

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

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ABSTRACT

The objective of this study was to list and analyse risk management tools applicable in managing farm risks. A literature search of several large literature databases was conducted. By using risk management-related keywords, a total of 13,559 articles discussing risk management were identified. Of these, 157 articles were selected for closer analysis applicable to dairy, cattle, pig or crop production. Both journal articles and book chapters in English were included. The articles were categorized based on the applied risk focus and type of risk management tools presented. In accordance with this, potential farm risk management tools were searched from the research studies associated with production, assets, economics and finance, human health and safety, and the environmental risks on farms. An important outcome of the study was a tool case for farm risk management stages, in which either the potential farm risk tools can each be used to address a single risk or the tools can be holistically applied. Farmers face multi-risk management demands, but comprehensive literature studies on multi-risk management tools on farms have been rare. Farm risk management tools and information provided to farmers are not at a sufficient level if we compare them to the current risks and social demands that farmers are facing. The possible farm risks should be clarified to farmers that they can identify them on farms. Furthermore, in order to integrate farm risk management tools, the links between the risks should be made visible among farm operations and farm production processes. Complexity and usability are future challenges in the further development of tools for managing farm risks. Applying the new farm risk tools in a sustainable manner requires farm managers to adopt new knowledge management techniques. Education programmes are needed to address the new skills that are required, and communication and co-operation between different research disciplines is also necessary.

KEYWORDS: farm; risk management; literature review study

1. Introduction

Various risks can cause serious damage on farms, but also have broader effects on society and the food supply chain (Marvin *et al.* 2009; Lowe *et al.* 2008). Animal and plant diseases, institutional risks, market risks, natural catastrophes, health and safety risks and farm financial risks emphasise the traditional sources of risks and the particular importance of risk management on farms (Huirne *et al.* 2007; Hardaker *et al.* 2004; Jung 2001; Florey 2001). An important problem is that farmers not only have to manage single risks, but also combinations of risks in their daily work and decision making. Some risk incident studies have pointed out that the handling of multiple hazardous risks on farms is a challenging task for farmers (Leppälä *et al.* 2013; Leppälä *et al.* 2012; Huirne *et al.* 2007; Hall 2007; Robinson 1999).

Risk is usually considered as a specific hazardous event and its consequences, which have a particular frequency or probability of occurrence. The positive side of risk can also be seen as a potential business opportunity (ISO 31000). On a general level, strategies proposed by risk management tools include avoiding risk, eliminating the risk source, reducing the risk likelihood or consequences, removing or sharing risk and retaining risk. The risk management process is based on tools for 1. Establishing the context, 2. Risk assessment, including risk identification, analysis and evaluation, 3. The control or treatment of risks and 4. Risk monitoring (ISO 31000). The corporate risk management literature presents broad frameworks or practical risk identification tools such as risk checklists and flowcharts to prevent the main corporate risks that may threaten or halt important business activities (Carnaghan 2006; COSO 2004).

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Corporate management tools have to some extent been applied in the farm management literature, which provides well-developed tools for risk decision making and risk analysis techniques, such as future price probabilities and economic farm management options (Nuthall 2010; Kay *et al.* 2008; Hardaker *et al.* 2004). A challenge is that the management tools used in other industries may not be suited to small enterprises such as farms, where the farm manager is both the manager and operator in most of the activities. However, it appears that the need for risk management tools in agriculture from a broader perspective is increasing worldwide due to increased competition, environmental and sustainability problems, new policy objectives, new food safety regulations and the changing risk context in general (Leppälä *et al.* 2012; Nuthall 2010; Lowe *et al.* 2008; Florey 2001). Furthermore, as sustainable farming policies, especially in European and Nordic countries, are calling for a more holistic risk approach in farming, we should also ask what practical tools are available for holistic risk management on farms (Leppälä *et al.* 2012; Marvin *et al.* 2009; Lowe *et al.* 2008; Robinson 1999). The objective of this study was to list and analyse risk management tools applicable in managing farm risks.

2. Methods

The literature review was a part of the larger 'Maaturva' project, which aimed to define the main risks and risk management tools in farm risk management studies. The project included a risk expert workshop, literature review, farm risk inquiry among farmers, ten farm visits and interviews and four case studies aiming to identify and develop suitable risk management tools for various farm management activities. A ten-day educational farm risk management programme for farmers during 2006–2007 was also arranged within the project (Leppälä *et al.* 2008).

Literature search

We conducted a comprehensive literature study to identify practical on-farm risk management tools by using two electronic databases, Scopus and CABI, and their respective search tools. The searches were limited to the titles, abstracts and keywords of agricultural journals articles and book chapters published from 1990–2011. To be included, the articles needed to be concerned with tools for managing risks on farms. Applicability to European agriculture was considered as an inclusion criterion for studies selected for analysis. The included studies were limited to the main production types in EU countries, which are crop, dairy, cattle meat and pig meat production (European Commission 2012). In the narrative synthesis method, the included studies are divided into groups to explore their relationships or differences and point out the diversity among them (Lucas *et al.* 2007). The chosen farm risk management studies were categorized by asking which risk management tools are focused on managing particular risks on the farm level. We also used the thematic summary method to categorise the studies into thematic risk tool groups (Sniltweit *et al.* 2012). Finally, we conducted a summary of the risk management tools applicable to managing risks on farms and identified some development challenges for various farm risk management tools.

