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Towards increased use of IPM: An investigation of Norwegian grain farmers' pest management practices and decision processes

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Abstract

The last decade, Integrated Pest Management (IPM) has become mandatory in many European countries, but implementation on farm level is lagging and evidence for the barriers and driving forces is lacking. The goal of this thesis was to expand the understanding of how to improve the implementation of IPM by investigating Norwegian grain farmers' pest management practices and decision processes. A survey of 617 Norwegian grain farmers was conducted in addition to in-depth interviews of 24 of the respondents. An IPM index was developed to categorise the respondents according to their use of IPM practices. Having an environmental mindset, being concerned with crop quality, having frequent contact with peers, and a high level of education was found to correlate positively with increased use of IPM, whereas decreased use coincided with having a low farming income and being concerned with entirely eradicating pests. The effect of the local conventions and norms regarding pest management appeared to affect the decision processes of the farmers in ways that presented both barriers to and drivers for increased implementation of IPM. Supporting the integration of the concepts of IPM into what is good farming practices in local farming communities is paramount for increased adoption of IPM.

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Contents

1. Introduction

Modern food systems represent both some of the greatest achievements of human civilizations as well as some of the greatest threats to the sustainability of global food production (IPES-Food, 2016). The main contemporary concerns centre around the need to develop technologies and practices, that do not harm the environment, are accessible to farmers and that lead to improvements in productivity with accompanying positive side effects on environmental goods and services (Pretty, 2008). In order to achieve this, business as usual is no longer an option.

Pest management is an essential part of any crop producing operation, as it aims to prevent pest damage in the form of any decrease in the quality or the quantity of the crops (Edward-Jones, 2007). The introduction of the large-scale use of chemical pesticides in the mid-1900's revolutionised pest management in modern agricultural operations (Peshin & Pimentel, 2014). Regretfully, misuse of pesticides has been shown to have detrimental consequences for human health, the environment and the future opportunities of farming the land (Millstone & Lang, 2013). It has proven to be connected to a plethora of issues such as a decline in biodiversity (van der Sluijs et al., 2015), reduction in insect pollinator populations (Lexmond et al., 2015) and worsening farmers' health (Millstone & Lang, 2013). Nevertheless, the pest control offered by pesticides, in current systems, might be essential to maintaining satisfactory crop yields. Cooper and Dobson (2007) pointed out that pesticides provide the benefits of effectively controlling pests and preventing diseases resulting in increased yields, improved quality and among other things, reduced health hazards. Alongside other advances in pest management, pesticides have contributed to an increase in yields by 70% in the EU and 100% in the U.S. since the 1960's (Chandler et al., 2011). In the same time-span, even though global population growth has been monumental, global food production has outpaced it such that there is 25% more food per capita these days. (Hazell & Wood, 2008). It is still important to not allow the historical benefits of pesticides to decide our future policies. As Edward-Jones (2007) stated, it is not necessarily the pesticides themselves that are creating the benefits, more often than not it is the pest control it provides. Integrating the desired pest control into a cropping system less dependent on pesticides is therefore necessary in order to ensure sustainable food production (Barzman et al., 2015).

Integrated Pest Management (IPM) is a method for controlling pest populations in crop production systems while reducing the associated economic, human health and environmental risks (Farrar et al., 2016). The strategy could arguably be used to aid an improvement of the sustainability of future agricultural production systems, environmentally by lowering chemical inputs, and economically by lowering the costs of buying pesticides. Although, lowering the use of pesticides might come at the cost of risking lower yields.

Pretty (2008) found that data from 62 IPM initiatives in 26 different countries indicated that these initiatives coincided with reduced pesticide use, and most of the initiatives showed an increase in yields while reducing pesticide use. This indicates that there is no certain correlation between pesticide use and yields. Of the few IPM initiatives where yields fall slightly but pesticide use drops dramatically, most were cereal-based productions in Europe (ibid.) However, given the hazards caused by the use of pesticides in these production systems, there might still be good reasons to advocate increased use of IPM despite a small decrease in yields. Although the reduction of pesticides is a desired outcome of IPM, Ehler (2006) warned against what he called "the other IPM" (Integrated Pesticide Management), where the reduction of the use of pesticides becomes the end itself. He deemed this dangerous, as it might lead to a "quick-fix mentality" where the root causes leading to unsustainable practices might be overlooked. Consequently, reduced pesticide use should come as a result of increased use of IPM and not the other way around.

IPM has been endorsed as the future paradigm for crop protection by many national and intergovernmental bodies (Stenberg, 2017). In the U.S., where IPM originated, national governing bodies have a long history of promoting the strategy. The U.S. Congress has supported large-scale IPM programs since the 1970s, and in the 1990s, the government established a national goal of reaching implementation of IPM on 75% of their crop area. Despite these efforts, implementation has been lagging (Ehler, 2006; Lefebvre et al., 2015; Puente et al., 2011). In the EU, since 2014, all professional users of pesticides (e.g. crop farmers) are obliged to follow the eight general principles of IPM (Lefebvre et al., 2015). Initially, the implementation of this obligation proved difficult as most member states had not yet fully operationalized or implemented the directive in time (Hokkanen, 2015; van der Sluijs et al., 2015), and although adoption of IPM might be more common in orchards and protected production systems, in arable and field crops the adoption remains marginal (Lefebvre et al., 2015).

This apparent lack of implementation is either a symptom of the farmers not choosing to use the practices related to IPM or a symptom of lacking assessment methods of the adoption (Puente et al., 2011). Due to the history of IPM as a universal, overarching concept and its multiple context-specific interpretations, measuring the degree of IPM implementation is very difficult (Ehler, 2006). There have been several attempts to quantitatively measure the use of IPM among farmers world-wide, either by farmer self-evaluation, scoring based on a weighted sum of management practices, or other methods (Hammond et al., 2006). Many of these have attempted to quantify the use of IPM relative to an arbitrary limit or ideal such that either the farmers are ranked on an IPM-scale or the farmers' practices are judged as IPM or not. Given the complex nature of IPM as a concept, any such ideal or arbitrary limit is debatable, since every farmer operates in a specific context. However, if the goal is to increase the use of IPM regardless of the degree of implementation, instead of comparing the farmers to an ideal or a limit, the scores might be used to investigate what causes certain farmers to decide to use more IPM practices than others do. In fact, that is precisely what was intended in this investigation.

A lack of understanding of farmers' decision processes was suggested by Hashemi and Dalamas (2010) as potentially explaining the lagging implementation. In order to empower farmers to implement sustainable agricultural practices that are now mandatory, there is a need to understand why farmers use their current pest management practices. In the conclusion of a global assessment on the harm of neonicotinoids (van der Sluijs et al., 2015, 154), the authors called for research on these issues: "There is a need for research to obtain a better understanding of the institutional and other barriers that hamper large-scale adoption of proven sustainable agricultural practices…"

The aim of this investigation was to expand the understanding of how to improve the implementation of IPM by investigating Norwegian grain farmers' pest management practices and decision processes. The following research questions were posed:

1. *To what extent do Norwegian grain farmers apply the eight principles of IPM?*

2. *What explains the variation in their use of IPM?*

3. *What characterises their pest management decision processes?*

To assess the extent of IPM implementation among the Norwegian grain farmers, their pest management practices were characterised according to the eight principles of IPM. The characterisation was based on the results of a survey of 617 of the farmers and in-depth interviews of 24 respondents. An IPM index was developed, which was used to examine the variation in the farmers' degree of IPM use. The variation was examined with variables from the questionnaire data, supported by the data from the interviews. The reasons behind the farmers' practices were examined by characterising the pest management decision processes of the interviewed farmers.

2. Background

This investigation was conducted in the context of Norwegian grain farming, where IPM has been promoted for many years. The incorporation of the legislation making IPM practices mandatory in 2015 is a key antecedent to the SMARTCROP research project this investigation is a part of. The interdisciplinary research project is aimed at researching innovative approaches and technologies for IPM in Norwegian agriculture. However, there are key antecedents to the incorporation of the IPM legislation that will be explained in the following chapter.

2.1 Definition of IPM

Integrated farming practices have been researched and discussed for many decades and the idea dates back to the 1920's (Morris & Winter, 1999). Since then, there have been countless definitions and terms used to describe the same concept. Lamine (2011) claimed that despite sharing the same basic principles, there is still some semantic confusion between similar terms. Despite this confusion, over the course of the last century, integrated farming practices have been cemented in the term IPM. As it best suits the context of this investigation, the definition of IPM used is the one given by the European Parliament in the Directive on the sustainable use of pesticides (EP/Rdir. 2009/128/EC):

> *Integrated pest management' means careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourages the development of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimise risks to human health and the environment.*

Additionally, the directive described eight principles of IPM acting as guidelines for practicing IPM. These principles are central to the structure of this investigation and are listed in the table below (table 2.1).

Table 2.1: The eight principles of Integrated Pest Management and examples of related practices. The shaded row indicates the timing in the sequence where intervention is found to be necessary or not. (Barzman et al., 2015)

	Principles	Description
I	Prevention and suppression	Crop rotation, adequate cultivation techniques, resistant cultivars, balanced fertilization, liming and irrigation/drainage.
II	Monitoring	Observations in the fields, scientifically sound warning, forecasting and early diagnosis systems.
III	Decision-making	Region and area-specific threshold values for intervention are essential.
Pest intervention necessary		
IV	Non-chemical methods	Sustainable, non-chemical methods must be preferred to chemical methods if they provide satisfactory pest control.
V	Pesticide selection	If pesticides are necessary, they should be target specific and with low side effects.
VI	Reduced pesticide use	The use of pesticides should be kept as low as possible without increasing the risk of the development of resistance.
VII	Anti-resistance strategies	Strategies should be applied to maintain the effectiveness of products and may include using pesticides with different modes of action.
VIII	Evaluation	The success of the applied plant protection measures should be evaluated.

An important aspect of these principles is their temporal hierarchy, meaning that certain principles should precede others. Based on how Barzman et al. (2015) described what they called the sequential rationale of IPM, four sequential elements were derived. First comes the element of preventing and suppressing the pest populations, which mainly occurs before and at the beginning of the growing season (Principle 1). Second, the pest situations are to be monitored (Principle 2), and based on a sound decision process, a choice of whether to intervene or not should be made (Principle 3). This decision (marked as the shaded row in table 2.1) is very important since it is the trigger for the third element. The third element of the sequence consists of intervening against the pest populations where the least disturbing control options should be considered first (Principles 4-7). This element is the only one that is optional. Ideally, the preventive and suppressive measures should be enough to keep pest levels below the threshold where intervention is necessary. The last element of the sequence consists of looking back at the actions taken during the season and considering if improvements can be made (Principle 8). The temporal hierarchy is not absolute, as one element of the sequence does not necessarily begin where another one ends. If, for instance, an intervention is necessary, it does not end the element of monitoring. Subsequently, the evaluation of that intervention might begin shortly after and does not have to wait until the end of the season. In the same way that the content of the principles serves as guidelines for the practices of farmers, the rationale explained above could serve as a guideline for their decision processes.

Although these principles suggest certain specific pest management practices, the general principles should be adapted and interpreted in the context where the pest management is taking place. For instance, irrigation is important in dry climates, whereas in Norwegian grain production, the practice is rarely required due to the relatively wet climate. Nevertheless, the principles and the suggested practices serve as a basis upon which a context-specific IPM practice can be built. The goal of implementing IPM is to provide farmers with the necessary tools for dealing with a complex pest situation and managing the pest that they do have, not the pests that they might have (Tooker, 2015). In line with Barzman et al. (2015), I suggest that one should not only focus on the practical tools, but also the decision processes related to the practices.

The broad and extensive definition of IPM as given by the EU directive and the related eight principles emphasises sustainable (both economically and ecologically) crop production with minimal risk to human health and the environment. As a brief summary of the history of the term demonstrates, the focus has not always been this all-encompassing.

2.2 The history of IPM

The precursor of IPM, “The Integrated Control Concept”, was first documented in a scientific journal in 1959 (Hofsvang, 2010). The definition the entomologists from California gave of the concept was: “Applied pest control which combines and integrates biological and chemical control” (Stern et al., 1959, p. 86). At that time, Stern et al. (ibid.) were concerned with what they claimed the major issues that widespread use of insecticides had caused in the U.S, such as increased resistance to pesticides, toxic residues on food and forage crops and hazards to those applying pesticides. Based on the assumption that many farmers generally applied too much insecticide, they argued that the proper solution was an integrated control based on economic thresholds and economic-injury levels. The idea was that if reasonable thresholds for pesticide intervention were followed, the overuse would cease. This is far from the preventive focus of contemporary IPM.

In the 1960s, following the pioneering stage of the integrated control concept, a rivalling concept with more focus on suppressive tactics, called “pest management”, gained popularity (Ehler, 2006). Despite the differences between the two, they soon became synonymous, and a landmark symposium hosted by the United Nations Food and Agricultural Organization (FAO) (1967, p. 19) defined integrated control as:

> ***Integrated*** *control is a* ***pest management*** *system that in context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economic injury.* (My emphasis added).

Progressing from the seminal definition of the concept given by Stern et al. (1959), the FAO panel of experts broadened the definition to include not only biological and chemical control directed towards controlling insect pests, but “all suitable techniques and methods” controlling “pest populations”. As emphasised, the symposium contributed to the merging of the broader term of pest management with the narrower integrated control concept. However, it was not until 1972 that the term “Integrated Pest Management” with its famous acronym was launched (Kogan, 1998). The following 30 years, despite a few efforts to fragment the concept, efforts were concentrated on implementing IPM rather than debating the concept itself (ibid.).

2.3 European agricultural policy changes

Regardless of the assessment methods, implementation of IPM is dependent on farmers actually adopting the practices related to the concept. Influencing behavioural change at farm level, which is needed in order to increase the use of IPM, is a clear aim of agricultural policies and its connected payments (Sutherland et al., 2012). In Western countries, in the 1990s, agricultural payments took a turn towards emphasising the multifunctional nature of agriculture and agricultural land (Kvakkestad et al., 2015). This indicates an inclusion of negative externalities such as pollution in what agricultural operations produce. In a report on Nordic agriculture, multifunctional agriculture was summed up as: “Multifunctional agriculture implies that agriculture delivers a combined set of private and public outputs like food products, landscape values and pollution.”(Prestvik et al., 2013). The Common Agricultural Policy (CAP) reform of 2003 led to an increased emphasis on “ecologization” of agriculture and strengthened schemes which compensate farmers economically for conserving nature and reducing the negative externalities (Burton & Paragahawewa, 2010; Lamine, 2011). Subsequently, the 2013 reform further improved the ecological requirements of the CAP, making diversification of production a requirement for receiving subsidies (IPES-Food, 2016) The increased focus on agriculture as something more than a service to provide food opened up for the inclusion of environmental and ecological rationales for policies such as the directive making IPM mandatory (Lefebvre et al., 2015).

Since the late 1990s, parallel to the development in other European countries, the multifunctionality of Norwegian agriculture has been essential in state policy (Kvakkestad et al., 2015). Simultaneously, attempts of implementation of more sustainable pest management strategies have been clear goals from Norwegian governments (Heggen et al., 2005). The Norwegian government decided to incorporate the EU directive on the sustainable use of pesticides, making IPM practices mandatory for all farmers as of June 1st, 2015. It is mandatory to the extent that farmers are obliged to acquire insight into the methods of IPM, apply the general principles and provide documentation of their practices (Plantevernmiddelforskriften, 2015). The principles had to be adapted to the Norwegian context as the methods of IPM are different in Norway than other European countries.

2.4 Norwegian agriculture

Agriculture accounts for less than 1% of the Norwegian GDP and is thus a small sector of the economy (Knutsen et al., 2016). Additionally, due to the short growing season and poor soil qualities in Norway, compared to neighbouring countries, domestic agricultural production has been reliant upon toll barriers in order to compete with foreign imports. Government intervention is very high in Norway. Recently the high degree of public involvement in farming has been called into question, especially by people from urban areas (Mittenzwei et al., 2016). However, a recent poll showed an immense support for Norwegian agriculture in the general population as 91% fully or partly agrees that domestic food production is important (Agenda & AgriAnalyse, 2017).

Agricultural production covers 3% of the land area in Norway. Of the approximately 1 million ha of agricultural land, 66% is covered by pastures, 4% is covered by vegetables and grain production accounts for 29%, or 290 000 ha of the total agricultural area (Bye et al., 2017). Compared to other countries in Europe, Norwegian grain production is small with the average area of grain production in the 28 countries in the EU being approximately ten times as high as Norway's (Eurostat, 2018a). Norwegian grain production is characterised by relatively small units producing mostly cereal grains. The main grain types produced are barley, oats and wheat, which in 2016 respectively accounted for 48%, 27% and 23% of the grain area (SSB, 2018b). 80% of the total grain production in Norway goes to animal fodder (Knutsen et al., 2016). In the last few decades, the grain area in Norway has remained stable, farms have increased in size and the number of farmers has consequently dropped (Storstad & Rønning, 2014). The structural changes of the farms primarily resulted from small farms being either leased or bought, making larger farms more common.

The grain farmers are mostly situated in the south-eastern and middle parts of Norway. This is partly due to better climatic and soil conditions, but also a consequence of a series of political changes to the farm payment system[1] in the 1950s. In 2016, the six south-easternmost counties (Østfold, Akershus[2], Hedmark, Oppland, Buskerud and Vestfold) accounted for 79% of the grain area and 82% of the total yield (SSB, 2018b). The remaining 21% of the grain area is mostly concentrated in the county of Trøndelag.

Norwegian farmers have vastly decreased their use of pesticides the last decades. However, this is mainly due to the switch to herbicides with a higher concentration of active substance (Aarstad & Bjørlo, 2016). Despite the long-term decrease in pesticide use, as figures 2.1 and 2.2 illustrate, the use of herbicides has risen in the last decade.

[1] Referred to as «Kanaliseringspolitikken» in Norwegian.
[2] Data from Oslo County is included in Statistics Norway's definition of this county, whereas in this investigation Oslo was not included.

In grain production, the use of glyphosate to combat couch grass and other perennial weeds during the fall has increased and now accounts for twice the amount of active substance as other herbicides (ibid.). This indicates that there is a potential to take measures to decrease the use of pesticides in Norwegian agriculture.

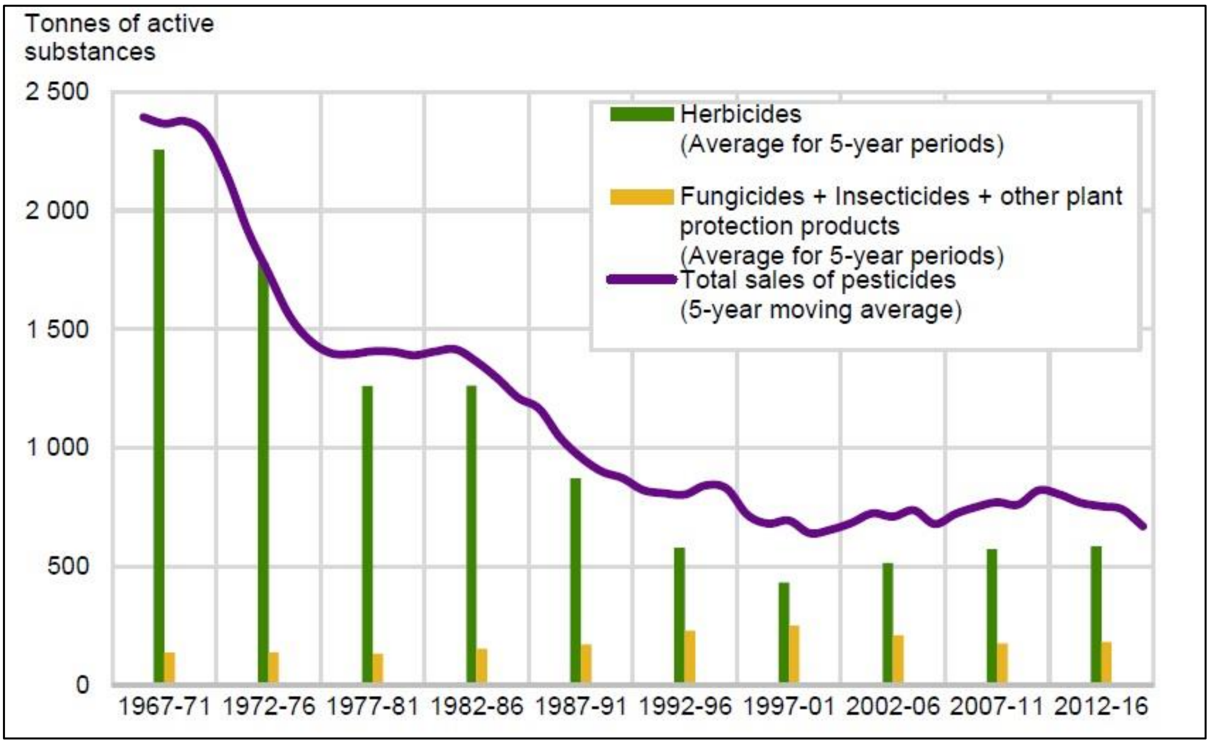

Figure 2.1: Sales of pesticides, average for 5-year periods measured as tonnes of active substances. (Bye et al., 2017, p. 21)[3].

Even though the highest number of pesticide application per season is in apple, strawberry and vegetable production, grain production covers a much larger area and accounts for most of the pesticide use (Bye et al., 2017). An assessment of the health and environmental risks of pesticide use in Norway showed that although grain production only accounted for around 30% of the agricultural area it produced most of the health and environmental risks associated with pesticide use (Refsgaard et al., 2006). These risks were mainly caused by the use of fungicides and herbicides in grain production.

[3] Reproduced with permission by the author.

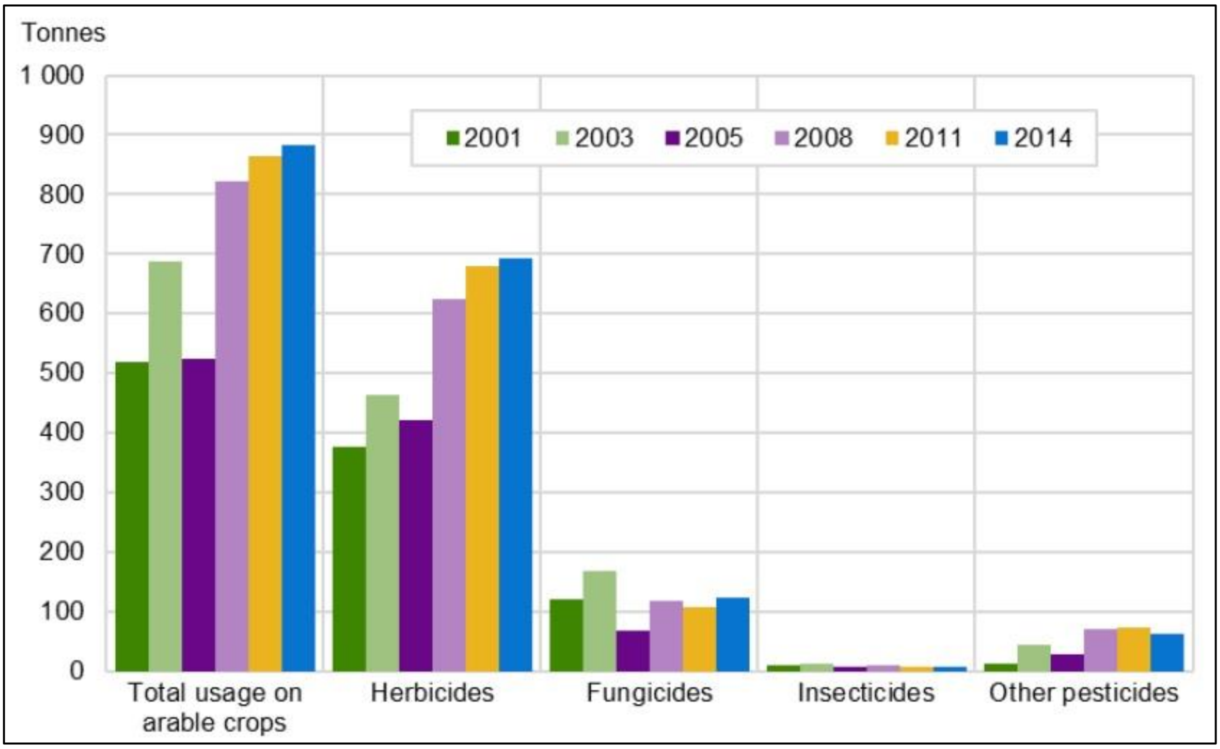

Figure 2.2: The use of pesticides of arable crops in Norwegian agriculture, measured as tonnes of active substances (Bye et al., 2017, p. 21)[3].

Figure 2.2 shows that the use of herbicides accounts for approximately 78% of the total use of pesticides on arable crops in Norway and the remaining 22% consists mostly of fungicides and growth regulators. Many of the most severe side effects of pesticide use in agriculture come from the relatively high use of insecticides in other countries. Interestingly, compared to other European farmers, Norwegian grain farmers mostly manages to grow their crops without the use of insecticides (Eurostat, 2018b).

2.5 IPM in Norway

In Norway, integrated farming strategies have been researched and practiced since the 1960s, although most of the effort has been concentrated in greenhouse fruit and vegetable production (Hofsvang, 2010). Around the year 2000, as a response to a governmental white paper, IPM guidelines specific for Norwegian agriculture were developed along with an index designed to measure the degree of IPM implementation (Heggen et al., 2005). The attempt to measure the implementation of IPM with the index allegedly failed due to it being too "bureaucratic" to be taken into use by the farmers (Stabbetorp, 2015). Less extensive attempts at measuring the implementation of IPM in Norway have been made in the form of proxies from survey data. Results from a survey conducted in 2003 showed that of farmers reporting to have reduced pesticide usage, they mostly did not attribute it to IPM (Hofsvang, 2010). Surveys conducted in 2003, 2008 and 2014 have all asked farmers about their knowledge of IPM. However, throughout that time span, increase in the knowledge of IPM has been absent with the percentage of farmers reporting to know IPM well, being respectively 23%, 30% and 20%[4] (Hofsvang, 2010; Kvakkestad & Prestvik, 2016). Results from the study in 2014 indicated that there was a potential to increase the knowledge and incorporation of IPM practices as 59% of the respondents did not know any farmers who used IPM (Kvakkestad & Prestvik, 2016). Although implementation of IPM might be difficult to measure, these are indications of the potential for increased adoption of IPM among Norwegian grain farmers. Since IPM practice became mandatory for farmers in Norway in 2015, there have been no documented attempts at measuring the implementation[5]. However, alongside other European countries, Norwegian authorities have lately increased their efforts to implement IPM by focusing on increasing farmers' knowledge and reducing their dependency on pesticides (Barzman et al., 2014).

[4] As opposed to the other surveys, this survey was conducted exclusively of grain farmers.

[5] Except the thesis work of Stabbetorp (2015). However, she did not have time and resources to properly adjust the measurements and thus I did not further evaluate her measurements.

3. Theory

In addition to studying the Norwegian grain farmers' pest management practices, in this investigation, the reasons behind their practices, namely their pest management decision processes will also be scrutinised. Individuals' decision processes may be guided by different logics – or rationalities. The word 'rational' bears different meanings in different societies and cultures, but stems from the Latin word 'rationalis' meaning reckoning or reason. Attempting to understand what characterises Norwegian grain farmers' pest management decision processes, a view on rationality based on institutional economics was developed. Added to that, in the complex context of pest management, the farmers are expected to be boundedly rational.

3.1 Decision processes lead to choices

The process of deciding leads to the moment where a choice of behaviour is made. In the words of the late philosopher Alan Watts, "Choice is the act of hesitation that we make before making a decision." He implied that the determining factors behind behavioural choices have already occurred at the moment of choice, making the act of choosing have merely a ceremonial function. When the time of choosing arrives, the decision is already made. This distinction is in my opinion useful, as it highlights one thing that was investigated in this thesis, namely the antecedence of the pest management practices of farmers. Registering what the farmers do reveals their patterns of choice, whereas understanding why they made the particular choices reveals their decision processes. The decision process can be described as a series of events occurring before a particular choice is made, but how those events affect the outcome of the decision process varies. As an example, a grain farmer might instantly choose to rush out and spray her wheat field with fungicides in response to a forecast of rainy weather. Thus, the final event in the decision process, which was the registering of the forecast, ended her hesitation about whether or not to spray her fields. However, that does not adequately describe the intricate decision process behind that choice. She might have multiple motivations for choosing to spray her field, ranging from the aversion for risk of economic losses due to a fungal pest outbreak, the motivation to act according to the conventions and norms of her society or she might have recalled a previous instant where the improper response to the forecast led to a severe pest outbreak. These motivations may be a part of her rationality, which is guiding her decision process regarding whether or not to spray her fields. Prior to addressing the proposed rationalities of Norwegian grain farmers, central views of rationality are discussed.

