two distinct datasets, consisting of 25,201 and 400 blocks, respectively, each with a side length of 0.5 km and a pixel size of 0.5 m. The LIDAR data were merged with those

related to the land use provided by the reports of PAT to obtain information related to the morphological characteristics of the cultivated areas.

2.2. Areas Classification

Through the use of ESRI ArcGIS Pro 3.3.0 software [54], the next step consisted in the classification of the different areas depending on two parameters: the type of cultivation and the slope steepness. This allowed us to generate a slope dataset.

2.3. Areas Categorization

Based on the information previously collected, each area was categorized based on the type of machinery that can be used. Specifically, in this phase, a new classification of the slope dataset was performed with respect to the level of roll-over risk for each type of self-propelled machinery using the Reference Stability Static Angle (RSSA) Machine Operating Slope (MOS) values provided by the EN ISO 16231-2 standard. In Table 2, the values of MOS and RSSA for the most common self-propelled agricultural machinery are shown.

Table 2. MOS and RSSA for the most common self-propelled agricultural machinery (adapted from [EN ISO 16231-2]).

Machine Type	Lateral Roll/Tip-Over		Front/Rear Tip-Over	
	MOS (%)	RSSA (%)	MOS (%)	RSSA (%)
Combine harvester without slope compensation system	12	18	18	27
Combine harvester with slope compensation system	20	30	20	30
Combine harvester with body levelling system	30	45	30	45
Forage harvester	25	37.5	25	37.5
Field crop sprayer	15	22.5	25	37.5
Root crop harvester	10	15	15	22.5
Grape harvester without body levelling system	20	30	30	45
Grape harvester with body levelling system	30	45	30	45
Combine harvester without slope compensation system	12	18	18	27
Combine harvester with slope compensation system	20	30	20	30
Combine harvester with body levelling system	30	45	30	45
Forage harvester	25	37.5	25	37.5

It must be noted that RSSA is computed by multiplying the MOS values per safety factor, which allows engineers to consider a safety margin. In accordance with the EN ISO 16231-2 standard, this factor is equal to 1.5.

These values (expressed in percentages) are provided for both lateral and front roll-over/tip-over by the EN ISO 16231-2 standard. To be more precise, EN ISO 16231-2 defines MOS as the "value indicating, for each type of self-propelled machine and each direction, the maximum slope on which the machine is intended to work according to good agricultural practice", while the RSSA "provides the calculated slope on which the machine is required to be stable" [48].

2.4. Risk Assessment Data

The final step of the process consists of the definition of risk assessment data, which can be distinguished into two main outputs:

1. Zonal histograms were developed on the vector parcels to associate the amount of the area potentially exposed to roll-over/tip-over risk when using specific agricultural machines according to the cultivation type of each area.

2. Safety procedures were developed for the proper use of machinery in each area, including information concerning allowed maneuvers, allowed implements, etc., In other words, combining data provided by the EN ISO 16231-2 standard and the steepness of the field, it is possible to identify for each type of machinery the slope areas where the machine can work according to good agricultural practice in any direction, those where only certain maneuvers can be carried out safely, and those where the machine cannot be used.

3. Results

In this section, the experimental results are summarized as follows: in the first part, information related to the categorization procedure is provided, while in the second part of the section, the outcomes of a specific case study concerning an area dedicated to viticulture are reported.

3.1. Categorization

In the first phase of the analysis, data related to the morphology of the territory were acquired. In Figure 3, mountainous and hilly areas of the region were identified.

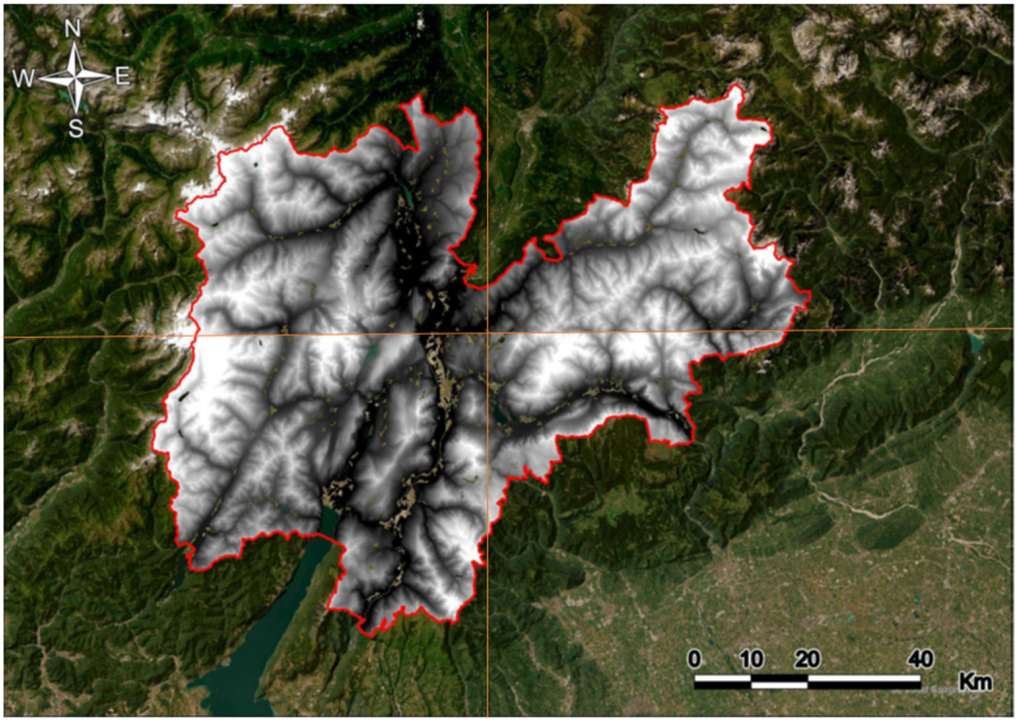


Figure 3. Autonomous Province of Trento digital elevation map to identify mountainous and hilly areas (dark grey) and flat ground (white/light grey).

Then, the slope classification was carried out: as shown in Figure 4, the lighter areas are those that have a lower slope (the white areas are those that have a slope less than or equal to 3%), while for greater slopes, the colour progressively darkens.