Risk management tools applicable in managing farm risks

Risk expert workshop

The potential risks on farms were listed in a risk expert workshop to modify the keywords for the preliminary literature search and farmer risk survey. The workshop included experts in farm occupational health and safety, farm machinery standards, agricultural engineering, SME risk management, farm insurance and business, and security education, as well as a dairy and a crop farmer (Leppälä *et al.* 2008). The Corporate Security Advisory and VTT in Finland had commonly used an outline of corporate risk fields, including techniques to prevent risks such as production security, health and safety, personnel security, security of buildings, the environment, rescue planning, areal preparedness, data security, crime prevention and security for foreign affairs (Lanne 2007). These risk fields were combined with the common risk sources in EU agriculture, defined as price risk, production or yield risk, human risk, asset risk, financial risk and institutional risk (Jung 2001). The risk expert workshop included a brainstorming session to explore the main farm risk keywords. The keywords and themes were documented, photographed and categorized. The keyword list concerning the main risks on farms was later updated based on the keywords in latest farm risk management studies published 2006–2011. (NJF 2010; Nuthall 2010; Niemeläinen *et al.* 2008; Huirne *et al.* 2007; Hardaker 2006).

3. Results

The whole list of risks handled in the workshop included those associated with personnel, economics, finance, buildings, production, business interruption, contracting, crime, data, occupational health and safety, rescue planning, market and price, foreign affairs, areal preparedness and environmental security. The identified and refined farm risk keywords and risk tool categories were determined to indicate the most important risks for in-farm activities. The keywords used and total numbers of search results are presented in Table 1. The search results yielded a total of 13,559 hits, but after applying of all search criteria limitations, 157 studies were chosen for more detailed analysis (Table 1). A current list of the studies is available on request from the authors.

The risk tool categories were defined as: 1. People health and safety; 2. Production and product risks; 3. Farm asset risks; 4. Economic and financial business risks, and 5. Environmental risks. The other risk categories (crime, data and areal preparedness etc.) handled in the risk expert workshop were found to be currently marginal on farms, but might become current in the future if the risk conditions change. During the literature search, studies on these other risks were also found to be rare or off-farm in context, and were thus excluded from the present analysis. The farmers who participated and were interviewed in the project appreciated the simpler model of risk categories (Leppälä *et al.* 2012; Leppälä 2008).

Farm asset risk management tools

Farmers manage valuable solid assets, including farm estates, arable land, forests, buildings, machinery and livestock. The analysed articles addressed farm asset risk management tools concerning invested property value

Table 1: Search protocol for Scopus and CAB Abstracts. The total number of search hits was 13 559, from which 157 articles were included in the analysis

Keywords	Date range: 1990-2011, Scope: Title, abstract, keywords, journals, books	Date range: 1990-2011: Scope: Title, abstract, headwords	Farm risk management studies applicable to European agriculture
	Scopus	CAB Abstracts	Total
	Search results	Search results	Included articles
“Farm risk management” OR “agricultur* 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⁾ terms were farm risk AND asset management OR farm property

²⁾ last terms were without inverted commas

³⁾ terms were farm AND injury OR safety risk management

⁴⁾ terms were “farm risk” AND environment management OR sustainable management

⁵⁾ terms were farm AND fire OR agricultur* fire safety risk OR “farm fire management”

losses and technical engineering assets (Table 2). The risk focus of the studies included fire incidents, farm building facility losses, land or soil property losses, animal health risks or herd value losses and asset property losses caused by natural disasters.

The analysed fire safety risk studies presented the possible risk sources and risk management tools to prevent fire risks on farms. Risk control through building maintenance and safety checks to monitor unsafe electrical installations and devices used in farm buildings were typical fire risk management tools (BS 5502 2004; Scott 1991). Farm fires spread toxic smoke to large areas and fire accident damage and costs are very high, which should be considered in fire safety and rescue planning (BS 5502 2004; Kinsman and Maddison 2001). Computer-aided fire risk programmes with warehouse inventory and alarm instructions are important management tools in fire safety planning, but also help fire departments in actual rescue situations (Kinsman and Maddison 2001). When focusing on other building risks, farm building structural planning, production volume and space calculation models are useful investment tools, for example when enlarging farm building spaces and production volumes (Meyer 2010). Furthermore, good air ventilation, quality measures and devices, ergonomic

design and hygiene control programmes help to maintain people safety as well as animal health, building materials and fodder quality (Banhazi 2009; Noordhuizen and Metz 2005).

Farmland investment strategies may help with land asset risks by providing useful land investment measures for farmers (Nartea and Webster 2008). Pasture and soil management includes cultivation techniques, planning tools and land-use indicator examples (Chamen *et al.* 2003; Logan 1991). These tools could improve soil quality and water system maintenance, which increases the value and quality of the invested farmland. Machinery asset risk studies include methods that help in field machinery selection, investments and maintenance. For example, power capacity measures help in machinery selection and investments (Kutzbach 2000). Another potential tool is a machinery lifetime and maintenance cost management calculator (Petrov and Trendafilov 2011). Farmers investing in automatic animal production equipment should note the building structure and space (Hovinen and Pyörälä 2011).