3.2 Universal rationality

The theory of rational choice, which is the basis of neoclassical economics, is deeply entrenched in the structures and institutions of modern societies (Jackson, 2005). This is the type of rationality stereotypical corporate executives talk about when they state that, "We have to rationalise our operations." According to the neoclassical economic model, in order for a choice to be rational, it must abide by the core principles of maximising expected utility with complete, transitive and continuous preferences of choice. These guidelines for how to behave rationally are universal and have only one form, and making rational choices by maximising individual utility is the essence of this model (Vatn, 2005). For a person to behave rationally in the neoclassical sense of the word, s/he has to stick to her preferences independent of the context. However, unless one is content with a model explaining most people as irrational, this theory of rationality poorly describes how people actually make decisions.

During the last half-century, many scholars have criticised the theory of rational choice (Jackson, 2005). Distinguishing between the normative and the descriptive strengths of the theory has been at the centre of the debate. Elster (1986, p. 1) described its normative nature as: "The theory of rational choice is, before it is anything else, a normative theory. It tells us what to do in order to achieve our aims as well as possible. It does not tell us what our aims ought to be." According to this view, each individual has their own aims, but the rational means of getting there are universal. However, it is in applying this normative framework to the real world, as a descriptive theory, that many proponents of the theory of rational choice make an error. This claim is supported for instance by the closing remarks of Peterson's (2017, p. 321) introductory book on the theory: "Surely, people could learn more about decision theory and eventually become more rational. In fact, this textbook is part of an attempt to make this happen." Like many others, he suggests that people should aim at being more rational, and in the eyes of neoclassical economics, the attempt to become more rational is analysed as a profit or utility maximising endeavour (Vedeld & Krogh, 1999). This leads to a situation where a failure to aim at maximising utility is a failure to be rational, thereby juxtaposing Elster's description where the theory does not tell people what their aims ought to be. However, there are alternative views on rationality, such as institutional economists' position, emphasising that what is rational depends on the social context within which decisions are made.

3.3 Non-universal, context-dependent rationalities

As opposed to neoclassical economists, institutional economists base their understanding of human behaviour on the theory of social construction. It explains people more as being directed by the norms, values and expectations of their societies, and less as autonomous utility maximisers (Vatn, 2005). Leaning on Berger and Luckman's (1967) way of defining social construction, not only does society inform people of which norms, values and expectations to hold, but through a reciprocal typification, individuals shape and negotiate these things with the societies they are a part of. The societies and their institutions are products of humankind and are not universal, but tied to the historical context of the societies. This brings with it a view of rationality which, as an alternative to a universal one, is socially contingent, socially created and recreated (Vedeld & Krogh, 1999). From a social constructivist's viewpoint, there is room for several rationalities, depending on the context.

3.4 Institutions

Institutional economics aligns with the view on individual rationality as being context-dependent, and therefore of different kinds. As opposed to neoclassical economists seeking to maximise individual utility, institutional economists seek to investigate the institutions governing people. In this investigation, Vatn's (2005, p.60) definition of institutions is used:

> *Institutions are the conventions, norms and formally sanctioned rules of a society. They provide expectations, stability and meaning essential to human existence and coordination. Institutions regularize life, support values and produce and protect interests.*

In this tradition, institutions are socially constructed through the processes of externalization, objectivation and internalization and these processes are continually ongoing as people both shape institutions, and are shaped by them (Vatn, 2005). These processes and the institutions need further explanation.

From the definition of institutions, there are three distinguishable categories. First, we have the conventions, dealing with how something is done in a social group. In a certain agrarian region, people do not consume unpasteurised milk. This is an example of one of their conventions on the same level as the convention that they drive cars on the right side of the road. This institution, as any other, has been constructed within the society through the course of a shared history of reciprocal typification (Berger & Luckmann, 1967). Adding the word “should” yields norms. In the same region, there might be a norm implying that one should not consume unpasteurised milk, as it might result in the transfer of harmful diseases. In this way, norms simultaneously represent and protect what is considered the right thing to do in society and thus reveals its values (Vatn, 2005). The last type of institution is formally sanctioned rules adding the “if else”-dimension. A group of newcomers to the region might begin to sell unpasteurised milk despite the norm or convention against such a practice. This might prompt the region to enforce a law (formally sanctioned rule) against selling unpasteurised milk by stating that “unpasteurised milk is not to be sold, if else, there will be a fine issued to the perpetrator”. Formally sanctioned rules are meant to protect the interests of the society, or a dominant group in that society, whenever there is a conflict of interest (ibid.). The three types of institutions are both internalized into individuals but also produced by them. In fact, the institutions’ survival depends on their constant reproduction by the people in the society (Screpanti, 1995).

Parallel to the reciprocal typification of actions, the actors are indeed also typified as institutions, and the types of actors are labelled as roles (Berger & Luckmann, 1967). In the example above, a dairy farmer as an institution is someone who does not sell unpasteurised milk. The agrarian region has established the institutions regarding the consumption of unpasteurised milk through externalization (decided to not drink unpasteurised milk), objectivation (decided that it is against a norm or rule to drink unpasteurised milk) and internalization (people in the region accept these institutions). In the same way the farmers in the example, as typified actors, are farmers who do not sell unpasteurised milk, the Norwegian grain farmers are farmers who, as typified actors, follow the institutions of their societies. Given that they do follow these institutions, an investigation of their decision processes is simultaneously a study of the institutions of their respective agrarian societies.

3.5 The problem of uncertainty

The problem of individual behaviour guided by a universal utility maximising rationality arises also when there is uncertainty (Screpanti, 1995). In trying to understand the pest management decisions of individual grain farmers, the normative strengths of the theory of rational choice must not be neglected. The farmers are indeed rational beings who through their farming activities seek to do well economically. Nevertheless, the complexity of the decisions and lack of information about solutions is the justification for adoption of an institutional rather than a neoclassical view of rationality in this investigation. To support this justification, I think Hashemi and Dalamas' (2010, p. 71) summary of the complexity of pest management decisions is to the point:

> *Pest management problems are often complex, requiring detailed information about many factors. The complexity is further compounded by the fact that farmers usually have incomplete information about both the problem and the potential techniques to manage it.*

The complexity of pest management situations makes the attempt to optimise practically impossible, and there is a need to simplify. One way of simplifying is to follow the guidelines of the IPM principles. The guidelines regarding the IPM principles encourage a sequential rationale for managing ones' pest situation. It is sequential, in the sense that every farmer should have a long-term pest management strategy that is split according to the timeline of crop farming. The crux of the matter regarding the pest management sequence is that if prevention and suppression of the pest populations are sufficiently successful, intervention is not necessary. A complete violation of a sequential rationale in the context of this investigation would be if a farmer does not engage in the sequential elements of prevention and monitoring and sprays anyway.

3.6 Bounded rationalities in social contexts

Having incomplete information about a problem and the possible solutions is an inevitable part of operating in the real world, and my main argument for proposing that farmers' rationality is bounded. By introducing the model of bounded rationality, Herbert Simon attempted to close the gap between the normative prowess of the theory of rational choice and the inability of the human mind to comprehend the complexity of the real world (Barros, 2010). Simon (1955, p. 101) stated about the theory of rational choice as a descriptive framework: "Actual human rationality-striving can at best be an extremely crude and simplified approximation to the kind of global rationality that is applied…" The idea of the model of bounded rationality is that individuals transform complex decisions into manageable ones by applying different measures. People proposedly either use satisficing outcomes as guidance instead of optimal ones, replace abstract goals with tangible sub-goals or fragment the decision and use specialists for certain parts (Simon 1979 p. 501 cited in:Vatn, 2005).

The background for the model is the claim that people face both uncertainties about the future and costs in acquiring information, which limits the extent to which maximising expected utility is possible (Jackson, 2005). Given the uncertainties of external factors, a farmer remains uncertain about the effects of a pesticide application and the cost of acquiring more information is an additional problem. Upon investing utility in acquiring more information in order to lower the uncertainty, one can never be certain that the endeavour of acquiring the information will be worthwhile. Not only is it a problem, but a paradoxical problem of self-reference according to Knudsen (1993, pp. 143-144):

> *To make a decision is cost consuming; therefore it must be decided whether it is worth making a decision. But to make a decision implies costs; therefore we must decide, whether it is worth making a decision on whether it is worth making a decision etc.*

My position is, to avoid this infinite regress, we all, intuitively, make the process of deciding far simpler than what is proposed by the theory of rational choice. This is where the societal institutions come into play. Screpanti (1995) argued that in order to simplify decisions, as a first move, individuals will precautionary stick to socially tested options supported by institutions.

He argued that individual rationality in this sense is relative to the given institutions. The question then becomes, what are the institutions that govern Norwegian grain farmers?

3.7 The rationalities of Norwegian grain farmers

According to the theory of social construction and the model of bounded rationality, institutions and the boundedness of rationality explains individuals' motivations for action in any given context. In this view, the Norwegian grain farmers are governed by many conventions, norms and formally sanctioned rules. Some of these institutions might be related to practices regarding fertilization, some regarding other aspects of their lives such as family business and social relationships in the community. What is of concern in this investigation are the institutions governing their pest management practices. I propose that good agronomy, antecedence and contextual constraints are important factors in the farmers' rationalities guiding their pest management decision processes.

Good agronomy is, as developed by Vedeld et al. (2003), "a social institution found among Norwegian farmers." As an institution, good agronomy includes conventions, norms and underlying values expressing the motivations of Norwegian farmers. Vedeld et al. (2003) found that the values underlying what the Norwegian farmers considered to be good agronomy were independence, propriarityship [sic.], proficiency, the management responsibility and production orientation. The farmers realise these values through managing their farms. Having a tight bond to the property of the farm, being able to carry out high-quality work and caring for future generations are examples of elements of farming that were found to be important to the Norwegian farmers (ibid.) However, the economic sustainability of their farming operations, tied to their production orientation, is the bedrock of the farmers' actions, as Vedeld et al. (2003, p. 7) described:

> *A satisfactory economic result, realized through the production orientation, is a precondition to maintain the farm for the farmer. The result may be that the farmers' intention or wish to take care of the nutrients on the farm in an environmentally acceptable way may have to yield for the economic "realities" in terms of securing high yields (high nutrient input) or cutting costs (low investment levels in manure tanks).*

Certain situations might force an internal conflict where one value has to give way for another, but the economic foundation of the farming operations trump the other values. Facing these "economic realities" in the context of pest management, the farmers might in certain situations refrain from the best pest management practices in order to sustain their means of realising the values of good agronomy.

Following the proposition of Norwegian grain farmers' tendency to be guided by institutions such as good agronomy, there might exist good practices regarding pest management that are socially and culturally contingent. These practices enable the farmers to conform to the ideals of good agronomy. Vatn (2005, p. 120) describes such practices as: "While it is impossible to assess and optimize all factors involved when producing a crop…experience is condensed in a set of rules or skills concerning 'what to do when'." The norms tied to the common cultural features of the agrarian societies are thus married with the conventions of how agriculture is practiced. The 'you should till the soil' is accompanied with 'and this is how you should do it'. These tried and tested practices simplify the pest management decisions of farmers, and meanwhile ensure that they remain farmers practicing good agronomy. At the same time, when considering the issue of IPM implementation in order to reduce the environmental impact of farming activities, the farmers might feel morally obliged to sacrifice some of their individual utility/income for the greater good of society. The environmentally sound practices might even become a part of what is considered as good agronomy in the community (Vedeld & Krogh, 1999).

In addition to the farmers being motivated by the institution of good agronomy, there might also be other interesting aspects. Screpanti (1995) pointed out that even though an individual complies with an institution, he or she still has to complete the decision process. In any situation, the decision maker seeks to improve the situation and subjective evaluations, as well as institutions, guide the process (ibid.) Elaborating upon the foundation of viewing the farmers' practices through the lens of good agronomy, I also propose that there are two other aspects worth investigating when seeking to understand Norwegian grain farmers' pest management practices, namely contextual constraints and antecedence.

Apart from socially contingent rationalities, there might be certain contextual factors constraining the possible practices a farmer can perform. Given the context-specific nature of IPM, these constraints are important to consider. Every grain farmer grows her/his crops in an individual context. Even though the institution might motivate them to practice pest management in a certain way, there might be contextual constraints limiting their possible choices. These contextual constraints might, for instance, be soil conditions, climate, time available for farming and available equipment. This is not to say that the institutions governing Norwegian grain farmers pest management practices are not context specific, but that there might be even narrower contextual constraints, specific to the individual farmer that are important when they make decisions.

In order to better understand farmers' decision processes, Lamine (2011) argued that studying the development of farms over a longer period of time is essential. She found that, among other things, antecedence was one of the main conditions for a maintained change to more sustainable pest management practices. In this investigation, the change in practices is not studied. Nevertheless, it might be important to consider the history of the farms and look for antecedents for their practices in the form of the farmers reporting incidents from the past that has an effect of their decision processes today. An example of an antecedent in the context of pest management is a farmer refraining from including oilseeds in his crop rotation due to a bad experience with growing oil seeds in the past. These antecedents are examples of the experiences that are condensed into the conventions of good agronomy, but as individuals farming in individual contexts, the antecedents to their current pest management practices might vary.

The concepts of good agronomy, contextual constraints and antecedents proposedly aids a characterisation of the farmers' reason behind their pest management practices. The concepts are all tied to the conventions, norms and formally sanctioned rules guiding the farmers' rationalities.

4. Methods

In order to address the research questions, a survey and in-depth interviews of the Norwegian grain farmers were conducted. The research for this investigation was done in collaboration with the SMARTCROP research group (Work Package 4.3).

4.1 Research strategy

A research strategy combining both quantitative and qualitative methods was chosen. This was done because pest management is a complex real-life phenomenon being hard to investigate with the use of any single research method. Under such circumstances, a mixed-methods research strategy is beneficial (Creswell, 2014). Mixed-methods research forces an integrated combination of both quantitative and qualitative methods which yields a broader and stronger array of evidence than any single method alone (Yin, 2009). Table 4.1 shows the integrated relationship between the research questions and the methods used in this investigation.

Table 4.1: List of the research questions and the data types used to answer them.

		Quantitative	Qualitative
RQ1:	To what extent do Norwegian grain farmers practice the principles of IPM?	✓	✓
RQ2:	What explains the variation in their use of IPM?	✓	✓
RQ3:	What characterises their pest management decision processes?		✓

The quantitative data was collected first, using a questionnaire, which was developed and distributed during the fall and winter of 2017/2018. Based on the findings from the questionnaire, an interview guide was developed and in-depth interviews were conducted both in order to complement the findings of the questionnaire and in order to provide data for answering the third research question. The interviews were conducted in March 2018. All inquiries were thus kept outside of the growing season, which can be a hectic time for grain farmers where they might be less inclined to accept the invitation to participate in the study. Both the questionnaire and the interviews were originally conducted in Norwegian. The following accounts of both the design and the results have all been translated by myself. All inquiries, recordings, and use of data have been reviewed and approved by the Norwegian Centre for Research Data.

4.2 Operationalisation of the central terms

Pest management practice is any action that discourages the development of harmful organisms. The farmers' pest management practices were characterised by describing the practices according to the eight principles of IPM (see section 2.1). In the process of implementing the EU directive in Norway, the general principles were adapted to the Norwegian context, thus suiting the purpose of serving as a catalogue of important pest management categories. One modification to the list of principles was done. From the farmers' perspective, pesticide application is a set of interrelated practices and therefore I chose to merge principle 5 (pesticide selection) and principle 6 (reduced pesticide use) into the category "pesticide application practice".

The Norwegian grain farmers' pest management decision processes were investigated by enquiring about the reasons for their way of practicing pest management. This is based on my definition of a decision process (see chapter 3), which is the reasons behind a behaviour.

4.3 Questionnaire methodology

In order to investigate the farmers' pest management practices and their use of IPM, a survey of Norwegian grain farmers was conducted in the form of an online questionnaire. The parts of the questionnaire used in this investigation were the ones documenting the farmers' pest management practices and background variables possibly explaining variation in IPM adoption among farmers. Examples of the background variables used were socio-economic characteristics and data from attitudinal questionnaire items.

4.3.1 Design

In table 4.2, an overview of the structure of the questionnaire is given where the rows marked in blue indicates the parts of the questionnaire used in this investigation. The first three topics of the questionnaire were used to characterise the pest management practices of the farmers, whereas the last four topics were used as background variables. A complete version of the questionnaire is located in appendix A.

Table 4.2: Overview of the design of the questionnaire inquiring Norwegian grain farmers about their farming operations.

Questions	Topic
1-7	How the pest management is run on the farm
8-11	Pest management practices
12-14	Where pest management advice and knowledge come from
15-22	Knowledge and perceptions of IPM, and attitudes to IPM
23-37	Responses to policy measures
38-40	Attitudes and perceptions of farming and pest management
41	How often they speak to other farmers
42-51	Socio-economic characteristics
52	Yield levels

The questionnaire was designed with an emphasis on enhancing the quality of the results by reducing the risk of errors. The risk of errors in sampling and coverage were minimised during sampling, whereas the risk of errors of measurement (inaccurate or imprecise answers) and non-response (systematic lack of response from people selected) were minimised during the design-phase of the questionnaire. Attempting to reduce these errors, Dillman's Tailored Design Method was followed (2009, p. 16): "Tailored design involves using multiple motivational features in compatible and mutually supportive ways to encourage high quantity and quality of response to the surveyor's request." Examples of such motivational features used are giving incentives to answer, using familiar language, keeping the questionnaire short and easy to complete and, among other things, designing good questions. Developing the questionnaire, Bernard's (2002) and Dillman et al.'s (2009) advice on how to develop good questions, appropriate response-scales and a suitable visual layout were followed.

During the process of designing the questionnaire, feedback from both farmers, experts from the local extension service and researchers was used to modify the questionnaire design. The feedback was recorded in the form of interviewing farmers while they were answering a prototype of the questionnaire and consulting experts and scientists about the questionnaire items. Assessments of the time it took to complete the questionnaire were also done. Finally, the questionnaire was programmed into Questback©'s online survey software.

4.3.2 Sampling

Information about potential subjects eligible for the survey was retrieved from data collected in conjunction with subsidy payment applications from the year 2016, provided by the Norwegian Agriculture Agency. Throughout the rest of the thesis, I will refer to this data as the subsidy data. The subsidy data contained contact information and details of the farmers' crop production, and allowed the application of inclusion and exclusion criteria as listed in table 4.3. The terms used to describe the population that is sampled is defined in box 4.1.

Table 4.3: The inclusion and exclusion criteria used in order to determine the survey population of the questionnaire.

Inclusion criteria	**Exclusion criterion**
✓ The person who manages the grain production on a farm; ✓ growing grains on at least 10 ha; ✓ conventionally; ✓ and is residing in one the six counties of, Østfold, Akershus, Hedmark, Oppland, Buskerud or Vestfold.	× Having participated in the questionnaire on the same topic from 2014.

Since the subjects of this study were the grain farmers practicing pest management, a request was added in the invitation letter asking the person in charge of the grain production on the farm to respond. This was done in anticipation of there being farms where someone other than the person managing the grain production is applying for the subsidies. It was anticipated not only because some farmers might cooperate, but also because of the time difference between the subsidy data (2016) and the time the questionnaire was distributed (2017/2018). Additionally, the opening question of the questionnaire enabled the inclusion of only those who reported managing the grain production on the farm.

The criterion of managing at least 10 ha of grains was set due to the ambition to include only farmers to whom the economic output of the grain production was substantial. With less than 10 ha of grain production, there is a decreased chance that the farmers can afford to have all the required farming equipment and consequently they might not perform many of the aspects of pest management themselves. 23% of the grain farmers in the six counties were excluded due to the criterion of area (SSB, 2018b).

Definition of sample terminology:

The survey population consists of all of the units to which one wishes to generalise survey results.

The sample frame is the list from which a sample is to be drawn in order to represent the survey population.

The sample consists of all units of the population that is drawn for inclusion in the survey.

The completed sample consists of all of the units that complete the questionnaire.

Box 4.1: Definition of terms used to describe the sample of the survey. Source: (Dillman et al., 2009, pp. 42-43)

Due to the focus on IPM in this study, only conventional grain farmers were surveyed. Organic pest management practices are often codified and IPM is not formally a part of their practices as they are stricter in terms of pesticide use (Lamine, 2011). Organically certified farms only constitute around 5% of the total number of farms in Norway, and grains are only grown on 14% of the total organic area. (Bye et al., 2017). However, my inclusion criteria do not exclude farmers who have mixed practices.

Most of the grain production in Norway takes place in the southeast (see section 2.4) and therefore it was important to prioritise this region in this study. However, the main reason for including only this region was practical limitations in covering other regions during the qualitative phase of the data collection. The research project was based in Ås, Akershus, which has a central location in the six counties. Therefore, covering the five adjacent counties in addition to Akershus was manageable within the projects’ time and financial frame.

The farmers who had responded to a similar questionnaire in 2014 were excluded because of the wish to not unnecessarily disturb farmers who responded to similar questions only a few years prior. It was assumed that by not excluding them, it might have negatively effected the response rate. There were 1000 farmers invited to respond to the questionnaire in 2014, but some of them resided in counties outside the region covered in this investigation as they also included farmers from the counties of Trøndelag, Rogaland, Telemark, Aust-Agder and Vest-Agder. Therefore, the exact number excluded from the sample frame in this investigation is not known. However, it is likely to be not far from 1000 as most of the grain farmers in Norway reside in the six included counties and the survey methodology used in 2014 included a random sampling of the survey population. Nevertheless, the exclusion of a random portion of the survey population should not affect the risk of any errors in sampling as the survey population remains the same and the sample drawn in the survey used in this investigation is still random.

4.3.3 Distribution

Distribution of the questionnaire was mainly done by sending the participants a link to the online questionnaire via email. Around 6% of the farmers in the sample were not registered with an email address in the subsidy data. To reach these, a text message was sent to the ones with a mobile phone number registered. It contained a link to the questionnaire and a prompt to reply with an email address. If no reply was registered, they were later called and given the opportunity to participate via a mailed questionnaire. A sample of the ones with neither email-address nor phone numbers were mailed a questionnaire. In the weeks following the initial distribution, several follow-up text messages and emails were sent, reminding the participants of the invitation to respond. As an incentive to answer, a lottery was hosted, where four of the respondents were randomly selected to receive a gift card valued at 5000 NOK each.

The application of the inclusion criteria reduced the number of the sample frame to 6038. According to Statistics Norway (2018b), the size of the survey population was 6131, indicating that the subsidy data matches the actual number of grain farmers. Subsequently, 1250 farmers from the sample frame were randomly selected to receive an invitation to participate in the survey. The reason for selecting that number of invitees was to lower the risk of sampling error, which occurs if only a small number of responses are retrieved from a population.

4.3.4 Response rate

Of the 1250 farmers invited to participate in the survey, 617 complete answers were registered. 27 invitees were removed from the sample, either because they reported not to be a grain farmer any longer, or due to a duplication of the invitations, resulting in a response rate of 50.4%. This resulted in risk of sampling error of any estimation in the questionnaire of ±3.7% within a 95% confidence interval[6]. This indicates that any errors in survey estimations are highly unlikely to be due to sampling error. The actual response rate is believed to be even higher since some of the invitations that we did not receive a response from have likely been sent to farmers who are no longer managing the grain production.

4.4 The IPM-index

Seeking to assess the use of IPM among Norwegian grain farmers, an IPM index was developed. The items in the index were primarily based on the eight principles of IPM put forward in the recently implemented directive (Plantevernmiddelforskriften, 2015). Following this description, the definition was made that the more a farmer practices pest management according to these principles, the higher her/his degree of IPM adoption is, relative to the other farmers in the same study. The index scores were calculated as a weighted sum of scores on practices related to the principles. Inspiration was drawn from an IPM index recently designed in Denmark showing promising results of being a good measurement strategy (Kudsk & Jensen, 2014). The Danish index was also a weighted sum of practices, but was designed as a self-assessment tool thus being more specific and extensive than the index used in this investigation, which was designed to be used in conjunction with questionnaire data. Additionally, the index used in this study had to be adapted to the local context. This was done by drawing inspiration from previous studies, consulting experts and test-interviewing subjects.

Puente et al. (2011) warned against the method of using weighted sums of practices to measure the use of IPM, primarily for two reasons; the first was that many previous attempts have divided the farmers in a binary fashion which does not reflect the complexity of IPM adoption;

[6] This calculation is based on the equation given by Dillman, Smyth and Christian (2009, p. 57) using the most conservative assumption regarding the probability of the responses on each questionnaire item.

and the second reason was that previous attempts at using weighted sums of practices have poorly addressed issues of weights and numbers of practices per aspect of IPM and thus arbitrarily landed on methods for calculating adoption rates. Addressing these warnings, first the IPM index was designed to measure the adoption of IPM as a continuous variable and relative only to itself. This means that by applying our index, no respondents are either marked as practitioners of IPM or non-practitioners. In this investigation, the aim of assessing the use of IPM with the index was not to classify the Norwegian grain farmers as a unit against other farmers or an ideal situation, and the results should not be interpreted this way. Consequently, the index was used as a tool to separate the farmers into who practiced more, and who practiced less IPM. Second, adjustments to the weighted sum of practices were made such that practicing any given IPM principle to a large extent, did not yield an unfair advantage over practicing any other IPM principle. This was done by accounting for the number of items associated with each of the eight principles of IPM.

During both the process of deciding which practices to include under each principle and the process of determining the weights associated with the principles and the practices, three regional pest management experts were consulted. To facilitate the process of determining the weights, a variant of the Delphi-method, called Mini-Delphi (estimate-talk-estimate) was used (Armstrong, 2008). The experts were first instructed to estimate weights individually according to instructions. They were asked to assign weights to each principle and practice according to how important it was in order to achieve the effect of increased use of IPM. The experts were asked to assign the weight “1”, as a floor, to the least important principle, and practice under each principle. Subsequently, they were asked to rank the other items according to these floors such that an item assigned the weight “2” was twice as important as the least important item. No upper weight limit was set. After the first round of estimation, a meeting was facilitated by the research group, where the experts could talk about their estimations. The goal of the meeting was not to establish a consensus of the estimation, but rather to allow any misunderstandings regarding the instructions or wordings of the items to be cleared. Additionally, the experts were given the opportunity to discuss the particularities of the pest management practices and give reasons for their estimations. After the meeting, a final individual round of estimation was done, and the average weights from the three experts were calculated. Table 4.3 shows the weights of the principles. The entire list of practices and weights along with a comprehensive method of calculating the score of the index is described in appendices B and C.

Table 4.3: The eight principles of IPM and the associated average weights set by regional experts to be used in an IPM index.

	Principles	$Weight_i$
I	Prevention and suppression	8.0
II	Monitoring	5.7
III	Decision-making	5.3
IV	Non-chemical methods	5.0
V	Pesticide selection	1.3
VI	Reduced pesticide use	4.7
VII	Anti-resistance strategies	3.3
VIII	Evaluation	2.7

The general method for computing the score of the index for each farmer is given by the two following equations, where "$Principle_i$" refers to the score on the eight principles, "$Practice_j$" refers to the score on the related practices and "$Weight_{i/j}$" refers to the weights of the principles or practices.

$$\textbf{Equation 1}: Index\ score = \sum_{i=1}^{8} Principle_i * Weight_i$$

$$\textbf{Equation 2}: Principle_i = \sum_{j=1}^{n} \frac{Practice_j * Weight_j}{\sum_{j=1}^{n} Weight_j}$$

The questionnaire data were entered into the second equation as a score of each practice ("$Practice_j$"). The different scales of the questionnaire items were translated into scores which were a fraction of 1 (e.g. a scale of 1-5 became 0, 0.25, 0.5, 0.75, 1). After multiplication with the associated weights and division of the maximum score of the principle, the score of each practice is, therefore, a fraction of the maximum score of each principle. The sum of these fractions is therefore maximally the weight of the principle. As an example, consider the questionnaire items included in the calculation of the score for Principle II (see Appendix B). The input from the questionnaire is two statements ranked on a scale from 1 (never) – 5 (always) regarding how often the farmers monitor their fields before spraying with herbicides and how often before spraying with fungicides. If a respondent reported to monitor half of his grain fields before spraying with herbicides and all his fields before spraying fungicides, scoring 0.5 on the first practice and 1 on the second, the calculation of his score on principle II would be:

Example: $Principle_2 = \frac{0.5*5,7}{5.7+8.3} + \frac{1*8,3}{5.7+8.3} = 0.80$

Consequently, in this example, the farmer would get 0.8 times the weight of principle II. In order to compute the farmers' index scores, the scores of all eight principles multiplied by their associated weights were summed according to the first equation. Lastly, a linear transformation of the index scores was performed such that the index returned scores between 0 and 100. This was done to make it easier to interpret the parameters from the statistical analyses.