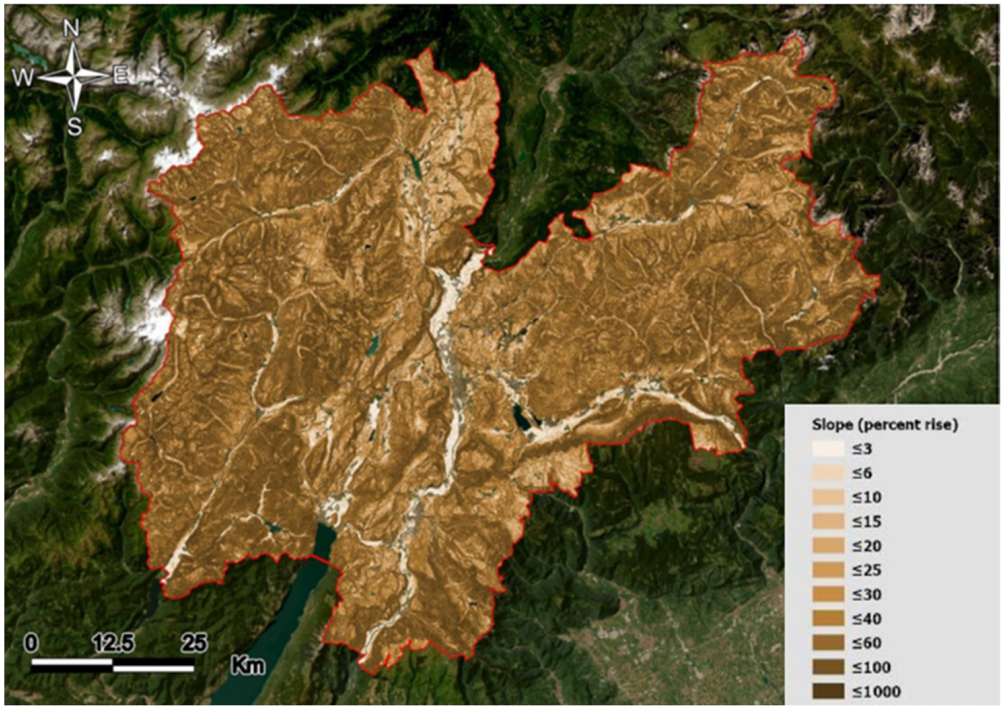


Figure 4. Definitive study area and relative slope (the slope steepness is expressed as a percentage).

Then, using the MOS values provided by EN ISO 16231-2, the different areas of the territory were categorized into three different categories:

- C1 (where there is no roll-over risk due to the slope steepness);
- C2 (where there is the risk of lateral roll-over);
- C3 (where there is a risk of both lateral and front/rear roll-over).

These data were merged with the different types of self-propelled machines reported in the EN ISO 16231-2: in Figure 5, a synthesis of this elaboration is reported considering the total surfaces expressed in hectares (e.g., for Type 1 machinery (Combine harvester without slope compensation system), the majority of the territory (525.735 hectares) belong to category C3, i.e., the most dangerous one).

CODE	MACHINE TYPE	AREA (ha) - ToT 597568					
		C1 -Area Ha Under Control	Area %	C2 - Area Ha - risk of lateral rollover	Area %	C3 - risk of both lateral and front/rear roll-over	Area %
Type 1	Combine harvester without slope compensation system	36093	6.04	35739	6.0	525735	88.0
Type 2	Combine harvester with slope compensation system	83354	13.9	n/a	n/a	514214	86.1
Type 3	Combine harvester with body levelling system	138328	23.1	n/a	n/a	459240	76.9
Type 4	Forage harvester (maize and grass)	111577	18.7	n/a	n/a	485991	81.3
Type 5	Field crop sprayer	61476	10.3	50101	8.4	485991	81.3
Type 6	Root crop harvester (beet, potato, carrot, onions)	36084	6.0	25393	4.2	536091	89.7
Type 7	Grape harvester without body levelling system	83354	13.9	54974	9.2	459240	76.9
Type 8	Grape harvester with body levelling system	138328	23.1	n/a	n/a	459240	76.9
Type 9	Cotton harvester	67042	11.2	n/a	n/a	530526	88.8
Type 10	Sugar cane harvester	36084	6.0	102244	17.1	459240	76.9
Type 11	Mower conditioner (same as for forage harvester)	111577	18.7	n/a	n/a	485991	81.3

Figure 5. Categorization of the territory in areas potentially exposed to different types of roll-over/tip-over risk (n/a = not applicable).

To put this information into practice, risk maps were derived as shown in Figures 6 and 7 which represent the false colour diagrams for the combine harvester without a slope compensation system (type 1 machine) and for the combine harvester with a body levelling system (type 2 machine), respectively.

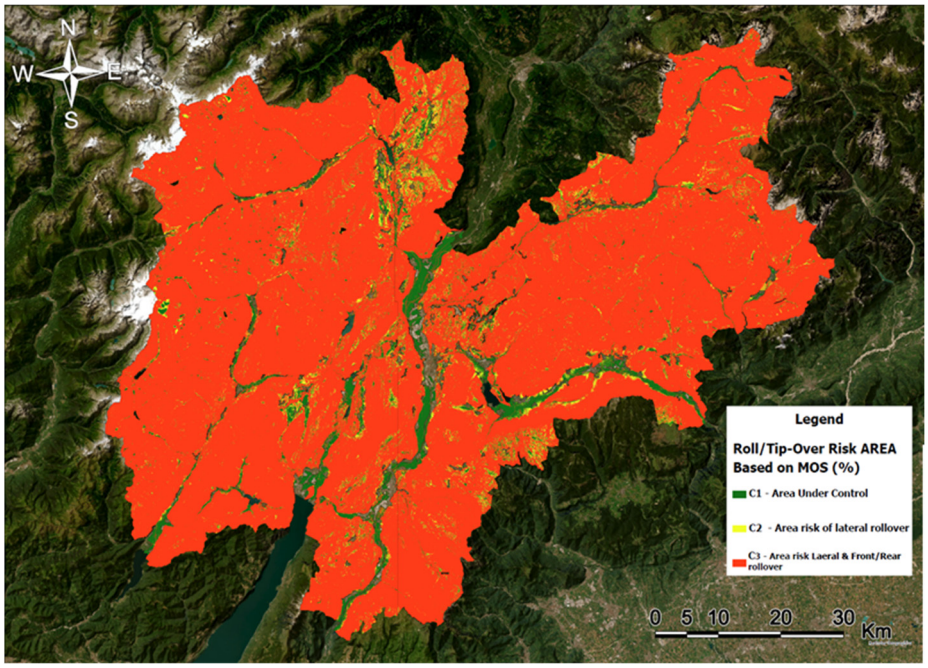


Figure 6. Map of roll-over risk level for combine harvester without slope compensation system (type 1 machine): green (category C1 area), yellow (category C2 area), and red (category C3 area).

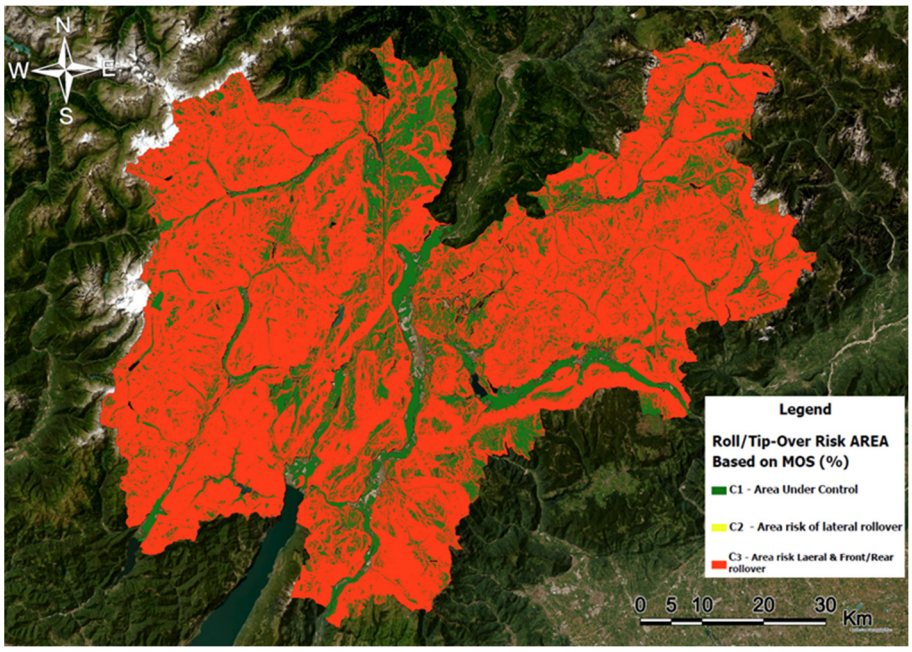


Figure 7. Map of roll-over risk level for combine harvester with body levelling system (type 3 machine): green (category C.1 area), yellow (category C.2 area), and red (category C.3 area).

