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# Definition of a Methodology for Gradual and Sustainable Safety Improvements on Farms and Its Preliminary Applications

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**Abstract:** In many productive sectors, ensuring a safe working environment is still an underestimated problem, and especially so in farming. A lack of attention to safety and poor risk awareness by operators represents a crucial problem, which results in numerous serious injuries and fatal accidents. The Demetra project, involving the collaboration of the Regional Directorate of INAIL (National Institute for Insurance against Accidents at Work), aims to devise operational solutions to evaluate the risk of accidents in agricultural work and analyze the dynamics of occupational accidents by using an observational method to help farmers ensure optimal safety levels. The challenge of the project is to support farmers with tools designed to encourage good safety management in the agricultural workplaces.

**Keywords:** safety; occupational accidents; agriculture

## 1. Introduction

To contextualize and define the occurrence of accidents involving farms we need to identify the main risk factors of specific work activities. It is important to remember that sectors such as farming are difficult to standardize and hence various risk types are often underestimated [1–8].

As reported in the literature, there are only two main macro risk categories for accidents involving agricultural work: environmental risks and health risks [1–8].

Among agricultural risk factors, the following three main areas of specific risks have, according to national and regional government data, a significant impact in terms of accidents and occupational pathologies:

1. Mechanical risks (about 60% of serious and fatal injuries);
2. Biomechanical risks due to repetitive movements and postural issues (in recent years there has been a significant increase in claims related to occupational injuries especially in those sectors with low levels of mechanization such as horticulture and floriculture);
3. Interference risks; serious and fatal workplace injuries due to poorly qualified or inexperienced farm workers who may also be employed on several farms.

The Demetra project therefore aims to analyze:

- Those farms where machinery is used;
- Farms where manual processes are still common (pruning and harvesting represent a particularly high biomechanical risk);
- Farms that carry out activities where they interact with other farms [9,10].

Following the preliminary investigative analysis, the initial phase of the project clearly showed that:

- As far as employment is concerned, the farming sector does not follow standard patterns and each individual farm may well demand specific solutions if safety levels are to be improved;
- Improvement pathways and tools need to be devised that work in association with governance models for SMEs (small and medium-sized enterprises) and family-run agricultural enterprises;
- We need to define operational procedures for two main areas: work organization and production, which require dedicated safety solutions for machinery and equipment;
- It is also essential to pay attention to the evolution of both production facilities and reception facilities, and so identify a set of innovative organizational and technical solutions to safety issues.

In the sampling and observational phases of the Demetra project described below we aim to develop a multifactorial procedure which promotes improvements in safety conditions by means of a guideline protocol based on the introduction of gradual, prioritized changes to working practices.

## 2. Materials and Methods

The preliminary observational and investigative steps of the Demetra model were divided into four evaluation phases:

- I. Definition of the productive and organizational components of the farm;
- II. Creation of a specific pyramidal matrix for each farm;
- III. Validation of the model through field tests;
- IV. Building of specific pathways to improve safety levels.

To analyze a farm, the following algorithm was used:

$$\text{Demetra model} = F(\text{Lo}) \times F(\text{Lp})$$

where:

- Lo = organizational level. Defines and analyzes safety management from the point of view of farm organization.
- Lp = the operational and productive level and defines different occupational areas.

The Italian agricultural sector is mainly founded on SMEs (small and medium-sized enterprises) characterized by a very small number of employees and production flows which are often poorly standardized, especially in the case of small farms where work is often seasonal and conducted out in the fields.

This representation of the farm defines the intervention levels of the Demetra model. It analyzes the farm as an open system including all its interactions with other external factors (Figure 1).

