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Piloting Innovative Insurance Solutions for Adaptation

D3.7 Potential for agricultural insurance in the Boreal region

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Summary

Farmers' ability to manage weather-based risks is limited in Finland because markets lack market-based risk sharing instruments. According to the concluded survey a majority of Finnish farmers strongly agree that there are weather risks in agriculture that they cannot manage using the currently available risk management methods. According to our study, a large majority of farmers agrees that new and innovative insurance products are needed to manage weather risks in agriculture.

The aim of this study is to evaluate Finnish farmers' interest in parametric weather insurance which is still a new and hypothetical insurance product in Finland and is not currently sold. Based on our study, we suggest that parametric insurance would be an essential complement to the supply of agricultural insurance products.

Finnish farmers are not a homogenous group in terms of their interest in risk management. We found three groups of farmers who differ from each other based on their opinions about parametric weather insurance. Two thirds of farmers can be considered potential customers for parametric weather insurance.

Unfortunately, we lacked a price attribute for parametric insurance, which is why price elasticity needs to be studied in future.

Keywords

parametric insurance, indemnity insurance, basis risk, farmers' opinions

1. Introduction

1.1 Weather risks and agriculture in Finland

Boreal biome or taiga refers to a circumpolar vegetation zone characterised by a forest of e.g. birch, poplar, and conifers. The boreal zone has long cold winters and short warm to cool summers. In northern Europe, there is remarkable spatio-temporal variation in growing season variables related to latitude, local topography, proximity to waterbodies, forest cover, and urban land use. Agriculture in the boreal region must adapt to relatively harsh conditions and is concentrated in regions and locations that are less harsh.

In Fenno-Scandia, there has been a significant shift in thermal growing season to earlier beginnings (on average 15 days over the 1951–2019 study period), increased length (23 days), and growing degree day sum (287 °C days) (Aalto et al. 2020). With food security concerns and accelerated global warming, northern regions are becoming new agricultural frontiers. Finland belongs to the boreal zone, although fields in Northern Finland are sub-Arctic. Finland is about 1,100 km long in a south–north direction, and climatic conditions vary considerably. The growing season is 170 days in southern Finland, but only 100 days in northern Finland. The sum of growing degree days (GDD) also varies considerably: in the south, the growing degree days sum is about 1,300, and in the north, 500. Frost occurs occasionally throughout the country even in the middle of summer. The abundance of light in summer slightly evens out the growing conditions between different parts of the country. The nights are short, especially in the central and northern parts of the country. On the other hand, radiation conditions limit the choice of plant varieties. Plants must be bred to survive in Finnish conditions. Climatic conditions significantly affect the location of crop production. Cultivation of wheat and oilseeds is limited to southern Finland. Barley, oats, hay, and potatoes, however, can be grown on suitable soil throughout the country. In much of the country, animal husbandry, and above all milk production, is the only sensible form of production (Kettunen 1995).

Finnish agriculture is experiencing a rapid structural transformation, with the number of farms declining quickly (Figure 1). The number of farms has fallen from more than 50,000 to fewer than 40,000. Despite this change, however, the amount of arable land under cultivation has remained unchanged. According to Natural Resources Institute Finland statistics, structural transformation has not conformed a large commercial farms, but remaining family farms have grown evenly. In Finland, the farm structure, the size of the field plots and the distance from the farm compound, is challenging, and it does not allow the creation of gigantic commercial farms. In Finland, the average size of field plots is about 2 ha, while in Sweden the corresponding average size of fields is more than 10 ha.

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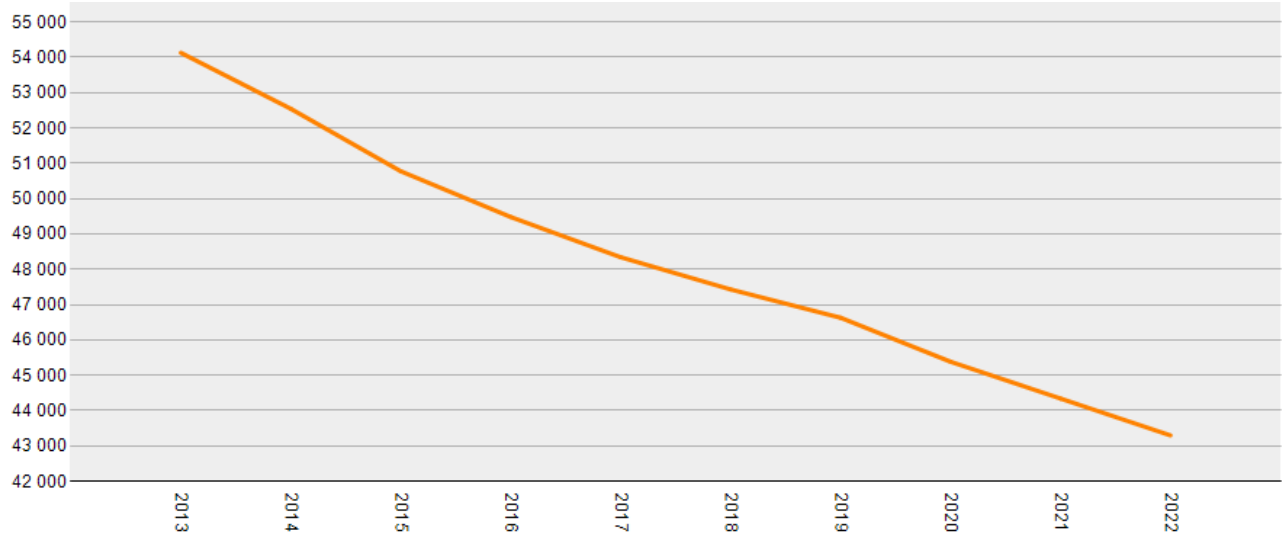

Figure 1. Number of farms (LUKE 2024).

Climate change is expected to increase ambient temperatures and extend the growing season in Finland. Most of the cereal yield increase is attributed to general warming. However, spring drought and heavy and long-lasting rains at harvest time can be detrimental for many crops. Weather extremes will challenge agricultural production more often. Plants with an indeterminate growth habit, such as grasses, potato, and root crops, may therefore benefit most from climate change in Finland. Pests, pathogens, and weeds may also benefit from increasing temperatures. Thus far, these have been controlled efficiently by harsh winter conditions. With increasing temperatures, these risks are also growing (Hilden et al. 2005).

Both climate change and structural transformation force farmers to improve their risk management. The income for farms' own labour and capital has decreased, even though farms' turnover has increased. Today, farms are more likely to face the possibility of bankruptcy (Niskanen and Heikkilä 2015).

There are many sources of risk in Finnish agriculture. Researchers often highlight the risks related to their own field of research as the most significant. This applies to researchers in crop science, agricultural technology, sociology, and economics alike. Even meteorological researchers scarcely differ from other researchers in this respect. It also appears that risk sources have a different impact on agricultural production over time (El Benni and Finger 2014).

Risk management in the EU Common Agricultural Policy (CAP) has multiple objectives. In the EU, price risks are the most important risk source for farmers, followed by weather-related risks, which represent a second major risk source for agriculture. European farmers are experiencing more frequent and more significant agricultural income crises, especially because of the war in Europe. For example, at the time of writing, farmers are protesting on the streets of Berlin and Paris against rising fuel prices and the influx of food from Ukraine into the EU's internal markets. Simultaneously, farms are increasing in size, financial margins are narrowing, and weather hazards are becoming more frequent and more difficult to forecast (Barrel 2023).

Stabilising farmers' incomes has become one of the CAP's objectives. However, instruments such as farming income insurance, mutual funds, and income stabilisation tools have remained marginal. The largest share of agricultural subsidies is paid on an area basis, and the rate has been flat for years. Counter-cyclical payments and premium subsidies for insurance are almost absent in the CAP. Furthermore, risk management under national agricultural policies in European countries has an ex-post (and ad-hoc) rather than ex-ante nature (Bielza Diaz-Caneja 2009). This cultural loading hampers the establishment of the insurance market for weather risks in the EU.