The entire method of calculating the index is too elaborate to be reported in this chapter, but can be found in Appendix C. It should be noted that the index also includes considerations of not performing a practice. As an example, the experts ranked not monitoring fields before spraying with fungicides as much worse than not using a weed harrow.

To exemplify what it means to move on the index, a farmer who always monitors her/his fields for fungal pests before spraying scores 11 points higher than a farmer who never monitors. This practice is however weighted very high, and to move 11 points by altering the behaviour on less important practices requires more. For instance, going from never spot spraying to always spot spraying and simultaneously from not using resistant cultivars to only using resistant cultivars changes the score 9 points.

4.5 Quantitative data analysis

The questionnaire data was imported into the statistical software, SAS©, which was used for calculating frequency tables, means and standard deviations, running factor analyses of attitudinal items and regression analyses.

First, socio-economic and other characteristics of the completed sample were compared to statistics of the survey population gathered from other sources in order to assess the risk of non-response error, which occurs if there is a systematic difference in the group of the completed sample compared to the non-responders. In other words, non-response error is zero if the non-responders are a random segment of the sample. Due to the relatively narrow inclusion criteria, only yield and area data were found from other sources fitting the same inclusion criteria. The other characteristics such as age, experience, income etc. were compared to the sources available at the time of writing. A request was sent to Statistics Norway asking for assistance, but no response was received in time.

In anticipation of the responses to three attitudinal questions from the questionnaire being correlated, a factor analysis was run. The three questions were:

Q47: **How meaningful are the following conditions to you as a farmer?**

8 statements, ranked on a scale from 1 (not important) – 7 (very important)

Q48: **Which conditions are important to you when you manage weeds and fungal pests?**

10 statements, ranked on a scale from 1 (not important) – 5 (very important)

Q49: **What is seen as good farm management in your local farming community?**

6 statements, ranked on a scale from 1 (not important) – 5 (very important)

The two first questions were analysed together, as they both regard the farmers own attitudes. The third question, regarding how the farmers perceived their local farming communities was considered separately. Factor loadings were used to measure the degree of correlation, and the cut-off was set to 0.5. Once a list of variables that load high on a factor has been established, an assessment of their meaning and subsequent labelling of the factors is to be done (Bernard, 2002). This assessment was done, ensuring that no ambiguous factors were accepted.

In order to analyse the variation of the IPM index, an Ordinary-Least-Squares (OLS) regression was run using the respondents' scores of the IPM index as a dependent variable and responses to questionnaire items (including the factors) as explanatory variables. Before regression analyses were run, the questionnaire item measuring principle number 5 was removed from the model. This was done due to the questionnaire item being part of the items involved in the factor analysis. The weight of the principle set by the experts was 1.3, thus clearly being the least important principle. The standard deviation of the responses to the sole questionnaire item (Likert-type scale from 1-7) measuring this principle was ±1.14, indicating a high degree of similarity in the responses to the item. Consequently, principle 5 explains a very limited amount of the variation in the responses regarding the IPM index. In order to ensure that the variables used in the regression analyses were independent, tests for multicollinearity was run. The models were also adjusted for heteroscedasticity. Additionally, 17 responses were removed due to too large degree of incomplete answers to central questions included in the calculation of the index scores.

One factor derived from the question regarding the farmers' perceptions of the local farming community (Q49) was removed due to multicollinearity with another factor. As a response to this, further regression analyses were run in order to examine the relationship between the factors related to the farmers' attitudes and the factors related to the farmers' perceptions of the local farming community.

4.6 In-depth interview methodology

4.6.1 Structure

In order to assess the farmers' pest management decision processes, 24 in-depth interviews of respondents to the survey were conducted. The aims of the interviews were to supplement the survey data with descriptions of how the farmers practiced pest management and to go beyond the descriptions and enable the explanation of why they practice pest management the way they do. The interview guide (see Appendix D) was constructed, separating the interview into five parts:

1) The historical and present context of her/his farming operation was laid out.
2) Current pest management practices were explained and reasoned.
3) An account of what good agronomy in her/his area was given.
4) Thoughts of what IPM is, and attitudes to it were expressed.
5) Responses to policy measures were made and discussed.

The interviews followed the structure of in-depth (or semi-structured) interviews as described by Bernard (2002). The interview structure allowed the farmers to choose the form of the answers and simultaneously limited the range of the answers not only to topics, but also to the contents of the interview guide. Thereby, it was made sure that the in-depth interviews resulted in data that was compatible with the quantitative data as well as extensive answers from all the interviewees. During the process of designing the interview guide, feedback from both farmers, experts from the local extension service and scientists were used to modify the design of the interview guide. Test interviews were conducted with questionnaire respondents in order to get feedback from the same group who were later being interviewed.

4.6.2 Sampling and recruitment

Selecting interviewees, non-probability sampling in the form of a combination of quota and convenience sampling was used (Bernard, 2002). A quota of four farmers for each of the six counties was set in order to ensure that some of the regional differences were accounted for. In order to choose which respondents to invite, they were grouped according to their postal codes and due to financial and time constraints, areas close to Ås, Akershus, were chosen. The areas chosen are shown in figure 4.1. Recruitment was conducted by calling the respondents and scheduling a visit. When possible, interviewees with varying responses to an item in the questionnaire regarding their attitude to IPM[7] were prioritised. The responses to this question were used as a proxy for their degree of IPM adoption since at this stage of the research project, the IPM index was not fully developed and could thus not be used as a measure of their adoption. It was done in order to increase the likelihood of the interviewees representing a varying degree of IPM adoption.

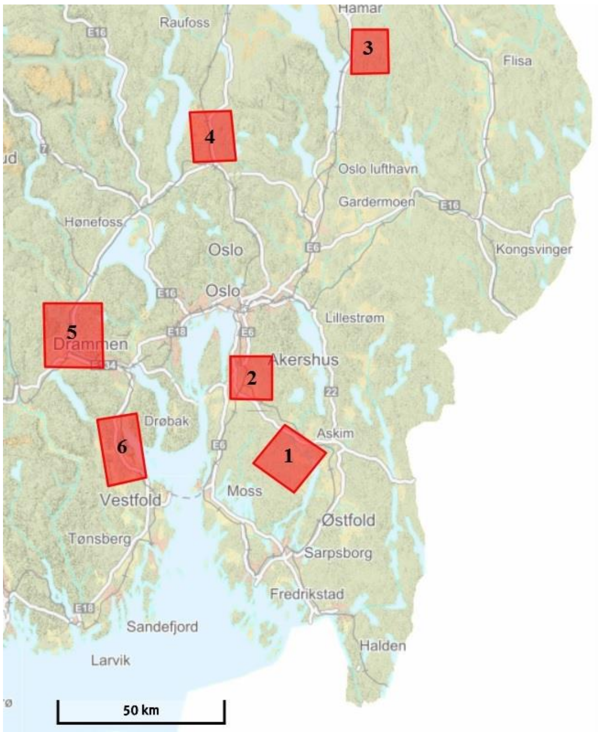

Figure 4.1: Map of the south-easternmost region of Norway with the red boxes indicating where the interviewees were recruited from. Map source: Norwegian Mapping Authority (2018)

4.6.3 How the interviews were conducted

The interviews were conducted in March 2018 by myself. I visited the farmers in their homes and the conversations usually lasted between 1-2 hours. Audio recordings were done of all the interviews and the recordings were later transcribed in a way that ensured the anonymity of the interviewees.

[7] Referring to question 20, statement 1: «Positive towards IPM despite it resulting in some reduced profitability» (see Appendix A)

During the interviews, I was under the impression that the responses the interviewees gave were honest and extensive. Being a master student from what previously was the Norwegian College of Agriculture, the interviewees seemed generally to expect me to already know a lot about grain farming. This meant that the farmers could speak freely about their practices without having to simplify their message too much. However, it should be noted that I have no agricultural background prior to this master's programme. Some of the interviewees sensed this by the way I spoke about grain farming, but it did not seem to particularly affect their responses. One interview was cut short by a sudden business issue the farmer had to attend to, but the remaining 23 interviews were completed within the time frame of 1-2 hours. During 20 of the interviews, only a male farmer and me were present. Two of the interviews were done with father and son present. The two remaining interviews were done with husband and wife present, where in both cases the woman was involved in the farming operations, but the man was responsible for the pesticide applications. All of the interviewees welcomed me into their homes and stated that they were glad to be able to contribute to the scientific inquiries.

4.7 Qualitative data analysis

The analysis of the qualitative data served two purposes. First, it served the purpose of enabling the characterisation of the Norwegian grain farmers' pest management decision processes. Second, it provided complementary data to the quantitative findings regarding the farmers' pest management practices.

Regarding the pest management practices, the interview data was analysed by looking for instances where the reported practices were elaborated. This analysis provided context specific descriptions of what the reported practices mean.

Analysis of the interview data revealed instances where the respondents explained why they practiced pest management the way they did. The instances were coded and sorted by themes, starting with a set of themes derived from the theoretical background: "Good agronomy", "Antecedents" and "Contextual constraints". Following the suggestions of Willms et al. (1990; cited in Bernard, 2002) and Miles and Huberman (1994; cited in Bernard, 2002) the general themes derived from the theoretical background were expanded upon during the analysis as new themes and subthemes occurred. During the analysis, the theme of "economy" was found to be very prominent in the interviewed farmers reasoning and was therefore separated as a subtheme of “good agronomy”. The other moderation done to the original list of themes was adding a separate theme called “other” which was used as a conglomeration of various reasons that did not fit in any of the other themes. During the interviews, I got the impression that some elements in the farmers’ decision processes were more widespread than others. The colour coding in the characterisation (table 5.7) reflects the degree to which each reason is mentioned by the farmers. Reasons that were mentioned by few, many or most farmers were coloured blue, black and red, respectively. However, since the interviews are not a representative sample of the survey population, the colour-coding does not represent the variation in any other population than the 24 interviewed.

In order to illustrate the farmers’ use of a sequential rationale of pest management (described in section 3.5), three farmers’ rationales were examined. One farmer followed a sequential pest management rationale to a large degree, one to a medium degree and one to a low degree. The comparison of the three highlights pest management practice according to a sequential rationale in the context of Norwegian grain farmers.

5. Results and discussion

The following presentation and discussion of the outcomes of the inquiries are structured after the research questions. Prior to that, the degree to which the completed sample represents the survey population will be discussed.

5.1 Characteristics of the respondents

The Norwegian grain farmers in this study are predominantly men with an extensive farming experience (table 5.1). A majority of the farmers have some form of farming education and many are part-time farmers where most of their household incomes come from other sources than the farming operations.

Table 5.1: Socio-economic characteristics of the surveyed Norwegian grain farmers.

		%	**Mean** (Standard deviation)
Age			**53 years** (±10,88)
Grain farming experience			**24 years** (±12,65)
Gender	Male	**93**	
	Female	**7**	
Education level	Primary or secondary school	**7**	
	Vocational high school	**43**	
	General subject high school	**15**	
	Higher education	**35**	
Farming education	No	**37**	
	Yes, from high school	**54**	
	Yes, from higher education	**12**	
Farm income	Low (0 – 99 999)	**25**	
	Medium (100 000 – 399 999)	**48**	
	High (400 000 →)	**27**	
Household income	Low (0 – 399 999)	**7**	
	Medium (400 000 – 999 999)	**57**	
	High (1 000 000 →)	**36**	
Occupation	Full-time farmers	**34**	
	Part-time farmers	**66**	

The respondents' average age of 53 was based on their age in 2017. The average age of farmers in Norway has risen the last decades with Statistics Norway (2018c) reporting it to be 51 years nationwide for those farming more than 10 ha and also 51 years for the farmers in the six counties included in this study regardless of the size of their farms. While I lack data on the survey population, this indicates that there is likely no major difference in the age of the respondents and the survey population. The data on age was key to investigate risks of non-response regarding the non-email distributions. Of the 72 who did not have an email address registered in the subsidy data, 11 (15%) returned a response, which is far from the 50,4% total response rate. In Norway, 90% of the population between 16-79 years reported having used the internet to access email, with the oldest segment of the population having lower access than the younger segments (SSB, 2017). Therefore, it might be assumed that a low response rate from farmers without an email address should result in a lower average age of the completed sample. The relatively high average age of the farmers in our sample indicates that the low response rate from the farmers without an email address registered did not lead to an error in non-response based on an older age group being excluded. However, there might be other systematic errors related to the low response rate from those without an email address.

The years of experience was reported as total grain farming experience and not specifically on the farm they were managing. The findings in this investigation are identical to the years of experience reported by Norwegian farmers in a survey from 2014 (Storstad & Rønning, 2014). Even though the previous study had different inclusion criteria than this project, it indicates that my respondents are as experienced as other Norwegian farmers are.

Among farmers nationwide managing over 10 ha of area, 14% were women, and among farmers in the six counties included in this study, 15% were women (SSB, 2018c), which is twice as high as our sample. This may indicate that our sample is different from the survey population in terms of gender distribution. However, it is possible that gender distribution is different among grain farmers compared to other farmers.

The income numbers as presented in table 5.1 were originally reported by the respondents in narrower intervals (see Appendix A) and the categories "low", "medium" and "high" consist of three intervals each. The respondents' mean farming income, calculated by using the mean of each interval as a representative was approximately[8] 260 000 NOK, whereas for grain farmers in the six included counties it was than half of that (SSB, 2018a). Only 23% of the grain farmers in the six included counties managed less than 10 ha, and even if they all had zero farming income it would not account for the discrepancy between our completed sample and the survey population. This indicates that my completed sample might have a significantly higher farming income than the survey population.

Of the respondents reporting to be part-time farmers, over half had full-time jobs outside the farm. The survey done by Storstand and Rønning (2014) found similar rates of part-time farmers and farmers with full-time jobs outside the farm. This indicates that my respondents have similar working hours outside the farm as other Norwegian farmers. The respondents' mean household income is approximately[9] 870 000 NOK. The household income was reported by the respondents as all sources of income to the household before taxes. Due to the lack of comparable statistics, it is difficult to make any judgments of how the income numbers compare to other farming populations. However, the difference in the respondents' household income and farming income seems reasonable given their high rate of working outside the farm and that we talk of household income.

The sizes of the respondents' grain area were on average 83% of their total area and varied a lot in size (table 5.2). The total area of the respondents' farms ranged from 10 ha to over 200 ha, and the diversity of the production was large, as some farmers concentrate on a few types of cereal grains, whereas others have a diversified production, implementing both multiple grain types as well as other productions such as animals, vegetables, berries etc. The average grain area of the survey population was approximately 35 ha, which is slightly lower than our completed sample (SSB, 2018b).

[8] The approximation is based on those checking the option of "over 700 000" on average making 800 000 and does not account for possible negative incomes from grain farming.
[9] The approximation is based on those checking the option of "over 1 200 000" on average making 1 300 000.

Table 5.2: Grain area and yield levels of surveyed Norwegian grain farmers. Area data was extrapolated by numbers from the subsidy data from 2016, yield data was self-reported as an average from the last five years.

	Area (ha)			Yield (tonnes/ha)	
	Mean	percentage of grain area	Standard deviation	**Mean**	Standard deviation
Total	**45.1**	-	±37.2	-	-
Grain	**37.4**	-	±31.4	-	-
Barley	**15**	40%	±17.2	**4.8**	±0.96
Oats	**11**	29%	±13.9	**5.0**	±0.87
Wheat	**9.9**	26%	±9.6	**6.4**	±1.05
Rye	**0.7**	2%	±3.3	**6.5**	±1.43
Oilseed	**0.7**	2%	±3.6	-	-

Table 5.2 shows that with a few exceptions, barley, oats and wheat were the grain types grown by the respondents in 2016. Of the grain farmers in the six included counties, the distribution of the main grain types were 40% barley, 30% oats and 28% wheat, matching the completed sample in this study (SSB, 2018b).

Wheat and rye were the two grain types reported by the farmers to on average give the largest yields over the last five years (table 5.2). The yield levels of grain farmers in the six counties included in this study were, as measured in tonnes per hectare, 5.1 for rye, 4.7 for wheat, 4.1 for barley and 4.0 for oats (SSB, 2018b). These numbers are lower than what the corresponding numbers reported by the respondents, but have a similar ratio between the grain types. It should be noted that the yield levels reported by Statistics Norway are converted to a set water percentage of 15, whereas as our respondents were simply asked to report their yield level numbers without regarding the water percentage. Another reason for the discrepancy might be that the farmers in the completed sample actually have higher yield levels than the survey population. This would support the previous indication of the respondents having a higher farming income than the survey population. A third possibility is that the smaller scale farmers included in the numbers from Statistics Norway have a lot lower yields than larger scale farmers and that the difference is caused by their effect on the mean numbers.

In a study from 2014, Kvakkestad and Prestvik (2016) found very similar characteristics among a similar sample[10] of Norwegian grain farmers. For instance, they also found only 7% women and similar farming income numbers. Their questionnaire methodology was very similar to the one used in this investigation, although they did not invite respondents via email, but rather mailed them a postcard containing instructions to access the online questionnaire. This slight difference might strengthen the possibility that both completed samples reflect the survey population. However, due to the lack of reliable information of the survey population, the possibility that a non-response error has skewed the completed sample cannot be excluded. Nevertheless, the similarities of the characteristics of the respondents and the available relevant characteristics of the survey population indicate that the respondents to a large extent represent grain farmers in the six included counties managing over 10 ha of conventional grain area.

5.2 Pest management practices

Pest management practices are any actions that discourage the development of harmful organisms in the farmers' fields. To which extent it is IPM or not depends on how much the practices align with the eight principles given by the directive on IPM. The following characterisation of the Norwegian grain farmers' pest management practices is structured after the eight principles of IPM.

5.2.1 Prevention and suppression (IPM-principle I)

A majority of the surveyed farmers plough most of their area, either during the fall and/or during the spring (figure 5.1). Only 2.25% of the farmers refrain from tillage practices altogether and use direct sowing on all of their area, whereas a few farmers skip ploughing and use other tillage methods on a varying degree of their area. One third of the farmers reported using only one of the tillage practices on all of their grain area suggesting that most farmers have a varied tillage practice.

[10] The only difference in the inclusion criteria was that they additionally included farmers from the counties of Trøndelag, Rogaland, Telemark, Aust-Agder and Vest-Agder.

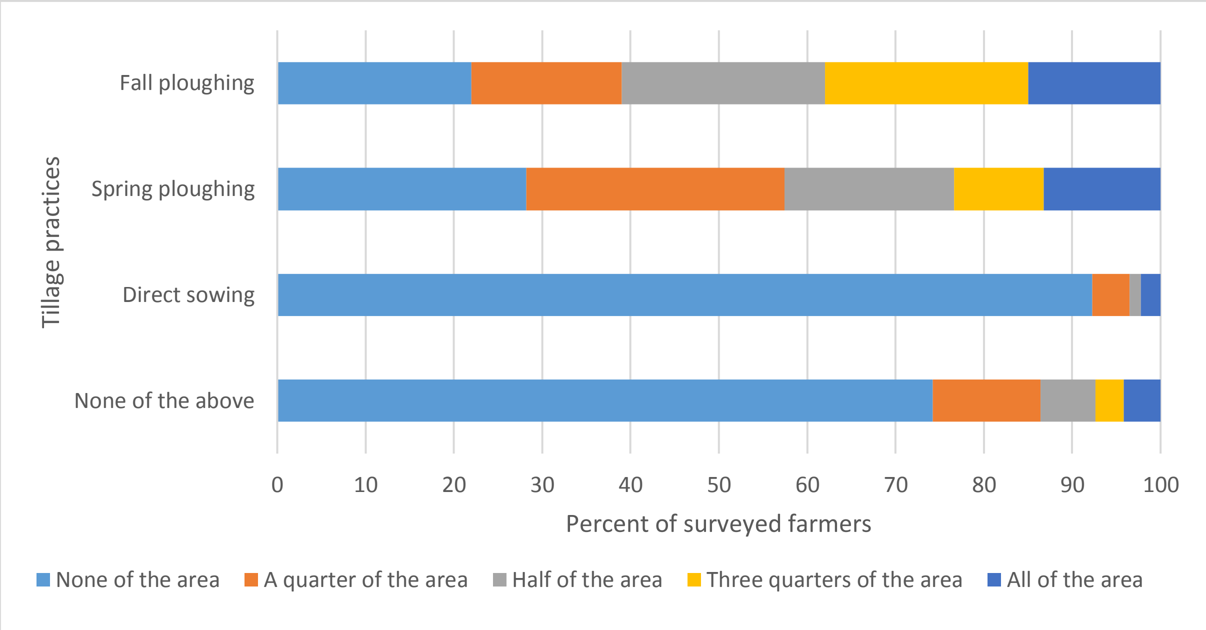

Figure 5.1: Proportion of the surveyed farmers that use different tillage practices on none, a quarter, half, three quarters or all of their grain area, respectively.

During the interviews, many farmers pointed out that the foundations of good grain production practice begins by ensuring adequate soil conditions for sowing. The farmers reported that after the extent of ploughing had been vastly decreased a couple of decades ago in favour of reduced tillage strategies, the increase in weed pressure made it necessary to bring ploughing back again. As one farmer recalls: «Yes, we practiced reduced tillage before. When my wife and I took over a decade ago, we continued practicing it a couple of years, but we had big issues with annual meadow grass and herbicide spraying. So we started ploughing again, and have been pleased since.» The farmers also reported that whether to plough during the fall or the spring was a debated topic. Fall ploughing was reported to consistently result in high yield numbers and quality, but increases the risk of erosion, whereas spring ploughing reduces the risk of erosion, but increases the risk of missing crucial timing windows that might affect the yields. One such timing window mentioned by the farmers was hitting the right time of sowing. Ploughing is not the only tillage practice used. Most of the farmers interviewed reported also using other tillage practices, mainly various types of harrowing. The farmers also explained that they adapt their tillage strategy according to what they are growing and the seasonal conditions. Ploughing appears to be a central part of Norwegian grain production. Even though the farmers are aware of the increased risk of soil erosion that ensues with ploughing, the benefits that intensive tillage practices give in terms of reduced weed pressure and yields that are more dependable, outweigh the risks.

A majority of the surveyed farmers reported entirely avoiding monocropping of wheat or barley (figure 5.2). Since these were two of the three most commonly grown grain types, it is likely that crop rotation is extensively practiced among Norwegian grain farmers.

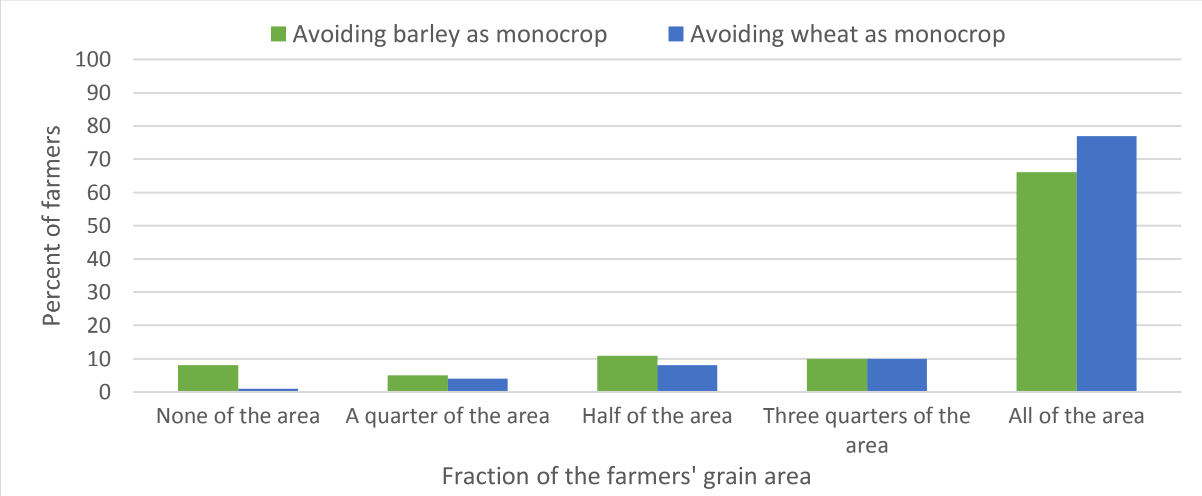

Figure 5.2: Degree of crop rotation among surveyed Norwegian grain farmers, measured as the fraction of their area where they did not grow either barley or wheat three or more years in a row.

During the interviews, the farmers reported that having as varied a crop rotation as possible was paramount for the success of their grain production. As one farmer stated: «I haven't sprayed with fungicides in barley the last three or four years. I think that has to do with my crop rotation. I use both oats and rapeseed as preceding crops for barley and wheat.» Only a few of the interviewed farmers reported growing wheat or barley year after year. Their reason was that they were seed producers. As one such farmer reported: «And when we're doing seed production, the production becomes pretty one-sided. That is because of the nature of seed production.» One reason the seed producers gave for having reduced crop rotation was that avoiding other seed types from sprouting in their fields is critical in ensuring the purity of their seed products. Another reason given was that they have signed contracts with seed distributors and become certified seed producers, thus incentivising their monocropping in order to produce seeds. However, crop rotation remains a centrepiece of preventive and suppressive pest management strategies for most Norwegian grain farmers, especially for reducing the pressure of fungal pests.

Another measure for reducing the fungal pest pressure, which is widely used among the surveyed farmers, is using resistant cultivars (figure 5.3). Trimming field edges in order to keep weeds from spreading was less commonly practiced as about half reported to not perform the practice on any of their area.

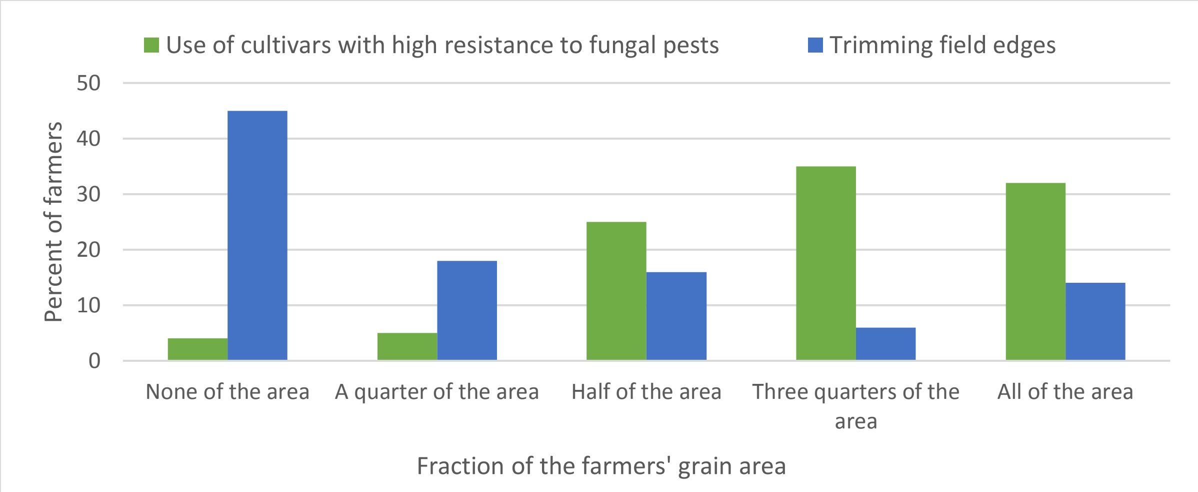

Figure 5.3: Fraction of the surveyed farmers reporting to practice growing fungus-resistant cultivars and trimming field edges.

During the interviews, the farmers reported that many of the cultivars that are available to them on the market are to a certain extent fungus resistant. Some cultivars are proposedly more resistant than others. One farmer stated, «Last year, I tried growing Mirakel, which is supposed to be resistant against fungal diseases, but none of them are entirely resistant, you know.» Despite growing a proposedly resistant cultivar, he still had to spray with fungicides later on in the season. The interviewed farmers claimed to prioritise resistant cultivars to a varying degree. Those who did not prioritise them often argued that the ones they grew instead were chosen due to increased yield projections. Resistant cultivars are thus widely used among Norwegian grain farmers, but results from both the interviews and the number of fungicide applications (see table 5.4) suggests that the cultivars are only resistant to a certain extent.

During the interviews, trimming field edges was very rarely mentioned as a preventive pest management strategy. One farmer reported that spraying the edges of your fields with pesticides is prohibited. On trimming his field edges, he stated, «There are very few places I have a problem with common mugwort or thistle. But I am a lot more aware of not spraying the edges any longer. I do not spray the surrounding shrubs either. I use a mower or the excavator.» By trimming his field edges, he attempts to prevent the weeds from spreading from the edges and into his fields. He also implied that spraying the field edges is a practice he was not very aware of previously. The low rate of using this practice reported by the farmers suggests that this practice is not regarded by many farmers as being key to successful pest management. This finding suggests that there is potential for increased use of the practice. However, due to the lack of emphasis on the practice during the interviews, further research is needed to determine the reason why the farmers refrain from the practice.