Comparing the maps shown for type 1 and type 2 machines, it emerges that the roll-over risk is much higher for type 1: the red and yellow surfaces are significantly more widespread for type 1 machines than for type 2, while in the latter case the green areas are more widespread.

Thus, the final step of the categorization consisted in adding information on the type of cultivation by developing risk maps that consider three variables for each type of machinery: MOS, slope steepness, and cultivation type. In other words, using ArcGIS software, the information related to cultivation type and steepness is merged to create specific roll/tip-over risk maps.

3.2. Case Study

To delve deeper into this aspect of the study, a specific analysis was carried out that took into consideration the grape harvester and slope of vineyards, focusing on a restricted area delimited by the Municipality of Trento: in Figure 8, the positioning of this area (identified by the white boundary) into the PAT region (identified by the red boundary) is shown.

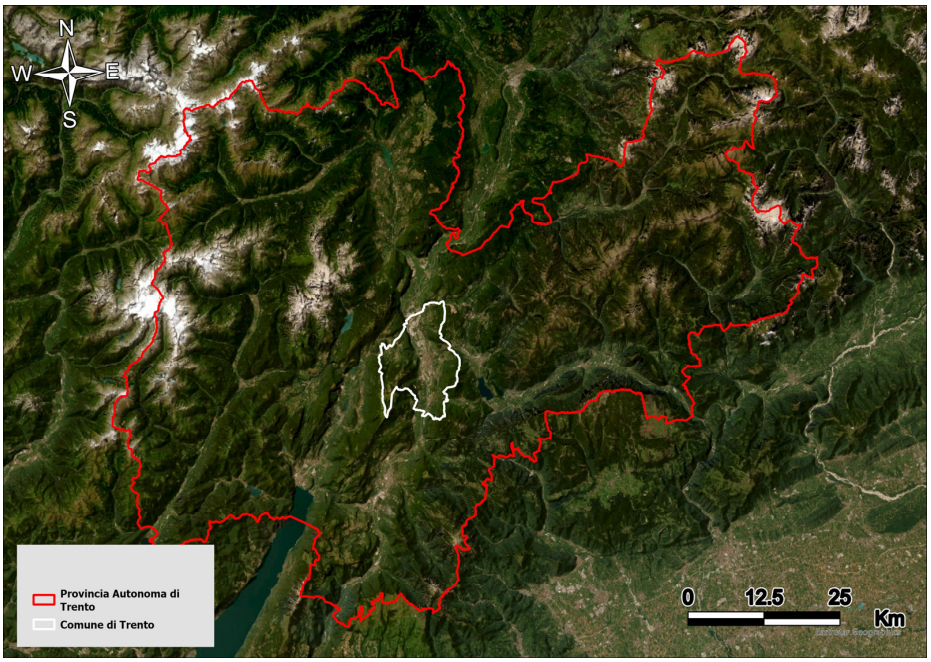


Figure 8. The municipality of Trento.

In this area, grape cultivation is very diffused, covering 1262.4916 hectares, i.e., almost 50% of the whole cultivated area of the municipality of Trento. In Figure 9, the map of the vineyards' location is represented: purple-coloured areas represent the vineyards, while the white border indicates the limits of the municipality.

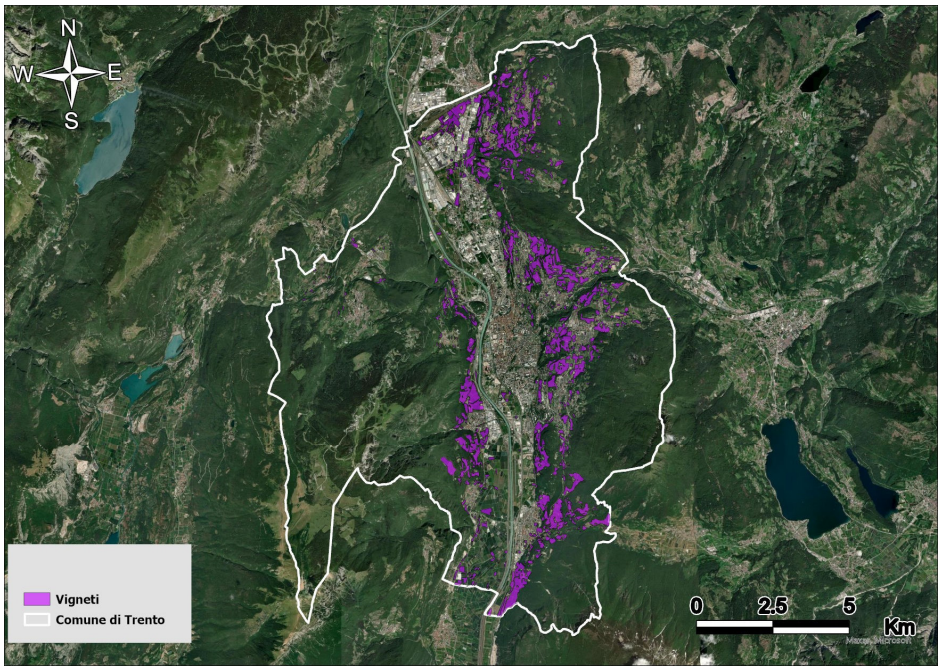


Figure 9. Vineyards in the municipality of Trento.

For this case study, the following machinery was chosen: (1) a grape harvester without a body levelling system (NO_BLS); and (2) a grape harvester with a body levelling system (W_BLS). The above-mentioned machines are most likely used in areas intended for grape farming. The total area dedicated to the cultivation of grapes was then analyzed to verify the slope of each field: these data were merged with the information related to MOS and RAAS of the machinery to determine the roll/tip-over risk. In Figure 10, data related to the risk level areas are reported for both kinds of machinery (NO_BLS and W_BLS).

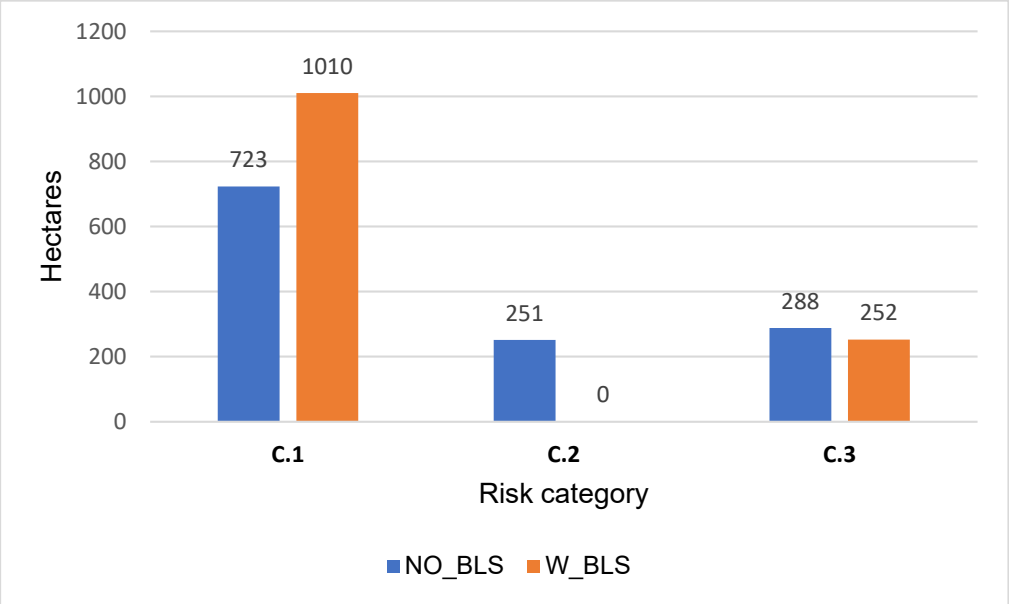


Figure 10. Area in hectares of the municipality of Trento where the use of grape harvesters with body levelling systems (orange) and without (blue) may expose farmers to roll-over risk according to risk category (C.1, C.2, and C.3).

