

Department of Industrial Engineering and Management

Systematic Risk Management on Farms

Jarkko Leppälä

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Jarkko Leppälä

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Abstract

The objective of this dissertation study was to increase understanding of systematic risk management on farms. Special attention was paid to the development and usability of holistic risk management tools, evaluating the effectiveness of farm safety risk management interventions and sustainability risk management on farms. The management of diverse risks is critical for farm business continuity. More management tools are needed to support farms in systematic risk management in practice.

A mixed methods research design was applied in this study. In the literature review (sub-study 1), potential risk management tools applicable to managing farm risks were listed and analysed. The survey in sub-study 2 (n = 130) provided an overview of the management challenges faced by farmers and the importance of various management skills. Sub-study 3 was a survey (n = 591) to analyse the farm risks, farm safety and security risk management practices, and the effectiveness of the Farmers' Occupational Health Service in risk management. The Farm Risk Map framework was constructed and its use was analysed on case farms in sub-study 4. Sub-study 5 was a case study in which risk management tools were applied to farm sustainability management.

The dependence on one person, fire risk incidents, machinery damage, infrastructure problems, a larger farm field size and high physical work strain were associated with a higher safety risk on farms. Higher safety risk among the membership of the Farmers' Occupational Health Service (FOHS) is probably biased by other variables. The farmers who carried out regular safety and security risk monitoring on their farm had fewer safety risk incidents. The new Farm Risk Map developed in this dissertation study can assist systematic and holistic risk management on farms. The case study in sub-study 5 presented how the farm sustainability risk management drivers can be monitored and used as risk buffers in farm sustainability management.

The new risk management tools developed in this study are being used on farms, research and in education. Changes in agriculture such as the increasing size of farms, farmer ageing and health risks, regional security problems, the adaptation of new technology and new production and business models may increase the need for risk management on farms. Current risk management on farms are not at a sufficient level in relation to the needs for farm safety and security and sustainable management. Improved knowledge of farmer management skills and the advanced use of holistic risk management tools on farms are needed. Cooperation between different research fields and farmer risk management education are required to develop risk management in agriculture.

Keywords agriculture, management, farm risk map, safety, security

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Systemaattinen riskienhallinta maatalousyrityksissä

Julkaisija Perustieteiden korkeakoulu**Yksikkö** Tuotantotalouden laitos**Sarja** Aalto University publication series DOCTORAL DISSERTATIONS 17/2016**Tutkimusala** Tuotantotalous**Käsitteilyajankohdan pvm** 06.10.2015**Väitöspäivä** 11.02.2016**Julkaisuluvan myöntämispäivä** 20.11.2015**Kieli** Englanti **Monografia** **Yhdistelmäväitöskirja (yhteenvedo-osa + erillisartikkelit)****Tiivistelmä**

Tämän väitöskirjatutkimuksen tavoitteena oli lisätä ymmärrystä systemaattisesta riskienhallinnasta maatalousyrityksissä. Tutkimuksessa kiinnitettiin erityisesti huomiota maatalousyrityksen holististen riskienhallintavälineiden kehittämiseen ja käytettävyyteen, turvallisuusjohtamisen vaikuttavuuteen ja kestävyysriskien hallintaan maataloilla. Useiden eri riskien hallitseminen on tärkeää maatalousyrityksen jatkuvuuden kannalta. Tarvitaan enemmän johtamisvälineitä tukemaan systemaattista riskienhallintaa maataloilla käytännössä.

Väitöskirjatutkimuksessa käytettiin monimetodista (mixed methods) lähestymistapaa. Osatutkimuksen 1 kirjallisuustutkimuksessa koottiin ja analysoitiin maataloilla käytettäviä riskienhallinnan välineitä. Osatutkimuksen 2 kyselytutkimuksessa (n = 130) tarkasteltiin maatalousyrittäjien johtamisen haasteita ja johtamistaitojen tärkeyttä. Osatutkimuksessa 3 analysoitiin maatalousyrittäjille suunnatussa kyselytutkimuksessa (n = 591) maatalousyritysten riskejä, turvallisuusjohtamista ja maatalousyrittäjien työterveyshuollon vaikuttavuutta riskienhallinnassa. Osatutkimuksessa 4 kehitettiin Maatilan riskikartta, jonka käyttöä analysoitiin case-yrityksissä. Viidennen osatutkimuksen case-tutkimuksessa sovellettiin riskienhallinnan välineitä kestävä kehityksen johtamiseen maatalousyrityksessä.

Kohonnut tapaturmariski maatalousyrityksissä liittyi korkeaan riippuvuuteen tilan avainhenkilöstä, toteutuneisiin paloriskeihin, toteutuneisiin konerikkoihin, tilan infrastruktuurissa ilmenneisiin ongelmiin, suurempaan tilan peltoalaan ja fyysisen työn rasittavuuteen. Työterveyshuollon jäsenyyden kohonneeseen tapaturmarisktiin vaikuttavat todennäköisesti muut muuttajat. Säännöllisesti turvallisuusriskejä seuranneilla viljelijöillä oli vähemmän tapaturmatapauksia. Tässä väitöskirjatyössä kehitetty Maatilan riskikartta avustaa systemaattista ja kokonaisvaltaista riskienhallintaa maataloilla. Osatutkimuksen 5 case-tutkimuksessa tarkasteltiin, kuinka kestävyysriskien hallintaa voitaisiin seurata ja käyttää puskurina ehkäisemään kestävyysriskejä maatalolla.

Tässä väitöskirjassa esitettyjä uusia maatalousyritysten riskienhallinnan välineitä on käytetty maataloilla, tutkimuksissa ja koulutuksissa. Maatalousalan muutokset kuten tilakoon kasvu, yrittäjien ikääntyminen ja terveysriskit, alueelliset turvallisuusuhat, uudet teknologiat sekä uudet tuotanto- ja liiketoimintamallit voivat lisätä riskienhallinnan tarvetta maataloudessa. Maatilojen riskienhallinnan välineet eivät tällä hetkellä riitä vastaamaan alan turvallisuusjohtamisen ja kestävä kehityksen tarpeisiin. Maatalousyrityksissä tarvitaan uusia tiedonhallintataitoja ja kokonaisvaltaista riskienhallintaa. Tutkimusalueiden välinen yhteistyö ja maatalousyrittäjien riskienhallintakoulutuksen kehittyminen ovat välttämättömiä tekijöitä riskienhallinnan kehittämiseksi maataloudessa.

Avainsanat maatalous, riskienhallinta, maatilan riskikartta, turvallisuusjohtaminen**ISBN (painettu)** 978-952-60-6634-9**ISBN (pdf)** 978-952-60-6635-6**ISSN-L** 1799-4934**ISSN (painettu)** 1799-4934**ISSN (pdf)** 1799-4942**Julkaisupaikka** Helsinki**Painopaikka** Helsinki**Vuosi** 2016**Sivumäärä** 152**urn** <http://urn.fi/URN:ISBN:978-952-60-6635-6>

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Dr Juha Suutarinen from Natural Resources Institute Finland (Luke) and risk management specialist Dr Mervi Murtonen from VTT Technical Centre of

Finland took the time to read my texts. They also were co-authors in my dissertation article. I also wish to thank my other co-writers and colleagues at Luke: Mr Kim O. Kaustell, M.Sc.; Ms Tiina Mattila, M.Sc.; Mr Timo Hurme, Biometrician; and dairy extension specialist Mr Esa Manninen, M.Sc., from Valio. Many thanks to Dr Roy Siddall for language revision and to Krista Kettunen from Luke for editing service.

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This study project has taken a lot of time, resources and work. However, if this work saves even one farmer's life or prevents even one serious accident from happening on a farm, it has paid back all the invested resources and been worth doing.

27th of November, 2015
Järvenpää, Finland

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List of Publications

This thesis is based on the following publications, which are referred to in the text by their Roman numerals:

- 1.** Leppälä, J., Rautiainen, R. and Kauranen, I. 2015. Analysis of risk management tools applicable in managing farm risks: A literature review. *International Journal of Agricultural Management* 4 (3): 110-122.
- 2.** Mattila, T. E. A., Kaustell, K. O., Leppälä, J., Hurme, T. and Suutarinen, J. 2007. Farmers' perceptions of necessary management skills in Finland. *Journal of Agricultural Education and Extension* 13 (4): 287-300.
- 3.** Leppälä, J., Kauranen, I. and Rautiainen, R. 2013. Effectiveness of occupational health service programmes in farmers' safety and security risk management. *International Journal of Agricultural Management* 2 (3): 130-140.
- 4.** Leppälä, J., Murtonen, M. and Kauranen, I. 2012. Farm risk map: a contextual tool for risk identification and sustainable management on farms. *Risk Management* 14 (1): 42-59.
- 5.** Leppälä, J., Manninen, E. and Pohjola, T. 2011. Farm risk management applied to sustainability of the food supply chain. A case study of sustainability risks in dairy farming. In: Burritt, R., Schaltegger, S., Bennett, M., Pohjola, T., Csutora, M. 2011. *Environmental Management Accounting and Supply Chain Management*. Springer: 111-130.

Author's Contribution

Publication 1: Analysis of risk management tools applicable in managing farm risks: A literature review

The first article is a review of studies concerning different types of risk management tools on farms to enhance farm safety and security. Work on the review started in an expert workshop by checking the literature keywords and preliminary main safety and security themes in agriculture. Jarkko Leppälä participated in the workshop and collected the brainstorming results with the wallpaper technique. Leppälä conducted the first literature search with the help of MTT library information specialist Sirpa Suonpää. After the first literature survey, Leppälä alone updated the literature review in 2010 and 2012 and added Scopus database search results in the study. Ilkka Kauranen helped with the review methodology and Risto Rautiainen helped with the relevant article selection and issues concerning agricultural risk management concepts and content. Krista Kettunen edited the Farm Risk Toolcase figure, while the whole content of the figure was prepared by Leppälä. Roy Siddall from Helsinki University Language Centre revised the language for this article as a subcontractor.

Publication 2: Farmers' perceptions of necessary management skills in Finland

The second article was a result of a survey conducted in the joint research project Well-Being Through Improved Farm Business Management. Jarkko Leppälä joined the project after it had started. The theoretical part of the article was developed by Mrs Mattila, Mr Kaustell and Dr Suutarinen. Leppälä took part in the analysis of the survey results linked to challenging management tasks, the literature review of farm management and management theories, and wrote parts of the introduction, results and discussion. Mr Timo Hurme performed the statistical analysis of the survey results Georgi Eckhard from Qualitext, a quality translation, proof reading and language checking company, did the language revision for this article as a subcontractor.

Publication 3: Effectiveness of occupational health service programmes in farmers' safety and security risk management

The third article is based on a survey carried out in MTT's farm safety and security risk management project (Maaturva). Jarkko Leppälä conducted the survey and was a leading operator in the theoretical, data processing, analysis and reporting tasks of the project. The third article started with the preliminary analysis conducted by Leppälä under the supervision of Professor Risto Rautiainen. Leppälä carried out all data processing and adapted it to the analysis methods and research questions, which were first developed by Prof. Rautiainen. Leppälä initially wrote all parts of the article. Ilkka Kauranen helped in reporting of the results and took part in writing the introduction, theoretical discussion and conclusion parts. Professor Risto Rautiainen from the University of Nebraska revised the language of the article.

Publication 4: Farm risk map: a contextual tool for risk identification and sustainable management on farms

The Farm Risk Map is a result of several farm risk management projects at MTT. There was also collaboration with VTT's risk management expert Mervi Murtonen, who helped to design the Farm Risk Map model. Jarkko Leppälä adapted systematic risk management tools to farms and tested the tool with farmers. Mervi Murtonen helped with the theoretical planning and took part in some of the interviews. In article 4, Jarkko Leppälä developed the Farm Risk Map model further and tested it with farmers. He also carried out the case study reporting and analysis. Roy Siddall from Helsinki University Language Centre revised the language for this article as a subcontractor.

Publication 5: Farm risk management applied to sustainability of the food supply chain. A case study of sustainability risks in dairy farming

Article 5 was a case study analysis concerning risk management tools for supporting sustainability on a dairy farm. Jarkko Leppälä conducted the interviews, the farm process and risk analysis and mainly adapted results to farm force field analysis. Esa Manninen helped with the risk analysis of the dairy farm process tasks and wrote the definitions concerning the dairy farm activities. Tuula Pohjola helped with writing the methods and discussion parts and reporting of the results. Roy Siddall from Helsinki University Language Centre revised the language for this article as a subcontractor.

1. Introduction

1.1. Background

Agriculture is crucial for human food production, but agriculture is a risky business in many ways (Kay et al. 2012; Olson 2011; Hardaker et al. 2004). Market competition, stakeholder demands and policy changes cause new challenges, but they also present possibilities for improved farm management (Kay et al. 2012; Lowe et al. 2008). Added to this, in various farm operations farmers face personal safety risks such as injuries, illnesses, and work strain (Leppälä et al. 2013a; Rautiainen et al. 2009; Leskinen 2004). Farm fire incidents, food safety, farm family problems, economic and ecological concerns have also increased the vulnerability of farms in recent years (Leppälä et al. 2015; Leppälä et al. 2012; OECD 2009; Lowe 2008). Figure 1 presents statistics on how various business and security risks have developed in the past decade on farms (Figure 1).

A current trend is that risk management aims to review and treat risks holistically throughout the organization or enterprise (EK 2014; IRM 2010; ISO 31000). Some recent farm management studies have also proposed a whole-farm or holistic risk management approach applied to farms (Leppälä et al. 2015; OECD 2009; Huirne et al. 2007; Hardaker et al. 2004; Chambers and Quiggin 2004; Robinson 1999). However, published studies with a holistic multi-risk management perspective or consideration of how to establish systematic risk management practices on farms to handle multi-risk complexity have been rare (Leppälä et al. 2015). Therefore, research on systematic multi-risk management is needed to help understand and address the complexity of activities and risks faced by farm managers (Leppälä et al. 2015; Lowe et al. 2008; Huirne et al. 2007; Hardaker et al. 2004).

Systematic risk management can offer opportunities for farms and farm management. Any business requires risk management, applied throughout its activities. Systematic risk management is a standard process in managing various enterprise or organization risks (ISO 31000; Pagach and Warr 2007; Carnaghan 2006; O'Donnell 2005; COSO 2004a). However, existing systematic risk management tools need to be adapted to be applicable for use on farms (Leppälä et al. 2012; Lowe 2008; Pannel 2000; Öhlmer et al. 2000; Jeffrey and Bauer 1995). Appropriate knowledge and skills, as well as planning and implementation are needed to develop management systems in an enterprise

(Juran and Godfrey 1998). One problem is that the development of management systems in agriculture, has suffered from increasing bureaucracy, paperwork and complexity (Leppälä et al. 2013; Taylor and Kane 2005; Taylor and Taylor 2004). When the agricultural business or working methods on farms change, the adoption of new skills and tools for risk management on farms is needed (Leppälä et al. 2015; Leppälä et al. 2013; Nuthall 2010; Hardaker 2006; Robinson 1999).