Two thirds of the surveyed farmers reported partially growing grains on rented land, and one third reported exclusively growing grains on their own land (figure 5.1).

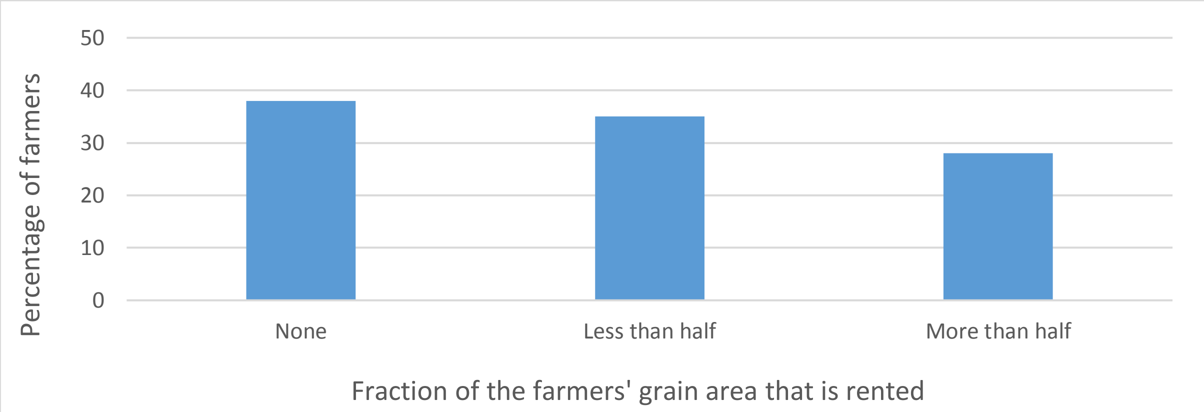

Figure 5.4: Amount of rented land used for grain farming among surveyed Norwegian grain farmers.

Proper drainage, often achieved by digging ditches was reported during the interviews as being a key aspect of preparing the fields for grain production. The lack of proper drainage was said to be a large problem on rented land. In response to a question regarding improvement of the soil conditions of the rented land, one farmer stated, «You would invest in the land if only you knew that you would be able to rent the land for 25 years, but nobody rents it out for that long.» Many of the interviewed farmers reported being upset about the small subsidy sum for digging drainage ditches. The amount of the surveyed farmers reporting to farm on rented land suggests that lack of proper drainage might hamper the prevention of pests for a large part of the farmers.

5.2.2 Monitoring & decision-making (II & III)

Monitoring is a widespread practice among the Norwegian grain farmers, as most of the surveyed farmers reported to monitor their fields before spraying against either fungal pests or weeds (figure 5.5). However, 42% of the farmers reported to not always monitor their fields before spraying with fungicides. This indicates that, despite frequently monitoring their fields, there might be some farmers who spray with fungicides either as a preventive measure or due to being certain of a pest outbreak without monitoring. Since monitoring is of little use if it does not affect the decision of whether to spray or not, the two principles are investigated simultaneously in this section.

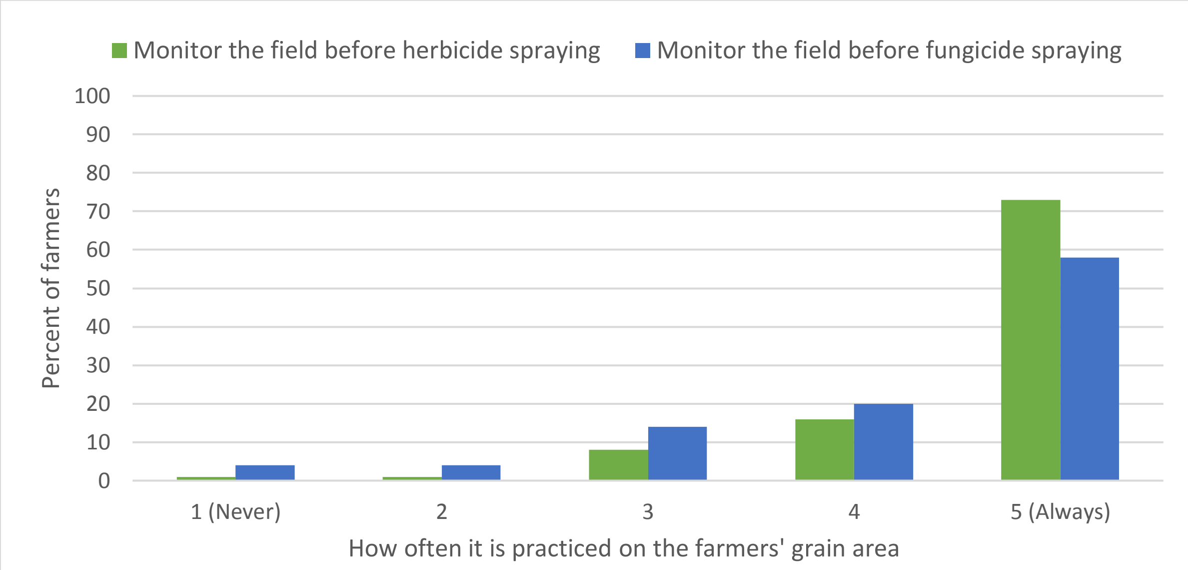

Figure 5.5: Reported rate of monitoring ahead of fungicide and herbicide spraying among surveyed Norwegian grain farmers.

During the interviews, the farmers reported that monitoring was one of the most important measures during pest management. Upon being asked if monitoring was important for deciding to spray with fungicides, one farmer replied, “Yes, it is. There is a threshold that has been developed. Both from VIPS[11] and from the extension service. You could also seek consultation, but the first amendment is to monitor the fields. Keep track of the development.” As he expressed, monitoring is done to keep track of the development in order to know whether the pest levels have exceeded the threshold where intervention is needed.

The regional extension services provide forecasting and reporting of the pest situation in the farmers’ regions. The forecasts are distributed both through the publically available web-based application, VIPS, and by a weekly email sent to the members of the extension service. 67% of the surveyed farmers reported being members of the extension service. The newsletters were reportedly used more often than VIPS (figure 5.6).

[11] VIPS is «Varsling innen planteskadegjørere» - a web-based decision support system for determining when there is a need to intervene against various pests.

Figure 5.6: Reported rate of following advice from the extension service in relation to fungicide spraying among surveyed Norwegian grain farmers.

The interviewed farmers described that the content of both VIPS and the newsletters are based on the same background information. Therefore, farmers reporting not to use VIPS might still get the same information if they read the newsletters and vice versa. Additionally, the information from the extension service might reach the farmers through other channels. During the interviews, many of the farmers reported that in addition to receiving newsletters and using VIPS, they frequently call extension service agents to discuss specific pest management decisions. Text messages were also reported to be sent out by the extension service in the advent of an outbreak of a pest that needs to be deal with urgently. However, the farmers also reported receiving decision-support regarding pest management from each other.

Figure 5.7 shows that most of the farmers speak with other farmers weekly or more than weekly. Over half of the farmers also speak to other farmers weekly or more than weekly about pest management during the growing season. This suggests that advice from other farmers might play a role in deciding whether to intervene against pests or not.

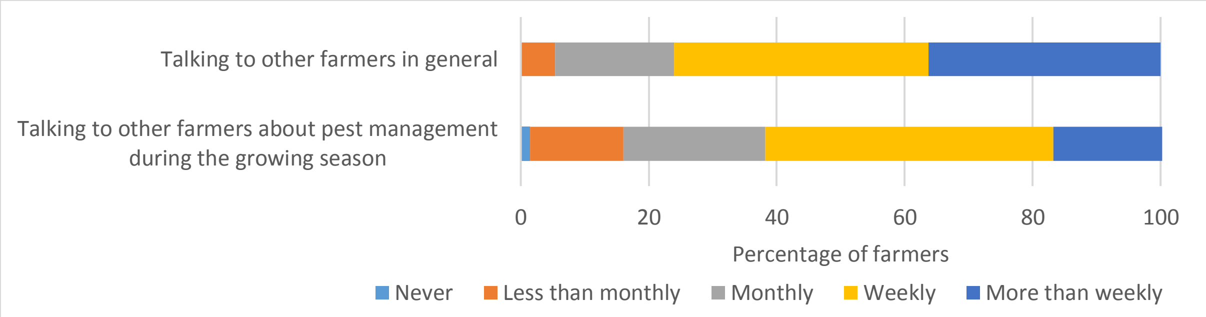

Figure 5.7: Proportion of the surveyed farmers reporting the rate at which they talk to other farmers in general and about pest management during the growing season.

The interviewed farmers reported to often use more than one source of decision-supporting information. As one farmer stated, «When I walk around in my fields, I'm always on the phone with my friends from around here. We discuss, consult the extension service, read a little and then it's a consequence of all those things that lead to what you do.» By using a combination of monitoring their fields, consulting both peers and the extension service and in some cases using the information provided in newsletters and an online decision-support system, the Norwegian grain farmers keep track of the pest situations in their fields and decide whether to intervene or not. The extension service appears to play a central role in the decision-support part of the pest management practices of many of the Norwegian grain farmers. However, it appears that the communication between the advisory service and the farmers usually regard urgent matters such as whether the farmers should intervene or not, or the dosage of the pesticide spraying. The communication does not seem to focus as much on the preventive and suppressive measures, which might be crucial for avoiding the intervention.

The substantial amount of farmers who are not members of the extension service have the possibility to access the same information from other sources, including VIPS, but they might be at a disadvantage due to the resources exclusively available to the members.

5.2.3 Non-chemical methods (IV)

Almost none of the surveyed farmers reported using a weed harrow in their grain production, whereas manually weeding was reported to be more widespread (figure 5.8). 48% of the surveyed farmers reported manually weeding patches of weeds and/or wild oats on all of their grain area. It is unclear whether those who reported manually weeding less did so because they did not have any suitable weeds to manually weed or whether they did have weeds but elected not to manually weed.

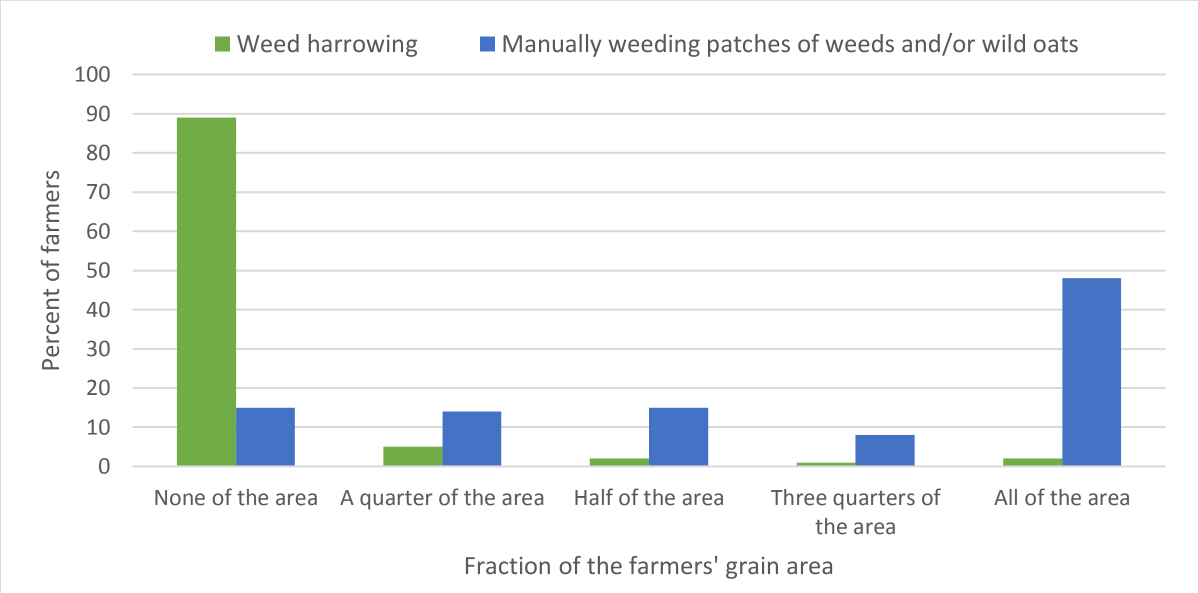

Figure 5.8: Proportion of the surveyed farmers that use two non-chemical methods on none, a quarter, half, three quarters or all of their grain area, respectively.

During the interviews, almost all the farmers pointed out that weed harrowing is a good idea in theory, but that in practice it is nearly impossible to use with a satisfactory result. As one farmer reported: «If only I had known that it would work. But if I first have to try harrowing and then end up having to spray after all, then it's completely wasted.». The farmers reported that in order to hit the right timing with the weed harrow, not only do the weather conditions have to be optimal, but also the development stage of the crops have to be ideal.

Many of the interviewed farmers reported that manual weeding was an integral part of their pest management practice. The manual weeding was reported to be used for only a select few weed species. As one farmer stated when describing which weeds he struggled with, "And there has been a lot of wild oats that we additionally manually weed. It has been a kind of a family activity!». This attitude towards weeding wild oats was recognised in multiple interviews and seemed to be a traditional part of what the farmers viewed as proper pest management practices. However, the farmers also reported that the pesticides used against wild oats recently have become cheaper, and many opt to spray instead of manually weed. When asked how he combated wild oats, one farmer reported having turned to spraying: «Yes, I've manually weeded a lot throughout my life. But the remedy against wild oats is so incredibly good.». This suggests that at least some of the farmers who reportedly do not use manual weeding practice on all their fields could have done it, but elect not to. In summary, non-chemical methods are used only against a select few weeds as pest intervention methods among Norwegian grain farmers.

5.2.4 Pesticide application practice (V & VI)

Table 5.3 shows that virtually all of the surveyed farmers use pesticides in their grain production and a majority reported to apply the pesticides themselves. Of those who did not apply the pesticides themselves, a majority still made many or most of the decisions regarding pesticide applications.

Table 5.3: Pesticide application practices among Norwegian grain farmers, showing the percentage of positive answers and the number of respondents to the questions.

	%	N
Pesticides used within the last three years	99	617
Has certificate for pesticide application	89	617
Applies pesticides her-/himself	83	544[a]
Still make all or many of the decisions regarding pesticide application, despite not applying pesticides her-/himself	71	160[b]

a: Only the farmers who had a pesticide application certificate responded to this question.

b: Only the farmers who did not have a pesticide application certificate or who did not apply pesticides her/himself responded to this question.

From the interviews, many farmers reported that by performing the spraying themselves it was easier to maintain control and make sure that everything was done correctly. Some farmers reported hiring other farmers to spray for them. One farmer in such a situation explained the process of deciding how and when to spray as, “We usually make a plan for spraying and fertilising. And then I monitor my fields and keep in touch with him extensively throughout the season.”

Barley was chosen as the crop used to exemplify the farmers’ pesticide applications due to it being the most widely grown grain type. 83% of the surveyed farmers reported having grown barley any of the last three years and thus answered the question reported in table 5.4. The table shows that herbicide and fungicide spraying on average is performed once per season in the surveyed farmers’ barley fields. The degree of variation in the number of fungicide applications is much higher than for herbicides. The farmers do not deviate much from spraying once against annual weeds in the spring as 93% of the farmers reported applying herbicides on average once every season. Insecticides are rarely used, whereas growth regulators and spraying with glyphosate after the growing season has ended is on average done every other year.

Table 5.4: Mean number of applications of various pesticides per year (based on what has usually occurred the past three years) in the surveyed Norwegian grain farmers' barley fields.

Pesticide type	**Mean** number of applications/year	**Standard deviation**
Herbicides[a]	1,02	±0,32
Fungicides	0,98	±0,57
Insecticides	0,13	±0,36
Growth regulators	0,47	±0,54
Glyphosate[b]	0,55	±0,45

a: Against annual or perennial weeds during the growing season.
b: Against weeds outside the growing season.

As reported during the interviews, pesticide use in a Norwegian grain farmer's barley fields begins in the spring with herbicide treatment against annual weeds. As one farmer exemplified the process, «We usually walk around and monitor the weed situation and then we spray with herbicides in the springtime.» The farmers reported to choose which pesticides to use mainly based on how effective they were against the weeds in their fields, but also with an explicit anti-resistance strategy in mind. In the other grain types, herbicide treatment appeared to be very similar to the practice in barley production. The frequency of fungicide application is best characterised as being varied, both between farmers and between crops. Fungal pest outbreaks result not only in reduced quantity of yields, but in the advent of too large amounts of fungus in the grain yields, the farmers risk not being paid a premium for their products. As will be elaborated upon in section 5.4.3, in order to handle this risk, the farmers reported using different tactics.

None of the interviewed farmers reported to have sprayed against insects the last years, although many of them claimed to know of farmers who still did. As one farmer stated: «I never use insecticides. There is no point to it. I used to have some aphids, but it usually passes if you can keep your cool.» Similarly, farmers growing other cereal grains than barley reported identical perceptions of the lack of need for insecticide treatment. However, in oilseed production, the farmers reported that the need for insecticides was greater. Growth regulators were reportedly used to a varying degree as it depends on the use of fertilisers as well as the cultivar. Barley crops were told by the interviewed farmers to take less damage from lodging than other types of grain and therefore they reported to be less reliant upon growth regulators in the production of that grain type. Glyphosate was reported to be used in the fall mainly to manage the perennial weed, couch grass. The farmers reported that in order to manage the couch grass populations, they often either ploughed in the fall or sprayed with glyphosate. Many of the farmers interviewed claimed that glyphosate was an efficient tool against perennial weeds that helped to reduce the amount of herbicides used the following spring. In recent years, the effects of the use of glyphosate have been heavily debated. In Europe, the debate culminated around EU officials' recent decision to temporarily approve the use of glyphosate for a few more years. During the interviews, the farmers stated that they were relieved by the decision as many of them thought the remedy was very beneficial and dreaded the thought of not having it in their pest management arsenal. However, given the limitations of this investigation, specific inferences of the farmers' use of insecticides, growth regulators and glyphosate could not be made. Throughout the rest of the thesis, the focus will be on the farmers' use of herbicides and fungicides during the growing season.

The surveyed farmers demonstrated a willingness to spot spray and choose the lowest recommended dosage as very few farmers claimed to never use either of the practices (figure 5.9). The response category that was most frequently used by the surveyed farmers regarding choosing the lowest recommended dosage was midway between never and always, indicating that this practice might not always be suitable. Regarding spot spraying, the most frequently used category was "5 (always)" with 48% of the farmers reporting to always choosing to spot spray.

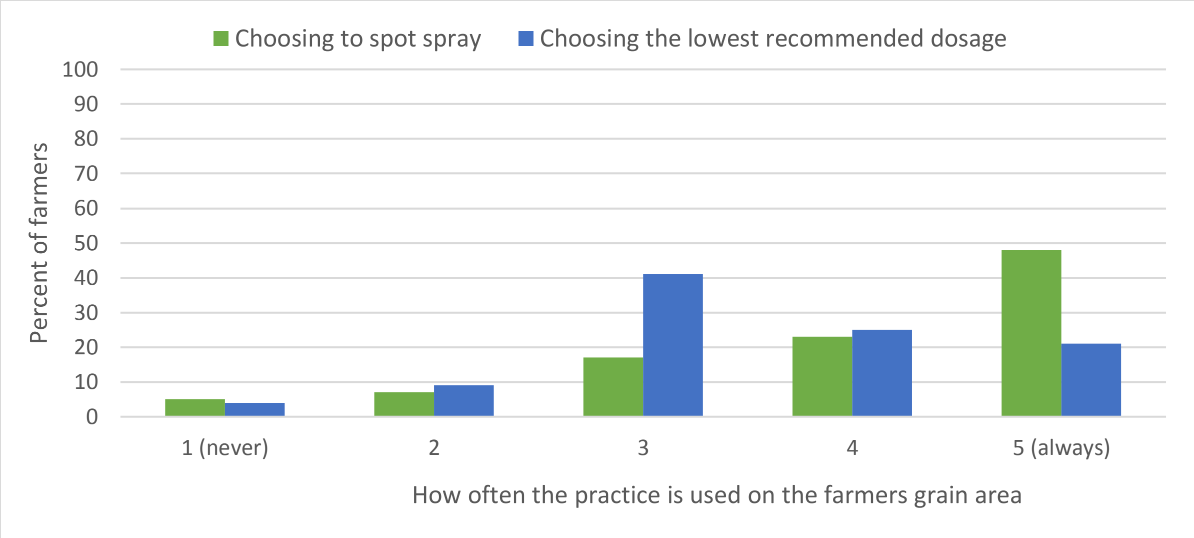

Figure 5.9: How often the surveyed farmers perform spot spraying and choosing the lowest recommended dosage.

During every interview where the topic of spot spraying against fungal outbreaks emerged, the farmers reported that it would be so risky that it was not something they even considered. This indicates that in this context, spot spraying means spot spraying against weeds. Depending on the weed type, the farmers reported varying attitudes towards spot spraying. Creeping thistle and wild oats were, for instance, reported only to appear in spots, thereby lending themselves vulnerable to spot spraying. Regarding other weed types such as for instance couch grass, some farmers were positive; «I happily spot spray with roundup[12] wherever I have couch grass, except in the field edges…If you manage to harvest early in the fall, spot spraying works well.»; whereas others were more negative; «If I have 80 decares of barley where there is couch grass here and there, I don't spray 80 decares, but I started trying out spot spraying against couch grass and the next year I could see where I hadn't sprayed. So, I have to feel very certain that there are no couch grass plants before I turn off the sprayer. Because with the human eye, it's hard to see.»

The interviewed farmers reported varying strategies for minimising the use of pesticides. Regarding herbicide spraying during the growing season, there seemed to be a consensus that one could use the lowest recommended dosage, but that if it dropped too low it could have the unwanted effect of promoting resistant weeds. As one farmer replied when asked whether he used the lowest recommended dosage, «Yes, I don't dare to go any lower. You could easily get some resistance that way.» Regarding fungicides, some farmers reported that using large doses

[12] The commercial name for the most commonly used product where glyphosate is the active ingredient.

was necessary and some farmers reported to keep the doses down. Ensuring that the conditions are right for spraying, especially against weeds, was also reported to be common practice. As one farmer reports: “Getting up 2-3 a.m. and spraying is really nice. It is brilliant to be doing it at that time.» The farmers reported that during those hours, there is less wind, and the target plants are more vulnerable, thus increasing both the effect of the herbicides and reducing the required amount.

During the interviews, the farmers emphasised the importance of pesticides in their grain production and from looking at the questionnaire data it becomes clear that they are nowhere near a scenario where pesticide application is optional rather than common practice. However, as one farmer explained, the pesticides are important mainly because there is no other alternative: “It is important for us not to use plant protection[13] other than when the plants need medicine, so we give them medicine. As is with public health care, we also need medicine when we are sick.” Even though they try to prevent their plants from becoming sick, they often do become sick, resulting in the need for pesticide application. During the interviews, the farmers also gave the impression of being extremely concerned with applying pesticides correctly and using as little as possible. One farmer, when talking about his pesticide application practice stated, «What’s important is that when you run things in a serious manner, doing it correctly becomes like a passion.» These findings support and exemplify the fact that Norwegian grain farmers manage to grow grains with a relatively low use of pesticides compared to other European farmers. However, pesticides remain a central part of the Norwegian grain farmers pest management practice and despite claiming to seek to reduce their use, they also emphasise the importance of correct use, which does not necessarily equal diminished use.

[13] Many Nowegian farmers use the term «plantevern», meaning plant protection, as a synonym for pesticides. A direct translation of the most common Norwegian term for pesticides is plant protection remedies.

5.2.5 Anti-resistance strategies (VII)

Most of the surveyed farmers reported to always or close to always take action during pest intervention in order to avoid resistance (figure 5.10).

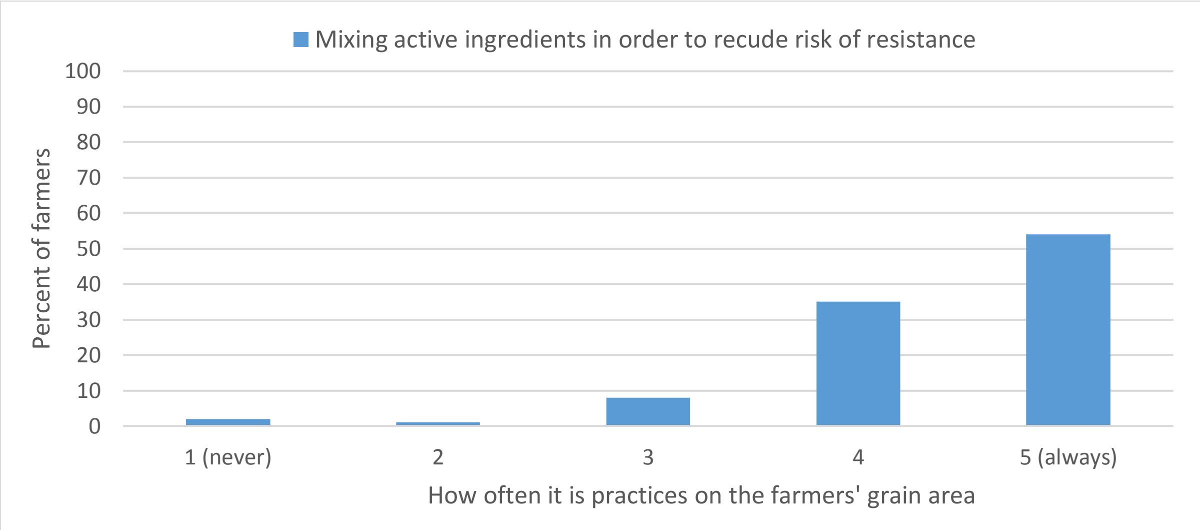

Figure 5.10: How often the surveyed farmers mix active ingredients in order to reduce the risk of resistance.

During the interviews, resistant weeds were reported to be a concern among the farmers and they expressed a suspicion that the problem had been caused by the switch to herbicides with higher concentration of active ingredients[14] and the resulting drastic reduction of the dosages. As one farmer stated, «Regarding herbicide spraying, reduced dosages were very popular one period, but I am certain that is the reason why we have gotten resistant weeds.» As emphasised in the previous section, a key part of the farmers' anti-resistance strategy is performing the spraying "correctly" as they reported to believe that it would result in reduced resistance. The mixing of active ingredients in order to reduce the risk of resistance was reported to be common practice. Not only did the farmers give the impression of having an anti-resistance strategy, but they claimed that the remedies they bought often come with the ingredients already mixed. It appears as if an anti-resistance strategy is integrated in what the interviewed farmers' deemed to be correct spraying practices.

[14] «Lavdosemidler», directly translated as low-dosage remedies. These substances have a high concentration of active ingredients thereby enabling the use of low dosages.

5.2.6 Evaluation (VIII)

A vast majority of the surveyed farmers reported to evaluate the effects of their pest interventions on all or most of their grain area (figure 5.11).

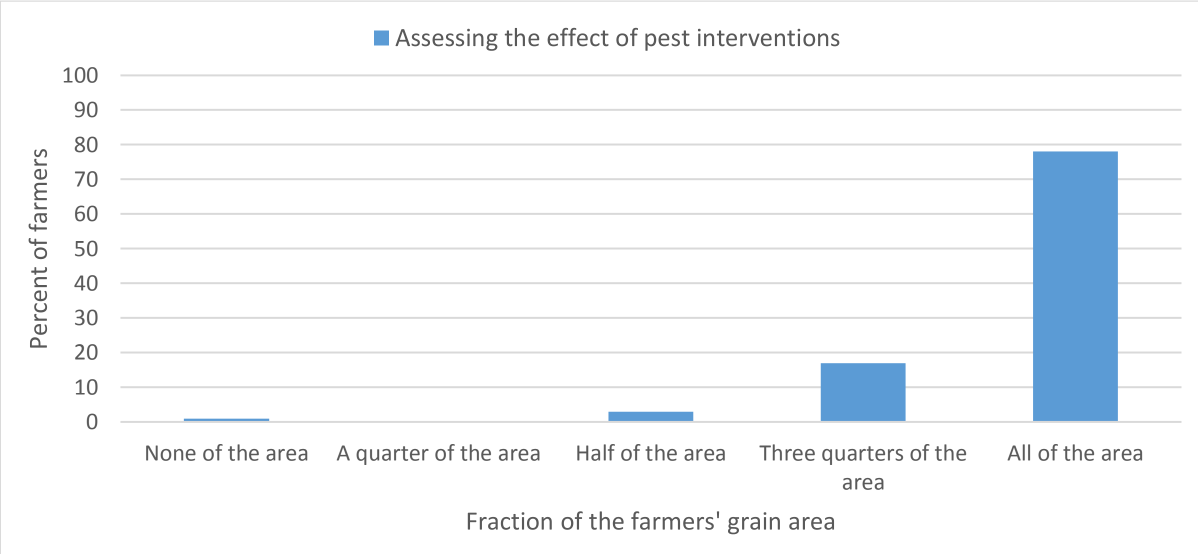

Figure 5.11: The fraction of the surveyed farmers' grain area they reported to assess the effects of their pest interventions on.