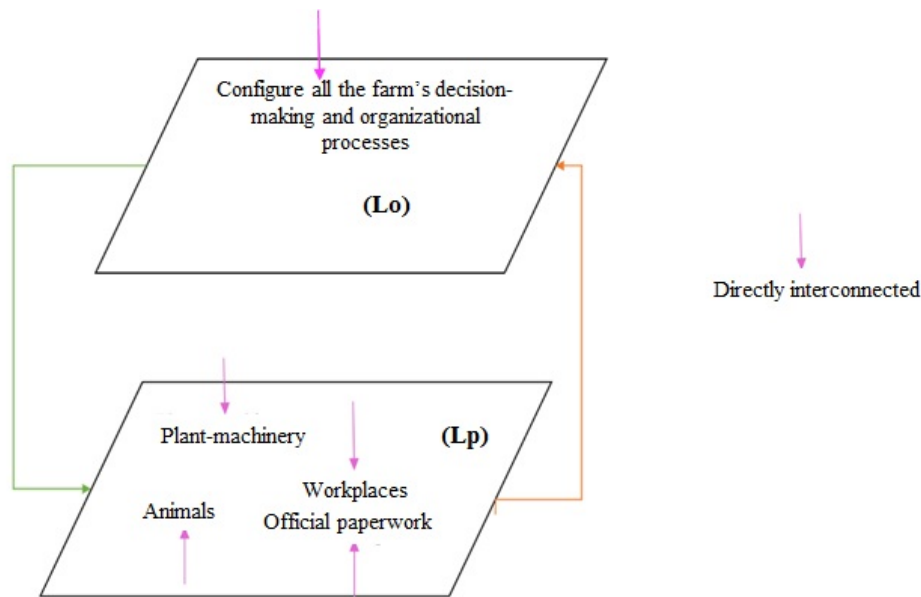


Figure 1. Representation of a farm's risk factors.

As shown in Figure 2, a plan to improve safety on a farm should consider all farming and non-farming factors that affect both production and organization and involve all specific activities.

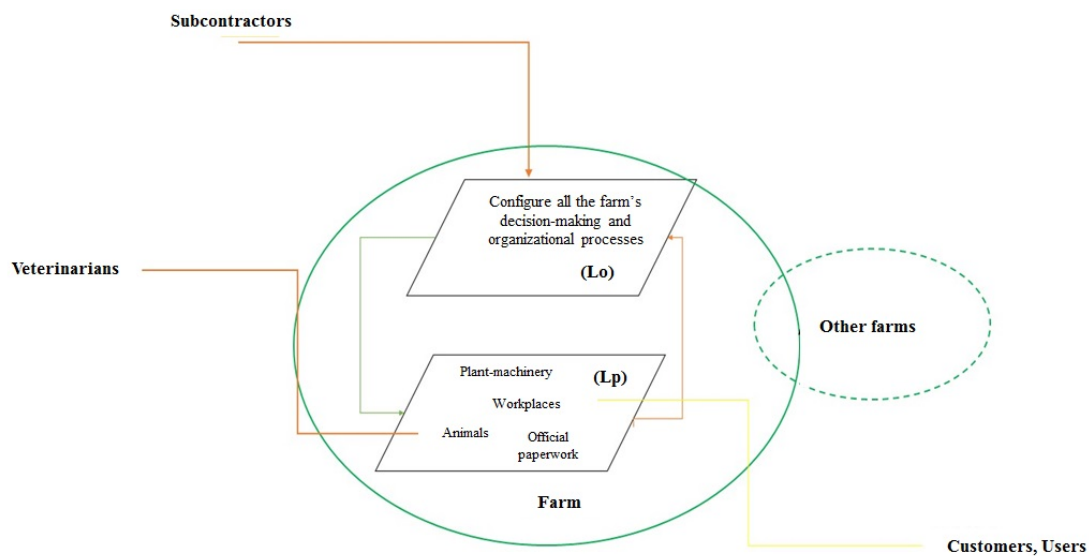


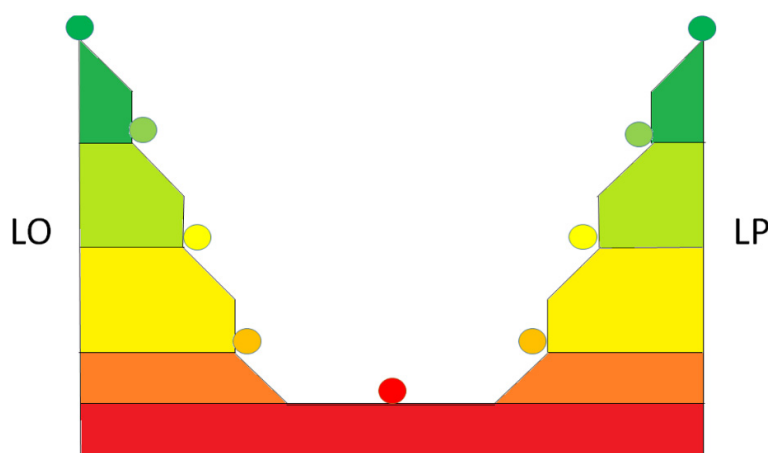
Figure 2. Representation of risk factors of a farm and external non-farming factors.