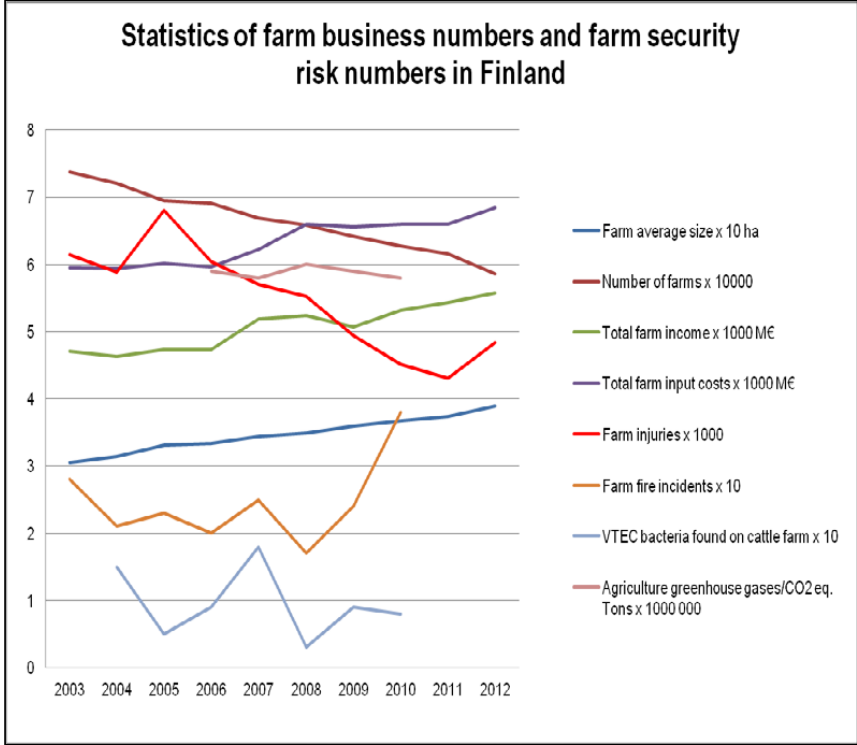


Figure 1. Statistics on farm business and security risk indicators on Finnish farms in years 2003–2012. The y – axis indicates the numbers of farm business variables and farm security risk variables in Finland (Mela 2014; Niemi and Ahlstedt 2014; Tike 2013; OSF 2012; FFI 2011; Evira 2011).

Various risks related to farming threaten the profitability, sustainability, safety and business security of farms (Leppälä et al. 2012; Huirne et al. 2007; Hardaker 2006; Just and Pope 2002). Modern farmers, in their daily work, have to simultaneously consider all these risks, which cause accidents and uncertainty in farm production and business (Figure 2). Systematic risk management should also control and monitor social aspects of safety and security risks to the individuals on the farm (Leppälä et al. 2012; Huirne et al. 2007). However, it is unclear how systematic risk management can be applied to farms in a holistic, usable and practical manner (Leppälä et al. 2015). Considering this, it is important to know more about farmers’ management processes, and how farmers identify, categorize, evaluate, prioritize, control and monitor

risks related to the farm and its sustainability (Leppälä et al. 2015; Leppälä et al. 2012; Leppälä et al. 2011; Mattila et al. 2007).



Figure 2. A tractor fire incident may include safety risks, production and economic losses and environmental risks (Photo: Jarkko Leppälä).

1.2. Objectives of the study

The objective of this dissertation study was to increase understanding of systematic risk management on farms. Special attention was paid to the development and usability of holistic risk management tools, evaluating the effectiveness of farm safety risk management interventions and sustainability risk management on farms.

This dissertation consists of five sub-studies, which had the following specific objectives:

1. The objective in sub-study 1 (publication 1) was to list and analyse risk management tools applicable in managing farm risks. A literature review of studies and tools applicable for managing risks on farms was conducted.
2. The objective in sub-study 2 (publication 2) was to provide a preliminary overview of the farmers' motivation and capacity prerequisites for adopting and improving their management skills. The study describes the importance and challenges in particular farm management tasks and needs for safety and security risk management among farmers.
3. The objective in sub-study 3 (publication 3) was to identify differences in risk management variables among Farmers' Occupational Health Service members and non-members and evaluate the association between the incidence of injuries and membership of the Farmers' Occupational Health Service while controlling for potential confounding variables. This study analysed the

main risks perceived by farmers, safety risk management variables among farmers and the effectiveness of safety and security management.

4. The objective of sub-study 4 (publication 4) was to present a new contextual Farm Risk Map for risk identification and sustainable management on farms. The Farm Risk Map framework provides a tool for preliminary risk context analysis on farms.

5. The objective in sub-study 5 (publication 5) was to analyse the use of risk management tools in dairy supply. The specific objective was to identify and analyse sustainability risks in the dairy farm case and its production processes in developing new small firm management tools using risk assessment information.

This synopsis is structured as follows. The first chapter introduces the background, motivation, objectives and methodology of the study. The framework in chapter two and its synthesis provide an overview of management systems, the systematic risk management process, farm context, farm risks and risk management tools on farms. Results of a literature review (sub-study 1), two surveys (sub-studies 2 and 3) and two case studies (sub-studies 4 and 5) are presented in order to apply and evaluate the use of specific risk management tools assisting systematic risk management on farms (Figure 3).

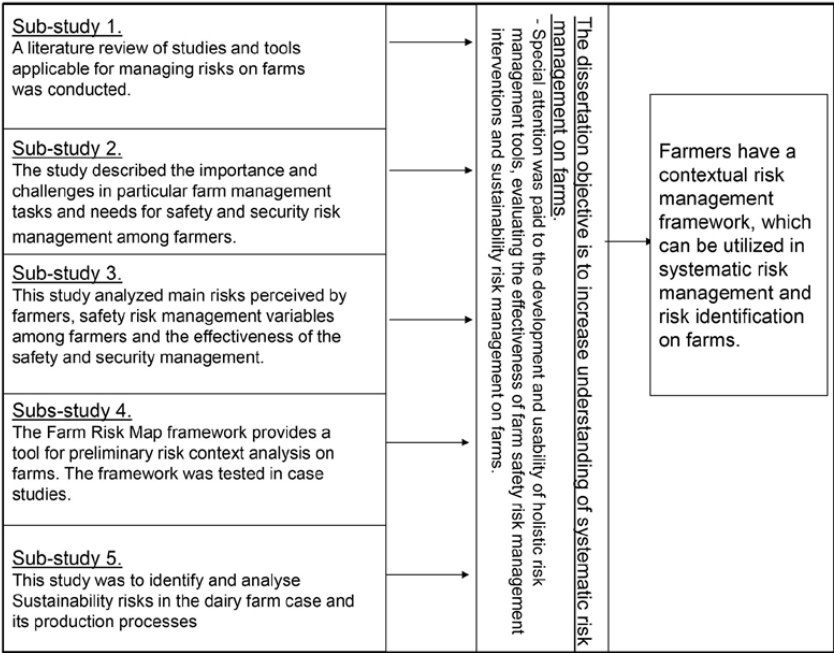


Figure 3. Outline of the dissertation.

1.3. Methodology

Research approach

The mixed methods approach and methodological triangulation were used in order to construct and evaluate risk management tools for farms. The constructive research approach is used, for example, in management science, work research and operation analysis studies to construct and test the workability of new models (Pohjola 1999; Kasanen et al. 1993). Pragmatism as a philosophical approach considers the practical consequences as the main factor of knowledge (Määttänen 2003; Rosenthal 1994). The practicality of risk management tools and knowledge of what works and how things are working in farm risk management were essential in this study. Mixed methods are useful to solve multi-disciplinary pragmatic problems (Creswell and Plano Clark 2006). In order to conduct a systematic risk management process, the enterprise context and various potential hazards and problematic conditions are first identified. Then, relevant risks are analyzed and risk control or treatment tools are selected. Risk control activities are subsequently implemented. The final stage is to monitor risks (ISO 31000; SFS-IEC 60300).

Data and methods

The main part of the data was gathered in the MTT Agrifood Research Finland's Maaturva project, which was carried out in 2005–2008 (Leppälä et al. 2008a). The project aimed to develop risk management tools for farms. The project tested several management tools with a group of farmers ($N = 10$) who were specialized in crop, dairy, cattle, vegetable, forest and pig production and rural business services. Three case farms were analysed in depth, which represented typical production areas in Finland, including crop, milk, meat and forest production. Two in-depth analysis cases also included tourism and contracting services. The usability of the management tools among farmers was considered in the tool design process. The design process included specifying the context of use, specifying the user and requirements, producing design solutions, and evaluating designs against requirements (SFS-ISO 13407). The approaches in agricultural risk management could be divided into the farm approach, market approach and governmental approach (OECD 2009). This dissertation study focused on the farmer point of view.

Several methods were used in the sub-studies of this dissertation. First, qualitative information was collected from relevant farm risk management studies, standards, regulations, official guides and requirements concerning farm risks and risk management tools. Sub-study 1 consisted of a literature review providing an overview of the on-farm risk management tools. Scopus and CABI electronic databases were used in the literature search. The titles, abstracts

and keywords of agricultural journal articles and book chapters during the years 1990–2011 were searched. Keywords used in the search were defined in a farm risk workshop. Keywords were augmented by adding key terms used in the current farm risk management literature. The main production types in EU countries, including crop, dairy, cattle meat and pig meat production, were also considered as an inclusion criterion for studies (European Commission 2012). The literature review applied the narrative synthesis and thematic summary method as analysis methods (Snilstweit et al. 2012; Lucas 2007). The focus areas in risk management tools were coded and analysed from the chosen studies in order to create a preliminary synthesis of these tools. Existing studies and tools were categorized in order to facilitate the further development of tools for risk management.

Sub-study 2 was a survey study describing the importance and challenges in particular farm management tasks and the needs for safety and security management among farmers. The questionnaire was sent out to 300 farms that had more than 30 hectares of cultivated land. In total, 130 farms responded, giving a response rate of 43%. The questionnaire included 48 management tasks and topics in farm management grouped into seven management categories: marketing, personal work and health, collaboration, funding and investment decisions, business operations, finding relevant authorities and information, and labour management tasks. Farmers were asked to rate their management tasks on a four-point Likert scale regarding their importance and difficulty. Analysis of the questionnaire responses included the calculation of medians, quartiles and mean values. The associations between the production type and self-assessed importance and difficulty were tested using the chi-square test (PROC FREQ procedure) in SAS 9 (SAS Institute, Cary, NC).

Sub-study 3 was also a farmer survey focusing on farm risk perceptions and safety and security management. This survey sample was limited to farms with over 20 hectares of arable land. The questionnaire was sent out to 1499 farmers, 39% of whom responded (N = 591). The sample was selected randomly from all areas of Finland. The differences in responses between members and non-members of the Farmers' Occupational Health Service (FOHS) were analysed focusing on farm safety and security management variables. The variables included respondent, farm, farm management, and farm safety management characteristics. Another group of variables addressed personal, asset, financial, environmental and other farm risks. Furthermore, ways of monitoring and controlling farm risks were enquired. The differences in farm and safety management between FOHS members and non-members were analysed, and factors associated with injury/close call incidence were identified using logistic regression methods. We used SAS Enterprise Guide 4.3 for frequency and logistic regression analyses.

In sub-study 4, the constructive approach and case studies were used to present a contextual risk management tool for farms. The usability criteria for the

tool design were that the tool would be easy to use, relevant for farmers, systematic, holistic and enable the visualization of farm risks. Empirical observation and theoretical model development were conducted in an iterative process. The iterative design process of the Farm Risk Map started in an expert workshop to identify the main structures of the farm risk model. An extensive literature review, farm safety and security risk survey results and farm case interview results contributed to the Farm Risk Map design. Sub-study 4 presented the Farm Risk Map framework and an analysis report following the testing the Farm Risk Map on two livestock farms. The Farm Risk Map structure and content were tested regarding the content relevancy, capacity data, farm activities and the collected risk data. The workshop and farm case tests also included other risk management tools, including checklists, fail-safe plan forms and risk matrix tools, but the analysis in sub-study 4 focused on the Farm Risk Map. The testing of this map on farms focused on the subjective views of the farmers on risks inside the farm and environment quality risks. In addition, the Farm Risk Map was discussed in farmer workshops, and ten case farms (representing dairy, beef, pig and crop production processes) participated in its design during the Maaturva project (Leppälä et al. 2008a).

Finally, the case study reported in sub-study 5 analysed the use of risk management tools assisting sustainable farm management on a farm. Interview data were collected from an average size dairy farm in the south-western part of Finland. The case farm had 40 hectares arable land and 20 cows. The recorded interviews aimed to identify the farm risks in the dairy production process. In the first interview, the risk analysis on the farm included the farmer's description of the milking process and identification of potential safety and security risks in different work activities. The self-assessed risks identified by the farmer were collected on a spreadsheet. The risk sources related to the farm environment, safety, production, economics and assets were classified into sustainability categories of economic, environmental and social dimensions. As part of the risk analysis, the farmer's background, objectives and resources were linked to the analysis. In the second interview, the farmer further evaluated the classified farm risks and their control tools, and in the last telephone interview the results were collected for a force-field analysis. The purpose of this analysis was to identify restraining and contributing drivers for the sustainability objectives in dairy production (Harwood and Humby 2008).

Limitations of the data

The literature review in sub-study 1 was a comprehensive study of existing farm risk management literature including 13,559 search hits. Applicability to European agriculture was a criterion for the studies and tools selected for analysis. The survey and case study participants were Finnish farmers. The results may have limited applicability to regions with different agricultural practices.

The response rates were 43% in sub-study 2 and 39% in sub-study 3. While these rates are typical for recent survey studies in agriculture, the high rate of non-response limits the generalizability of the results. The response rates also varied between questions. Non-response and self-reporting could cause biases. For instance, reporting of injuries in sub-study 3 could be under-estimated. According to Karttunen and Rautiainen (2011), 17% of survey respondents did not remember an injury event during the previous year, although a compensated claim was found in insurance records. Some over-reporting occurred as well, as six percent of the survey respondents reported an injury claim that was not found in insurance records. Under-reporting is expected when asking about risk incidents during the previous three years, and serious incidents are more likely to be reported. However, the study aimed to identify major risks on farms, addressing the likelihood and severity of risks, and the results describe the risks as reported by the respondents.

The risk management methods and the Farm Risk Map presented in sub-studies 4 and 5 were case studies, and the methods and the Farm Risk Map were not tested on a large group of farms. These sub-studies described how the tools were applied and evaluated in the case crop, hay, dairy and beef farms. The case farmers completed the risk questionnaire in the presence of the researcher. Some risks could not be observed during the visit by walk-through and relied on self-report by the farmer. Although the research visit had no connection to insurance or regulatory compliance, it is possible that farmers may downplay or not remember to mention risks in their operation. Self-report and observation implemented together increase the reliability of risk identification.

2. Framework of the study

2.1. Management systems

Management system research as a discipline has long roots going back to Frederick Taylor's "Scientific Management". Around the same time, the French philosopher Henri Fayol presented the idea of basic functions of management in his early 19th century work, which gave direction for modern management and management system models (forecasting and planning, organizing production, commanding, coordinating and controlling) (Hatch and Cunliffe 2006; Witzel 2003; Wren et al. 2002). Fayol claimed that if one of the main functional management elements is taken out, it may hamper the whole organizational system (Witzel 2003; Wren et al. 2002).