Regarding grape harvesters equipped with an automatic levelling system (BLS), one can see that 1010 hectares represents the overall area where there is no roll-over risk due to the slope steepness. This also means that the harvester equipped with a body levelling system is not stable enough for safely working on 15% of the area, which is classified as C.3.

In more detail, the whole territory was categorized by taking into account the single plots of the municipality, as shown in Figure 11 (risk categories when using the harvester without a body levelling system (NO_BLS)) and Figure 12 (risk categories when using the harvester without a body levelling system (W_BLS)).

Looking at these figures, one can note how in mountainous and hilly areas, the slope rapidly changes, and when using machinery not equipped with the levelling system, the risk level changes in a few metres. (Figure 11). Furthermore, working in the same parcel with different versions of the same type of machinery implies a significant variation in the roll/tip-over risk.

Thus, the proper choice of work equipment is paramount, as well as working procedures: for instance, in yellow areas of Figure 11, which indicate risk category C.2, horizontal maneuvers (such as turning around) should be avoided. Alternatively, in the red zones, which indicate risk category C.3, harvesting should only be carried out manually.

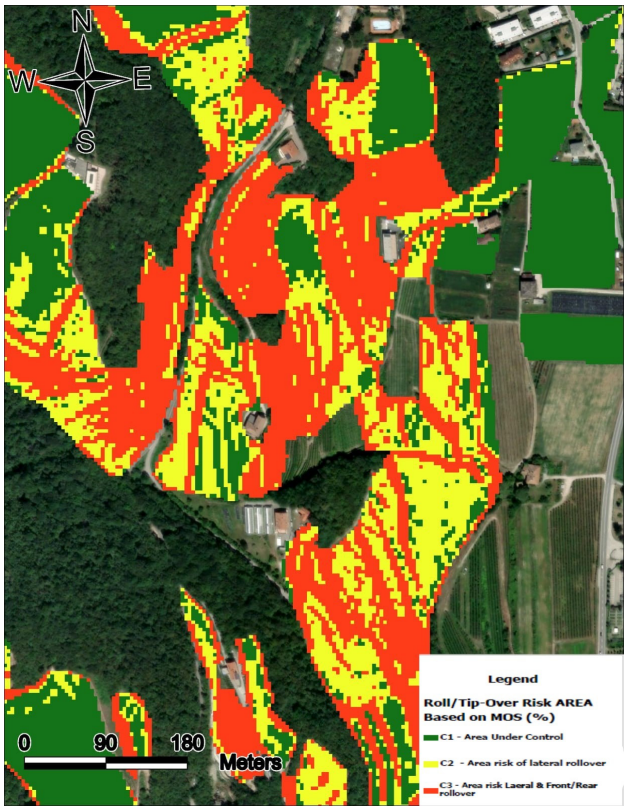


Figure 11. Details of categorization when using a grape harvester without a body levelling system (NO_BLS).

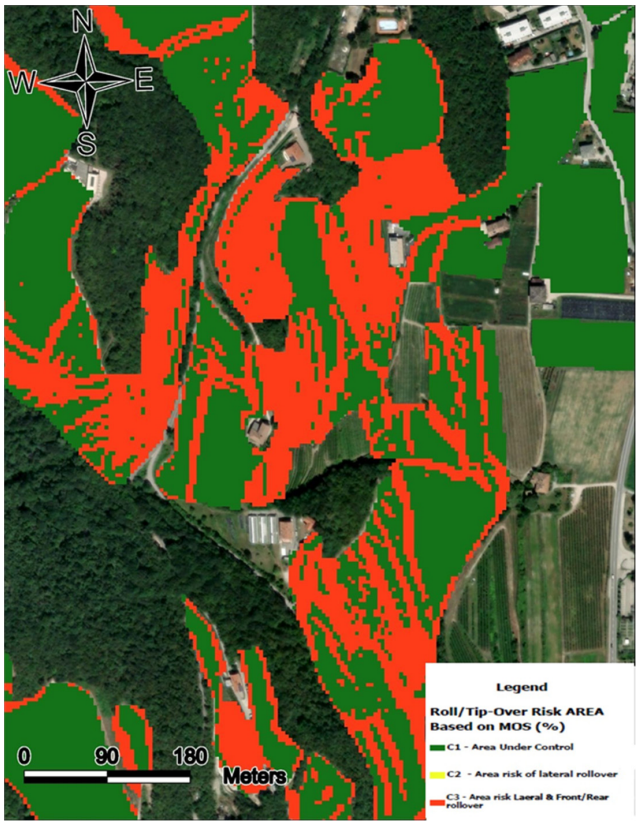


Figure 12. Details of categorization when using a grape harvester with a body levelling system (W_BLS).

4. Discussion

Recent advancements in machinery safety norms and standards have underscored an increasing awareness of occupational health and safety (OHS) from the perspectives of both equipment manufacturers and end users. These developments reflect a growing recognition of the hazardous nature of using agricultural self-propelled machinery when workers are frequently exposed to risks such as machinery roll/tip-overs [55]. Thus, significant challenges remain in the practical implementation of safety standards and working procedures [56]. This is particularly true concerning research integrating field slope steepness data with the operational characteristics of self-propelled agricultural machinery. Thus, a general contribution of this study relies on dealing with this gap in knowledge by presenting a methodology to provide farmers with specific information on the maximum safe working slope angles related to the parcels they farm depending on the machinery they use. Although this study presents the first results of a more thorough project, some practical findings can be outlined.

First, to effectively assess the roll-over risk of self-propelled agricultural machines, the proposed approach proves to be a valuable tool to enable the prediction of slope gradients in specific areas concerning plantation layouts and correlate them with the static stability angle of the agricultural machinery used on that terrain. By doing so, it becomes possible to generate a slope map that is tailored to both the specific topography and the types of machines operating in that environment.

In the literature, several studies have proposed advanced solutions integrating real-time detection mechanisms to enhance situational awareness and facilitate prompt communication of emergencies. For example, Bertacchini et al. [57] focused on advancements in driver assistance technologies: their research highlighted solutions that alert users in hazardous situations, such as instances where the vehicle experiences a loss of stability. Similarly, Liu and Koc [58] developed a detection and emergency notification system. These systems play a crucial role in accident prevention by providing timely notifications that enable drivers to take corrective actions before a critical situation escalates.

However, one of the key advantages of the proposed approach is its ability to provide a preliminary evaluation of whether a particular machine can safely operate on a given slope before reaching the area. This proactive assessment minimizes the risk of accidents by preventing machines from entering hazardous inclinations where stability could be compromised, thus avoiding risky situations.