During the interviews, the farmers reported leaving untreated strips in the fields in order to assess the effect of the pesticides used. One farmer said, «Growth regulators are a part of our production system, but we choose to use it carefully and we always leave a triangle. Mostly to learn whether it was important or not.» The triangles that they left untreated in their fields were often reported to document the fact that the intervention was necessary. In fact, none of the interviewed farmers reported leaving a triangle and then learning that the intervention was unnecessary. Not only was the evaluation of their pest interventions important, but the farmers reported to more of less constantly evaluate their entire pest management strategy. They claimed that the only concrete practice they were required to do in the aftermath of the recently implemented IPM directive was to document their evaluation of their entire pest management strategy. Summing up the interviewed farmers attitude to the demand for documentation, one farmer stated, «I think that having to document it for a group of bureaucrats is a big nuisance. It has to do with the pride I take in farming.» The farmers said that evaluation was something they did no matter if they had to document it or not. Upon being asked whether they believed that the documentation itself had an effect on their pest management strategy most of the interviewed farmers stated that it did not and that it was only a nuisance.

To summarise the surveyed farmers' pest management practices, except from principle number "IV" related to non-chemical methods, all the principles are practiced extensively. This includes pesticide applications, which is a central part of the farmers' way of both intervening against pests and preventing increased risk of future pest outbreaks. To which extent they practice the original principle of "reduced pesticide usage" is difficult as a baseline measurement is lacking. However, this investigation could serve as a benchmark characterisation of Norwegian grain farmers' pest management practices for future research projects.

5.2.7 The use of IPM

As a measure of the varying degree of IPM implementation among Norwegian grain farmers, figure 5.12 shows the distribution of the surveyed farmers along the IPM index. It shows that 75% of the farmers obtained scores within a 20-point window on the index (60-80) with the remaining respondents distributed both above and below those scores. The mean score was 68 with a standard deviation of 9,9. The distribution of the farmers on the IPM index indicates that there is a large degree of similarity when it comes to the use of IPM. Despite the similarities in the responses, the lowest score was 11, and the highest 92 indicating that the questionnaire data enabled a division of the respondents along the index.

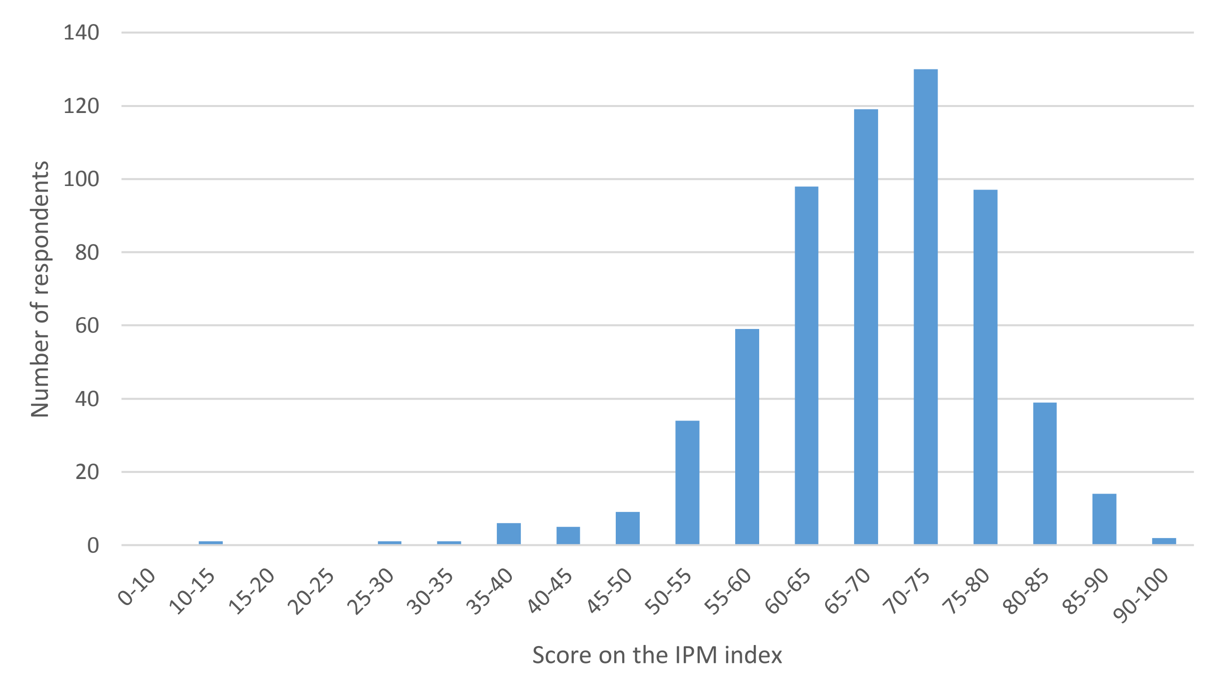

Figure 5.12: Distribution of the surveyed Norwegian grain farmers' scores on the IPM index.

It cannot be concluded that achieving a maximum score on this index is a good measure of ideal IPM use. However, it should be reiterated that this IPM index was not meant to measure the implementation of IPM among Norwegian grain farmers per se, but rather to separate the respondents of the questionnaire along a scale from less to more implementation of IPM practices.

Using a questionnaire in order to assess the farmers' use of IPM practices rather than self-assessment tool, as other researchers have done, limits the specificity of the measurement. This is because the questionnaire had to be kept within reasonable length limitations and contained questions regarding other topics than only the farmers' practices. Thereby, only a few aspects of the possible IPM practices were measured, whereas an index such as the one developed by the Danish researchers (Kudsk & Jensen, 2014) contains more practices and measures the use more precisely. However, the practices measured in this investigation were elected to represent the most important aspects of IPM in the Norwegian grain farming context, and the elaborate election method ensured that.

One example of an area where the index used in this investigation could be improved is measuring principle V (Pesticide selection). During the development of the questionnaire, we were unable to find suitable general questionnaire items regarding practices related to this principle. In the index, principle V is, therefore, the only principle that is not measured based on the farmers' report on their practices. Instead, a proxy in the form of an attitudinal questionnaire item was used.

Puente et al. (2011) warned that when measuring the use of IPM in a group of farmers one should consider that all practices are not equally suitable for all surveyed farmers. In general, the index used in this investigation has dealt with this warning by limiting the study to a fairly homogenous group of farmers and by rigorously consulting both regional experts and farmers in order to ensure context specificity. However, the response scale 1 (none of the area) – 5 (all of the area), used in many of the questionnaire items measuring the farmers' practices could in some cases be interpreted differently by different respondents. For instance, regarding the question of how much of their area they grow barley or wheat on three or more years in a row, the results indicated that some of the farmers have interpreted this as how much of their total area and some have interpreted it as how much of their barley and wheat area. To deal with this, scores were given according to their actual barley and wheat area (see Appendix C). Ideally, the questionnaire should have been even more unambiguous. Nevertheless, the index has multiple strengths such as its context-specificity, the elaborate weighting and the fact that it considers both how good performing one practice is and how bad the lack of performing the same practice is. The latter aspect has yet to be implemented by other IPM indices and future research should consider implementing it as it aids differentiation between more and less important practices.

Figure 5.13 shows that the interviewees reported a similar distribution along the IPM index as the rest of the respondents to the questionnaire. The qualitative data thus contains responses from farmers with a varying index score and the goal of interviewing farmers with a varying degree of IPM use was accomplished.

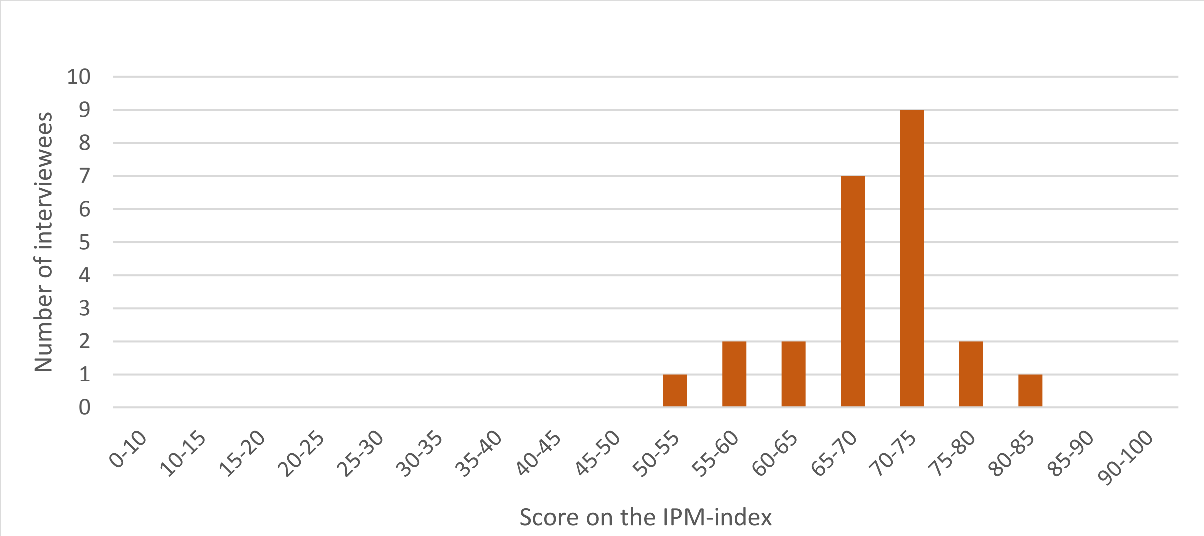

Figure 5.13: Distribution of the interviewed Norwegian grain farmers' scores on the IPM index.

During the in-depth interviews, many of the farmers regarded themselves as practitioners of IPM. A key point being emphasised by several farmers was that IPM was something they had been doing for ages. «It's something everybody does and have been doing throughout the years. At least the way I know it. IPM has been practiced even though it hasn't been called exactly that.» Most of the interviewed farmers reported that practicing IPM was part of what they considered correct practice. This finding is similar to what was found to be the case among Danish farmers: "From reading the eight IPM principles laid out in the EU framework directive, many farmers have responded that "IPM is just part of good farming practice".." (Kudsk & Jensen, 2014, p. 482). During the in-depth interviews, the Norwegian farmers were asked what they thought "good grain farming" in the context of pest management was. Most of the farmers insisted that some of the most important aspects was to never perform any operation on the fields unless the soil conditions were appropriate[15], maintaining high-quality and high-quantity yields and not spraying more than necessary. The fact that IPM practices, for the most part, does not seem to be new to the farmers, along with the fact that the characterisation of the farmers' pest management practices showing that many IPM practices are used by a majority of the farmers, indicates that implementation of IPM is not what should be discussed in Norway, rather it is the varying degree of practice. Not all farmers practice it to the same extent, and if

[15] The Norwegian term is «laglig» which in the Norwegian farming context has a more rich meaning than any single translated English word has.

increased implementation of IPM is wanted no matter how large the implementation is, an investigation of what determines the variation in the use of IPM is necessary.

5.3 Drivers for and barriers to practicing IPM

The Norwegian grain farmers' pest management practices take place in contexts within which certain aspects might be driving forces for the use of IPM and others barriers. With an institutional view on their rationalities, an assumption follows that not only are tangible aspects such as socio-economic characteristics and the characteristics of their farms important factors, but also their attitudes and perceptions of their local communities. Prior to presenting the analysis of the farmers' scores on the IPM index, results from the questionnaire regarding the farmers attitudes to farming and pest management and perceptions of their local farming communities are presented and analysed.

5.3.1 Patterns of the respondents' attitudes

Figure 5.14 shows that for the Norwegian grain farmers, being skilful, up to date in terms of knowledge and contributing to domestic food production were ranked as the most important aspects of being a farmer.

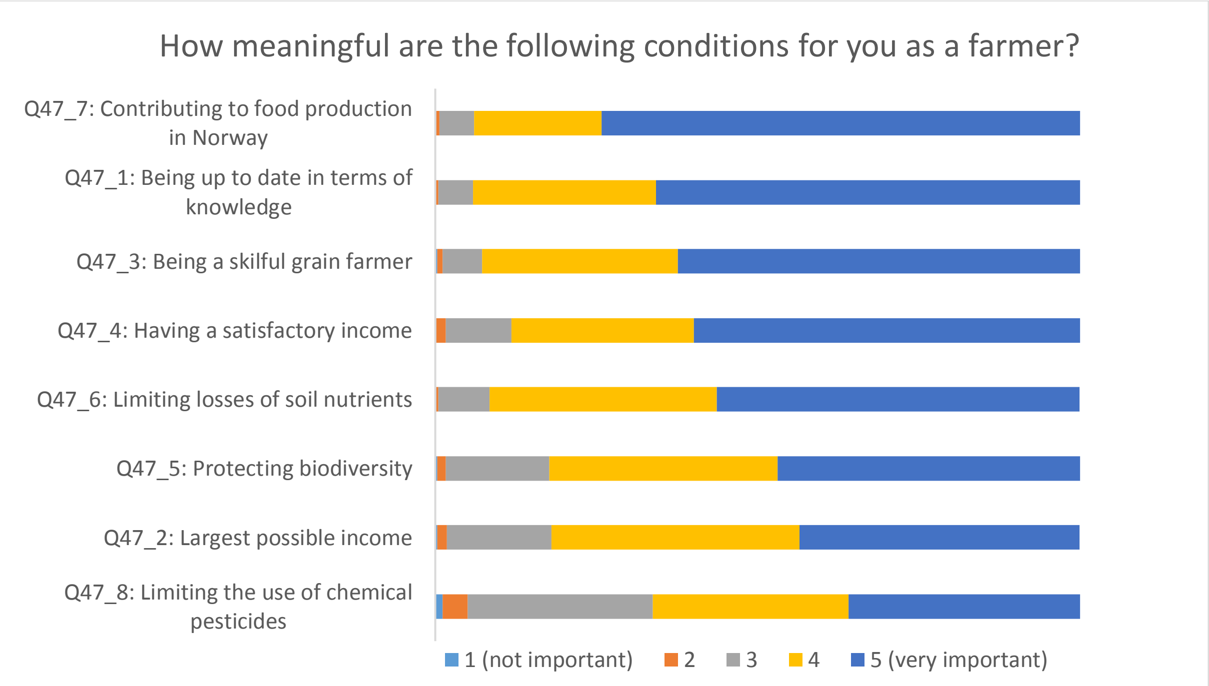

Figure 5.14: Responses of the surveyed farmers to statements related to a question regarding their attitudes towards farming. The response scale was a Likert-type scale form 1-5 where 1 = "not important " and 5 = "very important".

Even though statements such as limiting the use of chemical pesticides and maximising income were ranked as less important than other statements, none of the eight statements were ranked as unimportant.

When considering statements related to a question regarding attitudes towards pest management, the respondents ranked maximising crop quality, preventing pesticide-resistance and producing grains without traces of pesticides as the most important aspects (figure 5.15).

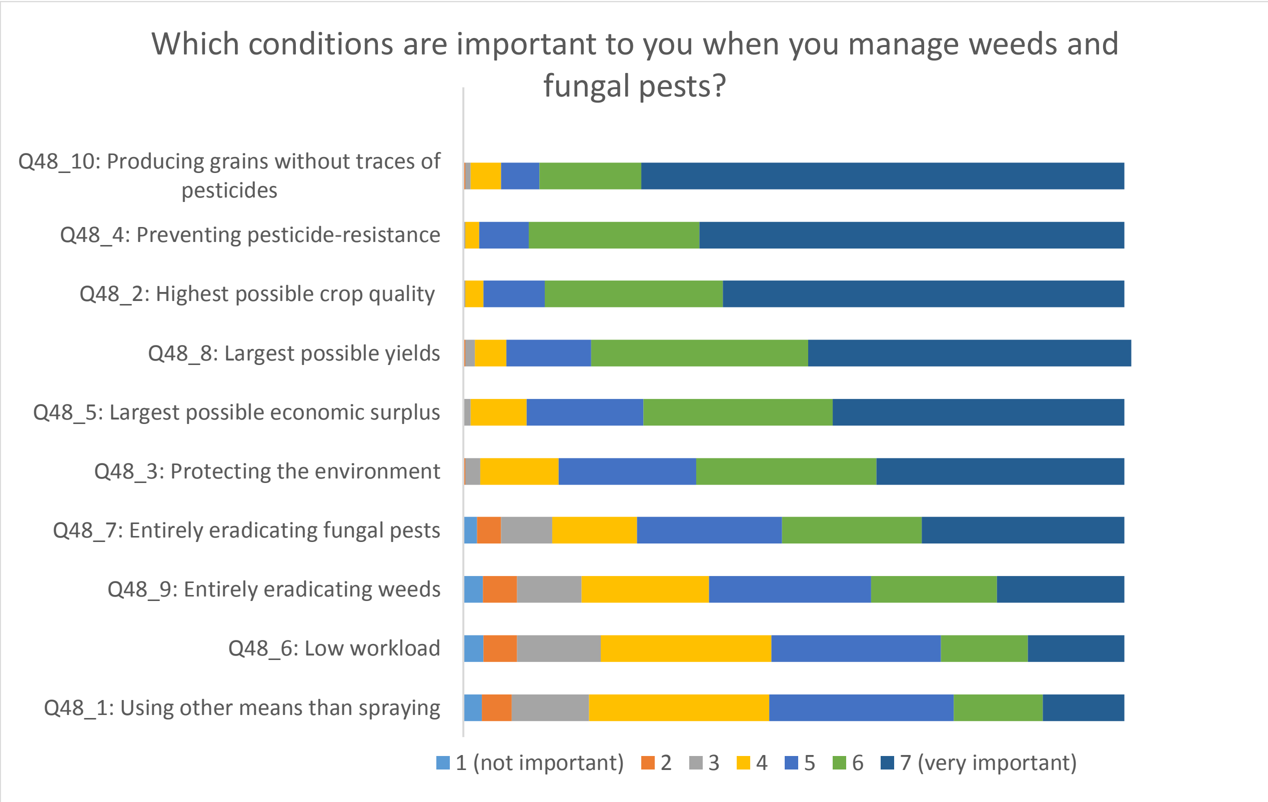

Figure 5.15: Responses of the surveyed farmers to statements related to a question regarding their attitudes towards pest management. The response scale was a Likert-type scale from 1-7 where 1 = "not important " and 7 = "very important".

The statement that was ranked as least important to the farmers was using other means than spraying. On the one hand, during the interviews, the farmers emphasised that reducing the use of pesticides to a minimum was part of correct pest management. On the other hand, as figure 5.14 and 5.15 show, the aspects of being a farmer and pest management ranked least important were limiting the use of pesticides and using other means than spraying, respectively. During the interviews, the farmers also emphasised the importance of pesticides in their grain production. It might be that the reason why using other means than spraying was ranked as not particularly important was that the farmers feel like they have no alternative. It appears that other considerations such as securing the grain production in a skilful manor in order to secure the income is even more important than limiting their impact on the environment.

Factor analysis of the responses to the questions reported in figure 5.14 and 5.15 yielded four groups of statements that were correlated enough to be used as factors. Each factor represents an observed pattern of covariance, suggesting that some underlying variable is present that is influencing all the included items in the factor. Table 5.4 shows the four factors and their correlation coefficients (factor load numbers).

Table 5.4: Factor analysis of the surveyed farmers' responses to two attitudinal questions. Only questionnaire items with a factor load number > 0.5 were included.

		Factor load number			
Q nr.	**Questionnaire statements**	1	2	3	4
Q47_2	*Largest possible income* [a]	0,817	-	-	-
Q47_4	*Satisfactory income* [a]	0,766	-	-	-
Q48_5	*Largest possible economic surplus* [b]	0,723	-	-	-
Q48_8	*Largest possible yields* [b]	0,674	-	-	-
Q47_3	*Being a skilful grain farmer* [a]	0,627	-	-	-
Q47_5	*Protecting biodiversity* [a]	-	0,832	-	-
Q47_8	*Limiting the use of chemical pesticides* [a]	-	0,763	-	-
Q47_6	*Limiting losses of soil nutrients* [a]	-	0,692	-	-
Q48_3	*Protecting the environment* [b]	-	0,681	-	-
Q48_4	*Preventing pesticide-resistance* [b]	-	-	0,755	-
Q48_2	*Highest possible crop quality* [b]	-	-	0,706	-
Q48_10	*Producing grains without traces of pesticides* [b]	-	-	0,658	-
Q48_9	*Entirely eradicating weeds* [b]	-	-	-	0,905
Q48_7	*Entirely eradicating fungal pests* [b]	-	-	-	0,882

a. Statements ranked by the farmers relating to question 47: "How meaningful are the following conditions for you as a farmer?" Ranked on a scale from 1 (not important) – 5 (very important).

b. Statements ranked by the farmers relating to question 48: "Which conditions are important to you when you manage weeds and fungal pests?" Ranked on a scale from 1 (not important) – 7 (very important).

The first factor consists of statements regarding whether the farmers find it important to have a large income, produce large yields and be a skilful grain farmer. I named the underlying variable affecting these items "economic mindset". The second factor consists of statements regarding limiting the environmental impact of farming and protecting the environment. Interestingly, if it is important to limit the loss of soil nutrients, it is simultaneously important to the farmers to limit their use of chemical pesticides. In the context of Norwegian grain farming, these two considerations are often contradictory as an attempt to limit the loss of soil nutrients generally results in increased need for pesticides. With this caveat in mind, I named the factor “environmental mindset”. The third factor consists of statements regarding ensuring high-quality crops and limiting the risk of compromising the quality. I thereby named it “crop quality”. The fourth factor consists of items related to the eradication of weeds and fungal pests from the farmers’ field, therefore I named it “clean fields”.

Four questionnaire items were not sufficiently correlated with the other statements of the two questions to be included in any of the factors. These items were:

Q47_1: *“Being up to date in terms of knowledge”*

Q47_7: *“Contributing to food production in Norway”*

Q48_1: *“Using other means than spraying”*

Q48_6: *“Low workload”*

“Q47_1” and “Q47_6” were the two statements the farmers ranked as most important regarding the question. Interestingly, they did not have high enough correlation with any of the four groups. “Q48_1” and “Q48_2” were ranked as the least important statements regarding the question. “Using other means than spraying” could intuitively have fit into the factor named “Environmental mindset”, but as discussed in the previous section (5.2.3) the Norwegian grain farmers appear to not be confident that they have any other good alternatives than spraying. However, limiting their use of chemical pesticides is important among those who have an environmental mindset. “Low workload” could intuitively have fit into the factor “economic mindset”. However, despite many of the farmers working full-time jobs outside their grain farming operations, having a low workload when managing the pest situation was not ranked as particularly important, whereas other aspects of their economy such as having a satisfactory income and maximising their surplus were more important.

5.3.2 Perceptions of their local farming community

The surveyed Norwegian grain farmers perceived that maximising their yield and having few weeds and fungal pests were among the most important aspects of good farm management in their local farming communities (Figure 5.16).

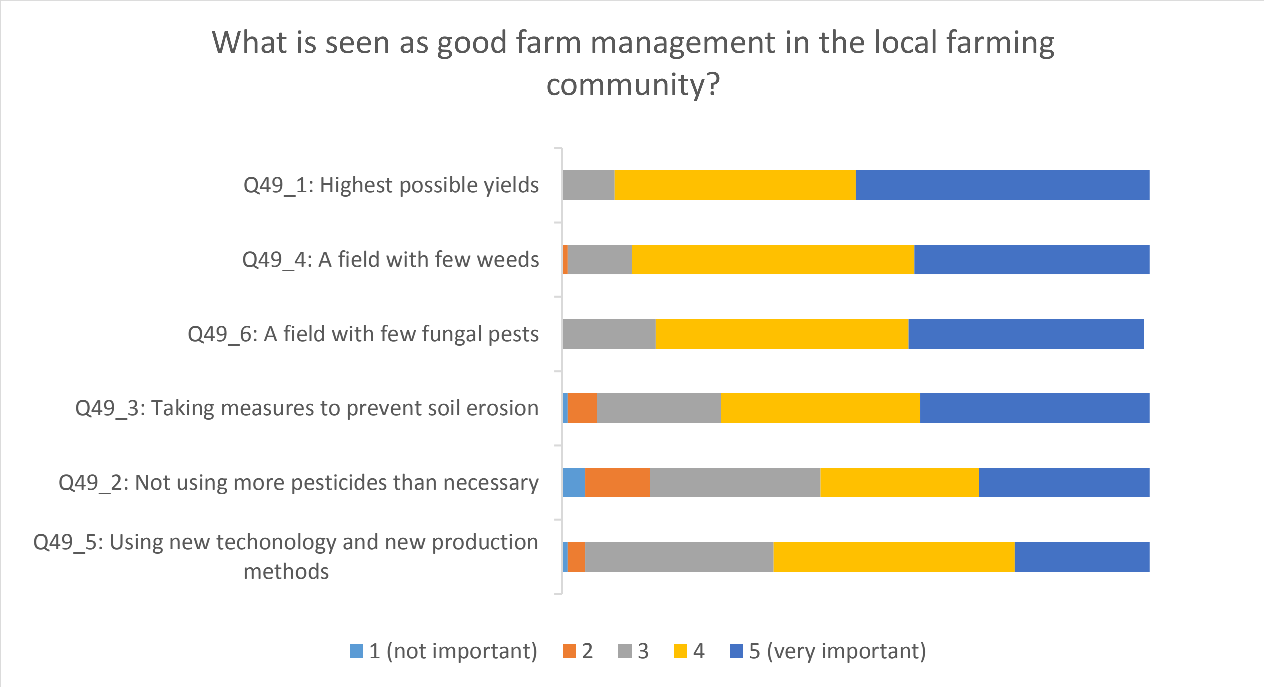

Figure 5.16: Responses of the surveyed farmers to statements related to a question regarding their perceptions of the local farming communities' attitudes. The response scale was a Likert-type scale form 1-5 where 1 = "not important " and 5 = "very important".

Similar to the question regarding the farmers' own attitudes to farming, none of the statements to the question regarding their perception of their local farming communities were ranked as unimportant. Following the trend from the previous sections, the farmers seem to find using as little pesticides as possible less important than other aspects of good farm management.

Factor analysis of the responses to the question regarding the farmers perceptions of their local farming communities yielded two groups of statements were correlated enough to appear as factors. Table 5.5 shows the two factors and their correlation coefficients (factor load numbers).

Table 5.5: Factor analysis of the surveyed farmers' responses a question regarding their perceptions of their local farming communities. Only questionnaire items with a factor load number > 0.5 were included.

		Factor load number	
Q nr.	Questionnaire statements	5	6
Q49_2	*Not using more pesticides than necessary* [a]	0,910	-
Q49_3	*Taking measures to prevent soil erosion*[a]	0,892	-
Q49_4	*A field with few weeds* [a]	-	0,805
Q49_1	*Highest possible yields* [a]	-	0,783
Q49_6	*A field with few fungal pests* [a]	-	0,713

a. Statements ranked by the farmers relating to question 49: "What is seen as good farm management in your local farming community?"

The fifth factor consists of statements regarding limiting the environmental impact of farming and protecting the environment. It is similar to the second attitudinal factor and comes with the same caveat (table 5.4). I, therefore, called the factor "perceived environmental". The sixth factor consists of statements regarding limiting the amount of pests in the fields and maximising yields. This factor is similar to the fourth attitudinal factor, but instead of being concerned with entirely eradicating weeds and fungal pests the items in this factor is more related to maximising yields and keeping pests away. Despite the difference, I called the factor "perceived clean fields".

The statement "Q49_5: *Using new technology and new production methods*" was not found to be sufficiently correlated with the other statements to be included in any of the two factors. The statement did not intuitively fit into any of the two factors as none of the other items were related to the topic of adapting new technologies. During many of the interviews, the farmers mentioned that technologies such as drones, sensors and even field robots could be included in their pest management practices in the near future. Although that topic was not pursued in this thesis, the results indicate that the Norwegian grain farmers perceive using new technologies as less important than other aspects of pest management. Therefore, future research could benefit from focusing on the farmers' willingness to adopt new technologies.

5.3.3 Examining the variation in the use of IPM

The intention of this analysis is to examine which aspects of the farmers' contexts appear as barriers and drivers to their use of IPM. Given the significantly low P value of the F-test, the independent variables were shown to improve the fit of the model and allow inferences about the relationship between the variables to be made (table 5.5). The adjusted R^2 value indicates that in addition to the independent variables included in this model, other factors are also affecting the farmers' use of IPM.

Table 5.5: Regression analysis of the surveyed farmers IPM index scores explained by independent questionnaire items.