Feed safety management and specific herd welfare controls were found to be examples of animal disease risk management tools. Disease control is easier to maintain in smaller animal groups and by identifying

Table 2: Studies concerning asset risk management tools on farms

Focus	Risk management tools	Author
Fire safety	Safety behavior, fire safety check and planning, fire alarms and extinguishers, standards, regulations, water sources, rescue planning, fire models, material safety and inventory, building maintenance	Allareddy et al 2007; BS 5502 2004; Kinsman and Maddison 2001; Scott 1991; Shutske et al. 1991
Building facilities	Size and volume planning, checklists, spreadsheets, regulations, quality management, maintenance skills, air quality monitoring, building standards	Sorge et al. 2011; Moore et al. 2010; Meyer 2010; Boersema et al. 2009; Banhazi 2009; Noordhuizen and Metz 2005; BS 5502 1992
Land/soil value	Farmland investment strategies, land management models, sustainable land use and planning, land monitoring and indicators	Nartrea and Webster 2008; Chamen et al. 2003; Bouma 2002; Logan et al. 1991; Foran et al. 1990
Machinery assets	Machine capacity calculation, machinery selection, lifetime analysis, machinery investments, automation facilities, maintenance plan, costs, machinery standards	Petrov and Trendafilov 2011; Kutzbach 2000; ASAE 1998a
Herd value/ animal health	Wildlife and cattle contact management, feed safety management, herd welfare controls, farm biosecurity management, herd contamination risk pathways	Wilson et al. 2011; Sorge et al. 2011; Ellis-Iversen et al. 2008; Bas Rodenburg and Koene 2007; Leirs 2004; Faust et al. 2001; BS 5502 1990
Natural or areal crisis risks	Flood risk management, natural crisis management, damage prevention, food logistic planning, land-use planning, insurances, evacuation plans	Posthumus 2009; Haen 2008; Linnabary et al. 1991

possible pathogen contamination pathways in the animal shed (Sorge *et al.* 2011; Bas Rodenburg and Koene 2007). Potential animal welfare risks in the animal shed also include sharp edges, structural damage, dirty water basins, uneven floors, insufficient bedding and inadequate space for animals (Sorge *et al.* 2011; BS 5502 1990). Animal herd contact with wildlife (rodents and other animals), neighbouring herds and farm visitors might also spread animal diseases from one farm to another (Wilson *et al.* 2011). If herd vaccinations are not sufficient and documented, these incidents may even lead to a need to dispose of the whole herd (Faust *et al.* 2001). Biosecurity management and building standards help farm managers to improve animal housing conditions to minimize animal and worker health risks (Wilson *et al.* 2011; Faust *et al.* 2001; BS5502 1990).

Studies on natural or areal crisis risks include tools for natural crisis management in particular areas, and strategies for preventing damage to farm assets. Land-use planning is an example of a way to mitigate the flood risk (Posthumus 2009). Furthermore, if the climate or an area becomes more unstable, insurances, food security and logistic planning, evacuation plans and other risk tools will be called for to mitigate the effects of storms, floods, droughts or other areal insecurity (Posthumus 2009; Haen 2008).

Farm production risk management tools

Production risk management tools are aimed at handling hazards in farm production process tasks and activities (Table 3). The analysed studies included risk tools for crop and livestock production, machinery operations, work organization and climate management tasks. In animal production, strategies to control production risks include animal welfare measurement tools such as disease prevention programmes including a risk assessment questionnaire on production tasks for farmers and animal health tests (Sorge *et al.* 2011). Farmer education has been used in improving disease control (Sorge *et al.* 2011), upgrading process control methods, and complying with authorities or co-producers' regulations (Taylor 2004; Noordhuizen and Welpelo 1996). Animal herd health

risks may reduce productivity, but also cause human health threats due to zoonosis risks (Holt *et al.* 2011).

In crop production, risk management tools are based on the handling of biological vegetative processes. Methods to minimize yield risks include the handling of drainage and irrigation systems (Balaghi *et al.* 2010), weed management and plant disease control with crop rotation, selection of the appropriate planting date, plant diversification (Dillon 1999), precision farming techniques for fertilizer and land nutrition management (Lowenberg-DeBoer 1999), traffic control on the field (Chamen *et al.* 2003) and crop yield and revenue insurances (Harwood 1999). The utilization of agricultural biotechnology is challenging. Biotechnology may reduce the use of pesticides and increase crop yields, but has raised conflicting opinions over animal and plant production biosecurity, food safety and possible long-term threats to environmental bioprocesses (Pidgeon *et al.* 2007; von Borell and Sørensen 2004).

Government regulations and quality management systems aim to ensure product quality and in this case food safety. Spreadsheet and checklist tools include standardized questions about operational food production risk factors that indicate, for example, animal disease risks (Boersema *et al.* 2008). Quality system management applications on farms, such as principle component analysis (PCA) (Holt 2011), standards and regulations, good farming principals or hazard analysis critical control points (HACCP), can be used in farm product risk management (Noordhuizen and Frankena 1999). The HACCP method has been criticized as being too complex and expensive to use on farms (Taylor 2004). Potential solutions have been proposed in the form of education and extension. Extension services educate farmers in the standard quality terminology and develop easy-to-use tools to be applied in farm management (Noordhuizen and Welpelo 2011; Taylor 2004).

A major part of farm production work involves dealing with farm machinery. Tools for handling machinery operational risks include maintenance programmes, machinery safety standards and manuals (ASAE 1998), machinery co-operation (Artz *et al.* 2010) and fleet or time management practices (Sørensen