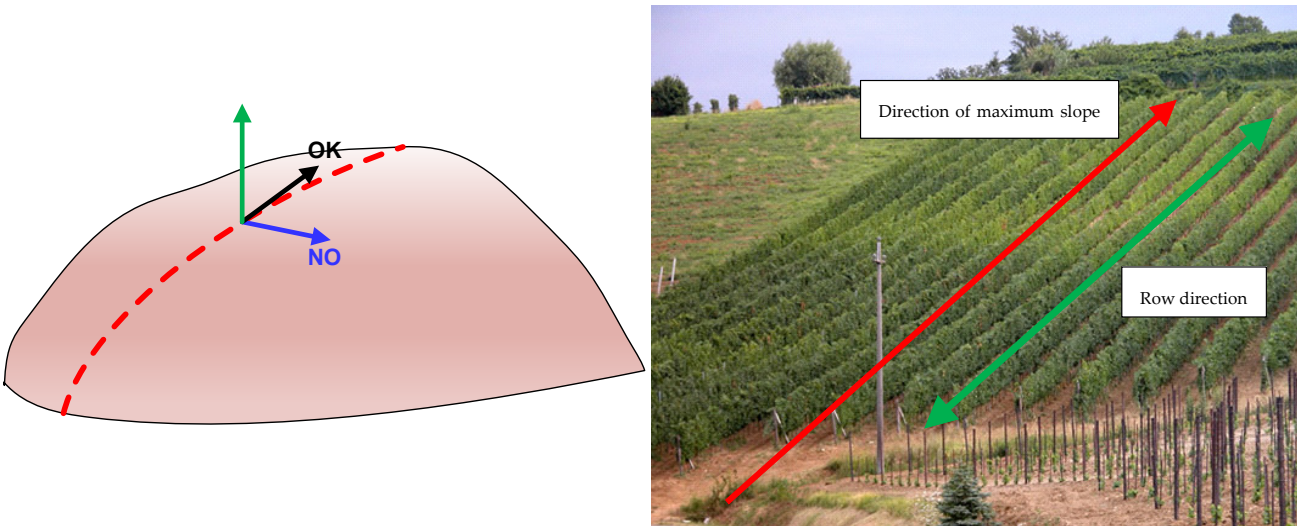
Consequently, this tool offers a significant added value in enhancing safety measures, reducing the likelihood of roll/tip-overs, and preventing potential injuries to operators.

By integrating this predictive capability into agricultural planning and machine operation, farmers and agricultural professionals can make more informed decisions, ultimately improving both safety and efficiency in field operations. This output is in line with Cutini et al. [59], who pointed out that when using a self-propelled fruit harvester (SPFH) equipped with a limiting device on the pivoting axle, the vehicle maintains roll-over stability, even if one wheel becomes detached from the ground, thus fostering the proper choice of work equipment.

Moreover, when dealing with implements, substantial shifts in the centre of gravity occur, greatly increasing the risk of tipping, as stressed by several researchers [60–62] who observed that this risk is particularly pronounced on sloped terrain, where stability and traction may be further compromised. These findings highlight the importance of operational adjustments, especially in scenarios involving steep slopes and fluid-carrying equipment.

The importance of correct machine maneuvering is also a relevant issue that has emerged from the analysis, as in mountainous and hilly areas, the slope rapidly changes. In fields classified as C.2 (yellow areas), the risk of lateral overturns is high, and farmers must

follow paths parallel to the slope lines (red dotted line in Figure 13a) only. At the same time, this information can also be useful in the case of planning row alignment in novel plant cultivation (Figure 13b). Accordingly, proper training and information are needed to avoid risk-taking behaviours. This aligns with research findings of several studies underlining the fact that farmers are prone to incorrect maneuvering due to a mismatch between perceived and actual risk [63–67]. Moreover, it confirms the research findings by Cogato et al. [68], who emphasized that GIS mapping offers the ability to determine the potential mechanizability of a block in advance, thereby supporting operative and management decisions.



(**a**) (**b**)

Figure 13. Slope lines for safe work activities in C.2 areas: (**a**) correct (OK) and incorrect (NO) working paths; (**b**) safe directions for planting new cultivations.

This information can be made available to farmers both through traditional means, such as farmers' associations and cooperatives, as well as by means of specific software tools that can be used individually before starting work activities. This type of information can be used to create practical, territory-specific guidelines to enhance safety awareness and accident prevention. These guidelines could help farmers determine which machinery can be used safely in specific areas, assess risks associated with slope steepness, and adopt appropriate operational solutions to minimize roll-over/tip-over risks. This output can reduce the lack of safety instructions when using self-propelled machinery, outlined by several studies [69–71]. This is consistent with Vigoroso et al. [45], who outlined the fact that when certain risks cannot be entirely eliminated, such as the risk of tractor roll/tip-overs due to steep slopes, additional safety measures must be implemented to alert operators, ensuring they are aware of high-risk areas. These warnings, combined with proper training and operational guidelines, help operators develop safer behaviours, such as adjusting their driving techniques, avoiding dangerous inclines, and using specialized equipment.

Furthermore, the development of specific applications to be used by farmers individually is in line with previous studies, where the availability of an app for preventive risk assessment before starting work can improve farmers' awareness of the correct use of machinery by means of more user-centred tools [72–75]. This issue represents a future advancement in current research, aligning with INAIL's institutional objectives.

Further improvements are also needed to better integrate the EN ISO 16231-2 data with those related to both the field area to be cultivated and the machinery features, since several parameters of the latter can influence its operative behaviour, such as the presence

of liquids, the condition of tyres, and the presence of ROPSs, altering the roll/tip-over risk level [76–78]. Overall, it must be noted that the proposed approach concerns the use of existing machinery, which, in most countries, such as those in the European Union, is designed in accordance with the slope limits indicated by the EN ISO 16231-2 standard. Nevertheless, the slope mapping obtained in this study could also be used as a reference to improve machinery design with the aim of augmenting its usability in mountainous areas. In addition, the proposed approach may also be used for assessing the stability of tractors combined with specific interchangeable equipment (e.g., flail mowers, sprayers, etc.). However, in this case, it is preliminarily necessary to define the reference stability angles for each combination of tractors with specific implements, considering that EN ISO 16231-2 does not apply.

5. Conclusions

Working in hilly and mountainous areas always presents a roll/tip-over risk for farmers when using self-propelled machinery. An accurate mapping of the slope steepness can allow them to be more aware of the level of risk, and consequently of the correct behaviour to follow. Today's information technology tools allow us to map cultivated areas by means of 3D georeferencing tools and classify them into different categories depending on slope steepness. The current study presents the first part of a national research project promoted by the Italian Compensation Authority (INAIL), and the findings showed that the proposed approach enables the prediction of terrain slopes within specific cultivated areas in relation to plantation layouts, and correlates them with the static stability angle of the machinery operating in those regions. In this way, it becomes possible to generate detailed slope maps tailored to particular areas and machine types, allowing operators to assess in advance whether a given machine can safely operate on a specific slope before physically reaching the location. Such preventive analysis cannot completely solve these problems, but can certainly serve to significantly enhance safety measures, reducing the likelihood of roll/tip-over accidents and minimizing the risk of injuries. However, this positive outcome is related to the case study context only, and further validation is necessary. In particular, additional effort is necessary to expand the database of mapped areas covered by high-resolution digital terrain models (HR-DTMs). Hence, further research is needed to improve the coverage degree of the terrain model, as well as to integrate an automated risk analysis procedure driven by artificial intelligence into user-centred tools. These advancements would streamline the mapping process, reducing the time required for preventive risk analysis and making the tool more practical for widespread adoption in agricultural safety management.