R^2: 0.1873	**Adjusted R^2: 0.16644**	**F Value: 8.96**		**Pr > F: <.0001**	
Variable	Explanation	Parameter estimate	Standard error	t Value	Pr>|t|
Factor 1	"Economic mindset"	0.945	0.765	1.24	0.217
Factor 2	"Environmental mindset"	3.548	0.722	4.91	**<.0001*** **
Factor 3	"Crop quality"	2.467	0.895	2.76	**0.006** **
Factor 4	"Clean fields"	-0.597	0.311	-1.92	**0.055***
Factor 5	"Perceived environmental"	-0.635	0.464	-1.37	0.172
Age	2017 minus year of birth	0.030	0.038	0.79	0.428
Part-time farming	0 = full-time, 1 = part-time	-0.831	0.843	-0.98	0.325
Grain area	Measured in hectares	<.0001	0.001	-0.21	0.834
Low farming income	0 – 99 999 NOK	-2.031	1.144	-1.77	**0.077** **
High farming income	400 000 NOK →	1.105	0.915	1.21	0.227
Unknown farming income	Opted to not report farming income	3.993	1.366	2.92	**0.004*** **
Gender	0 = female, 1= male	-3.045	1.334	-2.28	**0.023** **
Degree of education	1 = Primary or secondary 2 = Vocational high school 3 = General subject high school 4 = Higher education	2.086	0.844	2.47	**0.014** **
Farming education	0 = no, 1= yes	1.163	0.844	1.38	0.169
Talking to other farmers about pest management	1 = never, 2 = less than monthly 3 = monthly, 4 = weekly 5= more than weekly	2.610	0.870	3.00	**0.003*** **

*: p-value < .10, **: p-value < .05, ***: p-value < .01

Regarding the underlying variables reflecting the farmers' attitudes, an increasing score on the second and the third factor is significantly correlated with increased use of IPM. This means that those who reported to find it important to both limit their environmental impact and simultaneously produce high-quality grains on average have a higher use of IPM than those who find it less important. The parameter estimates are relatively high in both cases, indicating that if a farmer on average found it one point more important on the questions regarding her/his attitudes to environmental aspects of farming, it would correspond with an increase in the score on the IPM index of 3.5 points. These findings align with the documented trend that a key factor to adoption of pest management less reliant on pesticides is attitudes towards health and environmental risks due to pesticide exposure (Lefebvre et al., 2015). Conversely, the farmers who found it important to entirely eradicate pests have a lower implementation of IPM on average. This is as expected since IPM is a strategy where the goal is not to entirely eradicate all pests, but to reduce the risk of harming the environment and human health while simultaneously ensuring a sustainable economic output. However, the size of the parameter estimate indicates that impact of these attitudes is of a lower magnitude than those of the second and third factor.

The first factor did not significantly correlate with the use of IPM. The reason why having an economic mindset does not appear to affect their use of IPM might be due to the factor containing statements regarding maximising income and yields. As Lefebvre et al. (2015) claimed that there is evidence for, the farmers who adopt IPM to a higher degree might be willing to trade maximisation of income and yields for a reduction of the risk of harming the environment and human health.

It appears that how environmental the farmers perceive their local farming communities to be does not significantly affect their use of IPM. Multicollinearity with the factor "economic mindset" excluded the factor "perceived clean fields" from the model. The multicollinearity indicates that there is a relationship between these two factors. With an institutional view on the rationalities of the farmers, there are good reasons to believe that how they perceive their local farming communities has an impact on their own attitudes. Given that their own attitudes were shown to correlate with their use of IPM, it could be interesting to investigate what influences their attitudes. This prompted further analysis, described in the next sub-chapter.

Neither variations in the age of the respondents, nor the size of the grain area they managed, nor whether they were part-time farmers were found to significantly correlate with the extent to which they practiced IPM. Due to multicollinearity, total area, rented area and farming experience were excluded from the model. During the in-depth interviews, many farmers suspected that as soon as the younger generation takes over the farms, increased use of IPM would follow. As an example, speaking of increasing the use of IPM, one farmer said, «I feel like I register a change now that younger farmers take over.» Upon being asked why, he said, «older farmers have in a way been doing things their way». However, the results from this study suggest otherwise. When investigating barriers to IPM implementation among cranberry farmers in Massachusetts, Blake et al. (2007) found that the farmers with the highest degree of IPM adoption were highly experienced, full-time farmers with large cranberry operations. Parallel, an investigation of the use of IPM among farmers in Wisconsin found a positive relationship between large farms and IPM adoption. However, as Blake et al. (2007) pointed out, previous research regarding which socio-economic variables that play a factor in IPM adoption is not conclusive, as opposing findings are documented. This study on Norwegian grain farmers could neither support nor disprove their findings. It might be that the varying contexts that the farmers operate in makes comparisons across borders difficult. Nevertheless, it appears that the size of the Norwegian grain farmers' area, their age or whether they have a job outside the farm or not is no limitation to their adoption of IPM.

During the in-depth interviews, two opposing narratives were prominent regarding whether large-scale farmers were practicing more IPM than small-scale farmers were. Upon being asked what he thought was necessary in order to achieve more use of IPM, one farmer claimed, «I would have been better if I only had more land and if I was a full-time farmer.» thus exemplifying the narrative that larger the scale of your farming operations, the better your practices become. Conversely, some believed that large-scale farmers do not have the time or resources to manage all their land properly. As one farmer stated: «I've registered that they do not achieve the yield levels that us smaller farmers do…Practicing IPM is not that easy when you have 3000 decares[16], but there might still be some who are very good.» They are thus not questioning the ability of the large-scale farmers, but rather the possibility of managing to practice IPM on a large scale. In a study of the degree of pest management technology adoption among cereal farmers in the UK, Sharma et al. (2010) found that full-time, younger farmers use the largest amount of technologies. Given that IPM adoption often requires implementation of pest management techniques, one should expect to find that younger, full-time farmers would

[16] 10 decares (da) = 1 hectare (ha) Norwegian farmers use decare as the unit for measuring area.

be the farmers practicing IPM to the largest extent. However, it might be that practicing IPM is not so much about implementing new technologies as it is about practicing good agronomy.

The income variables “low farming income” and “high farming income” are dummy variables that are measured against the dummy variable “medium farming income” (100 000 NOK – 399 999 NOK). This means that farmers with a low farming income practice significantly less IPM than those with a medium farming income. It is not surprising that a low farming income coincides with a lower use of IPM as it should not be forgotten that IPM is not only about lowering the risk of harm to the environment and human health, but also about simultaneously ensuring a justifiable economic result of the production. No significant difference was found between those with a high and a medium income. This indicates that the farming income is relevant up to a certain point. This supports the finding that having an economic mindset does not significantly correlate with increased use of IPM either.

The farmers who did not wish to report their farming income scored significantly higher on the IPM-index than the farmers with a medium farming income. There were 48 (8%) of the respondents who did not wish to report their farming income. There might be several reasons why certain farmers elected not to report their farming income, and many reasons might be of a private nature[17]. Further investigations of this issue is beyond the scope of this thesis, but future research being done in the same context should consider this observation as there might be a common factor among these farmers that positively correlate with their score on the IPM index.

Female Norwegian grain farmers were found to practice IPM to a greater extent than male farmers. However, as previously discussed, the women in this study might not be representative of the survey population thus compromising the reliability of this result. It should be noted that the relatively large parameter estimate (negative because of the way gender was measured) should be viewed in the light of gender being an aspect of the farmers that can only take two values. Therefore, the effect of gender is limited to approximately 3 points as opposed to for instance “crop quality”, which in principle can vary between values 1-7. Nevertheless, this

[17] During the data collection, some farmers reported to be displeased with this question being in the questionnaire. They were under the impression that the governing politicians would use income data against the farmers in budget negotiations.

finding suggests that in pursuit of increasing the implementation of IPM, supporting a higher rate of female farmers could be beneficial.

Looking at the education variables, a higher degree of education significantly correlates with increased scores on the IPM index, whereas having a farming education does not. Previous research on IPM adoption among farmers in New Jersey found that a high education level coincided with IPM adoption (Hamilton et al., 1997). Barzman et al. (2015) stated that due to the conceptual and knowledge-intensive nature of IPM, a practice based on its principles cannot be encapsulated recipe-like recommendations. It is therefore not surprising that farmers who have a higher degree of education and therefore are likely to be more trained to comprehend abstract conceptualisations consequently are better at practicing IPM. However, the finding regarding farming education was somewhat unexpected. It appears that the Norwegian grain farmers manage to practice IPM regardless of their farming education level. Nevertheless, the positive parameter value and the low p-value suggest that there is at least some relation between having a farming education and increased practice of IPM. There might be other educational resources not included in the survey that are important. During the interviews, many of the farmers emphasised that one such resource is the certification course that has to be taken every ten years in order to remain a certified pesticide user. During that course, the farmers reported learning about IPM and correct pesticide practice. The course was reported to have both theoretical and practical contents. Given the conceptual and knowledge-intensive nature of IPM, demonstrating IPM in practice might be less feasible than explaining the concepts. Therefore, it might be that farmers with a higher general education level are better equipped to learn from the theoretical contents of such educational resources than farmers with a lower level of general education. However, further research is needed to investigate this relationship more thoroughly.

How much the farmers talk to each other about pest management during the growing season is shown to positively correlate with the use of IPM among Norwegian grain farmers. A social sciences study conducted in Europe found that isolated farmers were less likely to engage in IPM opposed to farmers in groups who construct locally adapted solutions by learning from one another, advisors and researchers (ENDURE, 2010). This is similar to what has been documented in this investigation, and during the interviews, the farmers also emphasised the importance of discussing the complexities of pest management. One farmer, who during the interview reported to be part of a group of farmers who regularly meet to discuss grain production said: «To gather and discuss things is also key. It becomes a bit more integrated when you get more viewpoints on a matter.» He thus indicated that using discussions with peers as decision-support was important for making good judgments. How often they talk together is also not necessarily an aspect of individual farmers, but maybe a feature of a certain community. There might be communities where farmers talk more together about pest management rather than individual farmers who are more eager to talk to other farmers about pest management. In this investigation, the unit of analysis is individual grain farmers. Future studies should consider controlling for the effect of separate communities.

5.3.4 The role of perceptions of the local farming community

Table 5.6 presents four models where each of the individual factors are explained by the factors related to the farmers' perceptions of their local farming community. The regression analyses show that the farmers' perceptions of their local farming communities significantly correlates with their own attitudes. The results all point in the same direction, namely that the more a farmer perceived that in her/his community, being environmental and keeping her/his fields clean was important, the more important were the items related to all the factors of her/his own attitudes.

Table 5.6: Four models of the factors regarding surveyed Norwegian grain farmers' attitudes and their correlation with the farmers' perceptions of their local farming communities.

	Dependent variable	Independent variables	Parameter estimate	Standard error	t Value	Pr>|t|	Adjusted R^2	Pr> F
A	*Economic mindset*	*Environmental community*	0.119	0.026	4.63	**< .0001*** **	0.22	<.0001
		Clean fields community	0.460	0.045	10.24	**< .0001*** **		
B	*Environmental mindset*	*Environmental community*	0.246	0.029	8.55	**< .0001*** **	0.16	<.0001
		Clean fields community	0.164	0.051	3.24	**0.0013*** **		
C	*Crop quality*	*Environmental community*	0.094	0.025	3.71	**0.0002*** **	0.14	<.0001
		Clean fields community	0.338	0.045	7.59	**< .0001*** **		
D	*Clean fields*	*Environmental community*	0.359	0.059	6.09	**< .0001*** **	0.18	<.0001
		Clean fields community	0.788	0.103	7.63	**< .0001*** **		

*: p-value < .10, **: p-value < .05, ***: p-value < .01

To make sense of the regressions, one should consider that all of the three factors, "economic mindset", "crop quality" and "clean fields" are aspects of agronomical considerations that improve the output of the farmers' grain operations. Hereafter, these three factors will be referred to as the agronomical factors. The factor "environmental mindset" does not contain these agronomical considerations as preventing soil erosion and protecting biodiversity does not increase the output of their grain operations. At least not in the short term. It should be noted that two of the attitudinal factors ("crop quality" and "clean fields") contain questionnaire items with a scale from 1-7 and the other two factors have a mix of items with that scale and a scale from 1-5. This means that the parameter estimates of the independent variables in model C and D might, therefore, be higher than in models A and B simply because the scales are different. The parameters of the regressions can therefore not be directly compared across regressions. Nevertheless, the difference between the two scales is small and the overall picture is not influenced.

Looking at the parameter estimates, we first observe that they are all positive and significant. This means that living in a perceived "environmental community" also increases the level of the agronomical factors as well as living in a perceived "clean fields community" increases "environmental mindset". Nevertheless, the numbers for "clean fields community" is at least twice as high as "environmental community" in models A, C and D. It is opposite when it comes to the factor “environmental mindset” in model B. This indicates that if a farmer perceives that clean fields are an important aspect of her/his community, it is likely that s/he finds considerations regarding the agronomical factors more important than in the opposite situation. The same is true for considerations regarding the factor “environmental mindset”, but in this case, perceiving the local community as environmental is an even more important factor than perceiving that clean fields are important in the local community. From the above, we observe that the local farming community – as perceived by the farmer – influences the farmer’s own mindsets. Parallel to the discussion of the role of the local culture in how much the farmers talk to each other, the local culture also influences the farmers’ mindsets.

The fact that all parameter estimates are positive may seem somewhat confusing. From the analysis of the IPM index scores, it was shown that two of the attitudinal factors positively correlated with the use of IPM, one was not significantly correlated and one had a negative correlation. Both the factors that were found to positively correlate with the use of IPM were also found to positively correlate with the factors regarding their local community. In other words, if a farmer perceives his community as environmental, s/he is likely to have a more environmental mindset, which further correlates with an increased use of IPM. Following this logic, one should expect to find that if the farmers perceived their local communities as environmental they should be less likely to find it important to have clean fields themselves. However, the opposite was found. To check whether the earlier mentioned caveat regarding the environmental factors had an impact (see section 5.3.1), the analyses were run separately with both questionnaire items included in the factor. This did not change the results of the analysis.

In the analyses above, it can be shown that if a farmer perceives that the local farming community finds it is important to have clean fields, it coincides with the farmer finding the agronomical factors important. One way to explain this finding is to consider the literature documenting the fact that visible features of farming affect farmers’ attitudes. According to Robert Burton’s concept of a “good farmer”, visual representations, such as having a tidy, weed-free field with high yields are symbols that have both cultural and economic value (Sutherland, 2013). In attempting to be “good farmers”, if the farmers perceive that these aspects, displaying agronomical competence, are important in their local communities, they might become more important to themselves. I suggest that despite certain aspects of the environmentally protective practices such as limiting soil erosion and using less pesticides might be visible to neighbours, the aspects of the agronomical factors such as having high yields and tidy, weed-free fields are even more visible throughout the growing season. An aspect of reducing pesticides is, for instance, using lower dosages, which is very hard to detect from a distance.

During the interviews, the farmers indicated that they do keep in touch with their local farming community and keep track of the fields of their neighbours. Burton and Paragahawewa (2010, p. 98) argued that because farming is open to direct, uninvited and unavoidable scrutiny of the peer group and that agricultural land becomes a display of the farmers knowledge, values and work ethic, "Clearly therefore, any activity visible on the land that is not indicative of 'good farming' may restrict the generation of cultural capital, damage the reputation or status of the farmer and, consequently, lower their access to social capital." In this view, the Norwegian grain farmers might seek to avoid the restriction of access to social capital through displaying that they are "good farmers". However, during the interviews, the farmers insisted that they did not think less of other farmers who were unsuccessful. When asked whether one should have a tidy field in his community, one farmer replied, «No, but of course we keep track of each other. I can look and think, 'he has chosen the wrong crop this year'. But he didn't choose the wrong crop, it was the weather that turned bad on him.» He reported to discuss this particular failed field later on in the season with the other farmer and together they figured out a possible reason, "Later on in the summer, we found that maybe it was the timing of sowing. A small miss." Upon being asked whether they learn from each other, he replied, «Yes, absolutely. And there is no schadenfreude or anything, but you can clearly see if someone has been unlucky.» The farmer displayed that they keep track of each other, but that their first reaction is not to restrict the other farmer from social capital, but rather to try to learn from each other. From an institutional viewpoint, this makes sense. The institution of good agronomy is in constant flux and the practices related to the institutions are reviewed by the typified actors who sustain the conventions and norms. It might also be that the farmers actually do experience restricted access to social capital in the event of failing to display visible aspects of being a "good farmer". The fact that some of the interviewed farmers indicated that it was not the case does not adequately investigate the proposition.

Nevertheless, the findings from the analyses indicate that by attempting to be a "good farmer", the less visible institutions representing environmental values might have to give way to the displays of agronomical competence that are more visible throughout the growing season. Given the limitations of the thesis, non-visible aspects were however not controlled for and it might be that the agronomical factors coincidentally are more visible than the environmental aspects. Eventual future investigations should consider the dimension of visibility of the farmers' actions.

5.4 Pest management decision processes

While the previous sections have focused on describing the farmers practices and which underling variables correlate with a varying degree of IPM practice, in this section, the reasons behind their practices are scrutinised.

5.4.1 Reasons for the interviewed farmers' IPM practices

When making decisions about pest management practices, the interviewed farmers appeared to rely partly on the conventions and norms of their communities with an emphasis on ensuring adequate profitability, and partly on individual components such as antecedents and contextual constraints (table 5.7). The reasons listed in the table below should be considered in relation to the characterisation of their practices given in section 5.2 where multiple examples related to the items in the following characterisation is given. Following the presentation of the reasons, a brief discussion of each of the categories is given.

Table 5.7: Pest management decision process of interviewed Norwegian grain farmers. The colour of the text indicates the extent to which the interviewed farmers seemed to share this reasoning. Red = “most”, black = “many”, blue = “a few”.

	Good agronomy	Economy	Contextual constraints	Antecedence	Other
Preventive and suppressive measures	Ploughing is a very efficient mean in order to reduce the weed pressure. Due to timing of harvesting and varying weather conditions, tillage practices should be adequately adapted. Good drainage and good crop rotation ensures low pesticide usage. Rotating between wheat and barley is not particularly beneficial. Oats are good, but peas or oilseeds are even better. Despite lower income, oats should be used in the crop rotation because of the benefits of reduced pesticide use and increased yields levels.	Driving on the fields in any form is costly and should be minimised. There are subsidies for not ploughing in the fall. Choosing fungus-resistant cultivars because you save money on needing fewer pest interventions. Trying to maximise the amount of wheat and barley because it pays best. Willing to sacrifice a little bit of the income in order to ensure a good crop rotation	Poor drainage and liming limits prevention and suppression. Stones in the soil prevents harrowing and harvesting is hampered. Optimal crop rotation is prevented by time constraints in the harvesting period, capacity for drying of grains and climatic conditions. Soil conditions prevents spring tillage. Jobs outside farming forces simplification of the production, thus preventing elaborate prevention methods.	More ploughing has shown to reduce weed pressure. Willingness to try out new grain types is hampered by bad experiences. Insect infestation of rapeseed fields prevents them from wanting to try growing it again. Experiences with organic farming has provided insight into alternative measures.	Low market demand for oats repelled the inclusion of oats in crop rotation. Family members with a certain authority prevents the farmers from autonomously choosing preventive measures.
Monitoring	Frequent monitoring throughout the growth season is crucial for having control of the pest situation and being able to hit the correct timing of pest intervention. Monitoring is very important against fungus because timing is important.		Time constraints prevents sufficient monitoring.	Monitoring does not matter against fungus since it is too late if it has already struck.	
Decision support	Forecast systems such as VIPS allows the preparation for potential pests that are spreading. One should listen to the extension service because their expertise is trustworthy. Thresholds should be used to aid the decision of whether or not to intervene.				
Non-checmial methods	Weed harrowing is difficult to time. For proper use, the correct timing is crucial to hit as both soil and plant conditions must be optimal. Wild oats should be weeded manually because it is efficient.	A weed harrow is not worth the investment. Remedies against manually weedable weeds become cheaper now.	Varying soil types and climatic conditions prevents the use of weed harrow. Not having access to a weed harrow prevents the use of it.		

Pesticide application practice	In order to achieve high yield quantity and quality, pesticides are necessary. One should not go lower than the lowest dose as it will result in increased risk of resistance. By doing the pest management yourself, you have the control. One should use the doses recommended by the extension service because if less is used it could drastically reduce how effective the treatment is. The use should be limited as it is both expensive and harmful to the environment. One should use as little as possible. Fungicides are unavoidable when growing wheat. Fungicides should in principle not be necessary when growing oats. Mixing a small preventive dose of fungicides with the herbicide spraying was usually done, but lately this practice has disappeared because it is not necessary. In principle, insecticides should not be used when growing cereal grains. Experience is paramount for performing spraying correctly. One should use as little pesticides as possible because the products should not contain traces of pesticides.	Keeping the pesticide bills as low as possible. Using pesticides is a way of reducing the risks of lower yield quality and quantity. If the field seemingly does not have the potential to return high yields, the use of pesticides should be limited. Pesticides are not more expensive than the reduced earnings of low yield quantity and quality. Pesticides have become more expensive thus resulting in lower use. Pesticides are the cheapest alternative to efficiently manage pests.	Sense that the need for fungal treatment is increasing due to wetter climate. Increased crop quality demands have forced the farmers to spray even more with fungicides. Nozzles of sprayers are not efficient. Larger, better sprayers allows better timing of spraying.	Cautious about using low-dosage remedies since they are not as effective and have caused resistance. Not spraying prophylactically against fungus results in attacks. Insecticides are useless because the insects do not cause that much harm and natural predators control the pest insects. Herbicide treatment early in the summer is essential. If it is skipped, then weeds will take over the fields. Not using growth regulator on certain cultivars leaves the fields flat as well. One year, when the summer was exceptionally dry, not spraying against fungus went well. Not spraying against fungus was OK when there was no outbreak before the application deadline.	Nobody enjoys spraying. Environmental concerns regarding spraying causes the farmers to use less. Some do not use insecticides or growth regulator because they are principally against it due to environmental concerns. Reducing pesticide usage for personal health reasons.
Anti-resistance strategies	Correct use of pesticides prevents resistant weeds from developing.			Resistance due to the use of low-dosage remedies causes them to use more broad-spectrum remedies.	
Evaluation	One should leave small areas in the fields untreated in order to evaluate the effect.		Evaluations of the practices always have to be put in the context of the weather conditions that season.		

As expected, the conventions and norms of good agronomy, displayed as typified actions were found to be a major part the farmers' pest management decision processes. These institutions regularise their farming operations such that they can move forward without performing complex calculations related to every decision. An example of how they are following the conventions and norms of good agronomy is given by a farmer regarding how to manage fungal pests, «We usually spray the wheat a couple of times. But the second time, there should be a need before you do it. One doesn't do it just to have it done.» This is a typical example of how the farmers reasoned their practices. First, they described what they do and how they do it, and then they justified their practices by either emphasising that it is "how things are done around here" or "how it should be done around here". This particular farmer knows that when he grows wheat, fungicide spraying is to be expected and that particular evaluations must be done regarding the second dosage. As he expressed, by evaluating carefully the second time, he ensures that he sticks to, and reproduces the convention of fungicide application practice. However, it might also be that he does this to maximise his profits.

Throughout the interviews, the central position of the economic realities of pest management was emphasised by the farmers. A typical statement was "at the end of the day, the bottom line is what counts." The interviewed farmers reported seeking to make their grain farming operations profitable. However, in critical moments, maximising profits did not appear to trump the importance of producing high quantity and quality grain yields. This point was illustrated during one of the interviews where two farmers[18] discussed their tillage practices: «Economically, it pays off to reduce tillage up to a certain point. There probably is a reason that other people do it.» The other farmer replied, «It results in less costs for everything you do on the fields. Everything costs less, so you get a lot less back.» The first farmer responded, «Yes, but you don't get proportionately less back. I don't think. No matter how much we had reduced, we wouldn't have gotten below 400 kilos per decare. My father was pleased with anything above 500. We're not quite there.» Here, the farmers displayed two components of bounded rationality. First, by demonstrating that they are not optimising the economic output. If they were, they might as well have reduced tillage. Second, by relating the success of their grain production in terms of tangible yield numbers. The farmers later specified that they were satisfied with yields above 600 kilos per decare. These farmers represent how maximising

[18] They were interviewed together because both were involved in the farming operations.

profits is on the farmers' minds, but how the practices manifested from conventions and norms related to good agronomy trumps the bottom line to the extent that satisficing is preferred over maximising.

Every farm is unique in terms of the soil conditions, weather patterns, the equipment available etc. These contextual factors were reported to place certain constraints on the farmers' pest management practices. As one farmer reported regarding weed harrowing, «There was a period where weed harrowing was considered. If you have nice sandy soil that is dry no matter what, it's fine, but we never got it out on our soil. It's not suited for it.» Not only are the physical aspects of the context important, but also time constraints and other limitations. Regarding crop rotation, one farmer reported, «I might not optimise efficiency. I have a job outside, so I cannot spend that much time farming. I try to grow two to three types and not more.» The farmers thus displayed a desire to simplify the modes of production when facing the complex reality. In one way, the contextual constraints limit the range of possibilities available to the farmers and thus is part of the simplification process. Nevertheless, the contextual constraints only limit the range of possible practices and do not exclude any overarching concepts such as the principles of the sequential rationale of IPM.

Antecedents played a big part in many pest management decisions. Specific experiences from the past were often given as explanations of present reasoning. As one farmer reported, «Sometimes, we've had fields that look nice, but then during the season, the weeds come after all. And that has really taught us a lesson where we've found that we have to spray against weeds each year.» Many of the farmers reported that spraying against weeds every season was necessary and the practice seems to be a part of good grain farming practice. On the one hand, this statement can, therefore, be regarded as an expression of general farming experience and more a convention than anything specific to this particular farmer. On the other hand, through this quote, the farmer expressed that there were specific events in the past where weeds had taken over his fields that was the reason for spraying each year. When investigating French cereal farmers, Lamine (2011) found that antecedence was one of the main conditions for a sustained change to more sustainable pest management practices. Antecedents thus appear as both potential barriers and drivers to the increased use of IPM. Past experiences might attract or repulse farmers from changing their practices based on whether the experiences were good or bad.

The interviewed farmers expressed a strong wish to state that they did not spray for fun, but rather because they have to. They reported to not enjoy the act of spraying itself and some expressed sympathy for the environment as the reason why they did not enjoy it. Others enjoyed it less for economic reasons. As one farmer stated, «You get the impression that [the Food Safety Authorities] think that we spray just for fun. And it is just too expensive to be doing that. We spray what we have to. It is plain and simply to get yields.» The Food Safety Authorities were reported to be the governmental body assigned to ensure that the farmers actually are implementing IPM practices. The interviewed farmers seemed to be under the impression that IPM as the Food Safety Authorities presented it was all about reducing the amount of pesticides used and whether they had considered using a weed harrow. However, as has been demonstrated in this characterisation of the farmers' decision processes there are multiple reasons why the farmers use their current pest management practices. Reducing the amount of pesticides is not a simple matter as the act of spraying is both an integral part of the institutions of good agronomy but also in many cases a necessity in order to produce grains. However, as will be demonstrated in the following section, there are situations where a reduction in the use of pesticides might be possible while still practicing good agronomy.

5.4.2 Three examples of sequential rationales

A long-term, sequential IPM strategy is paramount for being able to adapt the use of context-specific practices according to the circumstances. As highlighted in section 2.1, in the perspective of an ideal IPM decision process, there are four sequential elements to be considered. To describe how the Norwegian grain farmers follow the sequence when deciding how to manage their pest situations, the rationalities of three farmers from the in-depth interviews are described below. The three farmers will hereafter be referred to as Green, Yellow and Red.

Green: The ideal IPM-practitioner

Green is a farmer in his sixties who manages around 30 ha of grain area where he grows cereal grains. He is a part-time farmer who upon being asked if he enjoys farming responded, «Yes it is my hobby, my lifestyle. I have been doing this for 40 years. And when you have a job outside the farm, coming home and being able to do this is like therapy.» He mainly grows wheat, barley and oats. Due to a neighbour's rough past experience with oilseeds, he is reluctant to include any other grain types in his rotation.

Green's pest management strategy is based on a thorough evaluation of the previous season. He stated, «When I drive the combine harvester in the fall, I start planning next year. That's what we do. Continuous evaluation of everything.» Not only does he evaluate when he harvests, but he stated that he continuously evaluates his practices throughout the season. During the course of the interview, he emphasised how his strategies are dynamic and how he adapts to the circumstances. At the beginning of the growing season, his tillage practices, choice of cultivars and crop rotation strategies all revolve around limiting the risk of having to intervene against pests later in the season whilst simultaneously ensuring high-quality and high-quantity yields. Upon being asked if he has to monitor his fields often, he replied: «Yes, if the weather conditions dictate it. But it also has to do with the preceding crop and the tillage. The cultivars have also become better. More resistant, which is something that is important to me when I choose a cultivar.» He also reported to have extensive contact with the extension service and belong to a community of farmers who were eager to discuss grain production whenever they got a chance to do so.