Systems thinking provide a framework and tools to clarify and change complex patterns (Jacobsen 2001; Haines 2000; Senge 1994). Systems thinking describes how various systems or organizations work and how interdependent components are linked together to determine the performance in an organization (Schiuma et al. 2012; O'Donnell 2005). According to the General System Theory, the system includes the interactive parts of imported materials as input to make exported materials as output, and their feedback (von Bertalanffy 1968; von Bertalanffy 1950). Continuous development of systems intelligence is a new essential concept for the development of holistic systems thinking (Hämäläinen et al. 2014).

The holistic view of natural systems claims that the systems cannot be understood only as a collection of parts, but should be viewed as a whole (Hatch and Cunliffe 2006; Haines 2000; von Bertalanffy 1968). Holistic management has been applied to agriculture as a way to handle sustainability problems (Butterfield et al. 2006). However, the challenge in holistic enterprise risk management in agriculture is information management and how the goals, management, production activities, resources, people and risks can be simultaneously handled in a coherent manner (Leppälä et al. 2015; Wuerthner 2015; Huirne et al. 2007; Hardaker 2006).

In general, there are large numbers of risks in an enterprise production process that cause it to go wrong (Schiuma et al. 2012; Mingers and White 2010;

O'Donnell 2005). In larger organizations, have often a separate safety risk manager or unit which will take care of safety and security activities of the organization (COSO 2004a). In smaller companies such as farms, managers have to integrate risk management functions with other activities and the whole system management (Leppälä et al. 2012; Huirne et al. 2007; Öhlmer et al. 2000). Mental models are tools to help managers understand holistic complexity and system function structures. Good mental models are real life descriptions, which enable better change management and better success in organizations. Conversely, irrelevant mental models inhibit change and activities (Senge 1994). Managers can use systematic management techniques, advanced learning skills and communication networks in managing risks and improving the management systems (Carnaghan 2006; Haines 2000).

2.2. Systematic risk management

Risk management is defined as coordinated activities to manage and control risks in an organization (ISO 31000). Risks are often defined as specific hazardous events and their consequences, which have a certain frequency or probability of occurrence. The positive side in risk considers opportunities, the likelihood of success, value of success, and possible benefits, which affect people's risk-taking and risk perception (ISO 31000; CAS 2003). Cumming and Hirtle (2001) presented common tasks of firmwide risk management, which were simply divided into risk measurement (quantitative risk analysis) and risk management. Firmwide risk management tasks refer to the overall organizational process to understand and control the risks that the organization faces. The systematic risk management procedure is a more developed organizational risk management model including context analysis, risk identification, risk analysis, risk treatment and monitoring (Figure 4) (ISO 31000; SFS-IEC 60300; CAS 2003). For example, Hardaker et al. (2004) have introduced the steps in the risk management process applied to agriculture.

The risk management procedure

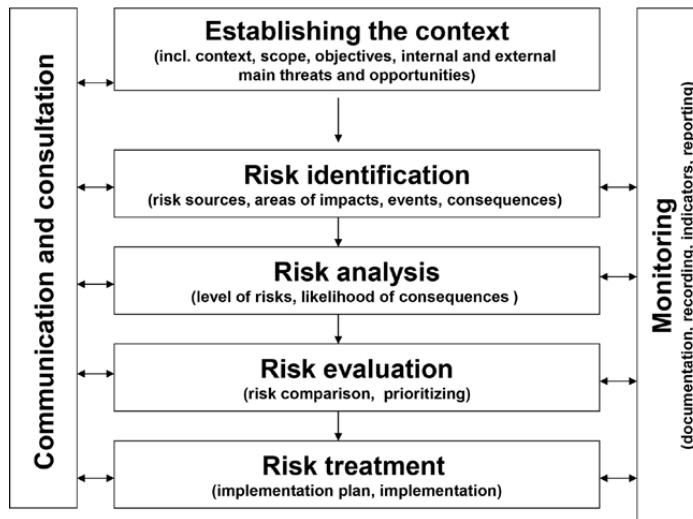


Figure 4. The main phases in the standardized risk management process (ISO 31000).

In the first phase, ‘Establishing the context’, the risk management context in an organization or enterprise is defined. The context analysis includes the determination of the external and internal parameters, scope and risk criteria for the risk management policy. In the risk assessment phase, the risks are identified, and the likelihood and impacts of risks are analysed and evaluated in a way that allows management choices and responses to be determined (ISO 31000; SFS-IEC 60300). Risk matrices are typical tools in risk assessment to combine the risk probability and impact (Figure 5) (Pritchard 2012).

Risk probability of occurrence	Risk consequence of a specified hazardous event		
	Slightly harmful (Low impact)	Harmful (Moderate impact)	Extremely harmful (High impact)
Improbable (Low probability)	1. Meaningless risk	2. Tolerable risk	3. Moderate risk
Possible (Moderate probability)	2. Tolerable risk	3. Moderate risk	4. Meaningful risk
Probable (High probability)	3. Moderate risk	4. Meaningful risk	5. Intolerable risk

Figure 5. Risk matrix tool used in risk assessment (Pritchard 2012; Leppälä et al. 2008a; BS 8800: 1996).

Risk treatment or control activities involve the actual risk mitigation procedures and their implementation, i.e. what is practically done to reduce and eliminate risks. Typical risk control methods include avoiding the risk, taking the risk, removing the risk, changing the probability or consequence of risk,

sharing the risk through insurances or contracts and retaining the risk. Monitoring involves continual checking, supervising, risk observing using documentation, communication, indicators and observation tools to monitor risks. Monitoring can be a part of risk control (Figure 4) (ISO 31000; COSO 2004b; SFS-IEC 60300).

Holistic risk management frameworks

Enterprise Risk Management (ERM) is a systematic enterprise-wide risk management procedure that closely follows the process of risk management standard ISO 31000 (IRM 2010). The ERM system has techniques and tools intended to handle all risks and hazards that threaten important enterprise business objectives or the main production activities (Pagach and Warr 2007; O'Donnell 2005; COSO 2004b; CAS 2003). In practice, ERM tools and techniques include risk checklists and spreadsheets, organization context models, process flow charts, risk identification workshops, benchmarking, risk maps, scenario analysis and other process analysis methods applied to the enterprise risk management process phases (Pritchard 2010; COSO 2004b; CAS 2003).

Corporate security management is another enterprise-wide management framework. It aims to identify, classify and control the main security risk sectors in the enterprise (Capric 2015; EK 2014; Lanne 2007; Kerko 2001). There are various similar concepts, such as corporate security management, safety and security management and business security management, all of which are based on categorizing enterprise security areas and finding suitable tools for managing the identified hazards and risks that threaten the organization, processes or event (CSO 2010; Lanne 2007; Virtanen 2003; Van Brabant 2001a; Van Brabant 2001b). According to Van Brabant (2001a), safety deals with accidents and diseases to humans and security deals with harmful events against enterprise assets, production and natural resources.

According to Reason (1997), safety analysis should include broader perspectives identifying safety indicators from human, technical, organizational and environmental factors. In general, methods for safety risk analysis can be classified based on the number of causes and consequences. A forward analysis is to analyse one cause and many consequences and backward analysis is focusing to one hazardous consequence and its various paths or reasons. Third strategy is a morphological safety analysis, which is to identify potential hazard sources or 'seed events' of the system being studied. In order to search risks in a system context, potential hazards causing undesired effects or events and conditions causing opposite effects against the norm or planned objectives, are observed and identified (Kjellen 2000; Reunanen 1993; Suokas 1988).

Security management also includes emergency and rescue activities, which are closely linked to safety management. In general, the risks that may serious-

ly threat the business continuity of the enterprise are seen as corporate security risks (Capric 2015; EK 2014; Lanne 2007; Kerko 2001). Added to this, resilience management is also a risk management approach that organizations can use to deal with disturbance, surprises and change, for example in regional security crises and multi-risk natural hazardous events (Mitchell and Harris 2012). In Finland, corporate security management has been divided into the main enterprise sectors by the Finnish Board of Corporate Security, such as production, occupational health and safety, personnel, buildings, environment, data, crime, foreign affairs, rescue planning and preparedness planning. For this reason, aligned of the management of hazardous risks with business objectives is an essential part of security management (Van Brabant 2001a, Kerko 2001). Some systematic risk management and corporate safety and security management tools could also be applied to farms (Leppälä et al. 2013a; Leppälä et al. 2012; Leppälä et al. 2008a; Hardaker et al. 2004).

2.3. Farm context

Farms are agricultural units producing material for food and non-food products such as fibre and fuel (Kay et al. 2012; Olson 2004). The industrial farm context includes the management of large areas of land, intensive crop and animal production processes, large machinery, high investments and the storing and selling of agricultural products. Farm productivity is based on a complex mix of engineering technology, economics, environment, and biological processes in the soil, plants, animals, water systems, weather and sunlight (Figure 6) (Kay et al. 2012; Olson 2004; Öhlmer et al. 2000).

Over 85% of the farms in Europe are family farms, where one or two persons manage the farm (Davidova and Thomson 2014). In larger organizations, tasks such as safety risk management are often managed by a special safety unit or chief risk officer, but in a smaller company, the manager has to manage all activities and risks (Kupi et al. 2009; COSO 2004b; Öhlmer et al. 2000). Smaller enterprises like farms have fewer workers, less financial resources and limited time for education, information search and planning compared to larger enterprises (Leppälä et al. 2012; Kupi et al. 2009; Öhlmer et al. 2000; Martin and Staines 1994). Furthermore, farmers in EU countries face many special laws, taxes, financial tools and insurances put in place only for agricultural enterprises (Sonkkila 2002). Despite these managerial functions that are specific to agriculture, there are also many similarities between farm management and general business management (Figure 6). Farmers, like other managers, delegate activities, schedule work operations, allocate resources, negotiate contracts and develop strategic plans (Leppälä et al. 2011; Kay et al. 2012; Olson 2004; Öhlmer 2000).

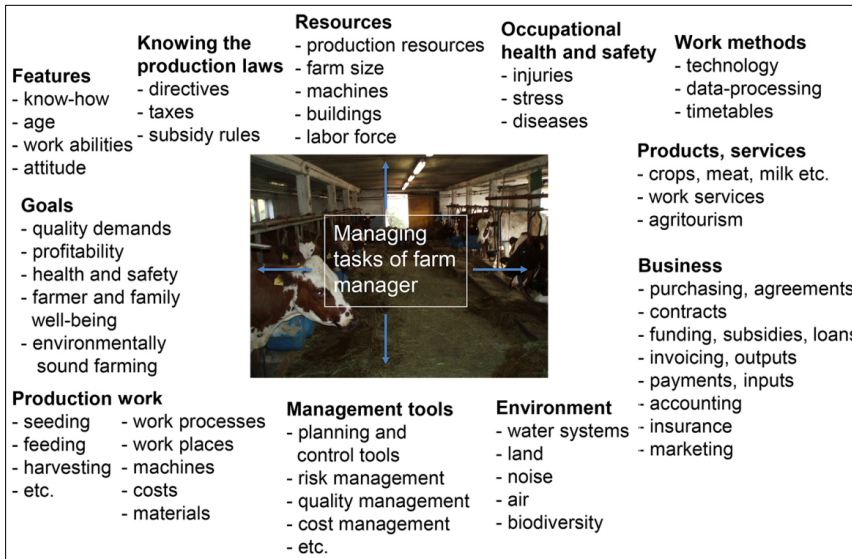


Figure 6. Management functions and tasks on farms modified from Leppälä et al. (2011 and 2008a).

Farmers prefer relevant and not too laborious management systems (Leppälä et al. 2012; Mattila et al. 2007; Taylor and Taylor 2004). Managing a farm is said to be one of the most challenging managerial jobs, where many critical skills are needed (Mattila et al. 2007; Öhlmer et al. 2000) (Figure 7). The agricultural extension service and commercial vendors provide managerial information and knowledge to farmers. Farm risk management tools should also be available (Leppälä et al. 2015; Leppälä et al. 2012; Jeffrey and Bauer 1995). Farms are continuing to increase in size and sales volume, and are increasingly complex units to manage and organize by one farmer (Kingwell 2011; Pannell et al. 2000). Kingwell (2011) listed complexity variables on farms, including the farmer’s annual labour, land use, enterprise diversity, revenue and expenditure diversity, the number of rotations and the farmer’s working hours. In general, complexity in an organization has three dimensions: informational complexity, computational complexity (number of input variables or operations) and the interactions between information and computational complexity (Maguire 2011; Moldoveanu 2005). The development of holistic risk management systems on farms requires appropriate knowledge management, which includes information availability, relevant systematic information management, motivation, skills and capacity in order to use information in an appropriate manner (Kingwell 2011; Evans 2004; Pannell et al. 2000).

2.4. Risks and risk management tools for farms

Farm risk categories

As was earlier pointed out, farmers face various risks, which need to be managed in a holistic manner (Leppälä et al. 2015; Leppälä et al. 2013a; Leppälä et al. 2012; OECD 2009; Lowe et al. 2008; Huirne et al. 2007; Butterfield et al. 2006). According to Fleisher (1990), there are actually numerous ways to categorize agricultural risks. Often, people have relied on very general or simple dichotomies such as man-made risks versus natural risks or financial risks versus production risks. However, the choice of the risk management category system should depend on the current context. Furthermore, the producer viewpoint, the passage of time and changes in risks are essential for carrying out risk management activities on farms (Fleisher 1990). Boehlje and Eidman (1984) have divided the farm risk types into business risks, including price, production risks and financial risks, which are linked, for example, to debts and other financial obligations. Hardaker et al. (2004) divided farm risks into production risks, price or market risks, institutional risks, human or personal risks, business risks and financial risks. As an addition to these risk categories, Olson presented legal risks, which include tax planning, contracts, environmental issues and governmental policies. Risks in this case are the inability to follow rules or lack of knowledge of rules (Olson 2011). Huirne et al. (2007) presented a whole-farm risk management approach, which includes production risks, price risks, regulative risks and human or personal risks. Kay et al. (2012) considered technical risks associated with production risks. Systematic risk analysis methods have been applied to agriculture in repeated risky decisions or routine tasks and in important decisions that involve large investments. The use of systematic risk management decision analysis in complex decision problems in agriculture involving, for example, multiple objectives, more than one person and incomplete information about the problem has been challenging (Hardaker et al. 2004).

The health and safety risks in agriculture are significant compared to other industries. Five out of every one hundred farmers are injured each year in Finland, and six out of 100 000 farmers have died in occupational accidents on average (Mela 2012; Rautiainen et al. 2009). In the EU, approximately five to six persons per one hundred agricultural workers (incl. farmers) have been injured yearly, and 12 per 100,000 agricultural workers have died performing agricultural work (Leppälä et al. 2014; Eurostat 2012). The social insurance costs from occupational injuries and diseases are over 30 million euros per year for Finnish farmers, while the disability pension costs have been approximately 55–70 million euros annually in recent years (Karttunen et al. 2015; Mela 2012). Common health problems include respiratory diseases, skin diseases, and musculoskeletal conditions from heavy repetitive work, which may also shorten the average working career of farmers (Karttunen et al. 2015; Kouimintzis et al. 2007; Donham and Thelin 2006). Rautiainen et al. (2009) identified injury risk factors on farms, including male gender, an older age,

livestock (vs. crop) production, a larger income and larger operation size. Most serious injuries were caused by motor vehicles, falls from elevation and slips, trips and falls. Family members and non-resident visitors are also exposed to risks in the farm environment (Leppälä et al. 2013a; Angoules et al. 2007; Lundqvist and Gustafsson 1992). Furthermore, Suutarinen (2004) has pointed out that management practices are associated with occupational health and safety risks and accidents on farms.