Demetra considers a series of variables for the management of farm safety planning, such as:

- The constant presence of people not involved in farming activities (veterinarians, technicians, National Health System employees, etc.).
- The presence of visitors, children and school groups (this occurs normally on educational and social farms).
- Productive and organizational activities carried out on one farm by other directly interconnected farms.
- Personnel working on more than one farm.

The logic behind the project and its analytical methodology is shown in Figure 3 through the construction of two distinct elements (pyramids), both characterized by safety levels and color bands which go from red (a serious degree of risk) up to green (an optimal safety situation). This methodology focuses on the position of each farm within the five color bands in the pyramids, so that targets can be set in a program of gradual safety improvements.

As shown in Figure 3 and Table 1, equating a farm’s safety performance to the different color-coded safety levels on the pyramids is part of a dynamic, observational process. Farm management and employees therefore have to be engaged in continual dialogue, and evaluate and optimize safety levels, in order to maintain its standards. A color code is assigned to each level: the positioning within a specific color band is represented both in Figure 3 and Table 1 as a result of the analysis carried out on a set of components characterizing the farm.



**Figure 3.** Schematization of the two-pyramid Demetra methodology (where LO = organizational level and defines and analyzes safety management from the point of view of farm organization, whereas LP = represents the operational and productive level and defines different occupational areas. Red Colour = represents maximum risk level; Green Colour = represents optimal safety conditions).

**Table 1.** Color bands used to build the pyramid.

LO		LP	
Color Code	Meaning	Color Code	Meaning
	Farm organized in an optimal way, which goes beyond the minimum safety levels, with regular internal audits and a safety management system		Production is carried out in a safe and correct manner, above the standards defined by the legislation
	Farm complies with statutory obligations, with proper management of all organizational aspects		Production and operating conditions comply with the regulations
	Farm with deficiencies at an organizational or management level which fails to meet its statutory obligations		Farm has deficiencies that can lead to risk scenarios in work activities
	Farm that has serious deficiencies and criticalities in the organization and management of the farm		Farm has deficiencies and criticalities that can lead to significant risk scenarios in work activities
	Farm without any organization or safety management system covering operational, productive and statutory areas.		Farm which lacks any internal system of risk assessment or safety management at operational, productive and statutory level.

LO = organizational level and defines and analyzes safety management from the point of view of farm organization; LP = represents the operational and productive level and defines different occupational areas.

To define a standardized methodology which is applicable in all scenarios and which takes into account the specific characteristics of agriculture and SMEs, a procedure has been defined whereby the four points below are analyzed for each farm. In this way, we can assign the correct position for the farm in the pyramid and so identify a pathway of gradual improvement:

- (1) Organizational management aspects: how the farm manages production and safety in the workplace.
- (2) Documentation: set of technical documents required by the government's health and safety standards.
- (3) Operational aspects: how the farm organizes its production according to the specific context in which it operates.
- (4) Interface: this defines the receptivity level of the farm in terms of work processes (subcontractors, mobility of the workforce between farms in the network, educational and social farms).

### 3. Preliminary Results

In our preliminary investigation eleven farms operating mainly in the vine-growing/winemaking (5), zootechnical (livestock/cereal or livestock) (4) sectors were evaluated. The cereal and zootechnical sectors are often closely interconnected in Italy because cereals are mostly used to feed livestock.

The Demetra model was used to analyze these 11 farms. They all showed a high level of specialization, except for one farm, which had different types of non-interconnected production (Table 2).

Our decision to investigate farms employing people on permanent and fixed-term contracts and family farms, was motivated by three factors:

- Gradual changes to Italian law which affect the employment of people on non-standard contracts (agistment, sharecropping, workforce employed on a network of farms);
- Situations in which family farms, in compliance with specific Italian laws, employ family members as subordinate workers;
- The propensity of farms, especially the newly established ones, to offer certain types of contracts which allow them to hire people who are qualified to drive farm tractors (the driver must be a skilled worker who cannot be paid by voucher) (Table 2).

The main results were as follows:

1. The farms we studied mainly specialize in one specific type of production in order to attain greater sustainability.
2. The surface-area of land farmed ranged from a few hectares up to over a hundred.
3. This area was not proportional to the farm's income or the number of people employed. In fact, in order to determine the real productive level of a farm, we need to consider certain key factors: the degree of mechanization, planting distances, production philosophy (organic production is more labour-intensive).
4. The farms we selected were representative, in terms of their characteristics and size, of the average Italian farm (Table 2).