Despite having a long-term strategy for preventing and suppressing pests, he cannot avoid using herbicides in the spring. Upon being asked what he would do if the prices of herbicides doubled, he responded that at the time you realise that you need pesticides, the price is irrelevant. "Because if you do not use pesticides you will most likely have a lower yield and reduced price for your product at the mill. This is all based on what you have seen in the fields. And where the threshold is. But, as I have emphasised earlier, I choose cultivars that allow me to minimise my use of pesticides.» A recent season, he reported having grown barley without spraying with fungicides. The cultivar he grew was supposed to be resistant to fungal pests. That particular season, he reported monitoring the fields every day and he became especially considerate after having read the newspaper, where another farmer growing the same cultivar reported having sprayed fungicides in his fields. However, Green suspected that his colleague had sprayed prophylactically, as he did not register the farmer in the newspaper claiming to have found any fungal pests. Green never noticed any substantial fungal pest outbreak in his crops and refrained from spraying. His yields were both high in quality and quality. This situation is an example of how meticulous planning and thorough execution of the first elements of the pest management sequence might enable grain production without fungal pest intervention.

Green's responses to the questionnaire resulted in a score on the IPM-index of 83, which is in the top 7% of the respondents. This suggests that there is a correlation between his long-term, sequential pest management strategy and his high degree of IPM adoption.

Yellow: Stuck in his good ways

Yellow is a full-time crop farmer who manages around 80 ha of farming area where he grows grains and potatoes. He rotates his crops such that he has two years of wheat and/or barley after one season of potato. One of Yellow's most sizable challenges is having a lot of stones in his soil. This contextual constraint limits his ability to use deep ploughing as a preventive pest management measure because it results in too much work having to clear his fields of stones.

Regarding how he decides whether to intervene against pests or not, he admits that the decisions are not always made with the purest sense of following the sequential rationale of IPM. Upon being asked how he decides the dosage and timing of pesticide application, he stated that experience was how he made the decision, and that his old age might have led to him being less willing to change according to new information: «Yes, I might have fallen into that trap to some extent. You get into a crop rotation and a system that is hard to break.» Speaking of how he manages fungal pests, he stated, «To fit all the pieces of the puzzle we've had to simplify in the grain production. One spraying. And the outcome is often that we spray less than if one does two sprayings. The results varies more though.» In this sense, he explains his long-term strategy of managing both of his crop productions, but apparently, there is not much room for considering whether to spray with fungicides or not. Upon being asked what he would do if the prices of herbicides doubled, he responded, «First of all, cutting herbicides is not an option. It will be like pissing in your pants.» He emphasised that his use of herbicides already was very thought through and that he had a thorough plan and reason for using what he meant was necessary.

His responses to the questionnaire resulted in a score on the IPM-index of 72, which is slightly above average. The limited ploughing is mainly what gives him a lower score than Green. This indicates that in Yellow's case, other considerations trump prioritising ploughing as a pest management practice.

Red: Conventions rule

Red is a full-time farmer managing around 45 ha of farming area, where he grows potatoes on a few hectares and cereal grains on the rest. He uses various tillage practices depending on seasonal variations, but ploughs all of his area either in the spring or in the fall. One thing that was repeatedly emphasised by Red was that it is important to "minimise the necessary operations in the fields and maximise the yields."

Upon being asked about his crop rotation, he replied, «Yes, I try to grow wheat where I had potatoes the previous season.» Subsequently, he was asked whether it had an effect on the yields, replying, «Yes, at least it doesn't get worse. They say it's supposed to help.» It might seem that Red follows the local conventions of crop farming and does not necessarily apply the dynamic sequential rationale that is required to abide by the ideal IPM decision process. Upon being asked how he manages his pest situation, he replied, «We have to spray against weeds and fungus. Herbicides on everything. Fungicides on almost everything. One has to.» Even though he emphasised trying to use as little as possible, in contrast to Green, he has no explicit strategy to prevent the need for using pesticides. However, by following the local conventions of crop farming he might still follow an implicit strategy to prevent the need for using pesticides. In fact, he demonstrated good knowledge of the sequences of pest management and regarding whether something special affects his tillage practices, he stated, «Yes, the weather. And how much time you have. If you see that there will be a longer period of nice weather, you could for instance plough more in the spring. There are a lot of factors that play a part here.» Nevertheless, compared to the two previously described farmers, Red does not explicitly seek to limit his use of pesticides by sequencing his strategy. Upon being asked how often he sprays against fungal pests, he replied, «Yes, one can put a small dosage in with the herbicides and then full dosage later.» On the one hand, one could say that a prophylactic practice such as putting some fungicides in with the herbicides is a sign of a long-term strategy. On the other hand, preventing more spraying by spraying is a questionable practice in terms of sustainability and a violation of the sequential rationale of IPM. After reporting his prophylactic practices, he was asked how he makes those decisions, upon which he replied, «It depends on how you can mix the remedies.

Of course, the economy plays a part there as well.» Again, he demonstrates that doing the right thing is important, but his focus is on the situation at hand without emphasising the long-term sequences of IPM.

Red’s responses on the questionnaire resulted in a score on the IPM-index of 52, which is in the bottom 6% of the responses. The main difference between his score and the two other farmers was his lack of monitoring ahead of spraying against both weeds and fungal pests in addition to not using decision-support systems as much as the other two farmers. This suggests that lacking a long-term sequential rationale for managing his pest situation correlates with his lower degree of IPM implementation.

What exemplifies the differences between Green’s, Yellow’s and Red’s sequential rationale the best is their responses to the question regarding what they would have done if the prices of pesticides doubled. Both Yellow and Red replied that they would have had to reduce their use of pesticides, whereas Green gave a long explanation of why he could do nothing in response to an increase in price because his strategy was constructed such that every time he applied pesticides he had to do it. Red responded that in addition to reducing his use, he could try to plough more, and Yellow would try spot spraying in addition to ploughing more and thus having to spend more of his time clearing his fields of stones. Despite all of the 24 interviewed farmers demonstrating an impressive eagerness to produce grains as best as they can, there was a clear difference in their degree of sequencing the pest management practices and decision processes. Interestingly, the reasons given for not following the sequential rationale appears to be more tied to the difference in the conventions and norms they follow rather than a difference in contextual constraints or antecedents. The local conventions and norms of pest management often align with the sequential rationale of IPM, but there is one area where the two sometimes collide, and that is regarding the management of fungal pests.

5.4.3 Spraying, a pest intervention or prevention?

In theory, by practicing IPM by the book, the farmers could mostly manage to avoid intervening against pests during the growing season. However, as the survey data clearly demonstrated, growing grains conventionally in Norway not only implies intervening against pests, but almost always results in the use of pesticides to do so. A vast majority of the surveyed farmers reported spraying their fields with herbicides once during the growing season, whereas the application of fungicides varied more. The decision process behind the practice of spraying against the two pests are different and reveals a violation of the ideally sequential rationale of IPM.

The main difference between the two pest interventions is that herbicides are most often sprayed curatively on the target pests, whereas fungicides often are sprayed both prophylactically and curatively. One farmer summed up how most of the interviewed farmers reported deciding how to intervene against weeds during the growing season, «We walk around in the fields and monitor and then we spray when the time is right early in the summer.» Many of the interviewed farmers reported that their extensive experience makes the scouting after weeds almost redundant. They reported that the time was right when the weed plants had reached a certain developmental stage and the monitoring was used to survey the development of the weeds and which types they had to intervene against. Nevertheless, the spraying is of a curative nature and fits into the sequential rationale of IPM as an intervention. On the contrary, fungicides are often applied without the farmers even having registered any outbreak. The same farmer as quoted above stated that when it comes to fungal pests, his experience has resulted in a more or less programmed fungicide-spraying regime. He stated that «In barley, for instance, there is no need to even attempt not spraying. Even though the field looks healthy, I've often experienced that if you wait around, the pests come and then it often is too late for spraying.» Far from all the interviewed farmers shared his opinion, as farmers like for instance Green adamantly claimed that fungicides should only be applied curatively. However, it seemed like to many farmers, in an IPM perspective, fungicides were often used as a preventive or suppressive measure and not as a pest intervention.

Another key difference between combating fungal pests and weeds is that evaluating the effects of weed interventions are much easier than evaluating the effect of the prophylactic fungicide spraying. One farmer reported regarding the evaluation of spraying, «I try to register after the spraying which weeds the spraying had a good effect on, and so on. And regarding the fungicide spraying, it's very interesting to see whether any fungal pests develop. Especially in the wheats.» The same farmer said that he prophylactically sprays against fungal pests in his wheat crops. The main difference in the evaluation is that he had observed the weeds in his fields before intervening and therefore his evaluation can be performed relative to the situation prior to the intervention. Conversely, when he sprayed against fungal pests, if there is no pest outbreak, he has no reference point. However, most farmers reported to leave a strip in their fields untreated, and by evaluating this untreated spot, they often conclude that fungicides are necessary. As one farmer stated about what he usually finds in these untreated spots, “Well, there the fields are flat[19]. Lodging, and additionally pitch black.” Many farmers reported that they were uncomfortable with this prophylactic spraying practice, but that they felt like they had no other choice than to do it. One farmer, when talking about the need for fungicides, stated: «It is just how the seasons have become. It’s not something you consider even, it’s necessary. You make an evaluation, but the evaluation gives the same answer each year. At least since I started growing grains.» The farmers reported that among other things, wetter seasons and increased demands for the quality and quantity of the yields were reasons for their continued prophylactic fungicide spraying. Whether the curative weed spraying is more important for the quality or quantity of the yields than a prophylactic fungicide spraying is not certain. Many farmers expressed that fungicide spraying pays off monumentally. One farmer stated, «I’ve tried to reduce the use of fertilisers and reduce the use of fungicides. Maybe I can save 100 000 NOK on that, but I will lose 300 000 – 400 000 NOK in income.» The farmers might, therefore, have good economic reasons to prophylactically spray their crops with fungicides.

In relation to the findings above, it can be shown that some farmers use fungicides as a preventive rather than a curative measure. In this sense, the evaluation of the spraying becomes a part of the monitoring in order to assess the need for an additional curative spraying. The analogy to the use of antibiotics in other sectors of agriculture is in my opinion to the point (the interviewed farmers even referred to their fields as “sick” if there was a fungal disease outbreak). In the same way that antibiotics should not be used prophylactically on animals, plants should not be prophylactically sprayed with pesticides.

In the article where the sequential rationale of IPM was explained, Barzman et al (2015) stated that the principle regarding prevention and suppression is the most important principle of IPM and often the one that implies the most fundamental changes to current practices. The main point here is that the farmers experience that they “have” to spray with fungicides prophylactically at a certain point in the growing season. However, that might be because of inadequate prevention and suppression earlier in the growing season. The cessation of prophylactic fungicide spraying and ensuing changes of the preventive practices appears to be a necessary fundamental change in order to increase the use of IPM among Norwegian grain farmers. However, as illustrated by for instance the farmer referred to as Green, there are those

[19] The reason their fields become flat is probably that they mix growth regulators with their fungicides. This means that the strips untreated with fungicides have also not been treated with growth regulators.

who do not violate the sequential rationale of IPM and use fungicides only as a necessary intervention. Much can be learned by following their lead.

Regarding weed management, the Norwegian grain farmers appear to be unable to prevent a curative intervention with herbicides early in the growing season. On the one hand, the sequential rationale of IPM is followed if the spraying is based on a need for intervention discovered after prevention, monitoring and a decision-making process has taken place. On the other hand, is a pest management strategy that always results in pest intervention, IPM? The interviewed Norwegian grain farmers claimed to have no alternative to spraying with herbicides in the spring. Investigating whether that is true or not is beyond the scope of this thesis. However, with the advent of new technologies such as drones for monitoring, sophisticated sensors and robots able to perform tillage operations that tractors normally cannot, there might be alternatives on the horizon.

6. Implications of the study

The directive making IPM mandatory for all farmers within the EU is almost a decade old. With a few exceptions, evidence for the extent of IPM implementation and drivers for adoption among European farmers is still lacking (Lefebvre et al., 2015). In this investigation, through a characterisation of the Norwegian grain farmers' pest management practices, it was shown that most of the principles of IPM are followed to a large extent by the farmers. These practices are not new to the Norwegian grain farmers, but rather part of what is good farming practice. Therefore, it can be argued that among Norwegian grain farmers it is more relevant to discuss the varying use of IPM practices rather than how to fix a lack of implementation. However, certain aspects of IPM were identified where there is room for increased implementation among the Norwegian grain farmers.

Puente et al. (2011) suggested that instead of trying to assess the adoption of IPM as a whole, one should instead focus on IPM components. Based on this investigation, two agronomical components of IPM were identified that should be focused on in the context of Norwegian grain farming. The first one is improving the management of fungal pests in order to prevent prophylactic spraying. The second is investigating the opportunities to reduce their dependency on spraying with herbicides early in the growing season. Regarding the latter issue, a non-chemical solution might be on the horizon. Researchers at the Norwegian University of Life Sciences are developing an agricultural robot that can be used in Norwegian grain farming conditions (Grimstad & From, 2017). Even though this robot is not yet able to perform heavy duty ploughing, it is, for instance, able to perform light tillage practices even in wet conditions where it would be ill advised to drive regular tractors into the fields (ibid.). One of the main reasons the Norwegian grain farmers refrain from weed harrowing is that they rarely find an opportunity to drive their heavy tractors out into the fields as it would result in the tractors dealing damage to the soil structure. In the event that technologies, such as the robot described, become viable within an IPM strategy, future research on farmers' use of IPM should consider including an investigation of farmers' willingness to adopt these new technologies.

The issue of preventing prophylactic fungicide spraying does not have a simple solution. It is more tied to the conventions and norms of good agronomy rather than being a technological hurdle. The practice of using pesticides as a preventive measure, by definition, causes decreased use of IPM. However, this investigation suggests that among the Norwegian grain farmers, there are differences in their perceptions regarding whether prophylactic fungicide spraying is necessary or not. Far from all the farmers reported making this specific violation of the sequential rationale of IPM. As illustrated in an exemplary case (see section 5.4.2), there are Norwegian grain farmers who seemingly practice the principles of IPM to the extent that it is possible.

Entrenched in the history of IPM is the emphasis on reducing the use of pesticides. The misuse of pesticides is what concerns policymakers, researchers and farmers the most and therefore what drives the desire to increase the use of pest management strategies less dependent on them. However, as Ehler (2006) argued, it is important that reducing the use of pesticides does not become the end itself. In other words, reducing the use of pesticides without adapting other practices simultaneously is not beneficial. As the interviewed farmers pointed out, when there is a need for pesticides, it is already too late to do anything else than treat their crops with the adequate "medicine". The focus should, therefore, be directed towards the preventive and suppressive components of IPM. The reduced pesticide use comes as an effect of adequate prevention and suppression, a sound assessment of the need for an intervention and by making non-chemical methods available if possible. However, merely focusing on the practices does not deal with the underlying reasons for varying adoption.

Many previous attempts at measuring the extent of IPM adoption have done so against an arbitrary limit, classifying farmers' practices as either IPM or not. Instead, in this investigation, an index was developed and the farmers' practices were measured relative to each other. In calculating the index scores not only is the impact of each practice considered, but also the impact of not performing the practice. The inclusion of local pest management experts and respondents in constructing the index ensured that the index is relevant for the target population and up to date in terms of what the principles of IPM mean in the context of Norwegian grain farming. This index methodology, which is based on the warnings and recommendations of previous attempts, is one of the main contributions of this investigation. Unlike previous attempts focusing on technology adoption (Sharma et al., 2010 and others), this index focuses directly on the farmers' practices related to each principle of IPM. This enables further analyses of which components of IPM are more or less adopted among the target farmer population. Future projects, primarily in Europe, seeking to assess the variation in the use of IPM among farmers should consider adapting this methodology. The use of a similar methodology should however result in different index items and weights depending on the context, as translating the principles of IPM to a different context should give different foci.

To measure the degree of adoption should, however, not compromise efforts to support the increased use of IPM. Considering the conceptual nature of IPM and the complex nature of pest management in general, simplifying the degree of adoption may come at the cost of keeping the concept of IPM intact. In review of the eight principles of IPM, Barzman et al. (2015, p. 1201) stated, "Our view is that lasting, robust and well-adapted strategies that effectively reduce reliance on pesticides cannot be encapsulated within recipe-like recommendations." Following this suggestion IPM should not be dissected into context-specific recipes for farming. Instead, the attention of researchers, extension agents and policymakers should turn towards the context-specific drivers for, and barriers to the increased use among the farmers. The analysis of the index scores in this investigation showed that among the aspects correlating with a high degree of IPM use among Norwegian grain farmers were, having an environmental mindset, being concerned with crop quality, having frequent contact with peers and a high level of education. Among the aspects coinciding with less use of IPM were being concerned with entirely eradicating pests and having a low farming income. These aspects indicate what might be important to focus on when addressing the barriers and drivers of implementation.

In the wake of making IPM practices obligatory, major efforts are being made in multiple European countries to decrease the barriers and drive the adoption of IPM practice among farmers (Barzman et al., 2014). In a recent governmental white paper, issued by the Norwegian Ministry of Agriculture and Food (2016), it was emphasised that the use of IPM should be increased by ensuring that the knowledge of context-specific IPM practices are spread and that the farmers document their practices. The effects of these two measures are questionable, as the inquiries of the Norwegian grain farmers suggests the barriers for increased implementation is neither a lack of information nor documentation. However, if the focus of the information being spread to the farmers would include specific emphasis on the sequential rationale of IPM in addition to context-specific IPM practices, the necessary changes in the farmers' decision processes might be pushed in the right direction.

Hashemi and Dalamas (2010) suggested that a common flaw among IPM programs is a lack of understanding of the pest management decision processes of farmers. In this investigation, the rationalities of the Norwegian grain farmers regarding pest management decisions appeared to be influenced by the conventions and norms of their local communities in addition to being affected by individual components such as contextual constraints and antecedents. The investigations suggest that the local culture affects the decision processes regarding aspects of the pest management practices, which may act as barriers to following the sequential rationale of IPM. When attempting to increase the implementation of IPM, a failure to address the conventions and norms that guide pest management decisions might render the ensuing policy measures lacklustre.

The economic realities of the farmers' grain productions were also found to be a prominent component of their decision processes leading to the practice of spraying. During the interviews, many of the farmers admitted that although they knew that they ideally should minimise their spraying, the risks of large short-term economic losses were too big to disregard. Given the nature of IPM as being a strategy focusing on long-term returns, it runs counter to economic policies that focus on current short-term profits and minimizing financial risk (Buhler et al., 2000). Consequently, if farmers do not trust that increased use of IPM will result in long-term returns, they might refrain from implementation. As Barzman et al. (2014, p. 426) summarised the challenges: "Implementing IPM in industrialized countries is not merely a question of managing pests but also of questioning the paradigm of simple, relatively cheap and reliable solutions obtained with pesticides." This investigation has shown that the needed trust in the long-term benefits of IPM should be built on an institutional level rather than an individual level since the local culture has a major effect on the individuals' rationalities.

A common assumption among critics of the change towards more sustainable farming practices has been that the change might compromise the productivity of the global food systems (Pretty, 2008). However, as Pretty (2008) argued, in the parts of the world where lack of productivity is a threat to sustainability, increased use of IPM tended to coincide with increased productivity. In the parts of the world where the main threat to sustainability is related to the negative externalities of the production, the increased use of IPM resulted in a negligible decrease in productivity and a large decrease in the negative externalities. The productivity of the Norwegian grain farmers was shown to be an important factor in their decision processes not only because it aligns with their values, but also because the intensifying structural changes of Norwegian agriculture demands it. However, the only sign of productivity being affected by the use of IPM was that the farmers with a low farming income practiced less IPM than those with higher farming incomes. The findings in this investigation suggest that increased use of IPM coincides with increased profitability – at least in the long term – as the benefits of decreased negative externalities eventually will pay off. In affluent production systems, such as European grain farming operations, the increased use of IPM might both assist the farmers in dealing with barriers to decrease the misuse of pesticides whilst simultaneously sustaining their economic output. Additionally, updating what “increased use of IPM” is, with novel measures (e.g. field robots, drones, and sensors), might further improve the sustainability of IPM. Despite there being context-specific IPM practices that can be used as benchmarks and recommendations today, the conceptual nature of IPM must not be washed out by attempting to determine what IPM “really is”. Continual re-evaluation of good, context-specific practices and decision processes is paramount for the increased sustainability of our future food systems.

7. Conclusion

This investigation of Norwegian grain farmers' pest management practices and decision processes was aimed at improving the understanding of how to increase the implementation of IPM among the farmers. The characterisation of their pest management practices according to the eight principles of IPM suggests that the farmers practice most of the principles to a large extent. Among Norwegian grain farmers, it is, therefore, more relevant to speak of varying use than a lack of overall implementation of IPM. However, certain components of IPM were identified, where there is room for improvement among the farmers. The implementation of IPM would increase among the farmers if non-chemical measures against weeds were incorporated to a greater extent and if the prophylactic spraying against fungal pests was diminished.

The varying use of IPM among the farmers was assessed with a novel index. Analysis of the index scores showed that having an environmental attitude, being concerned with crop quality, frequency of contact with peers and length of education correlated positively with the use of IPM. Having a low farming income and being concerned with entirely eradicating pests coincided with decreased use of IPM. The female farmers in the investigation were also shown to use IPM to a greater extent than the male farmers.

To further investigate the reasons behind the Norwegian grain farmers IPM practices, their pest management decision processes were characterised. The theoretical assumption that a central element of their rationalities were the conventions and norms of their local communities was supported. These institutions appeared to influence their pest management processes along with individual components such as antecedents and contextual constraints. This was further supported by the correlation between the farmers' perceptions of their local communities and their own mindsets. These findings suggest that the effect of the local culture on the individual farmers' rationalities – and thereby pest management decision processes – is substantial.

Moving towards widespread use of IPM demands less emphasis on the measurements of the exact adoption rates, and greater emphasis on integrating the concepts of IPM in what is manifested as good farming practices and decision processes in the farmers' local communities. The resulting alloy might assist in transcending the rift in our global food systems between what is conventional and what is sustainable.

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Appendices

Appendix A: Questionnaire

The interview guide was originally developed in Norwegian. The following is an English version translated by myself. The design of the questionnaire has also been altered in the following version as the original version was intentionally designed with a lot more space between each question and statement. Additionally, the text marked in red was not visible to the respondents, but serves as a reader's guide to through the contingencies of the questionnaire.

Q1: Who has the main responsibility for the grain farming operations on your farm?

Check one option.

- ☐ Me
- ☐ Me, together with someone else/others
- ☐ Someone else/others (DISQUALIFIED IF THIS OPTION IS CHECKED)

Q2: Have any pesticides been used on the grain areas on your production unit within the last three years?

Check one option.

- ☐ Yes
- ☐ No

Q3: Do you have a certificate for pesticide application?

Check one option.

- ☐ Yes
- ☐ No, but I previously did
- ☐ No, and I never have

If Q3 = «yes» and Q3 = «yes»

Q4: Do you apply the pesticides yourself?

Check one option.

- ☐ Yes, every application
- ☐ Others perform some applications
- ☐ No, others perform all applications

If Q4= «no/others_some» or Q3 = "no_before/no_never" given Q2 = "yes"

Q5: How many of the decsions regarding spraying in the grain fields do you make?

Check one option.

- ☐ Every decision
- ☐ Many of the decisions
- ☐ Some decisions
- ☐ Few decisions
- ☐ None of the decisions

If Q5 = "some/few/none"

Q6: Do you have knowledge of the pesticide applications performed on your grain fields?

Check one option.

- ☐ Yes
- ☐ No

If Q6 = "yes" or Q5 = "every/many" or Q4 = "yes_all"

Q7: Have you grown barley within the last three years?

Check one option

- ☐ Yes
- ☐ No

If Q7 = "yes"

Q8: Fill in the number of pesticide applications performed in your barley fields. Consider what has usually occurred the last three years.

If, for instance, you spray with fungicides twice a year, write 2 in the respective square. Write 0 for the applications you usually do not use. If, for instance you spray with insecticides every other year, write 0.5 in the respective square.

Glyphosate use in stubble	
Glyphosate in ripe barley fields	
Spraying against annual and/or perennial weeds during the growing seasons	
Fungicides	
Insecticides	
Growth regulator	
Spraying against wild oats or cockspur grass	
Other	

Q9: How well suited are the soil types on your farm for performing the following practices?

Check one box per row on the alternative that fits best.

	None of the area 1	2	3	4	All of the area 5	Don't know
Spring ploughing	☐	☐	☐	☐	☐	☐
Weed harrowing during the growing season	☐	☐	☐	☐	☐	☐

Q10: What is done on your grain area? Consider what has usually occurred the last three years.

Check one box per row on the alternative that fits best.

	None of the area 1	2	3	4	All of the area 5
Spring ploughing	☐	☐	☐	☐	☐
Fall ploughing	☐	☐	☐	☐	☐
Direct sowing	☐	☐	☐	☐	☐
Growing barley three or more years in a row in the same field	☐	☐	☐	☐	☐
Growing wheat three or more years in a row in the same field	☐	☐	☐	☐	☐
Using cultivars with high resistance to fungal pests	☐	☐	☐	☐	☐
Weed harrowing	☐	☐	☐	☐	☐
Assessing the effect of the pest interventions	☐	☐	☐	☐	☐
Manually weeding patches of weeds and/or wild oats	☐	☐	☐	☐	☐
Trimming field edges	☐	☐	☐	☐	☐

If Q2 = “yes” and Q3 = “no_before/no_never” and Q5 = “every/many/some/few” or Q4 = “no” and Q5 = “every/many/some/few” then “Don’t know” option was available

Q11: How often is the following performed on your grain areas? Consider what has usually occured the last three years.

Check one box per row on the alternative that fits best.

VIPS is «Varsling innen planteskadegjørere» - a web-based decision support system for determining when there is a need to intervene against various pests.

	Never 1	2	3	4	Always 5	Don't know
Monitor the field before herbicide spraying	☐	☐	☐	☐	☐	☐
Monitor the field before fungicide spraying	☐	☐	☐	☐	☐	☐
Decide fungicide spraying based on online decision support system (VIPS)	☐	☐	☐	☐	☐	☐
Follow advice of news letter from the advicory service	☐	☐	☐	☐	☐	☐

regarding fungicide spraying						
Choosing to spot spray	☐	☐	☐	☐	☐	☐
Choosing the lowest recommended dosage	☐	☐	☐	☐	☐	☐
Mixing active ingredients in order to recude risk of resistance	☐	☐	☐	☐	☐	☐

Q12: Are you a member of the Norwegian Agricultural Extension Service?

Check one option.

- ☐ Yes
- ☐ No
- ☐ No, but my partner is a member

Q12 = "yes" then option 2 and 4 was available

Q13: Where do you get advice and knowledge about pest management from?

Check one or more options.

- ☐ Certification course for the use of pesticides
- ☐ The Norwegian Agricultural Extension Service
- ☐ Crop specific IPM-guidelines
- ☐ Field trips or field days
- ☐ Other farmers
- ☐ Family
- ☐ Pest management journals
- ☐ Catalogue from The Norwegian Agricultural Purchasing and Marketing Co-operation or "Norgesfôr" (a fodder company).
- ☐ Distributors of pesticides
- ☐ Other: _____________

Q15: How well do you know the term Integrated Pest Management (IPM)?

Check one option.

- ☐ No knowledge
- ☐ Some knowledge
- ☐ I know it well

Here, a definition of IPM is presented in order for those who have no knowledge of the term to be able to answer the following questions.

I16: According to the directive on the use of pesticides, Integrated Pest Management is to:

1. Prevent harm from weeds, fungal outbreaks and other pests through measures such as crop rotation, resistant cultivars and tillage practices.
2. Monitor pests and use thresholds when available.
3. Use other means than spraying if they are sufficiently effective.
4. Choose pesticides that are as specific to the pest as possible while minimising the possible health and environmental risks.
5. Limit the use of pesticides, for example by reducing the dosage, reducing the number of application or limit the drift of airborne pesticide particles.
6. Take measures to prevent resistance.
7. Evaluate the effect of the pest interventions.

Q17: Compared to what was normal around five years ago, do you use IPM to a greater extent now?

Check one option.

- ☐ Use it to a lesser extent
- ☐ Use it to the same extent
- ☐ Use it to a greater extent

If Q17 = "greater extent"

Q18: You use Integrated Pest Management to a greater extent. Please list the most important measures.

Briefly describe up to three measures (at least one).