Production and food supply security risks involve threats to the sustainability of the farm enterprise, interruptions in the production of food products and the safety and quality of products available to the consumer (de Vos and Heres 2009; Phillipson and Lowe 2008; Lowe et al. 2008; de la Rúa-Domenech 2006). Asset risks to the farm infrastructure deal with property value losses in farm estates and losses in other assets such as investments in animal buildings, animal health or breeding and machinery systems (Hovinen and Pyörälä 2011; Ellis-Iversen et al. 2007; Allareddy et al. 2007; Regula et al. 2004). Farm family problems and divorce are also significant risk sources for property relations, finance and family welfare on farms (Leppälä et al. 2012; OECD 2009; Leskinen 2004).

Financial risks may involve assets, investments, debts, prices, costs, marketing of products and farm profits (Kay et al. 2012; Huirne et al. 2007; Hardaker et al. 2004; Fleisher 1990). A commonly acknowledged risk is that farm production may not generate sufficient revenue to cover the costs of production or service farm debts (Olson 2004). In environmental risks, the focus is on the quality losses of the natural environment and agroecology (Altieri 2002; Ikerd 1993). Environmental risks also include the pollution or eutrophication of water systems, pathogen outbreaks, and the ecotoxicity and genotoxicity of chemicals, causing reduced ecosystem quality (Reichenberger et al. 2005; Altieri 2002; Bouma 2002). Other considerable risk areas for farms could be risks to farm personnel, rescue planning, crime, data security, foreign trade activities and preparedness for areal crises (Leppälä et al. 2015; Leppälä et al. 2013a; Leppälä et al. 2008a).

Risk management system tools for farms

Some common quality management tools are also risk management tools (Olson 2011; Juran and Godfrey 1998). The Hazard Analysis and Critical Control Point (HACCP) system is a management system used in food industry, but it has additionally been tested for quality management on farms (Taylor and Kane 2005; Jokipii et al. 2005). However, it has been found that HACCP tools should be tailored to farm use in a more specific manner (Taylor and Taylor 2004). The Maaturva project at MTT aimed to develop practical farm risk management tools. The project tested several tools with a farmer group, including process mapping, checklists, risk mapping, Pareto charts of farm risks, cause and effect risk diagrams and fail-safe plans (Figure 7) (Leppälä et al.

2008a; Leppälä et al. 2008b). Approximately 40% of farmer employers have found farm risk identification useful on their farms, especially on large farms and livestock farms (Leppälä et al. 2013b). Some of the farmers reported that they have also used the Farm Risk Map, which is later presented in sub-study 4 (Leppälä et al. 2013b; Leppälä et al. 2012).

FARM – RM – FARM RISK MANAGEMENT ANALYSIS				Page: 1
Farm name: xxxx				Made by: JP
Further information:				Date: 17.8.2006
Risk event	Consequences	Present risk control	Risk value	Improvement actions
Energy use	Energy costs, loss of energy, non-renewable resource waste	Monitor and check electricity use, manual milking	3	Providing backup energy sources, repairing electricity wires and centers, new lamps, modernizing the cattle shelter, energy planning
Order in cattle shelter	Injury and fire risk is increasing	-	3	Cleaning and improving the order in the cattle shelter
Fire safety, wood oven in the cattle shelter with the animal dust	Fire accident, dust explosion	Fire door, one fire extinguisher, routine	4	Fire and electricity check with rescue authorities, fire plan, add fire extinguishers, locate oven outside the building, cleaning
Schedules and working alone	Work strain, stress, health risk, injuries, dependence on one person	Healthy lifestyle, food and routines, parents and husband	4	Scheduling, monitor working time, substitute and relief workers, work delegation, breaks, rest, hobbies,
Efficiency and ergonomics	Work disorders, process failures, work strain, stress, working costs, injuries	Routines and good physical health	4	Improving feeding process, provide helping tools for lifting, repair fodder storage system

Figure 7. Farm – RM – Farm Risk Management Analysis as an example of a fail-safe plan form (Olson 2011; Leppälä et al. 2008a).

National farm safety and health programme

The Farmers' Occupational Health Service (FOHS) is a national programme and a part of the Finnish health care system aiming to prevent health and safety risks among Finnish farmers. The programme is well established in Finland, with approximately 26,000 members, representing about 38% of farmers in 2014. In Finland, self-employed farmers have a mandatory pension system and accident insurance coverage for occupational injuries and diseases, and this voluntary FOHS programme. The FOHS members receive a discount in their mandatory accident insurance premiums. With state support and a small annual membership fee, FOHS provides safety risk management services such as health screenings, farm safety advice, walk-through safety assessments and

rehabilitation assistance. The FOHS programme aims to reduce and prevent injuries and diseases on farms (FIOH 2014; Taattola et al. 2008). However, some studies have concluded that FOHS members have a higher frequency of injury incidents in comparison to non-members (Karttunen and Rautiainen 2013a; Rautiainen et al. 2009). Further evaluation studies of the programme should be conducted. According to Cozby (2007), the effectiveness or outcome evaluation of programmes aims to determine whether the intended outcomes or goals of a programme have been achieved. An evaluator measures the outcomes, possible biases and impacts of the programme (Cozby 2007). The efficiency of safety management is typically determined by evaluating the likelihood of injury risk incidents (Reunanen 1993).

Risk management and sustainable agriculture

Sustainability management challenges are substantial in food production. Sustainable management in enterprises aims to maintain enterprise profitability, social welfare and the quality of the environment in the long term for future generations (UNEP 2006; Malkina-Pykh and Pykh 2004). An important issue in sustainable development is meeting the needs of the future and the present generations (UNEP 2006). The nature of sustainability is a continuous process of co-evolution in the changing environment, which tends to increase management complexity (Mitleton-Kelly 2003). An essential policy challenge in the food supply chain is the application of sustainable management practices in the farm context in a workable and safe way (Phillipson and Lowe 2008; Lowe et al. 2008; Malkina-Pykh and Pykh 2004). Furthermore, an essential social sustainability challenge is ageing and succession in EU agriculture (Davidova and Thomson 2014). In Finland, the average age of farmers in 2013 was 51.7 years (Niemi and Ahlstedt 2014).

Risk management could be seen as a part of sustainable agriculture. Sustainable development is future oriented, like risk management and a holistic systems perspective is also essential in the management of enterprise sustainability (UNEP 2006; Malkina-Pykh and Pykh 2004; Ikerd 1993). Sustainable management tools for farm units constantly need to be developed (Gold 2014; Leppälä et al. 2011; Campbell 2006; Malkina-Pykh and Pykh 2004). In managing sustainability risks in the food supply chain, tools and measures are needed that can be applied at the farm level. For example, sustainability criteria on farms can include farm productivity, product quality, the number of workers, worker safety, the preservation of natural resources, the quality of natural resources and quality of life (Leppälä et al. 2011; Malkina-Pykh and Pykh 2004).

3. Results

3.1. Literature review study of farm risk management tools

A review of studies and tools applicable for managing risks on farms was conducted in sub-study 1. The keywords in this literature search were based on five categories: 1) asset risk management, 2) production risk management, 3) health and safety risk management, 4) environmental risk management and 5) economic and financial risk management tools. None or few studies were found that addressed other risk categories such as data risks, crime and preparedness planning related to farms. The lack of these risk studies in agriculture indicates that these risks had been considered marginal in agriculture prior to the year of the literature search (2011). However, the situation may change, for example, because of increasing competition, animal diseases, natural disasters or areal insecurity, which means that the risk context on farms should be updated. Table 1 presents the keywords and total numbers of search results. A total of 13,559 items were identified in these searches. The final analysis included 157 studies, which were chosen after applying all search criteria limitations.

Risk management tools from studies were identified and divided into five categories. The types of risks management tools are presented in the Farm Risk Toolcase (Figure 8). Minimizing and mitigating specific risks is described in individual risk categories. The risk focus is different in certain individual risk tool categories. Farm asset risk tools deal with the usability and value of assets and related losses such as fires, breakdowns and animal diseases. Production risk tools address losses related to the quantity and quality of agricultural products produced and food safety losses. Human health and safety risk tools address injury and disease protection, working conditions, the farm safety culture, machinery maintenance, animal handling and physical hazards in farm operations. Environmental risk tools aim to manage environmental values and quality losses, while economic farm risk tools deal with profitability losses, finances, markets and policy risks.

Table 1. Protocol for the literature search.

Keywords	Date range: 1990- 2011, Scope: Title, abstract, keywords, journals, books	Date range: 1990- 2011: Scope: Title, abstract, headwords	The farm risk manage- ment studies applicable to European agriculture
	Scopus		CAB Abstracts
	Search results	Search results	Included articles
"Farm risk management" OR "agricultural" risk management"	52	13	3
Farm AND "risk management"	468	365	30
Farm risk AND security management or farm vulnerability	281	41	7
Farm risk AND "food safety" OR "food safety management"	344	319	7
Farm risk AND product quality management OR "farm production management"	90	4	7
Farm risk AND asset management OR farm property management	138	20 ¹⁾	4
Farm risk AND building management OR "animal house"	92	152	5
Farm risk AND machine management OR "farm machinery"	225	3752	21
Farm risk AND economic management OR "farm business management"	463	148 ²⁾	22
Farm risk AND injury OR "farm safety management"	564	855 ³⁾	24
Farm risk AND "sustainable management" OR "environment management" OR ecological risk" OR agriculture environment management	216	3999 ⁴⁾	18
Farm risk AND fire OR "fire management" OR "farm fire safety"	339	639 ⁵⁾	9
Total	3272	10287	157

1) The terms were farm risk AND asset management OR farm property

2) The last terms were without inverted commas

3) The terms were farm AND injury OR safety risk management

4) The terms were "farm risk" AND environment management OR sustainable management

5) The terms were farm AND fire OR agricultur* fire safety risk OR "farm fire management"

Holistic risk management tools are often based on integration and communication between different risk areas. Knowledge of risk consequences and sources is needed to mitigate the risks. A common challenge on farms is the avoidance of bad safety habits in pursuit of saving time or money. Many articles that handled risk management holistically included the sharing of risks through insurances and contracts and the management of some of the remaining risks through knowledge and safe behaviour. Other studies that handled holistic risk management on farms applied methods such as collaboration networks, management control systems, automation, mobile devices and Internet-based tools. In principle, successful risk management on farms involves the integration of business management, agricultural practices and safety culture. Farmers need knowledge and skills to use information effectively in aligning strategic goals and operative processes on the farm. The links between the risks should be made visible among farm production processes and farm operations. This requires the development of new information management systems and knowledge management techniques. Holistic and specific risk management tools can be used to identify and mitigate risks in a way that contributes to the achieving strategic goals of the farm operation.

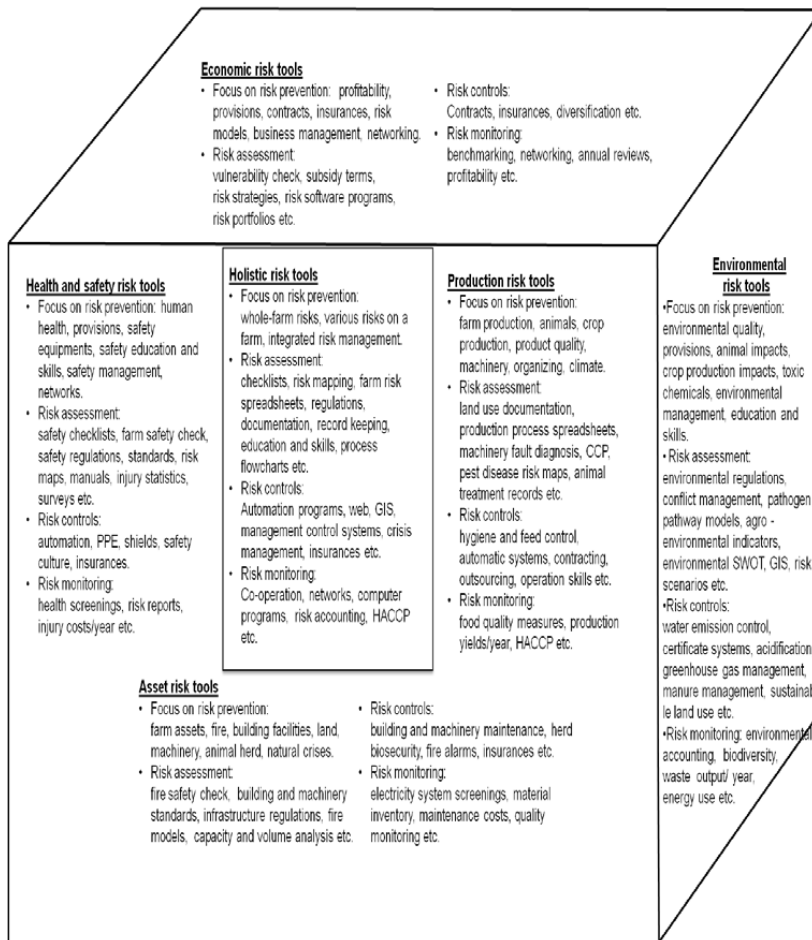


Figure 8. Farm risk management areas, concepts and tools (Leppälä et al. 2015).

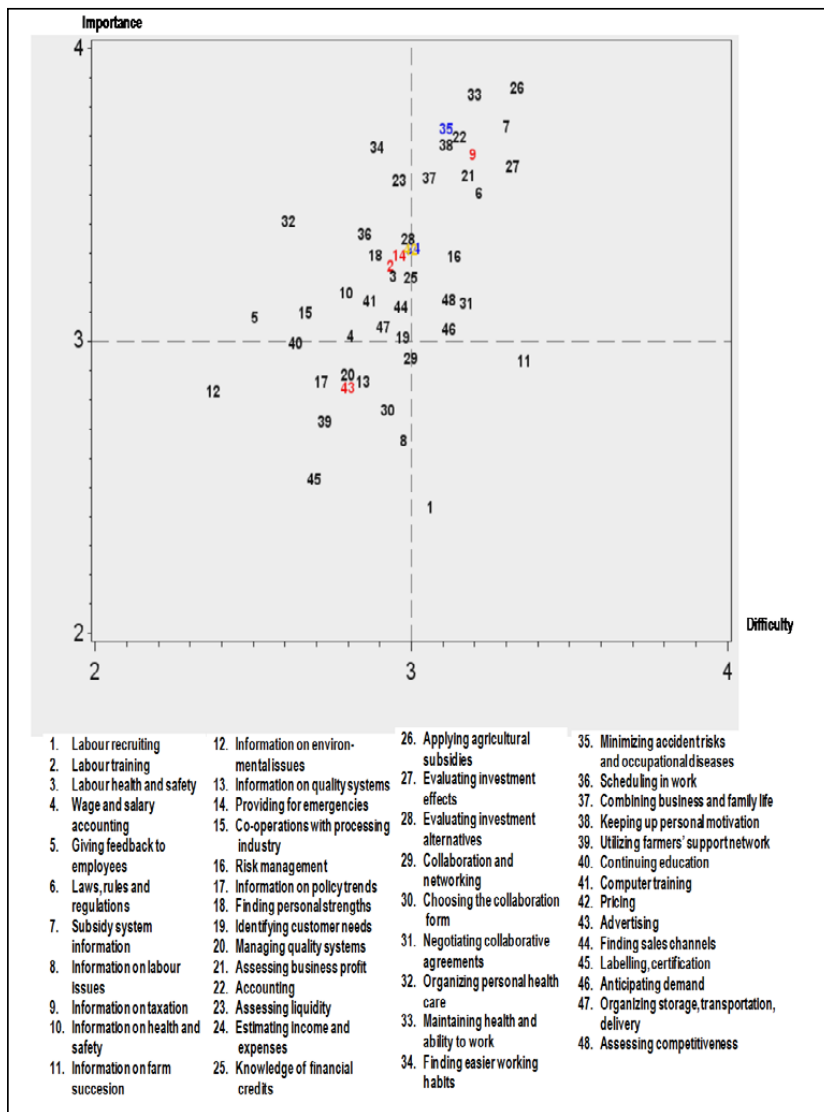
Tools to assist farmers in risk management are not on a sufficient level compared to the various risks currently faced by farmers. For example, a comprehensive record of possible risks should be available as a reference before conducting risk identification on a farm. Furthermore, there should be sufficient tools for subsequent risk management stages: analysing, controlling and monitoring risks. Other challenges arise from the usability of risk management tools on farms, especially related to risks in adapting to new production methods and technology. Farmer ageing and succession management on farms is a future challenge in Europe. Cooperation and integration between different research disciplines are required in farm risk management to develop holistic tools applicable to manage changing risks in agriculture.