Table 3: Studies concerning farm production and product risk management tools

Focus	Risk management tools	Author
Animal production	Animal production and welfare management, hygiene controls, HACCP, automatic production programmes, process management, feeding management, workbooks, regulations, animal handling, vaccination, treatment records, biotechnology, farm-to-fork database	Davies 2011; Hovinen and Pyörälä 2011; Sorge et al. 2011; Rostagno 2009; Hurd et al. 2008; Boersema et al. 2008; Ellis-Iversen et al. 2008; Nowak et al. 2007; Sischo et al. 2004; Stott et al. 2003; Aumaitre et al. 2002; van Schaik et al. 2001
Crop production	Crop rotation, soil management, automation, routing, regulations, insurances, biotechnology, precision farming, GPS, diversification, pest and fertilizer balance management	Pidgeon et al. 2007; Chamen et al. 2003; Bouma 2002; Kutzbach 2000; Dillon 1999; Harwood 1999; Lowenberg-DeBoer 1999; Logan et al. 1991
Product quality/safety	Education, farmer skill development, management systems, documentation, monitoring methods, traceability, insurances, regulations, biotechnology, biosecurity, farm simulator systems, standards and regulations, food chain quality assurance	Noordhuizen and Welpelo 2011; Nuthall 2010; Janssen et al. 2010; Pidgeon et al. 2007; Lund et al. 2005; Taylor 2004; von Borell and Sørensen 2004; Noordhuizen and Frankena 1999
Machinery operations	Automatic systems, fault diagnostic systems, maintenance, standards, regulations, usability and fleet management, scheduling, routing	Petrov and Trendafilov 2011; Hovinen and Pyörälä 2011; Crassaerts 2010; Sørensen and Bochtis 2010; Klee et al. 2003; Kutzbach 2000; ASAE 1998a
Work organization	Management skills, co-operation, worker management, regulations, working skills, work scheduling, record keeping, benchmarking, contracting, outsourcing	Nuthall 2010; Artz et al. 2010; Hueth 2009; Lund et al. 2005; Atkinson 2004; de Toro and Hansson 2004; Taylor 2004
Climate management on the farm	Climate risk models, early-warning systems, insurances, risk scenarios, user-focused climate information, risk coordination strategies, greenhouse gas mitigation methods	Balaghi 2010; Haen 2008; Hay 2007; Fuhrer and Booker 2003; Kutzbach 2000

and Bochtis 2010). Farmer collaboration, for example in machinery purchase and maintenance, production tasks and workforce sharing, is one efficient way to save costs and time (Artz *et al.* 2010). Machinery collaboration or other farm collaboration requires good communication, co-operative system rules and networking skills (Artz *et al.* 2010; de Toro and Hansson 2004). Outsourcing of farming activities increases the needs of the farm manager for contract management and insurance arrangements (Hueth 2009).

Human health and safety risk management tools on farms

Human health and safety risk studies have presented tools for preventing risks of injuries and diseases among farmers, their family members, farm workers and visitors (Table 4). The risk of serious injury is relatively high in farm work (Rautiainen *et al.* 2009). The basic management tools for farm health and safety management include administrative provisions or enforcement by law, technical innovations or devices and knowledge management tools such as human education or management skills aiming to affect human safety management and behaviour (Rautiainen *et al.* 2009; Lundqvist and Gustafsson 1992).

Technical innovations such as new ergonomic designs for personal protective equipment (PPE) and machinery safeguards are called for on farms in general (Carpenter *et al.* 2002). Automatic machinery systems may reduce the work strain for the farm manager and enable certain dangerous or routine work tasks to be performed on behalf of the farmer (Klee *et al.* 2003). However, the challenge is that automation is only good as long as it works without faults. Fault diagnostic systems and new types of safety sensors are aimed at increasing the reliability of automation in farm machinery applications (Crassaerts *et al.* 2010; Klee *et al.* 2003).

Safety assessment includes tools for risk identification, safety checks and a broad list of safety risk indicators

found from safety statistics and surveys. Farm safety risk checklists can be used in farm adviser or farmer self-management and risk identification tools (Rautiainen *et al.* 2010). Common farm safety risk indicators include farm characteristics (safety risks in farm work in general) (Karttunen and Rautiainen 2011; Rautiainen *et al.* 2009), personal characteristics (stress, alcohol and medication use, weak experience, hearing problems and old age) (Voaklander *et al.* 2009; Rautiainen *et al.* 2009; Spengler *et al.* 2004; Sprince *et al.* 2002), unsafe working behaviour or safety culture (long working hours, lack of personal protective equipment, unsafe machinery or animal handling) (Darragh *et al.* 1998; Layde *et al.* 1995), unsafe facilities (unsafe tools and electrical systems, defective buildings, unsafe building structures, lack of fire safety) (Chapman *et al.* 2009; Shutske *et al.* 1997) and unexpected natural events (natural disasters, floods, wild animals) (Haen 2008). In practice, a common challenge in safety engineering and safety management is that some users choose to minimize safety costs and maximize efficiency by removing safety applications from machinery (Narasimhan *et al.* 2011).

As farming involves numerous health and safety risks, farm managers need new safety solutions such as new ergonomic management and user-friendly best practice management tools applied to farm safety management (Narasimhan *et al.* 2011; Legault and Murphy 2000). In addition, programmes have been provided on farms for farm worker safety education (Langley and Morrow 2010), older and disabled farmers (Cole and Donovan 2008) and youth safety management practices on farms (Park 2003). Participation in farmer collaboration networks, health and safety membership programmes and farm-specific risk management programmes may provide new solutions for farmers (Kinnunen *et al.* 2009). Collaboration with farm stakeholders (e.g. farmers, industry, trade, research, education, authorities) and across research disciplines is a challenge, but also

Table 4: Studies concerning human health and safety risk management tools on farms