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References

1. Ichihara, G.; Matsukawa, T.; Kitamura, F.; Yokoyama, K. Risk factors for occupational accidents in agricultural enterprises in Japan. *Ind. Health* **2019**, *57*, 627–636. [CrossRef]
2. Baraza, X.; Cugueró-Escofet, N. Severity of occupational agricultural accidents in Spain, 2013–2018. *Saf. Sci.* **2021**, *143*, 105422. [CrossRef]

3. Fargnoli, M.; Lombardi, M.; Haber, N.; Puri, D. The Impact of Human Error in the Use of Agricultural Tractors: A Case Study Research in Vineyard Cultivation in Italy. *Agriculture* **2018**, *8*, 82. [CrossRef]
4. Mishra, D.; Satapathy, S. An Integrated SWARA, QFD, and ISM Approach for Agricultural Injuries in India. *Int. J. Decis. Support Syst. Technol.* **2020**, *12*, 1–24. [CrossRef]
5. Ivascu, L.; Sarfraz, M.; Mohsin, M.; Naseem, S.; Ozturk, I. The Causes of Occupational Accidents and Injuries in Romanian Firms: An Application of the Johansen Cointegration and Granger Causality Test. *Int. J. Environ. Res. Public Health* **2021**, *18*, 7634. [CrossRef] [PubMed]
6. Kogler, R.; Quendler, E.; Boxberger, J. Analysis of occupational accidents with agricultural machinery in the period 2008–2010 in Austria. *Saf. Sci.* **2015**, *72*, 319–328. [CrossRef]
7. Biocca, M.; Aiello, L.; Baldoin, C. Rovitis 4.0: An autonomous robot for spraying in vineyards. In Proceedings of the Safety, Health and Welfare in Agriculture and Agro-Food Systems, SHWA 2020, Ragusa, Italy, 16–19 September 2020; Springer: Cham, Switzerland, 2020; pp. 176–185. [CrossRef]
8. Gattamelata, D.; Puri, D.; Vita, L.; Fargnoli, M. A Full Assistance System (FAS) for the Safe Use of the Tractor's Foldable Rollover Protective Structure (FROPS). *AgriEngineering* **2023**, *5*, 218–235. [CrossRef]
9. Fargnoli, M.; Lombardi, M. NOSACQ-50 for Safety Climate Assessment in Agricultural Activities: A Case Study in Central Italy. *Int. J. Environ. Res. Public Health* **2020**, *17*, 9177. [CrossRef]
10. INAIL, Occupational Accidents Statistics. Available online: https://www.inail.it/portale/it/inail-comunica/pubblicazioni/dati-inail/dati-inail-dettaglio.2024.03.dati-inail-anno-2024.html (accessed on 15 January 2025).
11. Kim, K.; Kim, H.; Lee, M.; Jung, W.; Choi, D. Incidence Rates of Agricultural Machine-Related Injuries in South Korea. *Int. J. Environ. Res. Public Health* **2022**, *19*, 15588. [CrossRef]
12. Mayrhofer, H.; Quendler, E.; Boxberger, J. Occupational incidents with self-propelled machinery in Austrian agriculture. *J. Agromed.* **2013**, *18*, 359–367. [CrossRef]
13. Antunes, S.M.; Cordeiro, C.; Teixeira, H.M. Analysis of fatal accidents with tractors in the Centre of Portugal: Ten years analysis. *Forensic Sci. Int.* **2018**, *287*, 74–80. [CrossRef] [PubMed]
14. Rautiainen, R.H.; Ledolter, J.; Donham, K.J.; Ohsfeldt, R.L.; Zwerling, C. Risk factors for serious injury in Finnish agriculture. *Am. J. Ind. Med.* **2009**, *52*, 419–428. [CrossRef]
15. Vigoroso, L.; Caffaro, F.; Tronci, M.; Fargnoli, M. Ergonomics and design for safety: A scoping review and bibliometric analysis in the industrial engineering literature. *Saf. Sci.* **2025**, *185*, 106799. [CrossRef]
16. Facchinetti, D.; Santoro, S.; Galli, L.E.; Pessina, D. Agricultural Tractor Roll-Over Related Fatalities in Italy: Results from a 12 Years Analysis. *Sustainability* **2021**, *13*, 4536. [CrossRef]
17. Chowdhury, M.; Ali, M.; Habineza, E.; Reza, M.N.; Kabir, M.S.N.; Lim, S.-J.; Choi, I.-S.; Chung, S.-O. Analysis of Rollover Characteristics of a 12 kW Automatic Onion Transplanter to Reduce Stability Hazards. *Agriculture* **2023**, *13*, 652. [CrossRef]
18. Vigoroso, L.; Caffaro, F.; Micheletti Cremasco, M.; Cavallo, E. Innovating Occupational Safety Training: A Scoping Review on Digital Games and Possible Applications in Agriculture. *Int. J. Environ. Res. Public Health* **2021**, *18*, 1868. [CrossRef]
19. Fargnoli, M.; Parrella, E.; Costantino, F.; Tronci, M. Hybrid solutions for agricultural vehicles: A comparative life cycle analysis from the users' standpoint. *J. Clean. Prod.* **2024**, *485*, 144406. [CrossRef]
20. O'Connor, T.; Kinsella, J.; O'Hora, D.; McNamara, J.; Meredith, D. Safer tomorrow: Irish dairy farmers' self-perception of their farm safety practices. *J. Saf. Res.* **2022**, *82*, 450–458. [CrossRef] [PubMed]
21. Fargnoli, M.; Vita, L.; Gattamelata, D.; Laurendi, V.; Tronci, M. A reverse engineering approach to enhance machinery design for safety. In *DS 70, Proceedings of the DESIGN 2012, the 12th International Design Conference*; Dubrovnik, Croatia, 21–24 May 2012, Marjanovic, D., Storga, M., Pavkovic, N., Bojcetic, N., Eds.; International Design Conference: Dubrovnik, Croatia, 2012; pp. 627–636, ISBN 978-953-7738-17-4.
22. Caffaro, F.; Micheletti Cremasco, M.; Roccato, M.; Cavallo, E. It does not occur by chance: A mediation model of the influence of workers' characteristics, work environment factors, and near misses on agricultural machinery-related accidents. *Int. J. Occup. Environ. Health* **2017**, *23*, 52–59. [CrossRef]
23. Franceschetti, B.; Rondelli, V.; Capacci, E. Lateral Stability Performance of Articulated Narrow-Track Tractors. *Agronomy* **2021**, *11*, 2512. [CrossRef]
24. Capacci, E.; Franceschetti, B.; Guzzomi, A.; Rondelli, V. Energy Absorption in Actual Tractor Rollovers with Different Tire Configurations. *Int. J. Environ. Res. Public Health* **2021**, *18*, 6517. [CrossRef] [PubMed]
25. Fredi, P.; Lupia Palmieri, E. Morphological Regions of Italy. In *Landscapes and Landforms of Italy. World Geomorphological Landscapes*; Soldati, M., Marchetti, M., Eds.; Springer: Cham, Switzerland, 2017. [CrossRef]
26. Cecchini, M.; Zambon, I.; Monarca, D.; Piccioni, F.; Marucci, A.; Colantoni, A. Spatial Analysis for Detecting Recent Work Accidents in Agriculture in Italy. In *Innovative Biosystems Engineering for Sustainable Agriculture, Forestry and Food Production*; Coppola, A., Di Renzo, G., Altieri, G., D'Antonio, P., Eds.; MID-TERM AIIA 2019; Lecture Notes in Civil Engineering; Springer: Cham, Switzerland, 2020; Volume 67. [CrossRef]