3.2. Necessary farm management tasks and their challenges

Sub-study 2 pointed out the need to manage various safety and security risks on farms. The aim was to provide an overview of farmers' motivation and capacity for adopting and improving their management skills. This was studied by means of a farm management survey asking farmers what farm management tasks and skills they considered important. The management capacity dimension was evaluated according to the perceived difficulty of these farm management tasks.

Comparing the perceived importance and difficulty of various tasks revealed critical areas for farm management. The top five most important and challenging farm management tasks were: 1. applying for agricultural subsidies, 2. maintaining personal health and ability to work, 3. finding relevant authorities and information about subsidy systems, 4. accounting tasks in farm business operations and 5. minimizing the risk of occupational accidents and diseases. Other difficult tasks for farmers were assessing business profit, finding relevant information on regulations, evaluating investment effects on profitability, finding information on taxation, finding information and help on farm succession and preparing collaborative contracts (Figure 9). Farm succession was also considered difficult, reflecting problems in finding a successor to continue production on the farm. Farmers need help from advisory services for these management tasks.

Scheduling of work was considered most challenging on dairy farms, which are relatively complex, laborious and challenging farm management environments. Most of the farms in this survey were family farms (93%). Farmers have traditionally used their own family members as the workforce on the farm, but in this sample, 37% of the farms also used non-family labour. Labour recruitment is important for these farmers, and in general it was seen as a rather difficult management task among all respondents. These results point out the need for management tool development in several areas, including economic management, handling complexity, labour management, information management on legislation and production processes, and health and safety risk management.



Note: Values on a Likert scale of importance: 1 = unnecessary, 2 = fairly unnecessary, 3 = fairly important, 4 = important; difficulty: 1 = easy, 2 = fairly easy, 3 = fairly difficult, 4 = difficult.

Figure 9. The responses to all management task questions based on the farmer survey.

3.3. Current state of safety and security management on farms

Data from the “Maaturva” farm risk management survey were used to evaluate safety and security management functions on Finnish farms. The objectives of this sub-study 3 analysis by Leppälä et al. (2013a) were to characterize farmers’ safety and security risk management systems and to compare risk perceptions and risk management practices between members and non-members of the Farmers’ Occupational Health Service (FOHS).

The questionnaire was mailed to 1499 farmer clients of the insurance company Tapiola in November 2005. At the time 44% of Finnish farms had insurance provided by Tapiola. The relative proportions of different production types in the sample were approximately the same as the average in Finland. The questionnaire variables were adapted from the VTT Technical Centre of Finland's risk management tool for SMEs (PK-RH), the safety and security programme for enterprises by the security board of the Confederation of Finnish Industry, and a risk management guide for farmers produced by the insurance company Tapiola (Uusitalo et al. 2003; EK 2014; Tapiola 2002). The questionnaire variables are listed in Table 2 under groups and subgroups relating to respondent, farm, farm management and safety management characteristics (group A variables), as well as risk perception, risk control and risk monitoring measures (group B variables). The results contributed to evaluating the effectiveness of farm risk management activities in the FOHS programme.

Approximately 39 % (N = 591) of the survey population responded to the questionnaire. The main perceived risks among responding farmers were dependence on one person (70%), physical strain (48%), profitability (47%), local/regional crises (44%), injury incidents (43%), mental well-being (42%), fires (30%), natural disasters (30%) and building or field machinery breakdowns (25%) (Leppälä et al. 2013a). As in some earlier studies by Karttunen and Rautiainen (2013a) and Rautiainen et al. (2009), this study univariate estimates also showed that FOHS members reported more injury incidents than non-members. In this study, FOHS members had 1.5 times greater odds of injury incidents than did non-members. Univariate estimates also indicated that farmers who had been involved in injury incidents more often reported actual incidents involving fire risk, machinery damage, mental well-being risk, liquidity risk and building damage. Livestock farmers also suffered more injuries than crop farmers. Some variables, such as a part-time workforce and larger livestock herd size, had a close association (chi-squared test, $p < 0.2$) with the farm injury risk. These variables are bolded in the variable list included in the article appendices (Leppälä et al. 2013a).

Table 2. The questionnaire survey variables.

Group A		
Respondent and farm variables	Farm management variables	
<ul style="list-style-type: none"> * OSH membership * respondent sex * respondent age * * agricultural education * farming as a full-time occupation * field size (ha) * forest size (ha) * main production type * dairy cow (number) * beef cattle (number) * full-time workforce * part-time workforce * location 	<ul style="list-style-type: none"> * quality management training * profitability * computer used in farm management * production plans and goals documented * strategy documented * security training (fire, first aid, security management) * safety planning and budgeting yearly * self-assessment of farm safety * rescue plan for farm 	
Group B		
Risk perception: perceived risk/ actual incidents or close calls	Measures to control risks on farm	Measures to monitor risks on farm/ regular monitoring of:
<ul style="list-style-type: none"> * safety risk * physical strain risk * mental stress risk * risk to farm visitors * risk on farm family members * risk of losing production data * profitability risk * liquidity risk on farm * building damage risk * risk of field machinery damage * risk of other production machinery damage * crime or vandalism risk * rescue situation risk * fire risk on farm * local/regional crisis risk * risk to product safety * environmental risk on farm * dependence on one person * farm employee safety risk * electrical risk * natural disaster risk * product sale risk * water or energy supply risk * dependence on few suppliers 	<ul style="list-style-type: none"> * contracting (written, checked) * investment plan made * registering of assets * possibility to lock premises * use of safety evaluations on farm * use of necessary personal protection equipments on farm * safety guiding of farm visitors * safety guiding of farm workers * insurances updated * using bookkeeping services * using operators manuals * relief worker arrangements * fire prevention up dated * using data back up and computer virus protection * rescue plan for farm 	<ul style="list-style-type: none"> * production quality * safety and security * environmental quality * work process flow * work load * production costs * production tool condition * plans and objectives * sales and revenues * legislation * market prices

The analyses included controlling for potential confounders, i.e. farm and demographic and risk perception and management practice variables. The first task was to identify potential confounders by comparing background and risk management variable differences between FOHS members and non-members. The second was to examine differences in injury/close-call incidents using logistic regression and controlling for potential confounding variables (Table 3).

Table 3. Association of explanatory variables with FOHS membership and risk factors for injury incidents (Leppälä et al. 2013a).

FOHS membership as dependent variable	Multivariable estimates			Final model estimates		
Group A	<i>95% Confidence Limits</i>			<i>95% Confidence Limits</i>		
Respondent	<i>OR</i>	<i>LL</i>	<i>UL</i>	<i>OR</i>	<i>LL</i>	<i>UL</i>
Occupation: full-time farmer (vs. part time)	2.1	1.22	3.63	4.55	2.14	9.67
Farm						
Farm size: forest hectares < 80 (vs. ≥ 80)	0.59	0.37	0.93			
Main production: animals (vs. crops)	2.24	1.24	4.04			
Dairy cows (vs. no dairy cows)	2.45	1.3	4.63	4.78	2.5	9.12
Farm management						
Production plans and goals documented (vs. not)	3.45	1.77	6.74			
Computer used for farm management (vs. not used)	2.32	1.36	3.96			
Safety management						
Safety plans and budgets set yearly (vs. not)	1.91	1.1	3.34	2.28	1.09	4.77
Self-assessment of farm safety: high (vs. low)	1.55	1.02	2.37			
Security training (fire, first aid) (vs. no training)	0.36	0.18	0.71			
Group B						
Risk perception; perceived risks: high (vs. low)						
Risk of field machinery damage	0.60	0.38	0.95			
Risk perception; actual incident or close call during past 3 years: yes (vs. no)						
Injury incident risk on farm	1.65	1.05	2.61	2.28	1.21	4.31
Mental well-being risk	2.80	1.41	5.57	4.87	1.68	14.19
Profitability risk	2.66	1.09	6.48			
Measures to monitor and control risks on farm: yes (vs. no)						
Locking of farm facilities	0.45	0.26	0.77	0.40	0.19	0.82
Farm safety and security assessment done	2.63	1.18	5.84			
Regular monitoring of work process flow	1.57	1.04	2.38			
Injury event as dependent variable						
Group A	<i>95% Confidence Limits</i>			<i>95% Confidence Limits</i>		
Respondent	<i>OR</i>	<i>LL</i>	<i>UL</i>	<i>OR</i>	<i>LL</i>	<i>UL</i>
FOHS membership (vs. not membership)	1.49	1.00	2.22	1.29	0.78	2.10
Farm						
Farm size: field hectares < 40 (vs. ≥ 40)	0.26	0.09	0.80			
Beef cattle (vs. no beef cattle)	0.24	0.06	0.90			
Farm Management						
Quality management training (vs. no training)	1.46	1.00	2.12			
Computer used for farm management (vs. not used)	1.76	1.01	3.06			
Group B						
Risk perception; perceived risks: high (vs. low)						
Injury risk	1.61	1.07	2.42			
Dependence on one person	1.68	1.04	2.71			
Dependence on few suppliers	1.90	1.01	3.55	2.55	1.30	5.01
Risk perception; actual incident or close call during past 3 years: yes (vs. no)						
Physical strain risk	2.75	1.63	4.62	2.64	1.50	4.63
Risk on farm family members	5.31	2.49	11.30	6.13	2.78	13.52
Dependence on one person	2.52	1.28	4.98	2.71	1.30	5.66
Water or energy supply risk	2.31	1.35	3.94	2.24	1.27	3.95
Measures to monitor and control risks on farm: yes (vs. no)						
Regular monitoring of safety and security	0.43	0.25	0.74	0.41	0.23	0.73

FOHS members and non-members differed in many ways. FOHS members reported more injury incidents than non-members, despite the fact that FOHS members presumably receive more information on health and safety issues and are more active in safety risk management in general. In this study, FOHS members more frequently had personal and farm characteristics that exposed

them to injury. In addition, several other injury risk factors were identified in regression analyses, including a larger farm size (field size), dependence on one person on the farm, physical work strain, quality training, computer used for farm management and infrastructural problems on the farm. Farmers reporting physical strain incidents were 2,75 times more likely to have injury incidents. Regular monitoring of safety and security risks was a protective factor for injury incidents (Table 3). However, only 24% of the respondent farmers performed regular safety and security risk monitoring (Leppälä et al. 2013a).

The results indicating FOHS membership as a risk factor for injury are unexpected. However, when controlling for available confounders (Table 3), the univariate effect size (OR 1.49) became smaller (OR 1.29) and statistically insignificant. Many uncontrolled factors remain, for instance, it is common that farmers join the FOHS if they have an injury or occupational disease. They may also join if they are concerned about their level of safety and security risks. FOHS members may be more active and more knowledgeable about the risks, and they may therefore remember and report risk incidents more readily. Overall, farm safety risks are associated with other security risks on farms. Developing better tools for identifying, managing and monitoring risks on farms is recommended (Leppälä et al. 2013a).

3.4. The construction of the Farm Risk Map

Publication 4 presents the development of the Farm Risk Map, including the final content and results of testing for safety and security management on case farms. The Farm Risk Map is a result of *Maaturva* - Farm safety and security management project in Finland. The project aim was to develop farm risk management tools.

The Farm Risk Map includes 90 areas (Figure 10). These risk areas are divided into five categories. Each category includes risks that may disturb or even halt farm production. One category includes risk outside of the farm that may have impacts on the farm. These risk sources include finances, markets, networks, regulations, natural disasters, wars and regional crises. Another category includes risks that the farm activities and outputs may cause to people (consumers) or the environment outside of the farm. Furthermore, three categories deal with risks inside the farm: assets and finance, products and production quality and people safety (Figure 11).

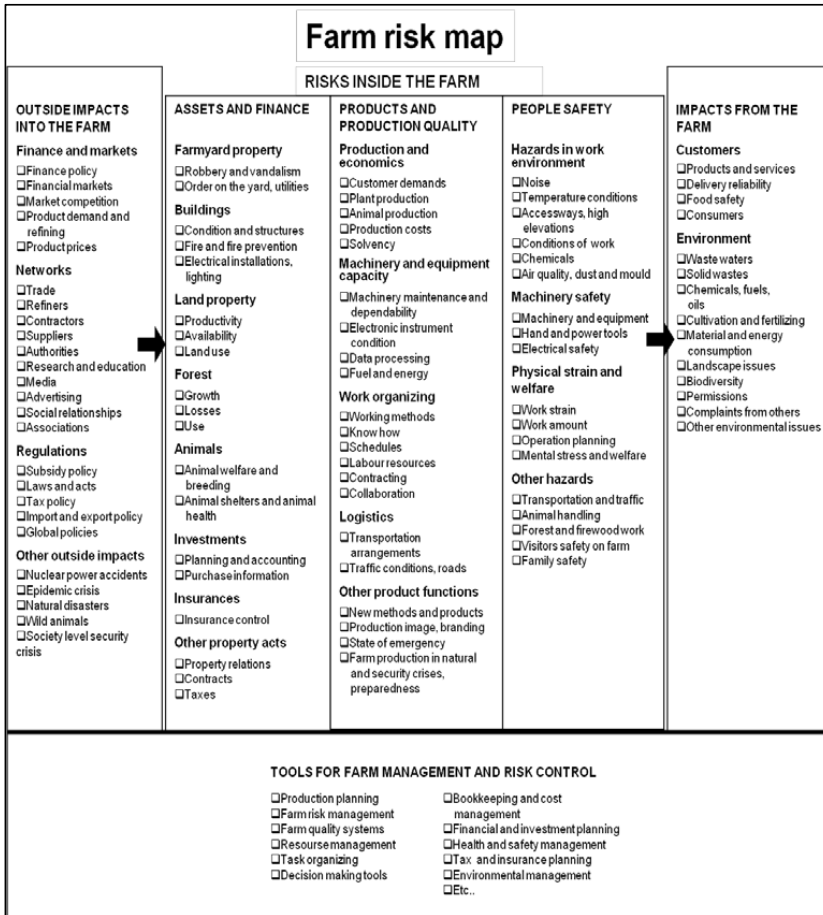


Figure 10. The Farm Risk Map used in preliminary risk identification on farms modified from Leppälä et al. (2012).