Focus	Risk management tools	Author
Administration provisions Health and safety equipment	Administration regulations and services, social security insurances, information, programmes, standards Mechanical protection (shields, seatbelts, covers etc.), PPE, protection clothes, ergonomic development and tools, air conditioning, lighting and visibility development	Myers 2009, Kinnunen et al. 2009, ASAE 1998b, Chapman et al. 1995 von Essen et al. 2010; Bunn et al. 2009; Cole and Donovan 2008; Mayton et al. 2007; Hard and Myers 2006; Bentley et al. 2005; Carpenter et al. 2002; Pedersen et al. 1999
Safety education and management skills	Safe working practices, knowledge, livestock handling, standards, self management (e.g. sleep, working pace, alcohol and medication use), safety and health campaigns and training, child safety, stress management, manuals, information, safety culture, electrical safety	Narasimhan et al. 2011; Langley and Morrow 2010; Chapman et al. 2009; Voaklander et al. 2009; Barten et al. 2008; Spengler et al. 2004; Stallones and Beseler 2004; Park et al. 2003; Sprince et al. 2002; Darragh et al. 1998; Driskill and Bouck 1997; Lundqvist and Gustafsson 1992
Safety assessment tools	Safety surveys, statistics, safety materials, checklists, safety certification, health screenings, standards, manuals, risk reports, identification of depression symptoms, safety planning	Karttunen and Rautiainen 2011; Narasimhan et al. 2011; Rautiainen et al. 2010; Barten et al. 2008; Hard and Myers 2006; Suutarinen 2004; Stallones and Beseler 2002; Hard et al. 2002; Petrea 2001
Safety control management	Safety control systems, medication, insurances, information, first aid guides, risk check tools, automation, warning signals, best management practices, grain storage engulfment prevention, machinery maintenance and investments	Crassaerts 2010; Langley and Morrow 2010; Chapman et al. 2009; Rautiainen et al. 2009; Barten et al. 2008; Angoules et al. 2007; Klee et al. 2003; Kingman et al. 2004; Legault and Murphy 2000; Layde et al. 1995
Safety network	Safety and health services, safety association memberships, health screenings, safety collaboration, worker safety checks, risk information management	Kinnunen et al. 2009; Thurston and Blundell-Gosselin 2004; Reed 2004; Chapman et al. 1995

recommend for farm safety reasons (von Essen *et al.* 2009).

Farm environmental risk management tools

In farm environmental risk tools, the focus is on the prevention of farm environmental impacts and quality losses in the environment (Table 5). Administrative provisions and regulations are common management tools in farm environmental management for authorities, but also provide information and opportunities to farmers concerning environmentally friendly farm management practices. For example, agrobiodiversity is a

‘free’ environmental commodity that is supported and protected by EU subsidies (Baumgartner and Quaas 2010). However, policy makers should note that some agro-environmental indicators may have a poor performance ability in the environment, which could also be an environmental risk in agriculture (Makowski *et al.* 2010). Criteria and measures for sustainable agriculture are then essential (Eckert *et al.* 2000).

Animal production impact studies have included tools for manure management, preventing manure pathogens from causing human diseases (Kai *et al.* 2008; Goss and Richards 2008). A good example of an eco-tool for controlling environmental risks on animal farms is a

Table 5: Studies concerning environmental risk management tools

Focus	Risk management tools	Author
Administration provisions	Environmental regulations, sustainable farming standards, subsidies, agroecosystem and biodiversity management, conflict resolution	Pannell 2011; Baumgartner and Quaas 2010; Makowski et al. 2010; Janssen et al. 2010; Atari et al. 2009; Eckert et al. 2000; Wagner 1999
Animal production impacts	Manure and fertilizer management, greenhouse gas management, acidification, pathogen pathway models, environmental impact simulation	Kai et al. 2008; Goss and Richards 2008; Duru et al. 2007; Topp and McGeachan 2003
Crop production impacts	Agro-environmental indicators (e.g. ROC, AUC), machinery emission management, land and water emission management, environmental impact assessment (EIA), sustainable land use	Makowski et al. 2010; Cupera and Smerda 2010; Bachinger and Zander 2007; de Vos et al. 2006; Lacroix et al. 2005; Fuhrer and Booker 2003; Zentner et al. 2002; Coale et al. 2002; Bouma 2002
Toxic chemical emissions	Pesticide management, certificate systems, buffer zones, sprayer cleaning and maintenance, information, pollution and chemical exposure management	Popp 2011; Harnly et al. 2009; Reichenberger et al. 2007; Sanchez-Bayo et al. 2002
Environmental management	Waste management programs, GIS, environmental risk calculations, environmental SWOT, agroecological information system (AIS), stewardship programmes, risk scenarios	Río et al. 2011; Janssen et al. 2010; Atari 2008; Goss and Richards 2008; Meinke et al. 2001; Lang et al. 1995; Wossink et al. 1992
Environmental education and skills	Educational programmes, resource analysis team, whole-farm planning, risk pathway models, accounting precautionary measures, information, low-input agriculture business plans	Clancy and Jacobson 2007; Summers et al. 2008; Wagner 1999

method involving the addition of sulphuric acid to slurry manure to reduce harmful air emissions and smell problems in the neighbourhood of pig farms. This method is classified as a Best Available Technology (BAT) in Denmark (Kai *et al.* 2008).

Crop production impact management includes simulation tools to analyse nutrient management to control water emissions (eutrophication) (de Vos *et al.* 2006), optimal crop rotation, conservation tillage and soil quality in plant production (Bachinger and Zander 2007; Zentner *et al.* 2002). Farmers could also use climate risk tools to analyse machinery fuel consumption and emissions to the atmosphere in the form of ozone gases (Cupera and Smerda 2010; Fuhrer and Booker 2003). Toxic farm chemical exposures have frequently been linked to pesticides used in crop management on farms. Buffer zones, constructed wetlands and subsurface drains reduce the negative effects of pesticides and potential spraying releases of ecotoxic and genotoxic chemicals on farms (Reichenberger *et al.* 2007). The cleaning of sprayers and hygiene management after spraying and during the spraying period control the risk of pesticide dust exposure in farm houses. For example, storing of work shoes in the home increases the risk of toxic chemical expose. (Harnly *et al.* 2009).