27. Vita, L.; Gattamelata, D.; Pessina, D. Retrofitting Agricultural Self-Propelled Machines with Roll-Over and Tip-Over Protective Structures. *Safety* **2021**, *7*, 46. [CrossRef]
28. Kogler, R.; Quendler, E.; Boxberger, J. Occupational accidents with agricultural machinery in Austria. *J. Agromed.* **2016**, *21*, 61–70. [CrossRef] [PubMed]
29. Gattamelata, D.; Vita, L.; Fargnoli, M. Machinery Safety and Ergonomics: A Case Study Research to Augment Agricultural Tracklaying Tractors' Safety and Usability. *Int. J. Environ. Res. Public Health* **2021**, *18*, 8643. [CrossRef]
30. Wang, L.; Liu, F.; Song, Z.; Ni, Y.; He, Z.; Zhai, Z.; Zhu, Z.; Zhou, Z.; Song, Z.; Li, Z. Advances in tractor rollover and stability control: Implications for off-road driving safety. *Comp. Electron. Agric.* **2024**, *226*, 109483. [CrossRef]
31. Kim, W.S.; Siddique, M.A.A.; Kim, Y.-J.; Jung, Y.-J.; Baek, S.-M.; Baek, S.-Y.; Kim, Y.-S.; Lim, R.-G. Simulation of the Rollover Angle of a Self-Propelled Radish Harvester for Different Load Conditions. *Appl. Sci.* **2022**, *12*, 10733. [CrossRef]
32. Fargnoli, M.; Lombardi, M. Safety Vision of Agricultural Tractors: An Engineering Perspective Based on Recent Studies (2009–2019). *Safety* **2020**, *6*, 1. [CrossRef]
33. Alfaro-Lopez, J.R.; Perez-Ezcurdia, A.; Latorre-Biel, J.-I.; Arana-Navarro, I.; Benito-Amurrio, M.; Villanueva-Roldán, P. The Integration of Mechanical Energy Absorbers into Rollover Protective Structures to Improve the Safety of Agricultural Tractors in the Event of Rollover. *Agriculture* **2024**, *14*, 1050. [CrossRef]
34. Gao, J.; Yin, C.; Yuan, G. Development of an Anti-rollover Warning and Active Intervention Controller for Wheeled Tractor. *Recent Pat. Eng.* **2024**, *18*, 55–66. [CrossRef]
35. Casazza, C.; Martelli, R.; Rondelli, V. Evaluation of a commercial tractor safety monitoring system using a reverse engineering procedure. *J. Agric. Saf. Health* **2016**, *22*, 215–225. [CrossRef]
36. Sun, D.; Chen, D.; Wang, S.; Wang, X. A dynamic instability detection and prediction system for high clearance tractor. *IFAC-Pap.* **2016**, *49*, 50–54. [CrossRef]
37. Chowdhury, M.; Islam, M.N.; Iqbal, M.Z.; Islam, S.; Lee, D.-H.; Kim, D.-G.; Jun, H.-J.; Chung, S.-O. Analysis of Overturning and Vibration during Field Operation of a Tractor-Mounted 4-Row Radish Collector toward Ensuring User Safety. *Machines* **2020**, *8*, 77. [CrossRef]
38. Cavallo, E.; Langle, T.; Bueno, D.; Tsukamoto, S.; Görücü, S.; Murphy, D. Rollover Protective Structure (ROPS) Retrofitting on Agricultural Tractors: Goals and Approaches in Different Countries. *J. Agromed.* **2014**, *19*, 208–209. [CrossRef]
39. Tinc, P.J.; Ayers, P.; May, J.J.; Purschwitz, M.A.; Park, S.; Bayes, B.; Sorensen, J. Implementing a National Tractor Safety Program: Using "Whole System in a Room" to Mobilize Partners and Implement Solutions. *J. Agromed.* **2016**, *21*, 127–131. [CrossRef] [PubMed]
40. Glasscock, D.J.; Rasmussen, K.; Carstensen, O.; Hansen, O.N. Psychosocial factors and safety behaviour as predictors of accidental work injuries in farming. *Work Stress* **2006**, *20*, 173–189. [CrossRef]
41. Irwin, A.; Poots, J. Investigation of UK farmer go/no-go decisions in response to tractor-based risk scenarios. *J. Agromed.* **2018**, *23*, 154–165. [CrossRef]
42. Caffaro, F.; Cremasco, M.M.; Roccato, M.; Cavallo, E. Drivers of farmers' intention to adopt technological innovations in Italy: The role of information sources, perceived usefulness, and perceived ease of use. *J. Rural Stud.* **2020**, *76*, 264–271. [CrossRef]
43. Qi, X.; Yao, X.; Cong, X.; Li, S.; Han, M.; Tao, Z.; Yang, X.; Qi, X.; Shi, F.; Wang, S. Profile and risk factors in farmer injuries: A review based on Haddon matrix and 5 E's risk reduction strategy. *Front. Public Health* **2024**, *12*, 1322884. [CrossRef]
44. Cividino, S.R.S.; Pergher, G.; Gubiani, R.; Moreschi, C.; Da Broi, U.; Vello, M.; Rinaldi, F. Definition of a Methodology for Gradual and Sustainable Safety Improvements on Farms and Its Preliminary Applications. *Agriculture* **2018**, *8*, 7. [CrossRef]
45. Vigoroso, L.; Caffaro, F.; Cavallo, E. Warning against Critical Slopes in Agriculture: Comprehension of Targeted Safety Signs in a Group of Machinery Operators in Italy. *Int. J. Environ. Res. Public Health* **2019**, *16*, 611. [CrossRef]
46. Görücü, S.; Cavallo, E.; Murphy, D. Perceptions of Tilt Angles of an Agricultural Tractor. *J. Agromed.* **2014**, *19*, 5–14. [CrossRef] [PubMed]
47. Tillapaugh, J.A.; Murphy, D.J.; Sommer, I.J.; Garvey, P.M. Operator assessment of tractor roll angle with and without a tractor stability visual feedback device. *J. Agric. Saf. Health* **2010**, *16*, 249–264. [CrossRef] [PubMed]
48. *ISO 16231-2:2015*; Self-Propelled Agricultural Machinery. Assessment of Stability—Part 2: Determination of Static Stability and Test Procedures. International Organization for Standardization: Genevan, Switzerland, 2015. Available online: https://www.iso.org/standard/61583.html (accessed on 22 January 2025).
49. Provincia Autonoma di Trento. Stem-WebGIS. Available online: https://siat.provincia.tn.it/stem/ (accessed on 22 January 2025).
50. Provincia Autonoma di Trento. PAT Statistics. Available online: http://www.statistica.provincia.tn.it/ (accessed on 22 January 2025).
51. Jin, S.; Sun, X.; Wu, F.; Su, Y.; Li, Y.; Song, S.; Guo, Q. Lidar sheds new light on plant phenomics for plant breeding and management: Recent advances and future prospects. *ISPRS J. Photogramm. Remote Sens.* **2021**, *171*, 202–223. [CrossRef]