1.2 Weather risk management tools in Finnish agriculture

Weather risk management tools in Finnish agriculture can be divided into two main categories. These categories are: informal agronomist tools for farm instruments; and insurance cover provided by either government or insurance companies, as market-based risk-sharing instruments (Figure 2). The Finnish government ran a crop damage compensation (CDC) scheme until 2015. The scheme was designed to cover weather-induced crop losses in Finland. The CDC scheme was fully financed by the government, i.e. participation was free of charge for farmers. The CDC scheme was terminated due to problems related to moral hazard (Myyrä and Pietola 2011). The shadows of this programme can be recognised to this day. Traditionally, farmers trust the government's ability and willingness to save them if faced by large weather risks. However, whether the government covers yield damage is down to policymakers' goodwill. The government is therefore not included in Figure 2.

Finnish farmers' relationship with weather risk has been studied. It is evident that Finnish farmers suffer from unfavourable weather conditions and have been willing to pay for weather risk management tools since the government withdrew from the market (Liesivaara and Myyrä 2014). However, these markets have not emerged.

The rapid structural development of agriculture has led to the production specialisation of farms. In the past, diversified production made it possible that the destruction of a plant or a variety due to extreme weather events would not entail a severe financial loss. Other plant species (and animal husbandry) may have survived, and production was more sustainable and robust. Currently, farms must specialise to achieve benefits from economies of scale. However, specialisation increases risks. Currently, Finnish farms may have only one or two types of grain in their production portfolio.

Farms produce bulk products for the needs of the food industry, and farms have little opportunity to specialize or produce special products. The direct sales market for special products is very limited in Finland, and consumers have not bought them on a large scale. In Finland, the food industry and trade are very concentrated.

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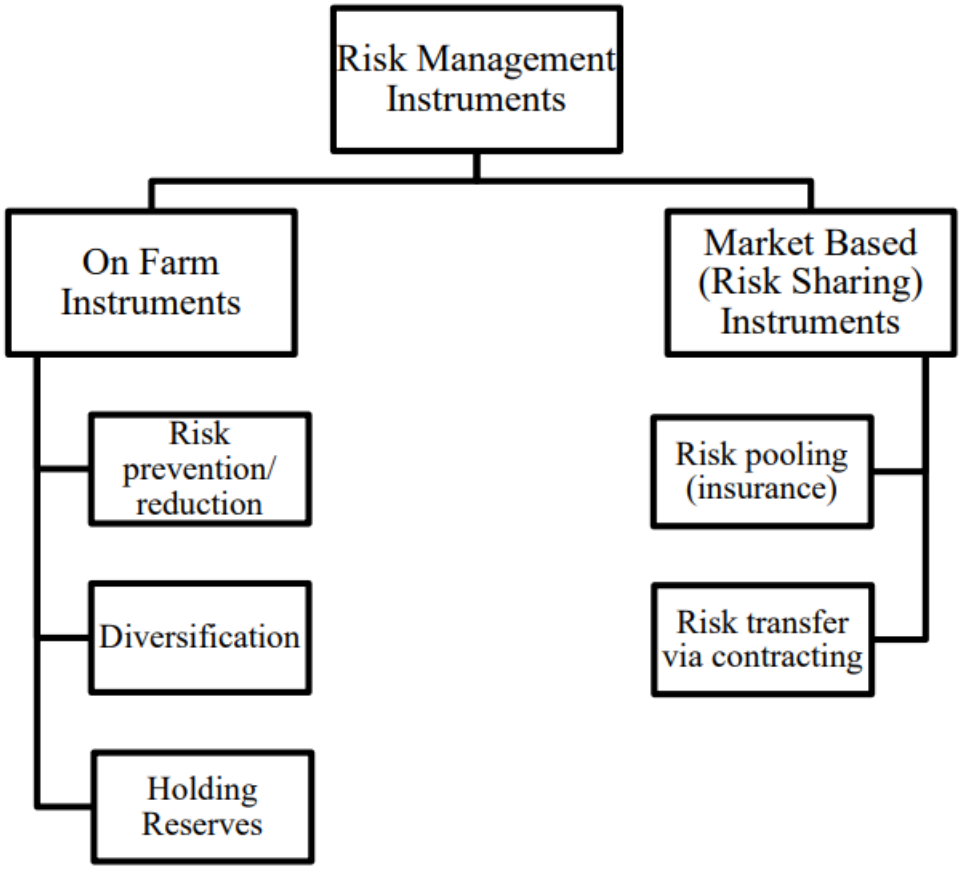

Figure 2. Risk management instruments. (Finger and Dalhaus 2017)

Farmers are not a homogenous group in terms of their attitudes towards weather risks. A third of farmers are recognised as willing to insure against unfavourable weather events, even if only shallow losses are expected. They therefore prefer insurance products protecting against yield losses to agronomic methods (Myyrä and Liesivaara 2015). At the farm level, this can be observed in how farmers recognise agronomist tools and skills to prepare against inter-annual weather variation. However, severe losses in one year are considered a threat to the continuation of traditional farming, and some farmers therefore seek insurance products that are more oriented towards catastrophe prevention.

Agronomist risk management tools against adverse weather conditions typically require fixed investments in either land or machinery. These investments include drainage or irrigation systems and are currently severely hampered in Finland due to a land tenure insecurity problem (Myyrä 2009). More than 40% of all arable land is farmed under short-term land lease contracts. Leaseholders are unwilling to make the investments necessary for weather risk management. Or rather, that the rental market mechanisms are not efficient enough for the rental farmers to have incentives to make basic improvements (Myyrä 2009).

Farmers' ability to manage weather-based risks is limited in Finland because markets lack market-based risk sharing instruments. Parametric insurance would be an essential complement to the supply of insurance products.

2 Framework

2.1 Moral hazard, adverse selection, and basis risk

Insurance could be an answer to the provision of financial protection against natural disasters resulting from extreme weather conditions. However, insuring farmers against crop losses is complicated. Insurers want to be sure that farmers are striving to protect their crops from natural disasters. Farmers are expected to follow the farming guidelines issued by insurance companies as much as they can when natural disasters strike. However, farmers have *moral hazard* incentives because they receive EU subsidies, regardless of their crop yields. They may not want to use any additional inputs to secure the yield when yield damage seems inevitable. Yet insurers want to avoid *adverse selection* by not insuring the most risky farmers.

Parametric insurance solves these problems by connecting insurance indemnity to a parameter such as observed weather conditions, rainfall, and temperatures, which are independent of an individual farmer's actions and are thus not affected by any moral hazard and adverse selection.

Parametric insurance is free from moral hazard and adverse selection because parameters are not subject to manipulation by individual farmers' actions. The price of freedom is that parameters that describe weather variability are not perfectly correlated with the yield variability (and especially with the income variability) farmers experience (Figure 3). This challenge is called *basis risk*. Basis risk is an unavoidable feature of parametric insurance.

In this study we ask farmers how they feel about basis risk. We also distinguish between upside and downside basis risk. Upside basis risk occurs when a farmer is eligible for an indemnity payment under parametric insurance even if that farmer has not faced any real-life damage (question C23). Downside basis risk is the opposite case and is addressed with farmers in question C24. We are aware of studies in which basis risk has been examined theoretically, but we believe that farmers' attitudes towards basis risk have not previously been investigated based on survey data in developed country conditions (Hott and Regner 2023).

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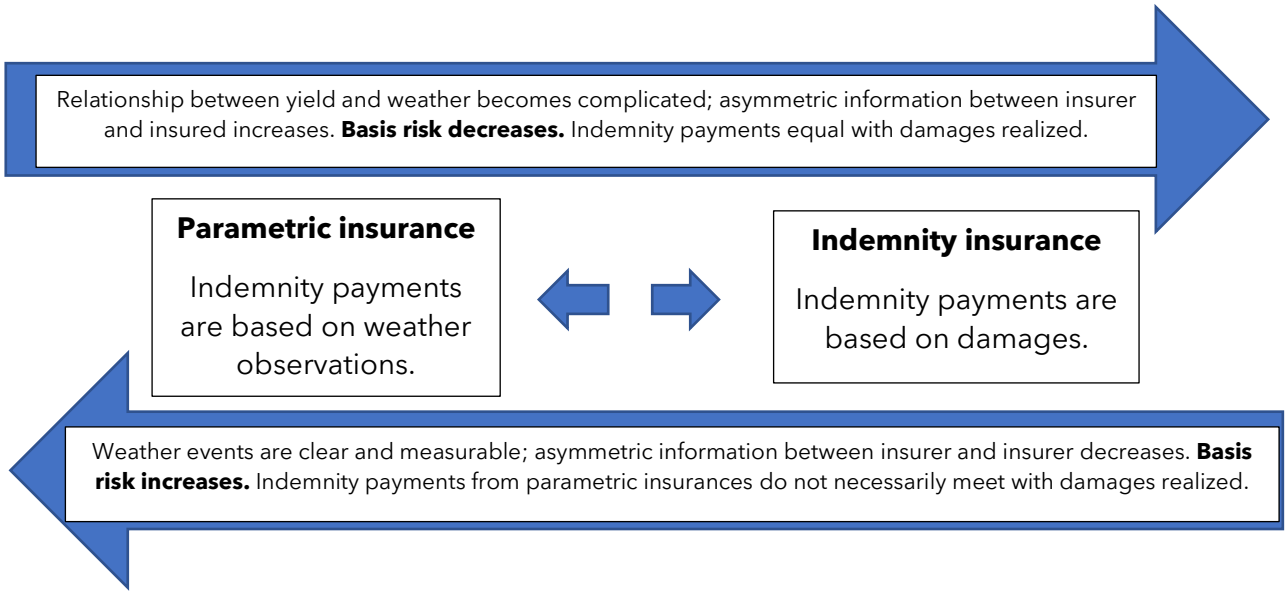