According to data in the sixth census of the Italian Ministry of Agriculture, most personnel were employed in a family context, although in some cases farms employed workers on a permanent contract (on average, family farms employed at least one or two people on a permanent contract) and/or fixed-term contract (Table 2).

The preliminary results from the application of the Demetra model allowed researchers to identify the different risk levels of agricultural accidents and to design appropriate, innovative ways of improving safety, as had been anticipated during the development phase of the Demetra methodology.

The main risk factors identified by the Demetra model are shown in Table 3.

Table 2. Sample characteristics.

Farm Number	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8	Farm 9	Farm 10	Farm 11
<b>Sector</b>	Vine-growing and cereals	Livestock-cereals	Vine-growing and winemaking	Livestock	Vine-growing and winemaking	Fruit and vegetables	Livestock and cereals	Vine-growing and winemaking	Vine-growing	Horticulture	Livestock
<b>Surface area (hectares)</b>	100	50	15	60	50	5	1500 managed, 30 under ownership	5	50	2	20
<b>Employees</b>	yes	no	yes	yes	yes	yes	yes	no (family members only)	no (family members only)	yes	Yes
<b>Outsource or make use of subcontractors</b>	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	Yes
<b>Payment by voucher</b>	yes	no	yes	no	yes	yes	yes	no	yes	yes	No
<b>Direct sales</b>	yes	no	no	yes	yes	yes	no	yes	no	yes	Yes
<b>Farm restaurant or shop; social or educational farm</b>	yes	no	yes	yes	yes	yes	no	yes	yes	yes	No
<b>Family farmhouse</b>	no	yes	no	yes	yes	no	yes	yes	no	yes	Yes
<b>Accidents</b>	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	Yes
<b>Governance</b>	Structured family-run enterprises	Family-run enterprises	Co-operative	Family-run enterprises	Structured family-run enterprises	Social farm	Subcontractors	Family-run enterprises	Family-run enterprises	Multiple owners and employers, family-run enterprises	Multiple owners and employers, family-run enterprises

**Table 3.** Summary of main risk factors.

Risk	Activities/Settings	Sector
<b>Environmental risks</b>		
Explosion	Presence of explosive atmospheres (Biogas plants, autoclaves, storage of granular and dusty material, presence of flours)	livestock, vine-growing and winemaking, cereal sector
Drowning	Streams, irrigation channels, ponds, lakes	all sectors
Fire	Presence of flammable substances, high fire load (e.g., barns), possibility of combustion, high-temperature fermentation	all sectors
Fall from height	Use of simple ladders, silo maintenance activities, fall while using agricultural machinery	all sectors
Fall from ground level	All open field operations, working in the presence of water and residues on the floor	all sectors
Contact with medium-sized and large animals	Care and management of the farm	livestock sector
Mechanical risk	Use of agricultural machinery, open field operations	all sectors
Working at height	Maintenance of and access to silos, wine tanks, use of aerial platforms, construction of rural buildings	all sectors in occasional way
<b>Health risks</b>		
Exposure to low temperatures	Working outdoors during winter, or working in cold storage units	winegrowing, wine, cereals, livestock sector
Exposure to high temperatures	Manual operations outdoors	horticultural, winegrowing, wine, cereal sector
Risks associated with microclimate in general	Protected crops, dairies, wineries, processing in hot, humid environments where there are considerable amounts of organic material	horticultural, wine, floricultural sector
Biological	Animal care and management, management of livestock excrement, direct contact with organic material (picking/harvesting, manual operations outdoors), irrigation	all sectors
Chemical	Treatment, fertilization, sanitization of production environments, prolonged use of chainsaw, brush cutters and grass trimmers (exhaust gas)	all sectors
Asbestos	Presence of asbestos roofs and manufacturing facilities built using asbestos	all sectors
Powders of organic and inorganic origin	Use of agricultural machinery for soil processing, food distribution, livestock—excrement management, plant logging and sawing	all sectors
Noise	Use of agricultural machinery and equipment, open field operations, transformation operations	all sectors
Electrocution	Use of agricultural machinery and electrical equipment	all sectors
Vibrations	Use of agricultural machinery and equipment, management of green and marginal areas	all sectors
<b>Organizational and cross-cutting risks</b>		
Postural issues (stooping, squatting, etc.)	Management of arboreal and herbaceous crops, in particular harvesting and pruning	horticultural, nursery, winegrowing, wine, livestock sector
Repetitive movements	Management of arboreal and herbaceous crops, in particular manual pruning; Processing of products, nursery operations (planting, transplanting, weeding)	horticultural, nursery, winegrowing, wine sector
Night-time operations	Ploughing, harvesting and soil management operations, animal management	cereals, livestock sector
Working in solitude	Driving farm tractors or other vehicles, in isolated places which emergency services will have trouble reaching quickly in the event of an accident	all sectors
Interference risks	Presence of several farms in one area, with shared equipment and personnel	all sectors