The category of assets and finance lists resource and infrastructure risks affecting farm activities (including fire, risks to building, animal diseases etc.). Farm property risk incidents in this category may cause serious economic losses to the farm business. Products and production quality risks involve issues that may have impacts on production processes and work fluency (including the availability of production inputs, machinery, labour, logistics and solvency). Damage to the brand and the public image perceived by the consumers may directly affect production through demand and indirectly through new rules on production. Risks in the People category may affect farm family members, workers, contractors or visitors. These risks include injury, illness or disability from hazards associated with the farm working environment, machinery and work organization. Transportation, animal handling and forest work involve substantial risks of injury incidents. Lastly, farm operation may cause risks to outside entities, particularly customers, consumers and the environment. Below these five categories are some tools for farm safety and security management and risk control.

The aim in developing the Farm Risk Map was to make it easy to use, relevant, systematic, holistic and usable for rapid visualization of farm risks. The farmer's point of view and relevance to the farm context were essential parts in designing this farm risk management tool. Several farm case studies were conducted to test the use of farm risk management tools and the Farm Risk Map.

Several different type of case farms were involved in the *Maaturva* project. Two farm cases were chosen to analyse in depth in this sub-study 4 . Both farm cases were involved in animal production, but farm I was smaller with more diverse production (cattle and sheep meat, tourism services), and farm II was larger and more specialized in dairy production. Both farmers were highly motivated to control their farm risks. With the help of the Farm Risk Map, the case farmers were able to identify and list various risks to assets, production, people and the environment associated with their farm activities (Table 4). Particularly in the case of farm I, with diverse production and tourism services, risk management appeared an inevitable part of farm management.

In the development of the Farm Risk Map, it was essential to show all risks in a one-page format. Testing on farms indicated that this format enabled farmers to see the interactions of various farm risks. For example, the farmers wanted to associate and handle economic risks connected to assets or production risks. Questions about functionality or threats to the farm or farm processes assisted the associations of risks. Considering risks simultaneously and connecting them to farm activities enabled farmers to identify strategically useful and feasible solutions to reach the overall farm objectives. After going through the specific farm activities, a holistic risk management plan was constructed. Farmers can use the risk management plan in farm production planning, goal setting, farm development, the management of change, worker management and in managing the individual processes on the farm.

The Farm Risk Map supported the risk management process and systematic analysis on farms as a preliminary risk identification tool. Dividing various risks into categories also helped in risk identification. Because farmers had no previous experience of systematic risk analysis, it took some time to familiarize them with the new framework, but after the idea was explained it was rather easy to complete the process. Safety-related training and guidance from an external expert can motivate and contribute to effective use of the tool. After identification, risks should be prioritized for control and monitoring. Without carrying out the whole risk management procedure, the identified farm risks may not be properly managed. The risk check and risk identification process on farms was easier when starting from the issues that the farmer knows well. The risk identification process could start with an asset, then production tasks and after that doing safety risk check, followed by outside impacts on other people and the environment. It was concluded that items on the farm risk checklist should be modified depending on the context (by farm production, country etc.). Large farms may have specific risk management issues, but the

Farm Risk Map can be useful in tailoring risk management to the specific farm situation.

Table 4. Risk factors found on the case farms.

	Assets and finance	Products and production quality	People safety	Outside impacts: Environment
Case farm I. - Cattle and sheep farm - Part-time farmer - Fields 20 ha, forest 20 ha, pasture 10 ha - 30 sheeps, 10 cows, 20 chicken, two bulls	Drainage, natural disasters, building breakage, electrical systems, rescue planning, fire systems, manure stocks, insurances, investment plans	Machinery and energy failures (age of machines), lack of relief workers, communication, schedules, crossroads, weeds, epidemics, storage management, animal care in crises, planning, profitability.	Machinery guards, lighting, falls, animal dust, ergonomics, injuries caused by animals, working alone, work strain, chemicals, social support, recreation, job satisfaction.	Sewage, manure emissions, waste storage, energy wastage, greenhouse gases, radiation accidents, landscape design.
Case farm II - Dairy farm - Full-time farmer - Fields 60 ha, forest 100 ha - 70 cows	Locking of buildings, asset register, machine sheds, fire, ventilation, fences, field conditions, forestry, animal welfare, natural damage.	Costs, machinery failures, manure removal, hydraulics, machinery faults, scheduling, communication, relief workers, contracts, cooperation.	Hot surfaces, falls, chemicals, hay dust, mould, machinery guards, child safety, lack of rest, working ability, injuries caused by animals, ergonomics, social support.	Chemical and fuel run-off, energy and water cuts, regional emergencies.

The Farm Risk Map and farm risk checklists based on the structure of the Farm Risk Map were originally published on the Agronet (2008) website in January 2008 in Finnish. By April 2011, there had been over 1200 visitors to this website, reaching about 100 visitors per month. The safety checklist based on the Farm Risk Map safety section was published on the Virtuaalikylä website maintained by the University of Applied Sciences (HAMK) in Finland. This safety checklist and other Farm Risk Map tools have been used in farmer education (Virtuaalikylä 2011). The safety checklist was further modified so that it is able to count risk points for each safety risk sector. It is then possible to create figures that help in visualizing the current risks on the farm (Figure 11).

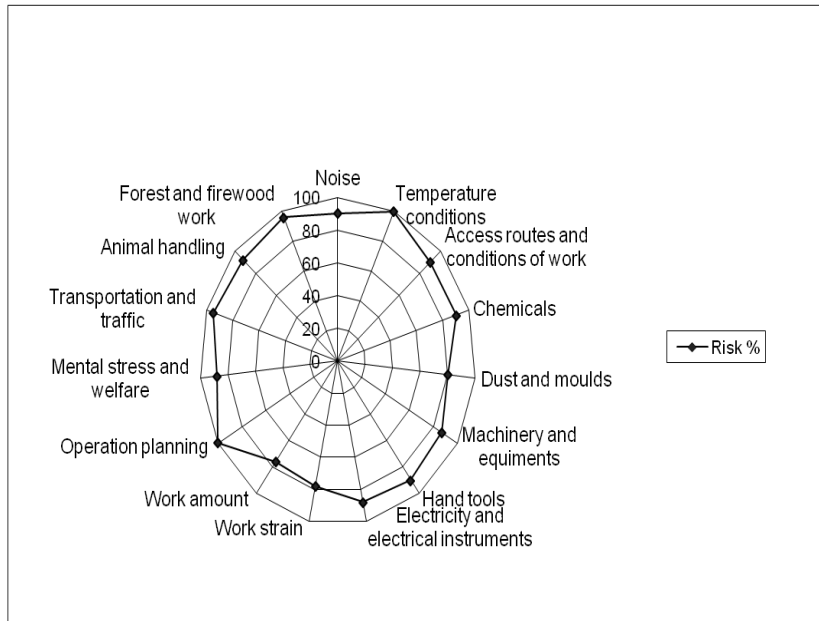


Figure 11. Visualisation of safety check results for a farm.

3.5. Risk check tools applied to farm sustainable management

The in-depth case study in article 5 identified and analysed sustainability risks in a dairy farm production process. The framework of the farm case included the milk supplier goals as a part of the milk supply chain. The study collected farmer perceptions on the use of risk management tools in sustainable farm management planning. Risk identification was carried out aligned with the production process analysis. In this case, risks in the dairy farm milking process were analysed and classified. The milking process phases were checked task by task on a typical dairy farm, aiming to find priority issues for the milking process (Figure 12). After risk identification for the milking process, sustainable management control tools were selected to manage potential production risks to the food supply chain. In this way, the process activities and objectives were considered in risk prioritizing.

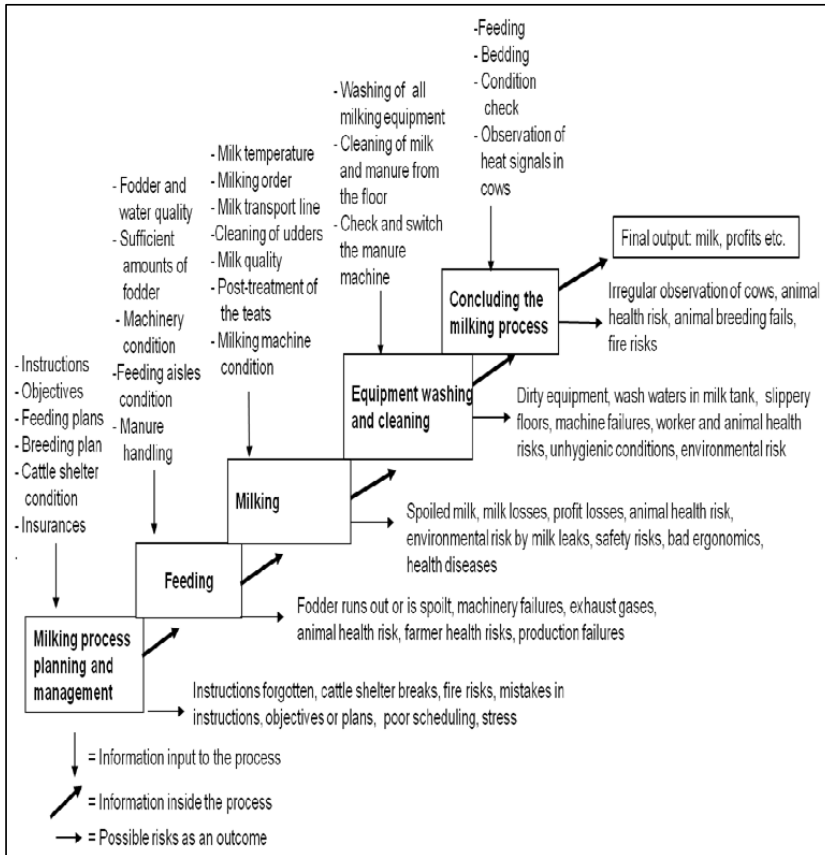


Figure 12. Work phases in the milking process and identified risks by the farmer.

After the risk analysis, risk factors were divided into categories, which accelerated the risk identification and analysis. The milking process phases were also used in the categorization (Table 5). This risk identification process is intended to be repeated periodically. Category divisions in this analysis included the dimensions used in sustainable development: risks for environmental, economic and social sustainability. However, in the farm case study, it was problematic to use these divisions as a farm management tool. For example, the milking process on the farm had several social and environmental risks, which included on-farm and off-farm perspectives. Without sufficient knowledge of management tools, it could be difficult to meet sustainable management demands on farms. Risks can be categorized according to the risk focus, source or potential consequences. Risk analysis provides measures and useful information of a particular workplace, action, process phase or task (Table 5).

Table 5. Potential risk management measures in the milking process divided into sustainable farm management categories (Leppälä et al. 2011).

Process phase	Environmental issues	Social & ethical issues	Economy issues
Milking preparations	<ul style="list-style-type: none"> • Environmental plans • Legislation • Areal natural aspects noticed • Areal cultural aspects noticed 	<ul style="list-style-type: none"> • Consumer safety • Animal health • Cattle shelter • Worker safety • Labor instructions • Areal cultural aspects noticed 	<ul style="list-style-type: none"> • Profitability measures • Schedule planning • Production quality • Efficiency • Assets • Insurances
Feeding	<ul style="list-style-type: none"> • Water consumption • Fodder production wastes • Fuel use • Machinery exhaust on air • Energy use 	<ul style="list-style-type: none"> • Worker safety • Cow welfare • Cattle shelter • Fodder storage • Fodder logistic 	<ul style="list-style-type: none"> • Fodder production costs • Fodder quality • Working costs • Critical point for profit
Milking	<ul style="list-style-type: none"> • Water use • Energy use • Milk waste • Material choices • Noise 	<ul style="list-style-type: none"> • Milk quality and safety • Worker safety • Cow safety • Milking technology and logistics 	<ul style="list-style-type: none"> • Milk yield • Milk quality • Material costs • Working costs • Critical point for profit
Washing and cleaning	<ul style="list-style-type: none"> • Water use • Wastes • Manure • Chemicals • Energy use • Materials 	<ul style="list-style-type: none"> • Consumer safety • Worker safety • Cow safety • Manure storing • Manure logistics and use • Smell on the area • Production image 	<ul style="list-style-type: none"> • Material costs • Working costs • Production quality and profit
Closing the milking procedure	<ul style="list-style-type: none"> • Fodder use • Durf use, • Cows' natural behavior 	<ul style="list-style-type: none"> • Cow safety • Worker safety • Fire safety • Asset security 	<ul style="list-style-type: none"> • Production quality • Profita • Fodder costs • Durf costs • Breeding costs

The force field analysis method was used to prioritize and evaluate the current state of the farm in relation to the sustainability categories. Figure 13 illustrates the main restraining risks or driving forces towards the sustainability goals. Points were given to the farm risk functions, based on whether they restrain or promote the sustainability goals of the farm. A Likert-type scale is used, with a score of five indicating a significant issue and one indicating a non-significant issue for the dairy farm. The sustainability criteria for the risk analysis were defined in the milking process with the help of a milk quality management handbook, which was tailored to the farm and provided by the dairy co-producer (Valio 2007). The points are allocated for every issue to indicate how significant the issue is to the sustainability of the milk production process from the farmer's perspective.

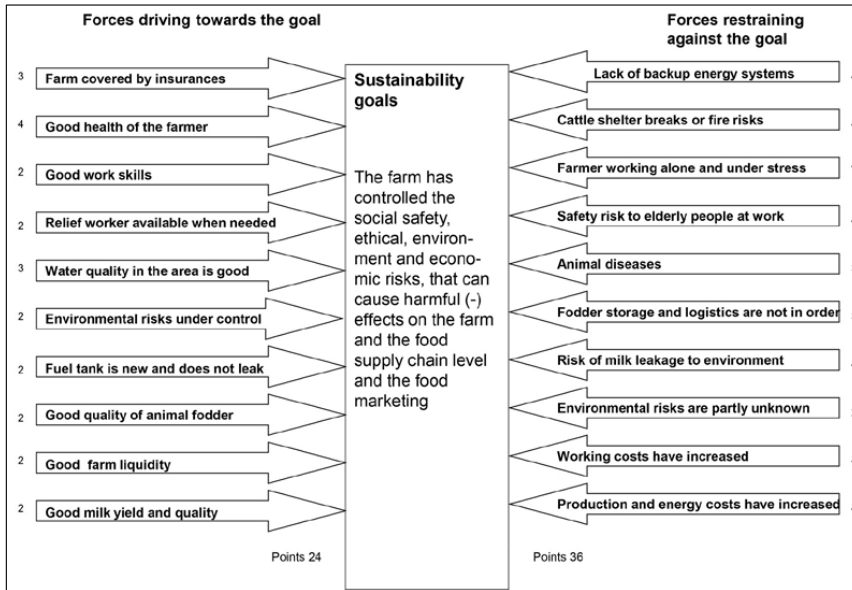


Figure 13. Force field analysis was used to prioritize risks separately in each sustainable category (Leppälä et al. 2011).