Figure 3. Relationship of insurance types in terms of basis risk when insuring farmers against unfavourable weather events affecting yield.

In indemnity insurance contracts, losses and the resulting indemnity payments are partly endogenous for the farmer, and the efficiency of contracts is therefore significantly decreased by asymmetric information problems. The reason is that insureds can use private information to change their behaviour at the insurer's cost. An example is increasing the likelihood of experiencing yield losses by decreasing the use of risk-decreasing inputs like pesticides (Smith and Goodwin 1996). This 'moral hazard' problem can make yield risks uninsurable and destroy the entire market for these risks. Parametric insurance does not suffer from the moral hazard problem, which is why it is important to study whether farmers in Finland are interested in such new insurance products, which remain hypothetical and are not traded in Finland.

The role of governments in yield insurance is crucial. Governments in the EU can support yield insurance through premium subsidies (European Commission 2013). Governments can also ruin the market by creating a 'charity hazard' problem. The 'charity hazard' problem means the crowding out of private insurance demand by government compensation (Robinson et al. 2021). This is also a potential risk in Finland, as we have a long history of government subsidy packages for farmers who are in trouble for various reasons.

2.2 What we have, and what we are looking for

There is currently only one commercial crop insurance policy available in Finland. It is a typical 'multi-peril crop insurance' policy (Figure 4). It provides cover against multiple weather conditions but requires a total loss. It therefore does not include any traditional cover and scale elements. Farmers can select certain perils against which they would like to be protected. These include spring droughts and heavy rainfall during harvest. The uptake

of this product has been weak, indicating that there is a need for different kinds of insurance products.

From the insurance company's perspective, the current insurance type involves high administrative costs. We need third-party inspectors to confirm the farmer's claim. These inspections must be carried out on the farm. Despite the inspectors' high level of professionalism, the insurance company is unable to obtain information about all the causes resulting in crop damage. The insurance currently in use in Finland is conditional on the total destruction of crop. However, there is no unequivocal definition of total crop destruction.

Index or parametric insurance policies have numerous advantages from the insurance company's perspective. This study maps farmers' opinions regarding parametric insurance.

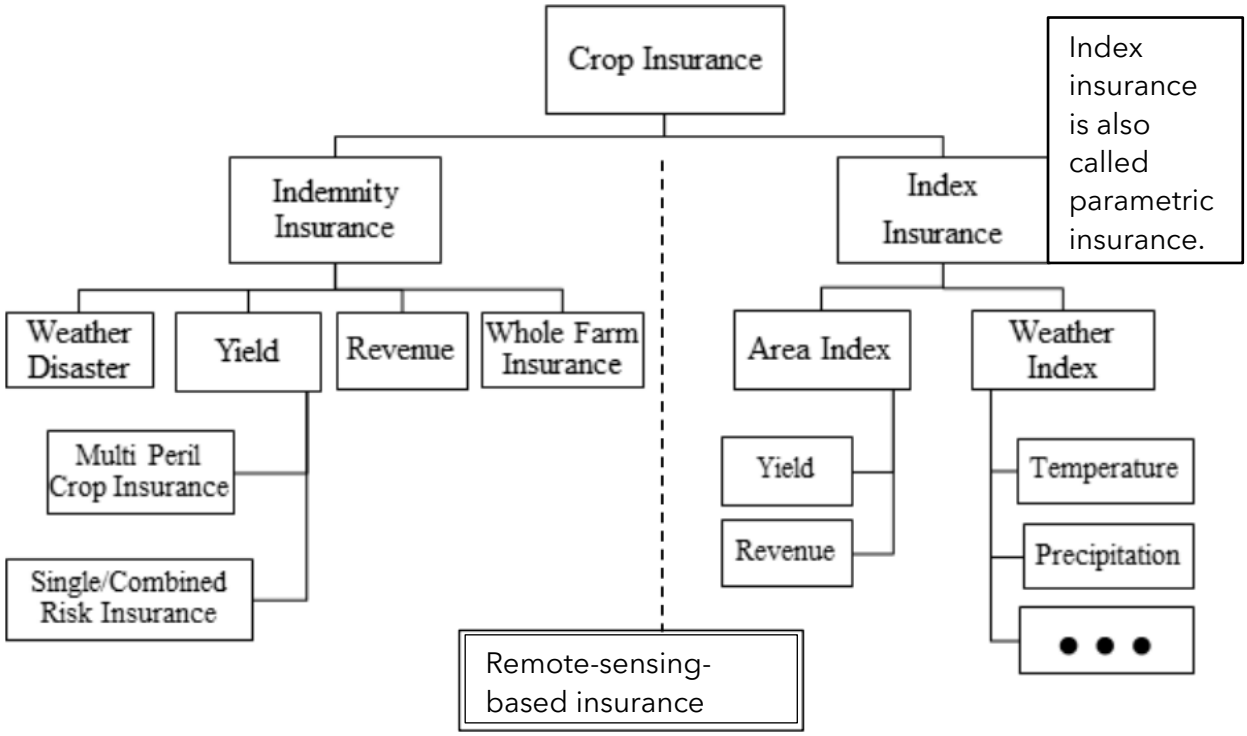

Figure 4. Crop insurance types. (Finger and Dahlhaus 2017). Parametric insurance included by writers.

2.3 Cost-effective solutions for weather risk management in agriculture

Farmers can mitigate the risks of agricultural business. The risk cannot be completed eliminated because it is extremely expensive. After a certain limit (risk-cost optimum, Figure 5), it is no longer profitable because costs increase significantly. There is a need for a cost-effective risk management tool for agriculture. Parametric and index insurance policies solve moral hazard and adverse selection problems. These insurance policies are also widely

tested in developing countries to offer cost-effective solutions for weather risk management in agriculture (World Bank 2011). However, to our knowledge, parametric insurance has yet to be scaled in European agriculture risk management markets. This may be connected with cultural issues, a lack of supply, legal restrictions, and farmers' attitudes. In this study, we test farmers' attitudes towards parametric insurance and especially basis risk, which is an integral part of parametric insurance. Cost-effectiveness is strongly related to the claims handling process. If it is unnecessary to monitor claims at the farm level, i.e. farmers tolerate basis risk, parametric insurance may also provide cost-effective weather risk management in Europe.