A holistic approach was common in the environmental risk management studies analysed in this review. With the help of computer-aided calculations, researchers, farmers and policy makers can improve data handling in order to control environmental risks, but also improve the integration of various risks. These computer tools include environmental system modelling and simulation models (Janssen *et al.* 2010) and geographic information system (GIS) applications (Rio *et al.* 2011). Areal spread maps are useful for farmers, showing the possible risk areas of farm crop diseases (Wagner 1999).

Farm environmental risks have long-terms areal effects, which make them a difficult problem for the future. Different climate, soil and cultural regions may require site-specific approaches to sustainable risk management (Meinke *et al.* 2001). Risk identification does not solve

any problems without practical tools for controlling environmental risks. Environmental SWOT analyses carried out on farms include risk identification, but also identify possible business solutions for farms (Atari *et al.* 2009). Multidisciplinary risk workshops and farm-specific plans have been reported as useful tools in some agro-environmental programmes, but new skills and tools for farm environmental management are required (Summers *et al.* 2008; Clancy and Jacobson 2007).

Economic risk management tools for farms

The economic risk management tools for farms in this review could be divided into administrative provisions, contracts or insurances to protect against uncertain future events, risk models to help in decision making, economic management control and network management (Table 6). A holistic and general farm view was common in economic risk management tools identified in this study. Often, the economic tools were applicable for both crop and animal farms. A commonly acknowledged financial risk is that farm production may not generate sufficient revenues to cover the costs of production or service farm debts (Franks 2010; Hardaker *et al.* 2004).

A farm owner needs to be aware of and understand policy regulations and institutional boundaries in farming, namely legislation, tax systems and subsidy systems (Jung 2001). Farmers in the EU face subsidy changes as an institutional risk (Flaten *et al.* 2005) or the risk of financial sanctions for breaching the subsidy terms and conditions (Jung 2001) and liquidity problems because of credit risk (Franks 2010). Insurances or subsidies for the main agricultural crisis risks such as animal disease epidemics are important risk management strategies (van Asseldonk *et al.* 2004). Choosing a relevant strategy for a farm is a complicated task. Basic strategy examples and risk management models are already available to assist the farm manager in decision making (Hardaker 2006; Hardaker *et al.* 2004). Farmers need easy-to-use tools, especially for economic risk management and strategic planning.

Table 6: Studies concerning economic and financial risk management tools for farmer use

Focus	Risk management tools	Author
Administration provisions	Risk management strategies, accounting tools, diversification, off-farm incomes, regulations, subsidies, tax management	Franks 2010; Schaper <i>et al.</i> 2010; Špička <i>et al.</i> 2009; Lacroix <i>et al.</i> 2005; Asseldonk <i>et al.</i> 2004; Flaten <i>et al.</i> 2005; Jung 2001; Wossink <i>et al.</i> 1992
Contracts, insurances	Hedging, contracting, insurances, diversification, spreading sales, risk strategy portfolio, holding reserves, expert simulation system (ESS), public-private partnerships, what-if analyses	Cole and Kirwna 2009; Velandia <i>et al.</i> 2009; Pennings <i>et al.</i> 2008; Berg and Schmitz 2008; Key and MacDonald 2006; Asseldonk <i>et al.</i> 2004; Meuwissen <i>et al.</i> 2001; Helms 1990
Risk modelling	Risk modelling software programs, risk strategy portfolios, utility function techniques, linear programming, multi-risk analysis tools, risk prioritization, risk sharing, diversification	Barnett and Coble 2009; Ogurtsov <i>et al.</i> 2008; Nartrea & Webster 2008; Huirne 2007; Hardaker 2006; Hardaker <i>et al.</i> 2004; Stott <i>et al.</i> 2003; Wossink <i>et al.</i> 1992
Management controls	Risk management systems, indicator selection, vulnerability check, HACCP, resilience planning, complexity handling, choice bracketing, disease controls, cost management, solvency ratio	Kleter and Marvin 2009; Haen 2008; Pennings <i>et al.</i> 2008; da Silva <i>et al.</i> 2008; Lien <i>et al.</i> 2006; Flaten <i>et al.</i> 2005. Meuwissen <i>et al.</i> 2001; Noordhuizen and Frankena 1999
Networking and management skills	Collaboration, education, skill management, mentoring, change management, web tools, strategy map, 7 business principals, choosing indicators, specification techniques, worker management, marketing pools, forward and direct selling	Malcolm 2011; Nuthall 2010; Schaper <i>et al.</i> 2010; Olsen <i>et al.</i> 2009; Pennings <i>et al.</i> 2008; Lund <i>et al.</i> 2005; Parker 2000; Martin and McLeay 1998; Harwood 1999; Beal 1996

In the case of price risk and volatile product prices in the market, a farmer can enter into a contract with co-producers to fix certain product prices (Velandia *et al.* 2009). The product yield risk can be managed, for example, with suitable farm product insurances (Velandia *et al.* 2009; Jung 2001). Variables affecting the adoption of these risk management tools were proportion of owned acres, off-farm income, education, age, and level of business risks (Velandia *et al.* 2009). Economic risk analysis and modelling could help farmers with decision-making problems and the prioritization of risks (Ogurtsov *et al.* 2008; Hardaker 2006; Hardaker *et al.* 2004). Computer-based practical software programs that aid farms in risk management are available on the market (Nuthall 2010; Hardaker 2006).