#### 4. Discussion

The Demetra project demonstrated, by means of a new analytical methodology, how a process of gradual and continuous improvement can increase the level of organizational and operational safety [9–13]. The analytical tools developed by the Demetra project for small and micro farms demonstrated that it is possible, with the correct analysis of accident risk levels, to ensure safety in agricultural contexts and confirmed that safety targets should be regarded not only as a cost but also as an investment which improves productivity, through the reduction/elimination of work-related injuries or deaths [2,6,9,10,12]. The project succeeded in raising the awareness and increasing the understanding of the farmers involved in this experiment, especially in cases of family-run farms whose owners decided to raise safety levels above the minimum required by Italian law.

Each level of the Demetra pyramids brings together a series of parameters that determine a matrix which allows us to identify the pathway to improvement. Each level includes the analysis of a series of factors that characterize the farm and identify the production organization and safety profiles together with the improvement pathway that should be followed. This method involves the following five steps:

1. Building a matrix that describes the farm's current safety performance;
2. Positioning the collected data in the matrix and the pyramid;
3. Defining aims according to the type of farm in question;
4. Identifying the technical and operational changes that need to be made in order to attain adequate safety levels;
5. Final positioning and assessment of whether aims have been achieved.

A fundamental aspect of the evaluation of a farm by means of the Demetra model is that, even though some parameters may be positive, the farm's real position in the pyramid is always determined by its lowest positioning within the color bands in the matrix, which corresponds to the highest level of risk.

The final results of the Demetra model applied to the farms studied were essentially the following:

- The farm owners/managers used the positioning of coloured matrices correctly in order to carry out the self-assessment of any critical points on their farm;
- The solutions proposed were not costly because they often involved simple changes to the organization or management of the farm;
- From an administrative point of view a series of easily applicable operational solutions and procedures were identified;
- The model promoted innovative solutions involving third parties, showing that a farm can be an "open workplace" which interacts with other networked farms;
- Structural changes are very often unnecessary for farms; in fact, in some cases, the reorganization of productive activities demanded operational solutions rather than structural;
- Changes to machinery and equipment can often be made by means of existing farm resources;
- The protocol and the improvement pathways designed for each individual farm provided objective feedback on the farm's safety status.

The innovative profile of the Demetra model also confirmed the following:

- Each farm has specific requirements where improvements in safety are concerned, and these are influenced by the nature of its governance, structure and production;
- During the risk analysis phase the farms implemented new knowledge and technical skills which were then transmitted to satellite farms or other family farms;
- This new process of safety improvements is easily adaptable to the typical Italian small and medium-sized enterprises and family farms; in fact, all the farms we analyzed were able to comply with Italian safety standards through the application of innovative processes, including those farms which initially had an extremely low safety rating.



The farms we studied displayed a series of critical issues which affect organization, management and administration. Farms also showed a range of activities involving subcontractors that are not managed in compliance with the specific Italian regulations [9–11,14–16].

The Demetra model puts forward an innovative method that can be used for any future experimentation in order to evaluate risk levels related to occupational accidents and diseases by following these steps:

1. Obtain specific farm data;
2. Apply the screened parameters to the coloured pyramid matrices;
3. Analyze the coloured pyramid matrices;
4. Classify farms according to their organizational structure;
5. Set objectives according to their organizational structure;
6. Plan operational and structural decisions in order to improve the safety of the chosen farms;
7. Evaluate the efficiency of new safety plans.

## 5. Conclusions

To summarize, the Demetra model is a new way to give farms a toolset which can help them define their accident risk levels and in turn increase the safety of all agricultural activities in the near future [10].

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