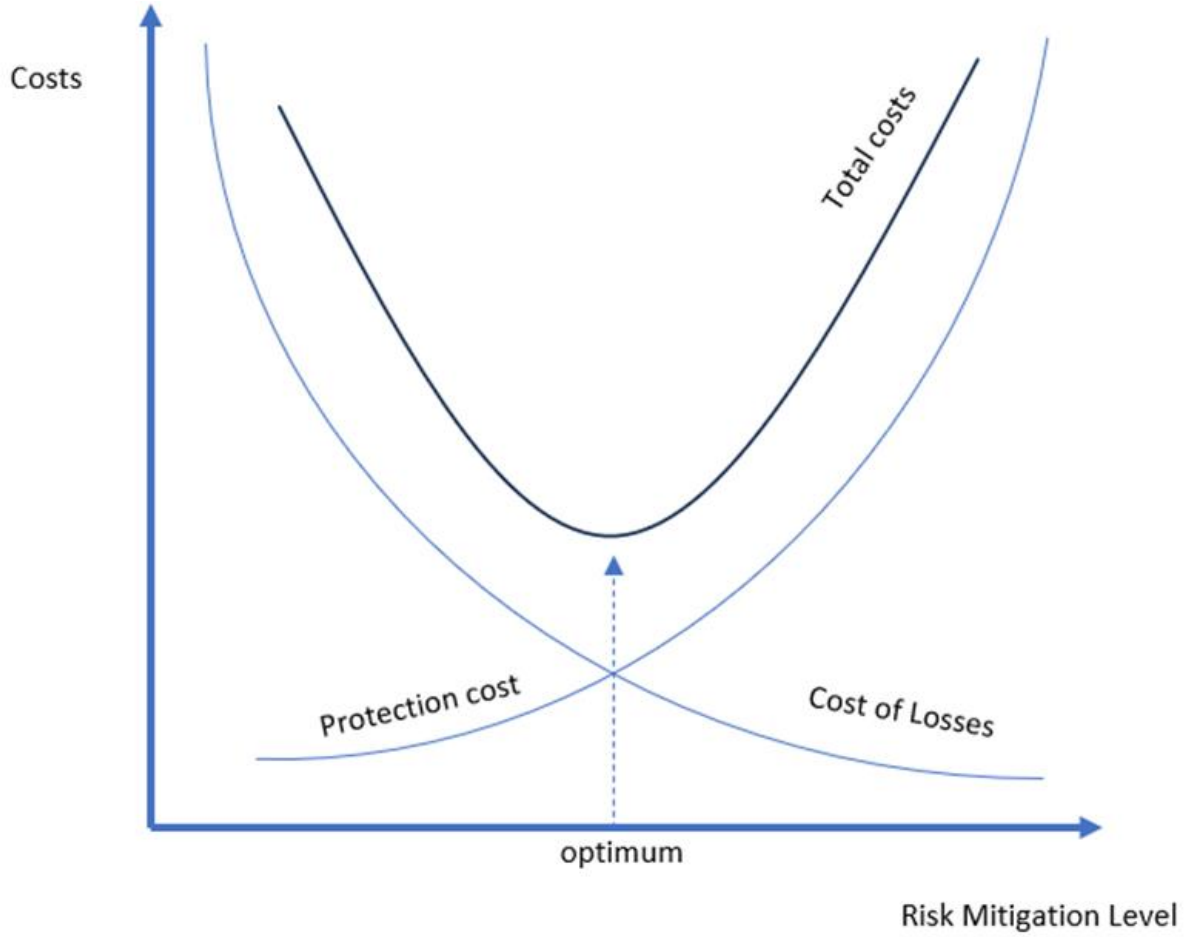

Figure 5. Risk-cost optimum.

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3 Data and Methods

3.1 Questionnaire

This study aims to evaluate Finnish farmers' interest in parametric weather insurance. Parametric weather insurance is not currently sold in Finland, which is why we study a hypothetical product. Currently, weather-induced yield variation, or yield risks, are insured with indemnity insurance. Indemnity insurance is based on insurance contracts, insurance claims, and claims inspection. In Finland, insurance contracts differ somewhat from those common in the United States or central Europe. In Finland, indemnity payments are typically paid only if the yield loss is total. We therefore have a culture in which the farmer's deductible has been very high, roughly 95%. Finnish farmers do not currently have access to partial or shallow loss yield insurance. Nor can they insure themselves against adverse weather events.

The data are collected using a questionnaire sent to LocalTapiola's farm customers. We observed a significant risk that the questionnaire cover pages affected customers' choices. This so-called anchoring effect has been shown to have a significant effect on Finnish farmers' answers in similar questionnaires regarding hypothetical yield insurance (Liesivaara and Myyrä 2014). In this study, we lack the resources to test the anchoring effects of different wordings on the questionnaire cover page. However, we carefully pretested the questionnaire with several expert groups.

The survey's first version was evaluated by experts working in LocalTapiola's Agriculture and Forestry business. This improved the questionnaire significantly. Some complicated structures and hard-to-formulate questions were removed. In addition, the questionnaire's final form was established. The questionnaire's next testing stage was with a LocalTapiola customer focus group. The focus group consisted of young farmers who were members of the Central Union of Agricultural Producers and Forest Owners (MTK). The young farmers had straightforward opinions about the real-life needs for parametric weather insurance. Some of the opinions were specific to certain local conditions and production lines. However, specific needs such as spring drought and excessive rains in the harvest season were included in the questionnaire.

The main format chosen for the survey was an opinion poll with a five-step Likert scale. The Likert survey is a pre-arranged scale from which respondents choose one option that best suits their view of the statements presented. It is often used to measure respondents' attitudes by asking to what extent they agree or disagree with a particular question or statement. This survey used a scale of 'Strongly agree', 'Somewhat agree', 'Neither agree nor disagree', 'Somewhat disagree', and 'Strongly disagree'. The actual statements form the body of the survey. When presenting the results, the class-scale variable is converted into distance scale numbers according to Table 1.

Table 1. Interpretation of opinions on a distance scale.

Class scale	Distance scale
Strongly agree	2
Somewhat agree	1
Neither agree nor disagree	0
Somewhat disagree	-1
Strongly disagree	-2

The Likert scale claims were grouped into five different groups. The aim of this grouping was to make it easier to respond to the survey. The groups of questions were the following: 1) Your interest in weather phenomenon insurance; 2) Weather phenomena to be insured, and how to measure them; 3) Compensation payable under weather phenomenon insurance; 4) Protection instructions / risk prevention; 5) Detection of weather phenomenon or crop damage (Table 2).

Table 2. Statements presented to respondents.

(A) Your interest in weather insurance
(1) I would like insurance that enables preventive measures to materialise the damage by paying the insurance compensation immediately when the weather phenomenon occurs.
(2) There are weather risks in agriculture against which I cannot currently hedge.
(3) I am interested in parametric insurance to protect against extreme weather phenomena.
(4) The weather-related variation of the crop level is small on my farm, on average less than +/- 30 per cent of the long-term average.
(5) I protect production from extreme weather phenomena by choosing plant species.
(6) The weather affects the organisation of the farm's production.
(7) Extreme weather events have increased.
(8) I recognise weather phenomena that affect the operation of my farm.
(9) I can manage all crop risks in agriculture using agrotechnical methods.
(10) I myself can influence how extreme weather phenomena affect the harvest.
(B) Protection instructions / risk prevention
(11) Parametric insurance encourages you to protect yourself from risks because you can get compensation, even if the damage has not materialised. It is therefore worth trying to prevent damage.
(12) Parametric insurance can be built so that the insurance company checks the damage on site, and only those who have suffered crop damage receive compensation. This increases costs and the price of insurance. I accept the increased costs.
(13) Compensation for parametric insurance can be paid, even if no concrete damage is found to have occurred. In weather phenomenon insurance, only the weather phenomenon is agreed and not cultivation or crop damage.
(14) One of the key advantages of parametric insurance is that insurance claims are paid quickly. It is inadvisable to slow down the process with an onsite damage inspection, as the realisation of the phenomenon is sufficient basis for indemnity payment.
(15) Agriculture needs new and open-minded insurance against weather risks.
(16) I am well acquainted with the protection guidelines for crop insurance policies currently on sale.
(17) It is right that crop insurance should be the same price for everyone, even those who do not follow protection guidelines.
(18) Insurance based on weather phenomena, which does not require farm-specific monitoring of cultivation methods and the determination of actual harvests, seems a modern way of managing weather risks.
(19) The harvest and cultivation activities of a farmer who has taken out parametric weather insurance must not affect the insurance compensation to which weather phenomenon insurance entitles you.
(20) Insurance compensation for weather phenomenon insurance should only be paid to those whose crops were also destroyed as a result of the weather phenomenon.
(21) Insurance compensation must be paid to everyone affected by an exceptional weather phenomenon (e.g. drought), regardless of the harvest on the farm.