Farm production tasks should be managed in the right manner, time and place; otherwise, part or all of the sales income could be lost. Hazard analysis of critical control points (HACCP), used in many quality management systems, should also include economic and financial critical control points and connect these points in a farm quality check (Noordhuizen and Frankena 1999). In addition, farmers should identify and combine current and future business strengths and risks on their farms to create farm-specific business risk plans (da Silva *et al.* 2006). With the help of choice bracketing, farm managers can deal with the complexity of risks and choose suitable risk management tools tailored to their own farm (Pennings *et al.* 2008). New business network tools using the Internet and communication or participation tools require new management skills from the farm manager, and can also be useful in farm risk management (Nuthall 2010; Lund *et al.* 2005).

4. Discussion

In this study, we listed and analysed risk management studies to find potential tools applicable in managing farm risks. Risk management tools were divided into five categories: asset, production, human safety, environmental and economic management tools. Altogether, a total of 13,559 articles discussing risk management were identified. Of these, 157 articles were selected for closer analysis in order to identify farm risk management tools. This study identified only a part of the available farm risk studies. However, the focus was not on finding all possible farm risk management tools and studies, but on identifying a comprehensive sample of useful studies and tools.

Handling of various risks on farms

The findings from the present review highlight that risk management on farms is a complex task and includes many uncertain variables. While farm risk management tools should aim to help in complex decision making, they should avoid simple one-sided solutions, which may cause more problems than expected (Hall 2007; Robinson 1999). The balance is even more difficult to achieve in complex decisions, when various stakeholders have conflicting interests in farms. The simultaneous handling of many objectives or risks increases the complexity and problems in management. However, farmers prefer simple and relevant management tools (Leppälä *et al.* 2012). While single-risk management tools provide the means to handle one risk at a time, tools for multi-risk management enable holistic risk

Risk management tools applicable in managing farm risks handling, for example in the event of natural hazards (Komendantova *et al.* 2014; Marzocchi *et al.* 2009). According to Komendantova *et al.* (2014), the multi-risk management approach is quite a new type of approach that requires further development and new innovations.

It appears that the holistic risk management approach has been increasingly applied in farm risk management studies during the last two decades. The determination of possible risks is needed in agriculture to help farmers to identify and control the risks on their farms. However, despite the multi-risk management demands in agriculture, comprehensive literature studies listing and analysing farm risk management tools according to the operational research focus of managing multi-risk consequences on farms have been rare. If demands for holistic risk management in agriculture are increasing, we should also have relevant methods and solutions for handling complexity and using holistic risk management tools efficiently on farms. It is known that farmers and other small-scale entrepreneurs have limited time for management duties. A Farm Risk Map has been developed to help farm managers in farm risk identification using a one-page figure and functional risk groups. (Leppälä *et al.* 2012).

Farm risk management tool case

A summary of the literature review results is presented in Figure 1. The holistic risk management tools that were present in all risk tool categories are included the box at the centre, and individual single-risk tools from each risk category are placed around it. Farm managers can use individual risk management tools and various holistic risk management tools simultaneously on their farms. The risk management focus of the tools is on describing the risk management context in various farm risk management studies. The tools in each section are divided into risk management process stages to define how farmers could identify, control or monitor risks on the farm level. This list of risk management tools can be seen as a preliminary example of a farm risk management tool case, whereby a farmer can choose the appropriate potential tools to use in a particular situation.

The results of the review in Figure 1 demonstrate that risks are managed and analysed in the farm risk literature with different types of tools in different categories. Integration in risk management reflects correlations between risks (CAS 2003). Thus, in general, the holistic risk tools in Figure 1 indicate the potential integration tools that can be used in multi-risk situations to identify, control or monitor risks on farms.

The single-risk fields also have individual risk management features. The handling of these risk features may require detailed risk identification or risk prevention. Economic business management risk tools involve analysing and preventing the loss of money, but could have also effects on other risk fields. Risk management in farm work activities requires different types of risk tools. Asset risk management tools aim to protect the investment value of fixed assets on a farm such as estates, land and machinery in a technical engineering manner. Production risk management tools on farms aim to avoid operational and product quality risks in agricultural production activities (crop and animal production). Safety risk management tools identify health risks from places, resources or production