52. Iqbal, J.; Xu, R.; Sun, S.; Li, C. Simulation of an Autonomous Mobile Robot for LiDAR-Based In-Field Phenotyping and Navigation. *Robotics* **2020**, *9*, 46. [CrossRef]
53. Aguiar, A.S.; dos Santos, F.N.; Sobreira, H.; Boaventura-Cunha, J.; Sousa, A.J. Localization and Mapping on Agriculture Based on Point-Feature Extraction and Semiplanes Segmentation From 3D LiDAR Data. *Front. Robot. AI* **2022**, *9*, 14. [CrossRef]
54. ArcGIS Pro. Available online: https://pro.arcgis.com/en/pro-app/latest/get-started/get-started.htm (accessed on 22 January 2025).
55. Cecchini, M.; Cossio, F.; Marucci, A.; Monarca, D.; Colantoni, A.; Petrelli, M.; Allegrini, E. Survey on the status of enforcement of European directives on health and safety at work in some Italian farms. *J. Food Agric. Environ.* **2013**, *11*, 595–600.
56. Zambon, I.; Piergentili, A.; Salvati, L.; Monarca, D.; Matyjas-Łysakowska, P.; Colantoni, A. Applied Research for a Safer Future: Exploring Recent Job Accidents in Agriculture, Italy (2012–2017). *Processes* **2018**, *6*, 87. [CrossRef]
57. Bertacchini, A.; Napoletano, G.; Dondi, D.; Larcher, L.; Pavan, P. Optimized energy-aware wireless system for identification of the relative positioning of articulated systems in the free space. *IEEE Sens. J.* **2014**, *14*, 1682–1692. [CrossRef]
58. Liu, B.; Koc, A.B. Field tests of a tractor rollover detection and emergency notification system. *J. Agric. Saf. Health* **2015**, *21*, 113–127. [CrossRef]
59. Cutini, M.; Brambilla, M.; Bisaglia, C.; Melzi, S.; Sabbioni, E.; Vignati, M.; Cavallo, E.; Laurendi, V. A Study of the Lateral Stability of Self-Propelled Fruit Harvesters. *Agriculture* **2017**, *7*, 92. [CrossRef]
60. Bietresato, M.; Pavan, S.; Cozzi, G.; Sartori, L. A numerical approach for evaluating and properly setting self-propelled forage harvesters. *Trans. ASABE* **2013**, *56*, 5–14. [CrossRef]
61. Jang, M.-K.; Hwang, S.-J.; Nam, J.-S. Simulation Study for Overturning and Rollover Characteristics of a Tractor with an Implement on a Hard Surface. *Agronomy* **2022**, *12*, 3093. [CrossRef]
62. Kang, S.; Kim, Y.; Park, H.; Kim, Y.; Woo, S.; Uyeh, D.D.; Ha, Y. Rollover Safety and Workable Boundary Suggestion of an Agricultural Platform with Different Attachments. *Agriculture* **2022**, *12*, 1148. [CrossRef]
63. Fargnoli, M.; Lombardi, M.; Puri, D. Applying Hierarchical Task Analysis to Depict Human Safety Errors during Pesticide Use in Vineyard Cultivation. *Agriculture* **2019**, *9*, 158. [CrossRef]
64. Cil, M.; Gedik, T. Research on factors affecting the risk-taking behavior of personnel working in the forest products sector. *Int. J. Occup. Saf. Ergon.* **2022**, *28*, 2315–2323. [CrossRef]
65. Špička, J. Socio-Demographic Drivers of the Risk-Taking Propensity of Micro Farmers: Evidence from the Czech Republic. *J. Entrepren. Emerg. Econ.* **2020**, *12*, 569–590. [CrossRef]
66. Fargnoli, M.; Lombardi, M. Safety Climate and the Impact of the COVID-19 Pandemic: An Investigation on Safety Perceptions among Farmers in Italy. *Safety* **2021**, *7*, 52. [CrossRef]
67. Cecchini, M.; Bedini, R.; Mosetti, D.; Marino, S.; Stasi, S. Safety Knowledge and Changing Behavior in Agricultural Workers: An Assessment Model Applied in Central Italy. *Saf. Health Work* **2018**, *9*, 164–171. [CrossRef]
68. Cogato, A.; Pezzuolo, A.; Sørensen, C.G.; De Bei, R.; Sozzi, M.; Marinello, F. A GIS-Based Multicriteria Index to Evaluate the Mechanisability Potential of Italian Vineyard Area. *Land* **2020**, *9*, 469. [CrossRef]
69. Fargnoli, M.; Lombardi, M.; Haber, N. A fuzzy-QFD approach for the enhancement of work equipment safety: A case study in the agriculture sector. *Int. J. Reliab. Saf.* **2018**, *12*, 306–326. [CrossRef]
70. Cutini, M.; Forte, G.; Maietta, M.; Mazzenga, M.; Mastrangelo, S.; Bisaglia, C. Safety-Critical Manuals for Agricultural Tractor Drivers: A Method to Improve Their Usability. *Agriculture* **2017**, *7*, 67. [CrossRef]
71. Nag, P.K.; Gite, L.P. Farm Accidents and Injuries. In *Human-Centered Agriculture. Design Science and Innovation*; Nag, P.K., Gite, L.P., Eds.; Springer: Singapore, 2020; pp. 175–204. [CrossRef]
72. Caffaro, F.; Bagagiolo, G.; Micheletti Cremasco, M.; Vigoroso, L.; Cavallo, E. Tailoring Safety Training Material to Migrant Farmworkers: An Ergonomic User-Centred Approach. *Int. J. Environ. Res. Public Health* **2020**, *17*, 2104. [CrossRef] [PubMed]
73. Rubino, F.M.; Puri, D.; Fargnoli, M.; Lombardi, M.; Mandić-Rajčević, S.; Colosio, C. Sicurpest: A Prototype of a User-Friendly Tool for Preventive Risk Assessment of Pesticide Use in Agriculture. *Toxics* **2025**, *13*, 89. [CrossRef] [PubMed]
74. Marucci, A.; Colantoni, A.; Zambon, I.; Egidi, G. Precision Farming in Hilly Areas: The Use of Network RTK in GNSS Technology. *Agriculture* **2017**, *7*, 60. [CrossRef]
75. Radočaj, D.; Plaščak, I.; Heffer, G.; Jurišić, M. A Low-Cost Global Navigation Satellite System Positioning Accuracy Assessment Method for Agricultural Machinery. *Appl. Sci.* **2022**, *12*, 693. [CrossRef]
76. Majdan, R.; Abrahám, R.; Tkáč, Z.; Drlička, R.; Matejková, E.; Kollárová, K.; Mareček, J. Static Lateral Stability of Tractor with Rear Wheel Ballast Weights: Comparison of ISO 16231-2 (2015) with Experimental Data Regarding Tyre Deformation. *Appl. Sci.* **2021**, *11*, 381. [CrossRef]

77. Melzi, S.; Sabbioni, E.; Vignati, M.; Cutini, M.; Brambilla, M.; Bisaglia, C.; Cavallo, E. Multibody model of fruit harvesting trucks: Comparison with experimental data and rollover analysis. *J. Agric. Eng.* **2018**, *49*, 92–99. [CrossRef]
78. Rondelli, V.; Capacci, E.; Franceschetti, B. Evaluation of the Stability Behavior of an Agricultural Unmanned Ground Vehicle. *Sustainability* **2022**, *14*, 15561. [CrossRef]

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