(C) Compensation for parametric weather insurance
(22) I want to determine the exact time of a weather phenomenon such as drought or exceptional rainfall so that I can protect myself against it with insurance. However, the insurance should be taken out no later than one month before the date to be insured.
(23) In parametric insurance, it can sometimes happen that a weather phenomenon occurs and you receive compensation from the insurance, even though you have not experienced any damage. That is right.
(24) In parametric insurance, it can sometimes happen that you experience crop damage, even if the weather phenomenon that triggers the insurance compensation is not observed. That is right.
(25) The current crop insurance requires normal cultivation operations in the area to be carried out. However, it is impossible to control them.
(26) It is easier to insure the weather risk in crop cultivation based on measuring the weather phenomenon than on measuring the actual harvest.
(27) The farmer himself can influence the occurrence of crop damage.
(D) Insurable weather phenomena and their measurement[1]
(28) Frost poses a threat to my crops.
(29) I want weather phenomena to be measured on my own farm if insurance compensation is paid on the basis of weather phenomena. The Finnish Meteorological Institute's modelling of weather phenomena is not valid.
(30) The weather statistics of the Finnish Meteorological Institute describe well the precipitation that took place on my farm.
(31) The Finnish Meteorological Institute is a reliable independent provider of weather data, and phenomenon-based insurance can be based on modelling results published by the Finnish Meteorological Institute.
(32) I have a weather station and can share the data it collects with the insurance company.
(33) In arable farming, harmful drought can be measured by the continuous number of days without rain from the time of sowing.
(34) Finland is a northern agricultural country, and the short growing season and the small amount of heat are the main weather risk.
(35) Weather phenomena form minimum factors (for example, drought) that prevent the effective use of other inputs (for example, fertilisers.

The sample of customers was extracted from LocalTapiola's Customer Relationship Management (CRM) database. The following rules were used: 1. The customer type is 'agriculture'; 2. The M segment is 1–3. This rule implies that the customer has a significant economic connection with agriculture. The customer either derives part of their income from agriculture or has significant fixed assets in agriculture; 3. The customer has not opted out of receiving emails from LocalTapiola; 4. We have the email address; 5. We know the customer's main agricultural production line.

Swedish is the second official language in Finland. The Swedish version of the survey was made for Swedish -speaking customers. The original statements in Finnish are presented in Appendix 1.[2]

3.2 Response rate and respondent representativeness

The survey response rate was 5.4%. According to a LocalTapiola specialist, this response rate is very close to the normal response rate of customer satisfaction surveys. This indicates that the survey was 'business as usual' in an insurance company context. The survey was implemented on the Surveypal platform, the main platform used at LocalTapiola.

[1] Reason for not been interested in parametric insurances might be due to fact that farmer is not affected by the peril mentioned in questionnaire. That is taken into account in grouping analysis (K-means). "Not interested" farmers are recognised to one of groups.
[2] Lost in translation between three languages might be possible, but impossible to prove.

The representativeness of the survey data was checked by comparing a sample drawn from the customer base (to whom the questionnaire was sent) with the survey respondents. From this comparison (Table 3), it seems that respondent representativeness was satisfactory. The size of the respondents is very similar if measured in farm size classes (M classes). In addition, the production line distribution is also very similar to the sample, although grain farms are slightly overrepresented among the respondents. The respondents represent the farm customers in the sample in terms of age. Farm characteristics are used when conformed opinion-based farmer clusters are described.

Table 3. Representativeness of the respondents.

Farm size (M class)	Sample, %	*Respondents, %*
M1	21%	*25%*
M2	47%	*47%*
M3	32%	*28%*
Production line		
Dairy (01)	14%	12%
Other animal production (02–12)	14%	10%
Grain farm (13)	47%	58%
Other plant production (14–23)	22%	18%
Forestry (25)	3%	1%
Age, years	54.50	*54.09*
Field area ha, own	38.73	*43.23*
Field area ha, leased	29.87	*34.77*

3.3 Latent farmer groups (K-means)

This study uses the K-means cluster analysis to find homogenous and recognisable farmer clusters. All 35 statements in the questionnaire (Table 2) are used for this task. A principal component analysis is not needed because farmers responded to all statements using the same Likert scale, which is transformed to numerical values according to Table 3 (-2 … 2). The number of groups was determined based on their reliability and interpretative interest. Later groups are described and named based on the farmers' average opinions within clusters.

The K-means algorithm is an algorithm for clustering n objects based on attributes into k partitions, $k < n$. The objective in K-means clustering is to minimise total intra-cluster variance, or the squared error function:

$$V = \sum_{i=1}^{k} \sum_{x_j \in S_i} (x_j - \mu_i)^2 \quad , \qquad (1)$$

where S_i are clusters for $i = 1,2\ldots k$, and μ_i is the centroid or mean point of all the points $x_j \in S_i$.

The most common form of the algorithm uses an iterative refinement heuristic that starts by classifying the input points into *k* initial sets, either at random or using some heuristic data. It then calculates the mean point, or centroid, of each set. It constructs a new clustering by associating each point with the closest centroid. The centroids are then recalculated for the new clusters, and the algorithm is repeated by an alternate application of these two steps until convergence. Convergence is obtained when the points no longer switch clusters.

This purely numerical approach to grouping respondents helps enrich the interpretation of the results. Based on the results, the clusters can be given logical names, and clusters include farmers with a similar opinion on the shown statements.

4 Results

4.1 Farmers' opinions

This study's main question seeks to reveal farmers' interest in parametric insurance (question A3). When farmers are asked directly, slightly more than half express an interest in parametric insurance. There is no mention of prices here, so no position can be adopted concerning price elasticity. Five per cent of respondents strongly disagree with the need for parametric insurance to insure risks related to extreme weather events. About a third of the respondents had not formed an opinion on this question (Figure 6).

Farmers strongly agree that there are weather risks in agriculture that they cannot manage with the currently available risk management methods (A2 in Figure 6). About 85% of farmers agree at least somewhat with this statement. The result is supported by the view that weather affects the organisation of production on farms (A6).

It is thought that not all farmers believe that climate change is real. There is no need for such a notion, as only 47 out of 618 respondents did not think that extreme weather events had increased. This is a strong result, as the respondents' average age was 54, and farmers have a long history and extensive experience of farming in harsh Northern climate conditions. As the results of claim A8 show, farmers monitor the weather and identify phenomena that affect the organisation of farm production. Sorvali (2023) came to the same conclusion: 'There is not much climate skepticism among Finnish farmers, and climate change is accepted as a real phenomenon.'

Finnish farmers do not have the cultivation methods that would allow them to manage all weather-related risks (A9 and A10). The result indicates that the yield variation experienced

on farms is exogenous and largely beyond farmers' capacity to handle. The result shows that weather risk management also requires insurance products.

Current crop insurance policies assume that yield risks are endogenous. In practice, therefore, it is assumed that farmers can influence crop damage by themselves. For this reason, current crop insurance policies include protection guidelines that oblige farmers to ensure, by using standard farming methods, that their crops are not destroyed by weather events. It seems that farmers are unfamiliar with these guidelines (B16). However, farmers do not accept that crop insurance premiums are identical for everyone, including for those who do not comply with the protection guidelines (B17). The result is confusing, but interesting. It is therefore absolutely necessary to accept the exogenous nature of crop risks[3].

Nearly three quarters of farmers agree that innovative insurance products are needed to manage weather risks in agriculture (B15). However, it is evident that farmers feel strongly that indemnity payments and the damage that occurs at the customer level must go hand in hand (B13). This is despite the fact that in parametric insurance, only the weather phenomenon is agreed, not cultivation or crop damage. This result may reflect the influence of current crop insurance policies available on the market. In current insurance policies, indemnity payments are based solely on damage that is observed and verified on the farm. Based on the results of this survey, the switch from indemnity to parametric insurance is challenging, at least in the short term. Farmers appear to believe that when they have insurance for yield risks by parametric weather insurance, the harvest and cultivation activities of a farmer must be accounted for. This holds despite the fact that indemnity payments are triggered solely based on weather parameters (B19).

[3] We did nod fin in our data strong evidence for production line sensitivity (table 8) for interest in parametric weather insurances.