Figure 13 describes a combination of the highest scores given by the farmer for social and ethical sustainability, environmental sustainability and economic sustainability issues. The points indicated that there were some important areas for improvement and the forces restraining the sustainability goals include stronger forces. However, the positive sustainability drivers act as buffers against the sustainability risks. These drivers included activities such as maintaining health and skills, having insurance, relief worker availability when needed, maintaining good milk quality and taking care of the quality of local water systems. The restraining forces against sustainability were activities such as lacking back up energy systems, fire and breakdown risks in the cattle shelter, ergonomically poor fodder logistics in the barn, working alone, very stressful production seasons, increasing production costs and a high risk of milk leakages (environmental and economic risk). Although the points were given subjectively by the farmer, the force field analysis helped the farmer to compare the farm drivers and risks against the sustainability objectives. This helped to prioritize risks and to find potential tools to mitigate them. The results of this analysis could be included in the farm’s development plan (Figure 14).

The dairy farm case illustrated the complexity of sustainable management problems on the farm level, which may cause effects on the food supply chain. The risks could be linked. The main sustainable management risks on the farm were:

1. the risk of severe image caused by serious farm-level environmental problems;
2. food safety and quality failures on the farm have serious consequences for the food supply chain;
3. animal diseases on the farm could lead to a collapse in the food markets, which could have devastating effects on farmers in the affected area; and
4. problems with farmer health will have negative effects on farm profitability.

The analysis revealed that the case farm sustainability risks could have effects from the farm level to the neighborhood and the entire food supply chain. It can be said that the food supply chain is as good as its weakest part, similarly to the supply chains of other products (Leppälä et al. 2011; Phillipson and Lowe 2008; Lowe et al. 2008). Furthermore, certain risks, for example in the social sustainability category, may be linked to economic effects, production quality problems and motivation to take care of the environment. It is essential for the farm to find and mitigate high priority risks, which hinder the main processes of the farm. The case study provided new information on sustainable management planning on a farm. The use of the risk management tools helped the case farmer to integrate sustainability objectives into farm management.

3.6. Summary of the results

The objective of this dissertation study was to increase understanding of systematic risk management on farms. Special attention was paid to the development and usability of holistic risk management tools, evaluating the effectiveness of farm safety risk management interventions and sustainability risk management on farms. This dissertation described a contextual risk management framework and presented new applications assisting systematic risk management on farms. The results of the farm risk management literature study, two farmer surveys and several in-depth analyses of using risk management tools on farms are presented in Table 6.

Table 6. Summary of the results.

<p>Sub-study 1: Analysis of risk management tools applicable to managing farm risks: A literature review.</p>	<ul style="list-style-type: none"> - Keywords related to major farm risks were identified in a farm risk workshop. They were: assets, production and products, health and safety, environment and economic risks. - The Farm Risk Toolcase presents the list of risk management tools. - Links between risks should be made clear in farm production processes and farm operations. This requires the development of new information management systems and knowledge management techniques. - Tools to assist farmers in farm risk management are not currently at a sufficient level compared to the various risks faced by farmers. The farmers need practical risk management tools and knowledge management tools to manage the various farm risks.
<p>Sub-study 2: Farmers' perceptions of necessary management skills in Finland.</p>	<ul style="list-style-type: none"> - The most important but challenging management tasks were managing agricultural subsidies, maintaining farmer health, farm business accounting and operations, minimizing the risk of occupational accidents and diseases. - The results pointed out the need for safety, security, economic, information and labour management tools in farm management.
<p>Sub-study 3: Effectiveness of the occupational health service programme in farmers' safety and security risk management.</p>	<ul style="list-style-type: none"> - The main farm risks perceived by the farmers were: dependence on one key person, physical strain risks, mental well-being risks, injury incidents, profitability risks, fire risks, natural disasters, local/regional crises, building breakdowns, field machinery breakdowns. - Membership of the Farmers' Occupational Health Service was associated with a higher injury incident risk. Although consistent with previous studies, this result may be biased due to the lack of appropriate control variables. Risk factors for injury also included a larger field size, dependence on one key person, physical work strain, perceived fire risk incidents, machinery damage and infrastructural problems on farms. - Regular monitoring of safety and security risks was a protective variable against injury incidents. - Membership of the Farmers' Occupational Health Service (FOHS) programme was associated with risk management more broadly than just health and safety. The members are more aware of risks, but the challenge is to engage farmers to make improvements in practice. It is also a challenge to evaluate this voluntary programme in a non-biased way.
<p>Sub-study 4: Farm risk map: a contextual tool for risk identification and sustainable management on farms.</p>	<ul style="list-style-type: none"> - The Farm Risk Map (FRM) framework was constructed and tested. The FRM includes a list of 90 farm risk areas, divided into 5 categories: off-farm risk sources, on-farm risks (assets and finance, products and production quality and people safety) and risks caused by the farm to society (to customers and environment). - Each category gives a different perspective and tools to handle farm risks. - The risk check on case farms was found to be easier, starting the risk identification process with an asset, then production tasks and after that doing safety risk check, followed by outside impacts on other people and the environment. - The Farm Risk Map assists in the risk context analysis and risk identification on farms, but farmers should also find tools to control and monitor risks. The farm risk check should be modified to fit the context (production, country, target etc.).
<p>Sub-study 5: Farm risk management applied to the sustainability of the food supply chain. A case study of sustainability risks in dairy farming.</p>	<ul style="list-style-type: none"> - The complexity of sustainability problems in farm production and the effects on the food supply chain were illustrated. Different risks and their causes and consequences could be linked. - The notable risks against farm sustainability objectives included product image risks related to farm-level environmental problems, food safety and quality risks, animal disease risks linked to the food supply chain reflecting back on farm profitability. - Sustainable management on farms is difficult without sufficient management tools. - Farm risk analysis gives farm managers useful information for a sustainable farm management plan. The main problem in risk management with multi-objective situations, as in sustainable farm management in practise, is to find risk control tools and to manage sustainability goals in the food supply chain. - The case farmer prioritized risks with force field analysis and identified possible risk control tools. Despite the problems in sustainability, many positive drivers were acting as buffers against the sustainability risks.

4. Discussion and conclusions

4.1. Theoretical implications

According to the systems thinking paradigm, the development of a holistic perspective would help in understanding enterprise complexity and the connections of interdependent components with enterprise performance (O'Donnell 2005). This could be based on mental models, which help business managers to simultaneously see the forest and the trees. Holistic mental models have assisted in self-organizing, complexity handling and holistic problem-solving compared to situations where these mental model tools have not been applied (O'Donnell 2005; Jacobsen 2001). Furthermore, Schiuma et al. (2012) argue that decision-support frameworks that increase understanding among managers of how knowledge assets interact with each other and with organizational performance are needed and beneficial for objective setting and management in companies. However, in the changing world, mental models of intelligent systems should not be closed but open for improvement, simultaneously taking into account system interdependencies, functions and consequences (Senge 1994). The links of key knowledge asset drivers to business performance in accordance with cause-and-effect chains should be clarified and analysed. The systematic risk management process on farms actually supports the analysis of the key knowledge assets and cause-and-effect chains on the farm. A new mental map framework for farms, the Farm Risk Map, was constructed in this dissertation study. The case farmers were able to form a broader safety and security perspective on the risks, to identify “seed events” of potential hazardous risks (see chapter 2.2.) and to integrate various risk types by using the Farm Risk Map. This Map helped the farmers to visualize the complexity of risks and undertake holistic risk management on their farms (Leppälä et al. 2012).

Prior to this study, farm risk management lacked a tool for establishing the farm risk context and for farm risk identification. No similar type of holistic tool to the Farm Risk Map has previously been applied in farm risk identification (Leppälä et al. 2015; 2012). Many farm risk management tools found in sub-study 1 concerned the management of single risks. Holistic tools for integrating and managing several risks have been constructed for other industries (Cabric 2015; COSO 2004b; Uusitalo et al. 2003; Kerko 2001). According to Fayol's management theory, fundamental functioning elements must be in place for an enterprise to succeed. Risks to such functional management ele-

ments may also threaten success and continuity of a farm. In this study, the general system view was used in constructing the Farm Risk Map model. The functional elements and risks on farms were 1. outside impacts on the farm, such as market risks and natural disasters, 2. impacts of the farm on the environment or on customers and 3. risks inside the farm to farm assets, production and to farm personnel.

4.2. Practical implications

The Farm Risk Map

The Farm Risk Map can be used as a farm context analysis and preliminary risk identification tool categorizing risks on a farm (Figure 14). The farm context evaluation is also needed, when new management systems and tools are developed and applied on farms. According to the farmer survey results in sub-study 3, the main farm risks were linked to the dependence on a key person, safety risks, production profitability and risks in assets. The results converged with those of the literature review and case studies, and the main risk categories included in the farm context were defined as assets and finance, product and production, and health and safety. Two other defined categories were outside impacts on the farm and impacts of the farm on customers and the environment.

The risk types and their several subcategories in the Farm Risk Map are collected into a simple one-page figure. In this figure, risks and their interactions can be checked on a general level on farms. The usability of the Farm Risk Map framework was tested with several case farmers. The usability requirements for the farm risk management tool were that it should be easy to use, relevant, systematic, holistic and enable the rapid visualization of farm risks. Farm risks can be categorized according to the risk focus, source or potential consequences, and evaluated from the perspective of a particular place, action, process phase or task (Leppälä et al. 2015). Categorization of risks helped the farmers in risk identification (Leppälä et al. 2012).

The Farm Risk Map could be used to perform a preliminary risk check on farms. It provided a broader risk checking tool, a more systematic approach for managing risks and improved context analysis for risk identification on the case farms. Some initial guidance was needed to motivate the farmers and assist them in using the Farm Risk Map. However, the case farmers were quickly able to learn and apply the Farm Risk Map, and could understand how the farm risk keywords were connected to farm processes and activities. Nevertheless, some preliminary knowledge or assistance in prioritizing the risks may be needed (Figure 14).

Farm risk map

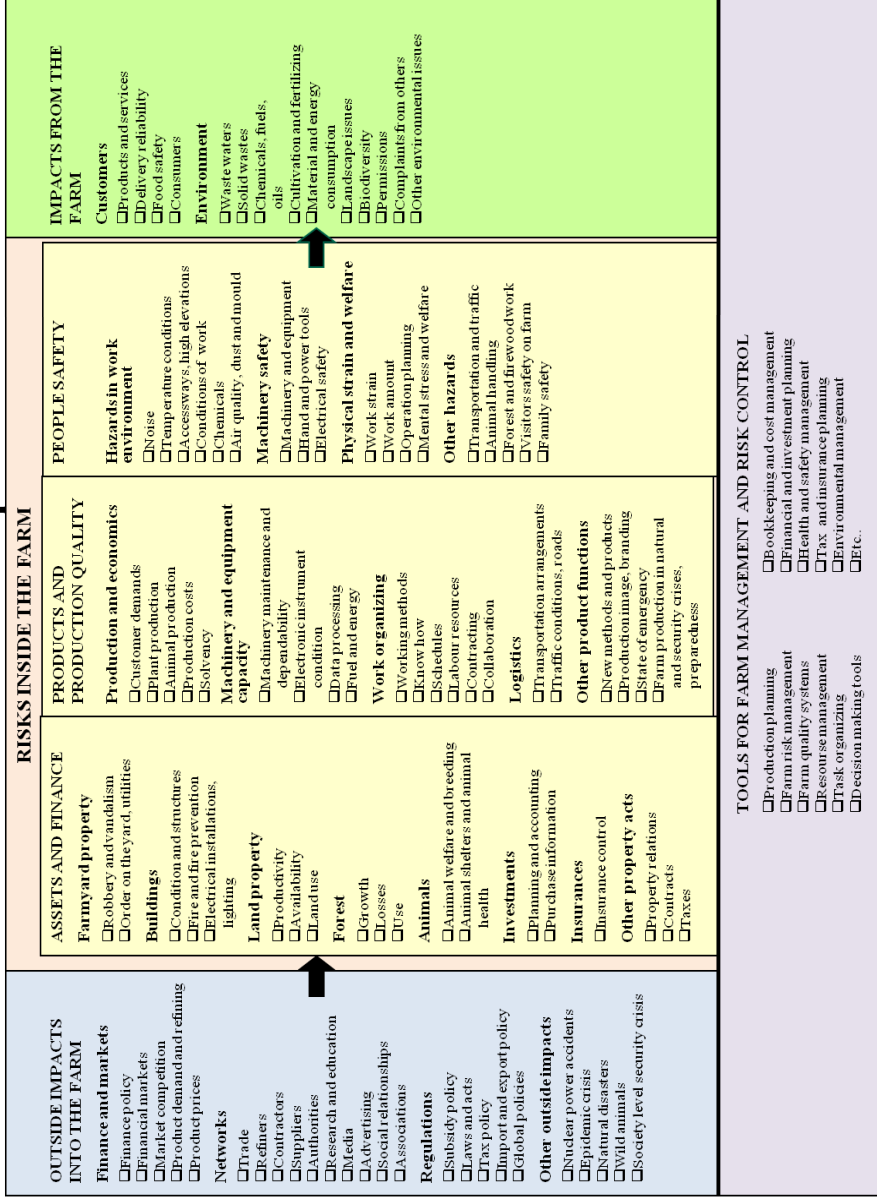


Figure 14. The Farm Risk Map (Leppälä et al. 2012; Leppälä et al. 2008a).

In order to identify risks on the farm, it was easier for the farmers to connect them to resources, places or areas, or everyday production activities, which were well known to them (Figure 15) (Leppälä et al. 2012; Leppälä et al. 2011). Furthermore, in order to enable the Farm Risk Map to be applied on different farm types, it is possible to modify the categories in the model and omit currently non-relevant risks. As farms are partly heterogeneous, it is essential that farmers can prepare a tailored risk management plan that suits their specific farm type. The Farm Risk Map has been used as a part of farmer education in Virtuaalikylä web sites (Virtuaalikylä 2011).



Figure 15. Risk identification was easier for the farmers, when they could connect them to resources, places or everyday production activities.

Risk management process tools applied to farms

The risk management process includes context definition, risk identification and analysis, risk control and risk monitoring stages (Figure 16) (ISO 31000). The preliminary farm risk context analysis includes checking of the main safety and security risks categories and possible risk events on farms. Objective and focus setting connected to the farm business strategy, assets, environment, human resources and production tasks support the context analysis (Leppälä et al. 2015). The risk identification is not sufficient if it focuses on the wrong risks, or if the farmer lacks risk control actions or does not fix problems on the farm. The Farm Risk Map can be used in risk context analysis and as a risk identification tool on farms. To perform a farm risk assessment, some risk matrices, process analysis tools and risk checklists are also available for further risk analysis (Leppälä et al. 2015; Leppälä et al. 2012; Agronet 2008; Rautiainen et al. 2010). In some studies, risk checklists have been reported as an efficient risk management tool, for example in hospital work (Gawande 2011).