1. ______________________
2. ______________________
3. ______________________

Q19: To which extent to you agree/disagree to the following statements?

Check one option per row on a scale where 1 = "Fully disagree" and 5 = "Fully agree"

Increased use of IPM in my grain farming will:

	Fully disagree 1	2	3	4	Fully agree 5
reduce the profitability	☐	☐	☐	☐	☐
reduce the quantity of the yields	☐	☐	☐	☐	☐
require me to use more time on grain farming	☐	☐	☐	☐	☐
require me to acquire more knowledge	☐	☐	☐	☐	☐
increase the risk of reduced yields	☐	☐	☐	☐	☐

Q20: Consider the following statements:

Check one option per row on a scale where 1 = "Fully disagree" and 5 = "Fully agree"

	Fully disagree 1	2	3	4	Fully agree 5
I am positive to Integrated Pest Management despite it resulting in some reduced profitability	☐	☐	☐	☐	☐
pesticides are not dangerous to the environment if you follow the instructions on the labels,	☐	☐	☐	☐	☐
People who mean a lot to me wishes that I minimise the use of pesticides.	☐	☐	☐	☐	☐

Q21: How do you think information about Integrated Pest Management is best distributed among grain farmers?

Check one option per row on a scale where 1 = "Fully disagree" and 5 = "Fully agree"

	Fully disagree 1	2	3	4	Fully agree 5
Through the extension service	☐	☐	☐	☐	☐
Through pest management journals	☐	☐	☐	☐	☐
Through local courses	☐	☐	☐	☐	☐
Through field days	☐	☐	☐	☐	☐
Through web-pages	☐	☐	☐	☐	☐

Other: ______________________________

Q23: You will now receive information about three thought up situations. In relation to each situation, we ask whether it will result in changes in the way you manage your farming operations.

<u>Situation 1</u>: The price of all herbicides double.

What would you do?

Check one option.

- ☐ I would use herbicides to the same extent as before
- ☐ I would reduce my use of herbicides to some extent
- ☐ I would reduce my use of herbicides to a large extent
- ☐ I would stop using herbicides
- ☐ I don't use herbicides

If Q23 = “same_extent”

Q24: Why would you use herbicides to the same extent as before?

Check one option per row on a scale where 1 = “Fully disagree” and 5 = “Fully agree”

	Fully disagree 1	2	3	5	Fully agree 5
Or else, the reduction in yields will be too large	☐	☐	☐	☐	☐
There are no good alternative ways to handle weeds	☐	☐	☐	☐	☐
Existing alternatives are too uncertain	☐	☐	☐	☐	☐
Existing alternatives are too time consuming	☐	☐	☐	☐	☐
Existing alternatives result in reduced profits	☐	☐	☐	☐	☐
Because I can switch to cheaper herbicides	☐	☐	☐	☐	☐

If Q23 = “reduce_some” or “reduce_large”

Q25: You would reduce your use of herbicides. What would you do instead?

Check one option per row

	Disagree	Agree
I would not make any further changes	☐	☐
I would change my crop rotation	☐	☐
I would plough more	☐	☐
I would harrow more	☐	☐
I would use a weed harrow more	☐	☐
I would trim the field edges more	☐	☐
I would spot spray more	☐	☐
I would spray less often	☐	☐
I would use a smaller dose	☐	☐
I would change to cheaper herbicides	☐	☐

If Q23 = “stop”

Q26: You would stop using herbicides. What would you do instead?

Check one option per row.

	Disagree	Agree
I would not make any further changes	☐	☐
I would change my crop rotation	☐	☐
I would plough more	☐	☐
I would harrow more	☐	☐
I would use a weed harrow more	☐	☐
I would trim the field edges more	☐	☐

Q27:

<u>Situation 2</u>: A subsidy for including oats in your crop rotation is introduced.

First, we want to know whether or not you grow wheat.

Check one option.

☐ I grow wheat
☐ I do not grow wheat

If Q27 = “grow_wheat”

Q28: To reduce the use of fungicides you receive a subsidy for growing oats every third year. If you comply, you will receive 1600 NOK per hectare every third year (the year you grow oats).

What would you do?

Check one option.

☐ I would elect to receive the subsidy and have oats in my crop rotation (at least) every third year
☐ I would not elect to receive the subsidy

If Q27 = “don’t_grow_wheat”

Q29: To reduce the use of fungicides you receive a subsidy for growing oats every third year. If you comply, you will receive 400 NOK per hectare every third year (the year you grow oats).

What would you do?

Check one option.

☐ I would elect to receive the subsidy and have oats in my crop rotation (at least) every third year
☐ I would not elect to receive the subsidy

If Q28 = “receive” or Q29 = “receive”

Q30: You would elect to receive the subsidy. Do you already grow oats (at least) every third year?

Check one option.

- ☐ Yes
- ☐ No

If Q30 = “yes”

Q31: Why would you elect to receive a subsidy like this?

Check one option per row on a scale where 1 = “Fully disagree” and 5 = “Fully agree”.

	Fully disagree 1	2	3	4	Fully agree 5
I view this subsidy as a reward for farming environmentally	☐	☐	☐	☐	☐
It is important that the society honours environmental farming	☐	☐	☐	☐	☐
My economy will improve	☐	☐	☐	☐	☐
The costs I have previously taken myself will now be covered	☐	☐	☐	☐	☐

If Q30 = “no”

Q32: Why would you elect to receive a subsidy like this?

Check one option per row on a scale where 1 = “Fully disagree” and 5 = “Fully agree”.

	Fully disagree 1	2	3	4	Fully agree 5
(More) Oats in the crop rotations is good for the environment	☐	☐	☐	☐	☐
The subsidy makes it profitable for me to have (more) oats in my crop rotation	☐	☐	☐	☐	☐
The subsidy does not cover the economic losses completely, but still motivates me to have (more) oats in my crop rotation	☐	☐	☐	☐	☐

If Q28 = “don’t_elect_to_receive” or Q29 = “don’t_elect_to_receive”

Q33: Why would you not elect to receive a subsidy like this?

Check one option per row on a scale where 1 = “Fully disagree” and 5 = “Fully agree”.

	Fully disagree 1	2	3	4	Fully agree 5
I already have oats in my crop rotation (at least) every third year	☐	☐	☐	☐	☐
The climate prevents me from growing oats on my area	☐	☐	☐	☐	☐
The subsidy is too low to make it profitable for me to have (more) oats in my crop rotation	☐	☐	☐	☐	☐
I think it’s better to manage fungal pests with spraying	☐	☐	☐	☐	☐
I think it’s better to manage fungal pests with tillage practices	☐	☐	☐	☐	☐
I have wild oats in my fields	☐	☐	☐	☐	☐
I have cereal cyst nematodes in my fields	☐	☐	☐	☐	☐
I think the society should use fundings on other measures	☐	☐	☐	☐	☐
I use other forms of crop rotation in my grain production (e.g. grass, rapeseed etc.) to reduce the extent of fungal pests	☐	☐	☐	☐	☐

Q34:

Situation 3: The price of all fungicides double

What would you do?

Check one option.

- ☐ I would use fungicides to the same extent as before
- ☐ I would reduce my use of fungicides to some extent
- ☐ I would reduce my use of fungicides to a large extent
- ☐ I would stop using fungicides
- ☐ I don’t use fungicides

If Q34 = “same_extent”

Q35: Why would you use fungicides to the same extent as before?

Check one option per row on a scale where 1 = “Fully disagree” and 5 = “Fully agree”.

	Fully disagree 1	2	3	5	Fully agree 5
Or else, the reduction in yields will be too large	☐	☐	☐	☐	☐
There are no good alternative ways to handle fungal outbreaks	☐	☐	☐	☐	☐
Existing alternatives are too uncertain	☐	☐	☐	☐	☐
Existing alternatives are too time consuming	☐	☐	☐	☐	☐
Existing alternatives result in reduced profits	☐	☐	☐	☐	☐
Because I can switch to cheaper fungicides	☐	☐	☐	☐	☐

If Q34 = “reduce_some” or “reduce_large”

Q36: You would reduce your use of fungicides. What would you do instead?

Check one option per row.

	Disagree	Agree
I would not make any further changes	☐	☐
I would change my crop rotation	☐	☐
I would plough more	☐	☐
I would harrow more	☐	☐
I would use more resistant cultivars	☐	☐
I would spot spray more	☐	☐
I would spray less often	☐	☐
I would use a smaller dose	☐	☐
I would change to cheaper fungicides	☐	☐

If Q34 = "stop"

Q37: You would stop using fungicides. What would you do instead?

Check one option per row.

	Disagree	Agree
I would not make any further changes	☐	☐
I would change my crop rotation	☐	☐
I would plough more	☐	☐
I would harrow more	☐	☐
I would use more resistant cultivars	☐	☐

Q47: How meaningful are the following conditions to you as a farmer?

Check one option per row on a scale where 1 = "Not important" and 5 = "Very important"

	Not important 1	2	3	4	Very important 5
Being up to date in terms of knowledge	☐	☐	☐	☐	☐
Largest possible income	☐	☐	☐	☐	☐
Being a skilful grain farmer	☐	☐	☐	☐	☐
Having a satisfactory income	☐	☐	☐	☐	☐
Protecting biodiversity	☐	☐	☐	☐	☐
Limiting losses of soil nutrients	☐	☐	☐	☐	☐
Contributing to food production in Norway	☐	☐	☐	☐	☐
Limiting the use of chemical pesticides	☐	☐	☐	☐	☐

Q48: Which conditions are important to you when you manage weeds and fungal pests?

Check one option per row on a scale where 1 = "Not important" and 7 = "Very important"

	Not important 1	2	3	4	5	6	Very important 7
Using other means than spraying	☐	☐	☐	☐	☐	☐	☐
Highest possible crop quality	☐	☐	☐	☐	☐	☐	☐
Protecting the environment	☐	☐	☐	☐	☐	☐	☐
Preventing pesticide-resistance	☐	☐	☐	☐	☐	☐	☐
Largest possible economic surplus	☐	☐	☐	☐	☐	☐	☐
Low workload	☐	☐	☐	☐	☐	☐	☐
Entirely eradicating fungal pests	☐	☐	☐	☐	☐	☐	☐

Largest possible yields	☐	☐	☐	☐	☐	☐	☐
Entirely eradicating weeds	☐	☐	☐	☐	☐	☐	☐
Producing grains without traces of pesticides	☐	☐	☐	☐	☐	☐	☐

Q49: What is seen as good farm management in your local farming community?

Check one option per row on a scale where 1 = "Not important" and 5 = "Very important".

	Not important 1	2	3	4	Very important 5
Highest possible yields	☐	☐	☐	☐	☐
Not using more pesticides than necessary	☐	☐	☐	☐	☐
Taking measures to prevent soil erosion	☐	☐	☐	☐	☐
A field with few weeds	☐	☐	☐	☐	☐
Using new technology and new production methods	☐	☐	☐	☐	☐
A field with few fungal pests	☐	☐	☐	☐	☐

Q50: How often do you talk to other farmers?

Check one option per row.

	Never	Less than monthly	Monthly	Weekly	More than weekly
How often do you talk to other farmers?	☐	☐	☐	☐	☐
How often do you talk to other farmers about pest management during the growing season?	☐	☐	☐	☐	☐

Q51: What is your gender?

Check one option.

☐ Woman
☐ Man

Q52: Which year were you born?

Write the year in the square (four digits, e.g. 1968)

☐

Q53: Do you own or rent the area you farm?

Check one option.

☐ Own all the area
☐ Rent less than 50% of the area
☐ Rent more than 50% of the area

Q54: What is your highest, completed education?

Check one option.

- ☐ Primary or secondary school
- ☐ Vocational high school
- ☐ General subject high school
- ☐ Higher education

Q55: Have you completed any agricultural education?

Check all suitable options.

- ☐ No
- ☐ Yes during high school/agricultural school
- ☐ Yes, during higher education

Q56: About how large was your total agricultural income in 2016?

Check one option.

- ☐ No income/negative income
- ☐ 1 – 49 999 NOK
- ☐ 50 000 – 99 999 NOK
- ☐ 100 000 – 199 999 NOK
- ☐ 200 000 – 299 999 NOK
- ☐ 300 000 – 399 999 NOK
- ☐ 400 000 – 499 999 NOK
- ☐ 500 000 – 699 999 NOK
- ☐ 700 000 NOK or more
- ☐ Do not wish to answer

Q57: How large was your households' total income in 2016?

Check one option.

- ☐ Under 99 999 NOK
- ☐ 100 000 – 199 999 NOK
- ☐ 200 000 – 399 999 NOK
- ☐ 400 000 – 599 999 NOK
- ☐ 600 000 – 799 999 NOK
- ☐ 700 000 – 999 999 NOK
- ☐ 1 000 000 – 1 199 999 NOK
- ☐ 1 200 000 NOK or more
- ☐ Do not wish to answer

Q58: Do you receive age pension at the time?

Check one option.

- ☐ Yes
- ☐ No

Q59: Work outside the farm.

Check one option and write how many percent of a full-time job the position is.

	No	Yes	Percentage of full-time position
Do you work outside the farm these days?	☐	☐	☐ %

Q60: How long have you been farming grains?

Write the number of years in the square.

☐

Q61: Estimate the average yield level across the last five years for the grain types you have grown:

Write the number of kilos per decare (kg/daa) for every grain type. If there are any types you have not grown, write 0 in the accompanying square.

Barley	☐
Oats	☐
Spring wheat	☐
Winter wheat	☐
Triticale	☐
Winter rye	☐

Appendix B: List of weighted principles and practices used in the IPM index

The following is a presentation of the entire list of the weighted principles and practices used in the IPM index. Due to the nature of the index (see Appendix C), both fully performing a practice and not performing a practice at all needed to be weighted. There is one exception which is tillage practices. The codes listed in the table are used to describe the calculation of the index.

IPM principle	Weight			Weight average	Code	Questions about pest management practices included in the questionnaire. (See notes (a-d) for response scales)	Weight			Weight average	Code
	Expert 1	Expert 2	Expert 3				Expert 1	Expert 2	Expert 3		
I: *Prevention and suppression*	9	5	10	**8**	Q11_1	Spring ploughing [a]	8	5	8	**6.3**	Wsprin
					Q11_2	Fall ploughing [a]	10	6	8	**7.7**	Wfall
					Q11_3	Direct sowing [a]	1	2	2	**1.7**	Wdire
					Q11_x	Other tillage practices[e]	3	3.5	4	**3.5**	Wharr
						No barley monocropping on the same fields[a]	7	5	9	**7**	Wbary
					Q11_4	Barley monocropping on the same fields[a]	2	2.5	1.2	**1.9**	Wbarn
						No wheat monocropping on the same fields[a]	7	6	10	**7.7**	Wwhey
					Q11_5	Wheat monocropping on the same fields[a]	2	2	1	**1.7**	Wwhen
					Q11_6	Use cultivars that are highly resistant to fungal pests on the entire area[a]	6	4	8	**6**	Wculy
						Do not use cultivars that are highly resistant to fungal pests[a]	3	2	2	**2.3**	Wculn
					Q11_10	Trim field edges on the entire area[a]	3	2	4	**3**	Wtriy
						Trim field edges on none of the area[a]	2	1	2	**1.7**	Wtrin
II: *Monitoring*	7	4	6	**5.7**	Q12_1	Always monitor the fields for weeds before spraying with herbicides[b]	7	4	6	**5.7**	Wherby
						Never monitor the fields for weeds before spraying with herbicides[b]	3	2	2	**2.3**	Wherbn
					Q12_2	Always monitor the fields for fungal outbreaks before spraying with fungicides[b]	10	5	10	**8.3**	Wfungy
						Always monitor the fields for fungal outbreaks before spraying with fungicides[b]	1	1	1	**1**	Wfungn

III: *Decision-making*	7	4	5	**5.3**	Q12_3/4	Always decide fungicide spraying based on the pest models from VIPS or advice in the newsletters from the extension service[b]	10	6	8	**8**	Wdecy
						Never decide fungicide spraying based on the pest models from VIPS or advice in the newsletters from the extension service[b]	1	1	1	**1**	Wdecn
					r_nlr	Get advice and knowledge about pest management from the extension service[c]	8	5	7	**6.7**	Wadvy
						Do not get advice and knowledge about pest management from the extension service[c]	1	1	1	**1**	Wadvn
					r_vei	Get advice and knowledge about pest management from grain type-specific IPM-guidelines[c]	3	3	2	**2.7**	Wguiy
						Do not get advice and knowledge about pest management from type-specific IPM-guidelines[c]	1	1	1	**1**	Wguin
IV: *Non-chemical methods*	6	2	7	**5**	Q11_7	Use weed harrow on the entire area[a]	6	3	5	**4.7**	Wweey
						Do noy use weed harrow[a]	2	1	1	**1.3**	Wween
					Q11_9	Manually weed patches of weeds and/or wild oats on the entire area[a]	3	3	7	**4.3**	Wmany
						No manual weeding[a]	1	1	1	**1**	Wmann
V: *Pesticide selection*	2	1	1	**1.3**	Q48_3	Very important to consider the environment when managing weeds and fungal pests [d]	5	3	6	**4.7**	Wimpy
						Not important to consider the environment when managing weeds and fungal pests [d]	1	1	1	**1**	Wimpn
VI: *Reduced pesticide use*	6	3	5	**4.7**	Q12_5	Always choose to spot spray[b]	8	3	7	**6**	Wspoty
						Never choose to spot spray[b]	1	2	2	**1.7**	Wspotn
					Q12_6	Always choose the lowest recommended dosage[b]	10	5	10	**8.3**	Wrecy
						Never choose the lowest recommended dosage[b]	1	1	1	**1**	Wrecn

VII: ***Anti-resistance strategies***	3	4	3	**3.3**	Q12_7	Always choose or mix remedies with different modes of action in order to prevent resistance from developing[b]	3	3	8	**4.7**	Wmixy
						Never choose or mix remedies with different modes of action in order to prevent resistance from developing[b]	1	1	1	**1**	Wmixn
VIII: ***Evaluation***	2	3	3	**2.7**	Q11_8	Evaluate the effects of the pest management practices used, on the entire area[a]	3	3	6	**4**	Wevay
						Evaluate the effects of the pest management practices used, on none of the area[a]	1	1	1	**1**	Wevan

[a] What is done on your grain area? Consider what has usually occurred the last three years. (1 = none of the area, 5 = the entire area)
[b] How often is the following performed on your grain area? Consider what has usually occurred the last three years. (1 = never, 5 = always)
[c] Where do you advice and knowledge about pest management from? (yes/no-question)
[d] Which conditions are important to you when you manage weeds and fungal pests? (1 = not important, 7 = very important)
[e] Derived from the other questions regarding tillage practice. See Appendix C for explanation.

Appendix C: IPM index calculation method

The general formula of calculating the scores of the IPM index is explained in section 4.4 of the thesis. However, the actual calculation formula is more elaborate[20]. The following is an extensive presentation of how the IPM index is calculated.

Translation of the questionnaire data:

The input that was used in the index was questionnaire data. The items from the questionnaire had various response scales that had to be translated to fit the format of the index. The logic behind this translation was that one practice cannot be scored higher or lower than another based on differences in the response scales from the questionnaire. Therefore, every score was translated to a fraction of one. As shown in Appendix B, there were four scales used from the questionnaire. Scales a and b were translated from 1 (never/all of the area) - 5 (always/all of the area) to 0/4, 1/4, 2/4, 3/4, 4/4. Similarly, scale d was translated from 1 (not important) - 7 (very important) to 0/6, 1/6, 2/6, 3/6, 4/6, 5/6, 6/6. Scale c was translated from yes/no to 1, 0.

Maximal and minimal scores:

The maximal and minimal scores are important for calculating the index-scores. The maximal score from each principle is given by the weight of the principle. This ensures that the maximal score of the index in total is the sum of all the weights of the principles. The maximal score of the practices within each principle is given by summarising the weights of the best possible practices in each principle (shown in the column "Max" in table A.1 below). The minimal scores were given by summarising the weights of the worst possible scores divided by the maximal score and multiplied by the weight of the principle (column "Min" in table A.1). The minimal score of the index was used in the final stage of the calculation of the respondents' index scores.

[20] Any reader attempting to understand this index is welcomed to contact the author. I personally recommend trying to understand the calculation of each principle starting with principle VIII and working towards principle I.

Table A.1: Maximum sum of the practices of each principle and the minimum score of each principle in the IPM index.

Principle	**Max** (practices)	**Min** (score of principle)
I	24.67	2.38
II	14	1.35
III	17.3	0.92
IV	9	1.30
V	4.67	0.29
VI	14.33	0.87
VII	4.67	0.71
VIII	4	0.67

IPM index score:

The index score is given by the sum of the scores of each principle as shown by the equation below:

$$Index\ score = \sum_{i=1}^{8} Score\ of\ Principle_i$$

The score of each principle are calculated as follows:

Principle I:

There are two special cases in the way the scores of principle I are calculated.

First, the way the tillage practices were reported made it possible to report using either practice on more or less than the entire area. For example, in the questionnaire, it was possible to claim to plough all the area both in the fall and in the spring. In order to not award more points than the maximum score, the scores of the tillage practices were divided by the sum of the scores of the tillage practices. If the sum was below 1, the remaining fraction of 1 was set as “other tillage practices”.

```
sum_plough = Q11_1 + Q11_2 + Q11_3

If sum_plough < 1,

then Q11_x = 1 - sum_plough,

if else Q11_x = 0

sum_tillage = Q11_1 + Q11_2 + Q11_3 + Q11_x
```

The second exception to the standard calculation formula was considering how to score the monocropping. The farmers reported how much of the area they grew barley and wheat three or more years in a row on the same field. However, from the subsidy data, we knew that they had other crops than barley and wheat as well. We therefore decided to give scores for monocropping only on the fraction of the farmers area where they had reported growing barley or wheat in the subsidy data. We also made the judgment that whether it is wheat or barley that is not monocropped on a given field is irrelevant and should therefore be given an equal score. The following variables were made:

```
Wbarwhen = (Wbary + Wwhey) / 2 = 7.35
```

`Nbarwhe` = Fraction of total area the farmer reported not to grow barley or wheat on in 2016

`Bar` = Fraction of total area the farmer reported to grow barley on in 2016

`Whe` = Fraction of the total area the farmer reported to grow wheat on in 2016

```
 (((((Q11_1 * Wsprin) + (Q11_2 * Wfall) + (Q11_3 * Wdire) + (Q11_4 *
W_harr)) / sum_tillage )
+ ((Nbarwhe * Wbarwhen) + Bar * (1-Q11_4 * Wbarwhen) + (Q11_4 *
Wbarn)) + Whe * ((1-Q11_5 * Wbarwhen) + (Q11_5 * Wwhen))
+ (Q11_6 * Wculy) + (1-Q11_6 * Wculn)
+ (Q11_10 * Wtriy) + (1-Q11_10 * Wtrin))
/ Principle I_max)
* Weight of principle I)
= Score of principle I
```

(The light blue colour is used for tillage practice scores and green for monocropping scores.)

Principle II:

```
 (((Q12_1 * Wherby) + (1-Q12_1 * Wherbn)
+ (Q12_2 * Wfungy) + (1-Q12_2 * Wfungn)
/ Principle II_max)
* Weight of principle II
= Score of principle II
```

Principle III:

Principle III has one exception. Since the same information is given via the online pest forecasting systems (VIPS) and the newsletters the farmers receives from the extension service, the questionnaire item with the highest score from each respondent was chosen. This is why Q12_3/4 is named what it is named.

```
 (((Q12_3/4 * Wdecy) + (1-Q12_3/4 * Wdecn)
+ (r_nlr * Wadvy) + (1-r_nlr * Wadvn)
+ (r_vei * Wguiy) + (1-r_vei * Wguin)
/ Principle III_max)
* Weight of principle III
= Score of principle III
```

Principle IV:

```
(((Q11_7 * Wweey) + (1-Q11_7 * Wween)
+ (Q11_9 * Wmany) + (1-Q11_9 * Wmann)
/ Principle IV_max)
* Weight of principle IV
= Score of principle IV
```

Principle V:

```
(((Q48_3 * Wipmy) + (1-Q48_3 * Wimpn)
/ Principle V_max)
* Weight of principle V
= Score of principle V
```

Principle VI:

```
(((Q12_5 * Wspoty) + (1-Q12_5 * Wspotnn)
+ (Q12_6 * Wrecy) + (1-Q12_6 * Wrecn)
/ Principle VI_max)
* Weight of principle VI
= Score of principle VI
```

Principle VII:

```
(((Q12_7 * Wmixy) + (1-Q12_7 * Wmixn)
/ Principle VII_max)
* Weight of principle VII
= Score of principle VII
```

Principle VIII:

```
(((Q11_8 * Wevay) + (1-Q11_8 * Wevan)
/ Principle VIII_max)
* Weight of principle VIII
= Score of principle VIII
```

Linear transformation:

Lastly, the scores were transformed from the original range to the range of 0-100.

The maximal score of the index was the sum of the weights of the principles, which was 36. The minimal score of the index was the sum of the minimal scores of the principles, which was 8.48.

The score of the index as transformed to a range of 0-100 then becomes:

```
3.633 * Index score – 30.82 = Index score (0-100)
```

Appendix D: Interview guide

The interview guide was originally developed in Norwegian. The following is an English version, translated by myself.

Preface:

Before beginning the interview, the interviewees were asked to read a letter explaining the procedure regarding data collection, anonymity and their rights to withdraw from the study at any point before publication. Oral consent was required by the participants and they were given the option to either choose data collection in the form of an audio recording or taking notes. I kindly asked for audio recordings, and all 24 chose that option. Subsequently, the interviews followed this guide:

- You are the experts at growing the crops, and your knowledge and insight is invaluable. This far we've conducted focus group interviews and the questionnaire that you participated in around Christmas. Now, I'm here to do an interview with you about the same topics as in the questionnaire. The goal of the interviews is to enable you to answer more thoroughly on the topics and explain not only what you do, but also why. Feel free to supplement with the information you feel is important in addition to the responses to my questions.

- Do you have any questions before we begin?

Introduction:

- Would you mind telling me about your farming operation?
    - Does it include other productions than grains?
    - How did you end up with the present production system?

- Would you mind telling me about your grain production?

    - What kind of crop rotation do you have?
        - How do you plan your crop rotation?
        - Which types of grain do you grow?
        - Has this changed over time?

    - What kind of soil types do you have?
        - Any risk of erosion?

Pest management practice

- What do you do in order to manage the pest situation in your fields?
  This question was central to the interviews and very broad. Depending on what they answered, I followed up with varying questions prompting the interviewees to elaborate their practices and decision processes thoroughly. Some of the most used follow-up questions are listed below:
  - Does it differ between grain types?

  - Which tillage practice do you perform?
    - Has this changed during the years?

  - How do you plan your pest management?
    - Are there any practices you perform each year?

  - How do you decide when to spray with herbicides?

  - How do you decide when to spray with fungicides?

  - How do you evaluate the effect of the pesticides?

  - How has the pest management changed over the years?
    - Why?

  - Do you have any challenges with managing your pest situation?
    - Which, and why?

Good grain production

- What is "good grain production" here in [their municipality]?
  - Has this changed over time?
    - How about pest management?

- Is having a field with few weeds important?
  - Do you focus a lot on not spreading pests between the farms in your community?

- Do farmers in your community talk together a lot?

- Does everyone have a similar production here, or are there multiple ways of doing it "correct"?

- How do you view your own production compared to the others here in [their municipality]?

- What do you think "good grain production" is?

- Is there anything you would like to see changed regarding the grain production?
  - In your production?
  - In others' productions?

- Is there anything standing in your way of practicing "good grain production"?
  - If so, what? And why?

Integrated Pest management

- What do you think of when we speak of the term Integrated Pest Management?
  - What do you think of it?
    - Positive or negative?

- Would you say that you have used IPM-practices more in the last five years?
  - Why?
  - If so, when did the changes occur?

- The directive enforced in 2015 brought certain new requirements. Do you feel that they have affected the way you practice pest management?
  - The practical impact is stricter documentation requirements. Has the fact that you now have to document your IPM-practice affected your pest management in any way?

- Do you in any way feel pressured to practice more IPM now than before?

- Is there anything standing in your way of practicing more IPM?
  - If so, what? And why?

Responses to policy measures

In this section, we went through the three situations regarding hypothetical policy measures from the questionnaire. I asked the interviewees not to consider what they had answered in the questionnaire.The interviewees were then asked about each situation and their response to the situation. Emphasis was put on allowing them to explain why they would choose either *response to the situations. The goal of this section was to understand the reasons for choosing either response, and not so much which response they would give.*

Closing

- What do you think needs to be done in order to achieve the goal of increased use of IPM?

- Is there anything else you would like to add?

I then thanked the participants for their time and urged them to contact us with any questions or additions they might have. Lastly, I wished them good luck with the upcoming season!

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