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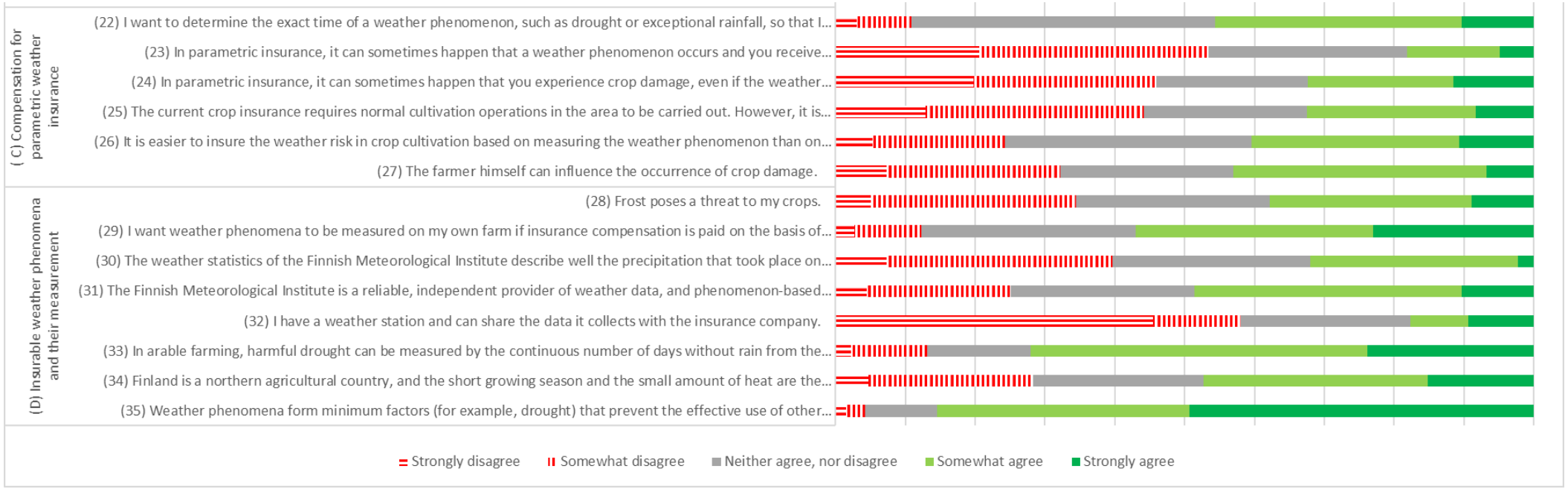

Figure 6. Farmers' opinions on weather related risk statements.

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Farmers strongly reject basis risk in C23 and C24. Fewer than one in five think it is fair to accept an indemnity payment if they have not faced any real damage. However, in parametric insurance, it can sometimes happen that a weather phenomenon occurs, and the customer receives an indemnity payment from their policy, even though they have not experienced any damage. The vast majority of Finnish farmers feel this would be wrong. The moral standard of Finnish farmers is especially high in this matter because receiving an indemnity payment without experiencing any real damage (upside basis risk) is perceived as wrong more widely than the alternative of not receiving an indemnity payment under index insurance (when real damage has occurred) (i.e. downside basis risk).[4]

This result poses significant challenges to the development of parametric insurance. Previous studies have found that the available weather data can explain only about 40% of crop variability in Finland (Pietola et al. 2011). Furthermore, the EU has imposed some strict limitations for parametric insurance and basis risk to be supported by agricultural subsidies (European Commission 2013).

In practice, variations in crop yields between years are influenced by many factors other than the weather alone. In addition, marketable weather indices can be overly simplistic weather graphs for explaining harvests' overall variability. For example, in certain convective weather situations, rainfall events can be small-scale, i.e. some fields on the farm may receive rain, while others remain dry. The accuracy of measurements and spatial representativeness of analyses varies between weather parameters. It is therefore quite natural that when hedging against fluctuations in crop levels with weather indices, there is always some basis risk. This study shows that basis risk issues are crucial for Finnish farmers. More spatially refined weather observation points may reveal harvest relevant micro-climate differences and as such may also reduce suspicion regarding various insurance products and official meteorological data. Acceptable quality observation system should be affordable for all farmers.

In the United States, index-based crop insurance policies have started to be included in 'Basis risk rider' features (Barnet et al. 2005). A basis risk rider can cover farm-specific claims not covered by index insurance. These features increase the price of insurance and administration costs considerably. However, farmers in the US seem to have been prepared to pay for such additional protection. The marketability of basis risk riders in Finland should be investigated.

Lichtenberg and Iglesias (2022) argue that cost rather than basis risk is the main obstacle to parametric insurance uptake. In this study, we did not test the price attribute on parametric insurance. However, OP Pohjola has already tested affordable crop insurance (indemnity insurance) that is suitable for everyone in the Finnish crop insurance market. This type of insurance did not generate demand either, and OP Pohjola abandoned it.

Eighty-five per cent of farmers say that weather phenomena form minimum factors (for example, drought) that prevent the effective use of other inputs (for example, fertilisers)

[4] Upside and downside basis risks could be assisted by new digital solutions to support parametric insurance. There are some hybrid parametric insurance - which triggers first by weather trigger, then farmers are required to take an "on-ground" photo for verification.

(D35). The effects of weather on agricultural production can be so evident that complex measurements or weather stations may not even be needed. A large majority of farmers think that in arable farming, harmful drought can be measured by the continuous number of days without rain from the time of sowing (D33). On the other hand, it can be difficult for an insurance company to define unequivocally what constitutes a rainy day. Is it enough that only rainfall is taken into account, or should evaporation also be considered? Such details need to be clearly defined during the development of parametric insurance. We might rely on some soil data from direct measurement (for example Soil Scout[5]) for this. Soil moisture a more direct measure of soil condition than a rainy day. But the cost of data might be an issue.

4.2 Latent farmer clusters

Clusters are formed using K-means analysis. The purely statistical method divided the respondents into three clusters based on all 35 statements. The sizes of the clusters are: C0 33%, C1 35%, and C2 32%.

Clusters are described with averages of respondents' opinions on the presented statements (Table 4–7). Opinions are measured on a Likert scale: 'Strongly agree' = 2; 'Somewhat agree' = 1; 'Neither agree nor disagree' = 0; 'Somewhat disagree' = -1; and 'Strongly disagree' = -2. Initially, the focus is on the statements that, based on their opinions, divided the respondents.

Farmers are clearly divided into two groups according to their interest in parametric insurance (A3). About a third of farmers are not interested (Cluster 0; -0,39) and two thirds are interested in parametric insurance to protect against extreme weather phenomena (Cluster 1; 0,91 and Cluster 2; 0,76).

Farmers in cluster 0 think that the weather-related variation of the crop level is small (on average, agree with claim A4). Farmers in clusters 1 and 2 disagree, on average, with claim A4. Farmers in clusters 1 and 2 also think to a larger extent that extreme weather events have increased (A7), and that weather affects the organisation of the farm's production (A6). Moreover, farmers in cluster 0 believe more frequently that they can manage all agricultural crop risks using agrotechnical methods (A9). This also applies to how extreme weather phenomena affect the harvest (A10).

[5] https://soilscout.com/

Table 4. Farmers' interest in weather insurance. Strongly agree = 2, … Strongly disagree = -2.

(A) Your interest in weather insurance	**C0**	**C1**	**C2**
(1) I would like insurance that enables preventive measures to materialise the damage by paying the insurance compensation immediately when the weather phenomenon occurs.	-0.19	**1.06**	**0.75**
(2) There are weather risks in agriculture against which I cannot currently hedge.	**0.70**	**1.57**	**1.51**
(3) I am interested in parametric insurance to protect against extreme weather phenomena.	-0.39	**0.91**	**0.76**
(4) The weather-related variation of the crop level is small on my farm, on average less than +/- 30 per cent of the long-term average.	**0.38**	-0.10	-0.18
(5) I protect production from extreme weather phenomena by choosing plant species.	**0.50**	**0.68**	**0.60**
(6) The weather affects the organisation of the farm's production.	**0.33**	**1.30**	**1.19**
(7) Extreme weather events have increased.	**0.56**	**1.18**	**1.21**
(8) I recognise weather phenomena that affect the operation of my farm.	**0.70**	**1.20**	**1.25**
(9) I can manage all crop risks in agriculture using agrotechnical methods.	-0.48	-1.08	-1.24
(10) I myself can influence how extreme weather phenomena affect the harvest.	-0.29	-0.60	-0.46

Farmers in Cluster 1 differ from other clusters based on their opinions on risk prevention in parametric insurance. They accept that compensation under parametric insurance can be paid, even if no concrete damage is found to have occurred. In weather phenomenon insurance, only the weather phenomenon is agreed, and cultivation or crop damage is not (B13). Furthermore, farmers in Cluster 1 are unwilling to accept the extra costs that arise from monitoring crop damage on site. In addition, farmers in Cluster 1 see the key advantages of parametric insurance – namely, that insurance claims are paid quickly (B14). They think it is inadvisable to slow down the claim handling process with an onsite damage inspection, as the materialisation of the phenomenon is a sufficient basis for indemnity payment.