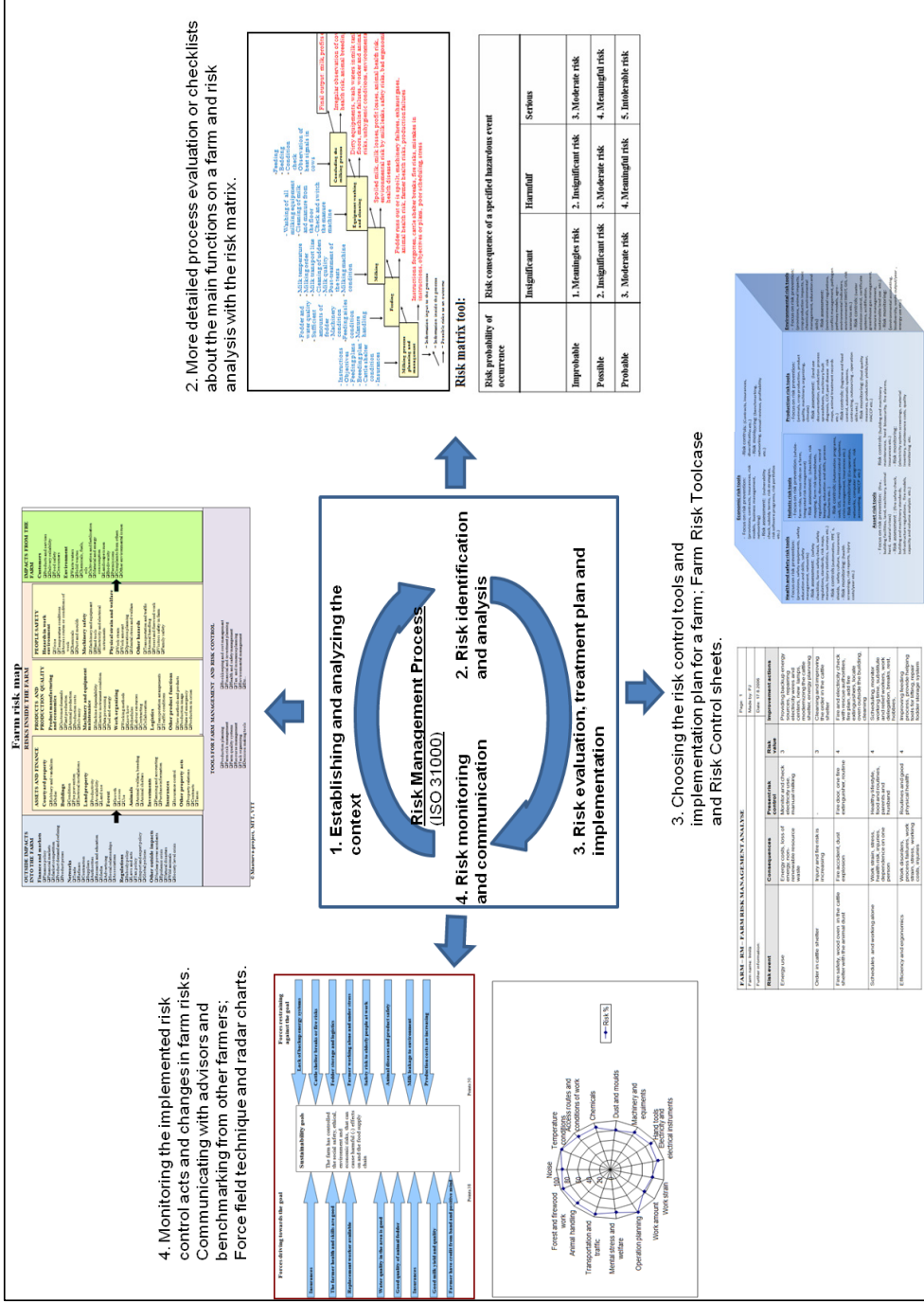


Figure 16. The risk management process tools and techniques applied to farms.

Identified risks are listed on implementation or fail-safe plan forms, which can be used as a part of farm risk management planning (Figure 16). This plan may include suitable risk control tools for important farm activities. Some of the risks cannot be totally eliminated, but the method of approaching risk mitigation drivers may be suitable for monitoring risks to keep them at a tolerable level. Force field analysis and radar charts can be used as risk monitoring tools. Risk management activities should be aligned with the farm goals (Leppälä et al. 2012; Leppälä et al. 2011). As in any enterprise or organization, it is essential for the farm safety culture that the farmer communicates and informs other farm personnel, workers or collaborators about the farm risks and their management.

Implications to enlarging farms

Over eighty-five percent of farms in Finland and elsewhere in the EU are small-scale family enterprises. It is expected that farm sizes in the EU and in Finland will grow in the future (Davidova and Thomson 2014; Niemi and Ahlstedt 2014). This change may increase the needs for farm risk management tools (Leppälä et al. 2015; Leppälä et al. 2014). As farm management is complex and includes various management tasks, the farmers need more specialized knowledge and operative and strategic managerial skills (Leppälä et al. 2013a; Leppälä et al. 2012; Mattila et al. 2007). For example, the results of sub-study 2 suggest that farmers were motivated to maintain and improve occupational safety and health, but they found it rather difficult.

Farmers also associated the knowledge management and evaluation of current risks as highly important management tasks. Integrating the risks and opportunity drivers in farm processes may provide advantages to growing farms, but similarly, uncertain and uncontrolled risks may prevent farm growth (Evans 2004; Pannell et al. 2000). Analysis of the negative and positive risks in farm processes provides farmers with useful information when assessing the farm strengths and weaknesses, which is important in enterprise management (Schiuma et al. 2012; Leppälä et al. 2011; O'Donnell 2005; COSO 2004b).

In sub-study 3, farms with larger field size reported more injuries than smaller farms. The development of safety management is consequently needed on enlarging farms. When the capacity of a farm, the amount of work and the production volumes increase, the workforce capacity and organization of work need to be checked and possibly rearranged.(Olson 2004). In this situation, the increased work amount and work strain among farmers and handling of debts after investments may increase farmer stress and safety risks. This could be a problem in enlarging farms. It is difficult for small-scale farms to make investments without a clear picture of farm business risks, work strain and operative risks during the changes (Leppälä et al. 2013a; Leppälä et al. 2011;

Lowe et al. 2008; Leskinen 2004). Small-scale farms can use capacity management tools, extension services or farmer meetings to arrange risk workshops and to use the Farm Risk Map to identify risks on the farm (Leppälä et al. 2015).

Health and safety risk management programmes

The effectiveness of risk management programmes on farms was evaluated in sub-study 3. In Finland, a number of public measures have been implemented to improve the occupational health and safety of farmers, but the effect of these preventative measures has been unclear. For example, contrary to the objectives of the Farmers' Occupational Health Service (FOHS) in Finland, it was pointed out that the injury rates have been higher among the programme members (Leppälä et al. 2013a; Karttunen and Rautiainen 2013a; Rautiainen et al. 2009). The FOHS programme is voluntary and it educates farmers about risks, their prevention, and insurance systems. Overall, FOHS members consider their farms to have more safety risks and other risks. Similarly, injury rates were also higher among farmers who have had quality management training. The FOHS members (as well as farmers with quality management training) are more active and more often full-time farmers, who were more aware of the risks and made greater risk control efforts than non-members. Another explanation for the lower injury rates among non-members of FOHS and potential source of bias is underreporting by non-members. Education and training may result in greater awareness, risk identification skills and reporting of risks. Many other differences, such as larger farm sizes (field and herd), dependence on one person on the farm, physical work strain, perceived fire risk, machinery damage and infrastructural problems on farms may bias the results (Leppälä et al. 2013a). Motivation to join the FOHS may also increase when a farmer has health problems, as it is expected to support their work ability (Leppälä et al. 2013a). Karttunen and Rautiainen (2013b) have also pointed out that accidents leading to injury are clustered and accumulated in particular groups of farmers. Furthermore, while most farmers are motivated to maintain and improve occupational health and safety on farms, they may find it fairly difficult (Mattila et al. 2007). Nevertheless, an important challenge in the FOHS programme is how to ensure the commitment of farmers, the practical implementation of programme objectives and monitoring of results on farms. In this study, the farmers who carried out regular self-monitoring of their farm safety and security risks had fewer safety risk incidents.

FOHS membership and services provide a good basis and network for management tools and services to identify the safety and security risks on farms. Often, those farms that have safety problems are multi-risk or multi-problem farms. When one risk is addressed, other problems may arise. The safety risk management goals and activities should be connected to a coherent and consistent approach in the strategic objectives of the enterprise (Kuusisto 2000;

Reason 1997). This is important for the farm safety culture and farmer motivation to maintain safety on farms. Added to this, if environmental or safety management intervention increases the management complexity or costs on the farm, it may reduce the motivation of farmers to make sustainability or safety improvements (Kingwell 2011; Mattila et al. 2007; Hall 2007; Pannell et al. 2000). Farms could have conflicting or false objectives. A holistic security view in farm management is needed if the farmer neglects good safety habits, intending to save money and time or in pursuit of meeting other objectives that are too demanding (Leppälä et al. 2015). Farmers should understand that farm safety and business objectives are going in the same direction. Farmer networks and communication, education, advisory services and risk workshops with other farmers, as well as viewing farms within a larger context may solve some of these motivational problems and support farmers in safety management. Benchmarking and ideas from other farmers may provide innovative tools to deal with safety management interventions (Leppälä et al. 2015; Chapman et al. 2009; Brumby et al. 2009).

Issues in sustainable farm management

Sustainable management challenges are substantial in food production. Practical risk management tools for managing sustainability risks on farms are needed. An essential policy challenge in the food supply chain is to apply sustainable management practices to the farm context in a workable and safe way (Phillipson and Lowe 2008; Malkina-Pykh and Pykh 2004). New information on the use of risk management tools in sustainable management planning on farms was provided in this dissertation study.

Positive sustainability drivers on farms identified in sub-study 5 could act as buffers against sustainability risks. The risk buffers were found to enable the farmers to continue their farming activities, while some of the farm activities and assets would need overhauling and redesign. However, in such conditions, risk-taking by the farmer is rather excessive (Leppälä et al. 2011). Kaustell et al. (2011) also found that barriers and enabling factors should be noted in order to develop health and safety management on farms. Farmers use many risk management tools, but they may be unorganized and intermittent.

When all essential farm risks are listed with the help of the Farm Risk Map, farm risk context analysis can be used to promote sustainable management on the farm. The aim in sustainable development is economically, environmentally and socially sustainable growth. Thus, the farmer should consider all sustainability risks, i.e. not just the economic risks, but also health and safety as well as environmental risks. However, various safety and security risks are rather common on farms, putting stress on farmers. The results of sub-study 3 indicated that 44% of the farmers perceived local or regional security risks as an important risk for their farm. Ageing and increasing health problems have also been connected to safety and security risks on farms (Leppälä et al. 2015;

Rautiainen et al. 2009). These risks could cause challenges to farm sustainability, production processes and business continuity, which in the long term may affect the sustainability of the food supply chain in particular regions. Such sustainability is only as good as its weakest part (Leppälä et al. 2011; Lowe et al. 2008). The management of sustainable development on farms is difficult without sufficient and relevant management tools. Tools to assist farmers in systematic risk management have not been at a sufficient level in relation to the sustainability and safety and security management risks faced by the farmers. The Farm Risk Map and other risk management tools presented in this dissertation can assist in systematic risk management and sustainable management on farms.

5. Research limitations and further research

The developed Farm Risk Map and risk management tools presented in this dissertation were tested and analysed with case farms, which included crop, dairy, cattle and pig production. The Farm Risk Map is a broad framework for farm risk management, but should be tailored for particular production types and particular farms in further research. For example, some studies have found differences in safety risks between dairy and pig farm work environments. The differences arise in work practices, human characteristics and behaviour, the working environment and resources on farms (Kolstrup et al. 2006). The Farm Risk Map could be also tested with a larger sample of farms in the future. In addition, to improve the use of these risk management tools on farms, they would benefit from detailed risk measurement analysis and new functional features. Further applications for small enterprises in additional rural and other industries are also possible.

Farms are facing policy changes, technological modernization, uncertain food markets, financial uncertainty, epidemic risks and natural disaster risks, which may result in new needs for farm risk management. Thus, the Farm Risk Map framework and risk management tools on farms need checking and updating, since important risks on farms tend to change over time. Furthermore, the analysis in this dissertation focused on the Farm Risk Map. However, the Maaturva project also included other risk management tools, which could be reported and analysed in further research. During the period from January 2012 to January 2015 there were 3758 visitors to the site, which is over 1000 visitors per year in Finland. The Agronet web pages were closed after MTT Agrifood Research Finland changed to become part of the Natural Resources Institute of Finland (Luke). The new web pages for the Farm Risk Map and farm risk management tools should be updated and published in Finnish and in English.

The survey conducted in sub-study 2 was limited to farms with over 30 hectares of arable land and the survey conducted in sub-study 3 was limited to farms of over 20 hectares. These survey samples are representative of mid- to large-sized farms in Finland. Furthermore, the self-reporting of injuries and accident numbers in the survey of sub-study 3 could be biased. A larger survey sample might reduce the possible bias in future studies. However, the survey in sub-study 3 had similar results, demonstrating a higher injury incident rate

among FOHS members, to those reported by Karttunen and Rautiainen (2013a) and Rautiainen et al. (2009). Several other studies also support the findings in sub-study 2 concerning the challenges in investments and change management on farms, the handling of institutional bureaucracy, health and safety management and worker management (Mattila et al. 2007).

Regular risk monitoring on farms was found to be a protective factor for farm safety risk incidents (Leppälä et al. 2013a). It is recommended that risk check procedures are periodically performed on farms. In principle, the inspection time frame in quality management programmes would depend on the product, the changes occurring in an enterprise and the possible risks (Juran and Godfrey 1998). Thus, determination of the time periods for risk monitoring on farms is a matter requiring further research. The biggest risk on farms according to the survey in sub-study 3 was the dependence and vulnerability of the key person on the farm. There is a lack of studies concerning risks to key farm personnel, farm divorces, areal preparedness, data management, resilience management and vulnerability on farms considered in relation to security and regional crises (Leppälä et al. 2015; Leppälä et al. 2013a). Farmer ageing and safety in the next farmer generation is a major agricultural challenge facing Europe in the future (Leppälä et al. 2015; Leppälä et al. 2014; Davidova and Thomson 2014). These are issues that warrant future research. The results of sub-study 3 also indicated that FOHS membership, quality management training and computer use in farm management associated with higher injury rates. However, these results certainly include statistical biases from other farm variables, and may also relate to the higher volume or activity in farming and, in the case of computer use, problems in adapting to new automation technology in agriculture. This could be a topic of further research. A potential issue for further research is the safety behaviour of farmers and farm workers (Leppälä et al. 2013a; Leppälä et al. 2012). The lack of safety behaviour or risk-taking behaviour among farmers could explain why many health and safety interventions have only a short-term or minor effect on farmer injury and accident rates (DeRoo and Rautiainen 2000). Working in a hurry, working negligently or forgetting the health and safety recommendations are potential problems on farms (Leppälä et al. 2015; Hagevoort et al. 2013).

Further research is needed to develop new risk assessment tools for food supply chain management. Farm production risks may seriously threaten the whole food supply chain. Traditional risk analysis tends to identify the causes of potential defined consequences and uncertain events, but holistic farm risk management, with more cyclical and holistic control tools, is also needed. The benefits of various risk management research disciplines should be integrated to provide relevant risk management tools for farms. Multi-risk management is considered to be a rather new area of research (Komendantova et al. 2013). Similarly, it is assumed that developing and designing holistic risk management tools for farms is a relatively new topic requiring further study in the future.

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