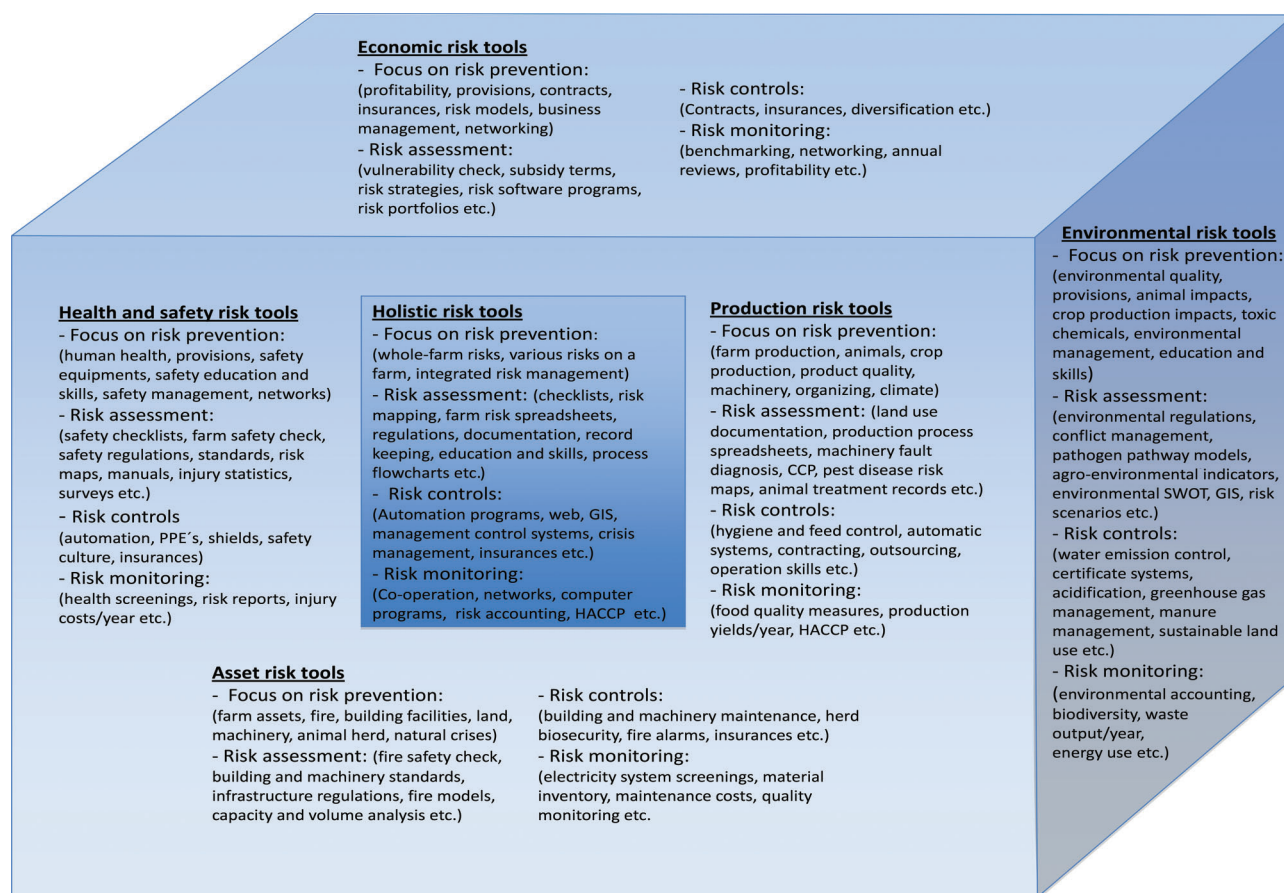


Figure 1: Farm risk management tool case for farm managers

activities and control them with specific safety management tools. Environmental risk management tools are focused on preventing farm environmental impacts and quality losses in the environment. The integration of risk management tools requires skills, methods and knowledge from different disciplines. Essentially, an optimal level of system functioning will not be achieved if system goals and activities are not coherent and consistent, for example in grain harvesting and grain dryer activities. In order to integrate farm risk management tools, the links between the risks should be made visible among farm operations and farm production processes. Sophisticated holistic risk management tools are called for in assisting farm managers in the multi-risk situations that they will face in the future.

The recent farm management literature provides well-developed analysis tools, for example, in insurances, product diversification, contract variables, the tax system, assets and investments, profit variability and cost-benefit analysis for farm risk management (Kay *et al.* 2012; Olson 2011; Nuthall 2010). These tools provide a good basis for the risk management process on farms, but should be more efficiently implemented by farmers, and also efficiently distributed for farmer use, including tools for risk management process stages.

Future challenges

Many farm risk checklists have included important risk indicators based on farm characteristics, the personal

characteristics of farmers, an unsafe working culture, unsafe facilities and unexpected events of natural hazards. However, each risk management category and the 'major hazards' should also include tools for handling the whole risk management procedure, including the identification, assessment, control and monitoring of risks (ISO 31000). The identification of risks is only useful if this knowledge is used in prioritizing risks and risk control activities such as problem fixing on farms.

Usability will be an important issue in the future development of holistic risk management. Risk management tools should be usable and suitable for managing and monitoring particular risks. For example, a continuing challenge for farm managers is to consider and coherently integrate safety, production environment and economic management goals in line with the changing production methods and increasing material volumes. In addition, if a beneficial multi-risk analysis tool is complicated for farmers to use in practice, it will not be adopted on farms.

Biotechnology and other novel agricultural production practices could be practicable but challenging for farms to implement without sufficient information and practical control methods. New risk management tools may have conflicting targets and evaluations in farm production. For example, in the use of biotechnology, a problem seems to be in the integration of economic and production benefits and long-term ecological and safety hazards. A shared vision of appropriate risk management tools would support effective risk

prevention. The development of criteria and measures for sustainable agriculture is essential. Added to this, new knowledge management skills and education are also needed on farms, especially in managing the various risks, in operating in an organisational network with various stakeholders, in ageing and succession stages on farms, in applying new information-handling techniques, computer-aided applications and in implementing new automatic systems in farm activities. Risk management knowledge may benefit farm capabilities and working abilities by providing the farm manager and farm workers with important information on production processes. Information and its efficient use in practice is a key to corporate risk management and corporate economic development (Mingers and White 2010; COSO 2004).

Extant risk management research has commendably succeeded in devising risk management tools for minimizing and eliminating risks on farms. However, sustainable farming policies, especially in European and Nordic countries, are calling for a more holistic risk approach in farming. The integration of different fields of risk management research and cooperation between different researchers is required in order to reap the benefits of the emerging new holistic approach.

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