For the insurance company, it is important to know how much monitoring and administration is needed to ensure that moral hazard and adverse selection are kept to a minimum. To accomplish this goal, the principle of deductible is used to make sure that the insured carries part of the risk, and that mistakes in offering too generous a coverage will be mitigated. More information is needed to tailor and monitor indemnity insurance products compared to parametric insurance. More monitoring involves higher transaction costs, which convert directly into higher premiums to cover the administrative costs of the insurance. Parametric insurance significantly reduces transaction costs. When farm yields are highly correlated with the parameter, they can provide protection that is even better than multi-peril indemnity insurance for yield (Barnett et al. 2005).

Farmers in Cluster 1 are ready for new insurance that do not examine the actual yield level on the farm, but under which indemnity payments can be based on extreme weather (events B18–21). Farmers in this group are potential buyers for parametric yield insurance in Finland.

Table 5. Protection instructions / risk prevention. Strongly agree = 2, … Strongly disagree = -2.

(B) Protection instructions / risk prevention	**C 0**	**C 1**	**C 2**
(11) Parametric insurance encourages you to protect yourself from risks because you can get compensation even if the damage has not materialised. It is therefore worth trying to prevent damage.	**0.34**	**1.18**	**0.47**
(12) Parametric insurance can be built so that the insurance company checks the damage on site, and only those who have suffered crop damage receive compensation. This increases costs and the price of insurance. I accept the increased costs.	**0.01**	-0.45	**0.58**
(13) Compensation for parametric insurance can be paid, even if no concrete damage is found to have occurred. In weather phenomenon insurance, only the weather phenomenon is agreed, not cultivation or crop damage.	-0.38	**0.60**	-1.10
(14) One of the key advantages of parametric insurance is that insurance claims are paid quickly. It is inadvisable to slow down the process with onsite damage inspection, as the realisation of the phenomenon is sufficient as a basis for payment.	**0.14**	**1.11**	-0.37
(15) Agriculture needs new and open-minded insurance against weather risks.	**0.21**	**1.48**	**1.12**
(16) I am well acquainted with the protection guidelines for crop insurance policies currently on sale.	-0.95	-0.51	-1.04
(17) It is right that crop insurance should be the same price for everyone, even those who do not follow protecting guidelines.	-0.59	-0.66	-1.26
(18) Insurance based on weather phenomena, which does not require farm-specific monitoring of cultivation methods and the determination of actual harvests, seems a modern way of managing weather risks.	-0.03	**0.84**	-0.44
(19) The harvest and cultivation activities of a farmer who has taken out parametric weather insurance must not affect the insurance compensation that entitles you to weather phenomenon insurance.	-0.12	**0.48**	-0.73
(20) Insurance compensation for weather phenomenon insurance should only be paid to those whose crops were also destroyed as a result of the weather phenomenon.	**0.75**	**0.28**	**1.55**
(21) Insurance compensation must be paid to everyone affected by an exceptional weather phenomenon (e.g. drought), regardless of the harvest on the farm.	-0.24	**0.38**	-1.18

In parametric insurance, a weather phenomenon can sometimes occur, and you receive compensation from your policy, even though you have not experienced any damage. We asked Finnish farmers whether they thought this was right (C23). There was a clear difference of opinion between farmer clusters on this issue. Farmers in clusters C0 and C2 disagree somewhat strongly, whereas farmers in C1 slightly agree. The same also applies to the case of downside basis risk (C24).

This study reveals that two thirds of Finnish farmers (C0 and C2) cannot accept basis risk in parametric yield insurance. The result raises the bar considerably for parametric insurance, especially at insurance companies operating on a mutual or cooperative basis, where equality between owner-customers is important.

However, all farmers agree that moral hazard and adverse selection challenges exist in indemnity insurance (C27). Farmers themselves can influence the occurrence of crop

damage. This result forces us to consider whether it would be fairer for policyholders if the farmer and farm-specific differences were removed from yield insurance, and if the insurance compensation were linked only to weather phenomena. A third of farmers (Cluster 1) think that it is easier to insure the weather risk in crop cultivation based on measuring the weather phenomenon than based on measuring the actual harvest (C26).

The potential for the use of parametric insurance products in agriculture is significant (Skees 2001). This potential in Finland is estimated in chapter 4.3. by describing farmer cluster with farm charasteristics.

Table 6. Compensation for parametric weather insurance. Strongly agree = 2, … Strongly disagree = -2.

(C) Compensation for parametric weather insurance	**C 0**	**C 1**	**C 2**
(22) I want to determine the exact time of a weather phenomenon such as a drought or exceptional rainfall so that I can protect myself against it with insurance. However, the insurance should be taken out no later than one month before the date to be insured.	**0.24**	**0.62**	**0.39**
(23) In parametric insurance, a weather phenomenon sometimes occurs, and you receive compensation from the insurance, even though you have not experienced any damage. That is right.	-0.46	**0.12**	-1.26
(24) In parametric insurance, sometimes you experience crop damage, even if the weather phenomenon that triggers the insurance compensation is not observed. That is right.	-0.11	**0.11**	-0.69
(25) The current crop insurance requires normal cultivation operations in the area to be carried out. However, it is impossible to control them.	**0.09**	**0.00**	-0.61
(26) It is easier to insure the weather risk in crop cultivation based on measuring the weather phenomenon than on measuring the actual harvest.	-0.05	**0.77**	-0.13
(27) The farmer himself can influence the occurrence of crop damage.	**0.13**	**0.02**	**0.16**

Parametric insurance usually relies on third-party weather measurements. This is to ensure that neither the insured nor the insurance company can manipulate the weather parameters. Trust is important.

It seems that farmers trust the Finnish Meteorological Institute as a reliable independent provider of weather data (D31). However, farmers in Cluster 2 did not agree nor disagree with this claim. Furthermore, farmers in Cluster 2 were sceptical about the spatial accuracy of the Finnish Meteorological Institute's rainfall measurements (D30).

All farmers were of the opinion that the weather observations used in parametric insurance should be measured on their own farm (D29). However, farmers report that they lack a weather station or the ability to share data with the insurance company (D32).

It is notable that weather measurements do not need to be 'scientific'. Farmers agree that in arable farming, harmful drought can be measured by the number of continuous days without rain from the time of sowing (D33). Things become complicated when the insurance company needs to define 'rain'.

Table 7. Insurable weather phenomena and their measurement. Strongly agree = 2, … Strongly disagree = -2.

(D) Insurable weather phenomena and their measurement	**C 0**	**C 1**	**C 2**
(28) Frost poses a threat to my crops.	-0.16	**0.29**	**0.08**
(29) I want weather phenomena to be measured on my own farm if insurance compensation is paid based on weather phenomena. The Finnish Meteorological Institute's modelling of weather phenomena is not valid.	**0.18**	**0.80**	**0.97**
(30) The weather statistics of the Finnish Meteorological Institute describe well the precipitation that took place on my farm.	**0.07**	-0.05	-0.42
(31) The Finnish Meteorological Institute is a reliable independent provider of weather data, and phenomenon-based insurance can be based on modelling results published by the Finnish Meteorological Institute.	**0.42**	**0.44**	0.00
(32) I have a weather station and can share the data it collects with the insurance company.	-1.23	-0.41	-0.68
(33) In arable farming, harmful drought can be measured by the continuous number of days without rain from the time of sowing.	**0.63**	**0.97**	**0.80**
(34) Finland is a northern agricultural country, and the short growing season and the small amount of heat are the main weather risk.	**0.51**	**0.35**	**0.02**
(35) Weather phenomena form minimum factors (for example, drought) that prevent the effective use of other inputs (for example, fertilisers).	**0.93**	**1.49**	**1.45**

4.3 Description of the farmer clusters

Based on farmers' opinions in Cluster 0, we can entitle this cluster as *Non-insurers*. Farmers in this cluster think that crop variation does not matter much to them, and that they can manage crop variation through their own actions[6]. Farmers also do not believe that climate change will increase extreme weather events. On average, farmers in this cluster are older, and they farm slightly smaller farms (Table 8).

Farmers in Cluster 1, *potential parametric insurers,* are interested in parametric insurance. They also accept basis risk as a natural part of parametric insurance. They are unwilling to sacrifice the speed of the claims handling process to achieve a smaller basis risk. It was expected that production line would have effect on farmers having higher interest towards parametric weather insurance. However, that was not the case in our data. Grain farmers where just slightly overrepresented on this farmer cluster (Table 8).

Farmers in Cluster 2, *conventional insurers*, do not tolerate basis risk. They think that there must be a conventional yield loss on the farm to be eligible for yield insurance compensation. They are interested in parametric insurance, but they do not accept indemnity payments that are based on weather parameters alone.

[6] We do not have data on farmers average yield performance. The previously defunct state-run CDC program favored low-yield farmers. Some low-yield farmers even specialized in applying for government crop damage compensations.

Table 8. Farm and farmer characteristics by cluster.

	Hectares own	Hectares leased	% grain farms	Age, years	% farmers	% land
All	43.23	34.77	58	54.10	100	100
Non-insurers, C0	38.27	26.44	58	56.50	33	30
Potential parametric insurers, C1	47.46	36.85	60	52.00	35	38
Conventional insurers, C2	43.47	40.26	56	54.03	32	32

5 Conclusions

Finnish farmers strongly agree that there are weather risks in agriculture that they cannot manage using the currently available risk management methods. Unfortunately, we did not have a price attribute for parametric insurance, which is why price elasticity needs to be studied in future.

A large majority of farmers agree that innovative insurance products are needed to manage weather risks in agriculture. Decision making and production is highly digitalised on Finnish farms. More than half of the milk is milked by robots, and a large proportion of tractors are equipped with GPS steering. Farmers are therefore familiar with handling data. Despite all this digitalisation, not all farmers are ready for parametric insurance to rely purely on weather parameters. Farmers somehow think that when they have insurance for yield risks by parametric weather insurance, the harvest and cultivation activities of a farmer must be accounted for. Farmers do not tolerate basis risk.

This study aligns with previous studies in finding that Finnish farmers are not a homogenous group in terms of their interest in risk management. We found three groups of farmers who differed from each other based on their opinions about parametric weather insurance. Two thirds of the farmers can be considered potential customers for parametric weather insurance.

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Piloting Innovative Insurance Solutions for Adaptation

Appendix 1. Original statements presented to respondents in Finnish

(A) Your interest in weather insurance
(1) Haluaisin vakuutuksia, jotka mahdollistavat vahingon realisoitumisen ennaltaehkäisevät toimenpiteet maksamalla vakuutuskorvauksen välittömästi sääilmiön esiintyessä.
(2) Maataloudessa on sääriskejä, joilta en voi tällä hetkellä suojautua.
(3) Olen kiinnostunut ilmiöpohjaisista vakuutuksista sään ääri-ilmiöiltä suojautumiseksi.
(4) Satotason säästä johtuva vaihtelu on tilallani pientä, keskimäärin alle +/- 30 prosenttia pitkän aikavälin keskiarvosta.
(5) Suojaudun sään ääri-ilmiöiltä kasvilajivalinnalla.
(6) Sää vaikuttaa tilan tuotannon järjestämiseen.
(7) Sään ääri-ilmiöt ovat lisääntyneet.
(8) Tunnistan sääilmiöt, jotka vaikuttavat tilani toimintaan.
(9) Voin hallita kaikkia maatalouden satoriskejä viljelyteknisillä menetelmillä.
(10) Voin itse vaikuttaa siihen, miten sään ääri-ilmiöt vaikuttavat satoon.
(B) Protection instructions / risk prevention
(11) Ilmiöpohjainen vakuuttaminen kannustaa omaan riskeiltä suojautumiseen, sillä korvauksen voi saada, vaikka vahinko ei olisikaan realisoitunut. Vahinkoja kannattaa siis yrittää ehkäistä.
(12) Ilmiöpohjainen vakuuttaminen voidaan rakentaa niin, että vakuutusyhtiö käy tarkistamassa vahingon paikan päällä ja vain satovahingon kärsineet saavat korvauksen. Tämä lisää kustannuksia ja nostaa vakuutusten hintaa. Hyväksyn lisääntyneet kustannukset.
(13) Ilmiöpohjaisen vakuutuksen korvauksia voidaan maksaa, vaikka konkreettista vahinkoa ei havaita toteutuneeksi. Sääilmiövakuutuksessa sovitaan vain sääilmiöstä eikä viljelystä tai satovahingoista.
(14) Ilmiöpohjaisten vakuutusten yksi keskeisimpiä etuja on se, että vakuutuskorvaukset maksetaan nopeasti. Prosessia ei kannata hidastaa paikan päällä tehtävällä vahinkotarkastuksella, sillä ilmiön toteutuminen riittää korvauksen maksuperusteeksi.
(15) Maataloudessa tarvitaan uusia ja ennakkoluulottomia vakuutuksia sääriskien varalta.
(16) Olen tutustunut hyvin nykyisten myynnissä olevien satovakuutusten suojeluohjeisiin.
(17) On oikein, että satovakuutukset ovat saman hintaisia kaikille, myös niille, jotka eivät noudata suojeluohjeita.
(18) Sääilmiöihin perustuva vakuutus, jossa ei tarvita tilakohtaista viljelymenetelmien valvontaa ja toteutuneen satomäärän selvittämistä vaikuttaa modernilta tavalta sääriskien hallintaan.
(19) Sääilmiövakuutuksen ottaneen viljelijän sato ja viljelytoimet eivät saa vaikuttaa sääilmiövakuutuksen oikeuttamiin vakuutuskorvauksiin.
(20) Sääilmiövakuutusten vakuutuskorvaus tulee maksaa vain niille, joilla myös sato tuhoutui sääilmiön seurauksena.
(21) Vakuutuskorvaus tulee maksaa kaikille poikkeuksellisen sääilmiön (esimerkiksi kuivuuden) vaikutuspiirissä olleille, tilalla toteutuneesta sadosta riippumatta.
(C) Compensation for parametric weather insurance
(22) Haluan itse määrittää sääilmiön esimerkiksi kuivuuden tai poikkeuksellisen sateen tarkan ajankohdan, jotta suojautuisin siltä vakuutuksella. Vakuutus olisi otettava kuitenkin viimeistään kuukautta ennen vakuutettavaa ajankohtaa.
(23) Ilmiöpohjaisessa vakuuttamisessa voi joskus käydä niin, että sääilmiö toteutuu ja saat vakuutuksesta korvauksen, vaikka et ole vahinkoa kokenutkaan. Tämä on oikein.
(24) Ilmiöpohjaisessa vakuutuksessa voi joskus käydä niin, että koette satovahingon, vaikka vakuutuskorvauksen laukaiseva sääilmiötä ei olekaan havaittavissa. Tämä on oikein.
(25) Nykyisessä satovakuutuksessa edellytetään alueen normaalien viljelytoimenpiteiden suorittamista. Niiden valvonta on kuitenkin mahdotonta.
(26) On helpompaa, että kasvinviljelyn sääriskin vakuuttaminen perustuu sääilmiön mittaamiseen kuin toteutuvan sadon mittaamiseen.
(27) Viljelijä voi itse vaikuttaa satovahingon syntymiseen.
(D) Insurable weather phenomena and their measurement
(28) Halla aiheuttaa uhan viljelykasveilleni.
(29) Haluan, että sääilmiöt mitataan omalla maatilallani, jos vakuutuskorvaus maksetaan sääilmiöiden perusteella. Ilmatieteen laitoksen mallinnus sääilmiöstä ei kelpaa.
(30) Ilmatieteen laitoksen säätilastot kuvaavat hyvin tilallani toteutunutta sadantaa.
(31) Ilmatieteen laitos on luotettava, riippumaton säädatan toimittaja ja ilmiöpohjainen vakuutus voi perustua Ilmatieteen laitoksen julkaisemiin mallinnustuloksiin.
(32) Minulla on sääasema ja voin jakaa sen keräämää dataa vakuutusyhtiölle.
(33) Peltoviljelyssä haitallinen kuivuus voidaan mitata yhtäjaksoisella sateettomien päivien määrällä kylvöajankohdasta alkaen.
(34) Suomi on pohjoinen maatalousmaa ja kasvukauden lyhyys ja pieni lämpösumma ovat keskeisin sääriski.
(35) Sääilmiöt muodostavat minimitekijöitä (esimerkiksi kuivuus) jotka estävät muiden panosten (esimerkiksi lannoitteiden) tehokkaan käytön.

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