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Winds of change for farmers: Matches and mismatches between experiences, views and the intention to act

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ABSTRACT

Agriculture is facing multifaceted changes. Farmers are eventually the ones who will implement changes or not depending on their knowledge, experience, views and other motives. To gain some insight into farmers' decision making and to identify possible hotspots that require knowledge sharing, encouragement and subsidies, a farmer survey was arranged. 38,091 invitations were sent covering 80% of Finnish farmers and 4401 answers were received without significant distortions of representativeness due to age, geographical area, farm type, farm size or education. The survey contained four groups of questions with structured statements on awareness of future changes, personal experience of changes, views towards different measures and intentions to act. Farmers have observed many weather-related changes. They often see a need to take measures to manage crops, soil conditions and farming system. The measures considered to be important were often implemented or they were in the farmers' near future plans. However, some mismatches occurred between scientific evidence and the farmers' understanding and observations of changes, as well as concerning measures needed in the future. Hence, more efficient means are needed to share knowledge concerning future changes and coping measures. Moreover, policy incentives are important for investments because the economic situation is challenging for farmers and the measures primarily aim to decline the environmental footprint of agriculture.

1. Introduction

Agriculture has always been in a state of flux. The original aim of producing food more efficiently compared to the preceding hunter-gathering economy has gradually been supplemented by increasingly multifaceted targets. Ideally, farmers would produce more food in less land area for an increasing human population and support higher standards of living in an environmentally, economically and socially sustainable way (Foley et al., 2011). This necessitates adaption to climate change, but also coping with fluctuations in markets and prices, agricultural and environmental policies, changes in consumption habits etc. (Soussana et al., 2012). Simultaneous action to reduce the environmental footprint of agriculture is needed, i.e. climate change mitigation, maintenance of biodiversity, and reductions of nutrient and pesticide loads in the environment (Rockström et al., 2009). Farmers need to cope with short-term shocks, while safeguarding their long-term sustainability, productivity and competitiveness.

Due to the multifaceted, but also justifiable aspirations that are set for agriculture alongside food production and security farmers' decision making has become increasingly challenging, and even further strained by the difficult economic situation (Scherer et al.,

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2018). Climate change is progressing rapidly at high latitudes (Ruosteenoja et al., 2016a) and many impacts on agriculture that are at least partly attributable to climate change have already been observed (Kaukoranta and Hakala, 2008; Lehsten et al., 2017). Climate change policies are needed to tackle the most relevant risks and to be able to benefit from any opportunities that may arise, as well as to promote development of effective measures to cope with changes and to ensure their timely implementation (Tuomenvirta et al., 2019).

In the end, the farmer is the one making decisions on how and when to operate. In this study the farmers were first asked to answer two sets of statements related to views on climate change and experiences on changes so far in their own farm or nearby locations. With additional questions and statements in the survey we assessed farmers' views and intentions to change farming practices that could sustain adaptation to climate change, improve resilience to climate change and variability, have an impact on nutrient leaching and biodiversity and in general sustain long-term sustainability of crop production systems. Furthermore, we aimed to identify any possible mismatches between farmers' views and their intention to act to enable the characterization of hotspots for future knowledge sharing and for the development of policies to encourage efficient changes in crop production systems.

2. Materials and methods

In total 38,091 out of 47,688 Finnish farmers (i.e., 80%) received the survey via email, as they had registered an email-address in the registry of the Finnish Food Authority. 4401 farmers answered the survey, corresponding to a 12% response rate of the farmers reached and 9% of all Finnish farmers. The person principally responsible for the decision making at the farm was asked to be the respondent. As an outcome, 87% were male, the average age was 51 years, the average farm size was 51 ha and 15% were organic farms. Some 43% of the respondents were cereal producers and 18% dairy farmers. Some 65% had secondary school education and 25% had a university degree. The annual revenue was $\leq$100,000 euros for 66% of respondents. No significant distortions of representativeness were found for age, geographical area, farm type, farm size or the level of education. According to a non-response analysis, including a possible coverage error, our data was interpreted as a representative sample of the Finnish farmer community.

In addition to the topics covered in this study, the farmers' values, as well as their general views on climate change and the future of agriculture in Finland were surveyed. There were four groups of survey questions which examined: 1) awareness of future changes (with nine structured statements (SS)), 2) personal experience of risks (21 SS), 3) views concerning different measures (23 SS) and 4) intended actions for each of the measure in the previous group of questions (23 SS). Hereafter, when we refer to intention, both intention to act (or not) in the future and already implemented measures are considered (Ajzen, 1991; Kormos and Gifford, 2014). Depending on measure the farmers may have implemented them only in a few field parcels and not at farm scale. The structured statements and the alternative answers are shown in Tables S1 and S2. The first three groups of questions were measured on a Likert scale with five alternatives for a farmer to select from and the fourth group with six alternatives with different time scales. The corresponding principle questions of these ensembles in the questionnaire were:

1) What do you think about the following statements?
2) In the 2000 s have you observed any of the following issues on your farm or near regions?
3) How important or unimportant are the following measures?
4) Have you implemented any of the measures or plan to do so on your farm?

The respondents were grouped for statistical analyses according to: 1) farm size ($<$ 30, 30–49, 50–99 and $\geq$100 ha), 2) farming system (organic and conventional), 3) farm type (horse/sheep, cattle, crop, pig and poultry farm), 4) age of farmer ($\leq$30, 31–50, 51–70 and $>$ 70 years), 5) education (unidentified, basic, vocational and university) and 6) geographical area (in total 16 Centres for Economic Development, Transport and the Environment, ELY Centres). A one–way analysis of variance (ANOVA) was used to evaluate whether there was evidence that the means of the respondent groups differed in the listed questions. When there were more than two groups, the Tukey's honestly significant difference (HSD) test was used in multiple comparisons. It tests all pairwise differences and controls the probability of making one or more Type I errors. A significance level of $\alpha = 0.05$ was used in all the analyses.

There is some disagreement amongst scholars about whether Likert data should be analysed with parametric or nonparametric statistics. However, especially for the 5-point Likert items the difference between these tests has most often been found to be negligible (de Winter and Dodou, 2010). Even though the 5-point Likert scale is ordinal, we decided to use a parametric test. Both ANOVA and HSD assume a normal distribution of the observations and equal variances of the groups. The risk of violations of these assumptions was reduced notably because of the large sample size (N = 4401). The analyses were performed using the ANOVA and MEANS procedures specified by the SAS Enterprise Guide 7.1 (SAS Institute Inc., Cary, NC, USA).

3. Results

3.1. General awareness of future changes and risks

According to the mean values of the answers, the most agreed statements were that the future winters will become milder and heavy precipitation events will become more frequent: 67% of respondents agreed with these statements and only some 3% fully disagreed (Fig. 1). Additionally, crop protection and flooding risks were considered higher in the forthcoming years: about 16% fully agreed, some 50% agreed more or less, while only 3% fully disagreed. Farmers were uncertain whether problems with soil erosion

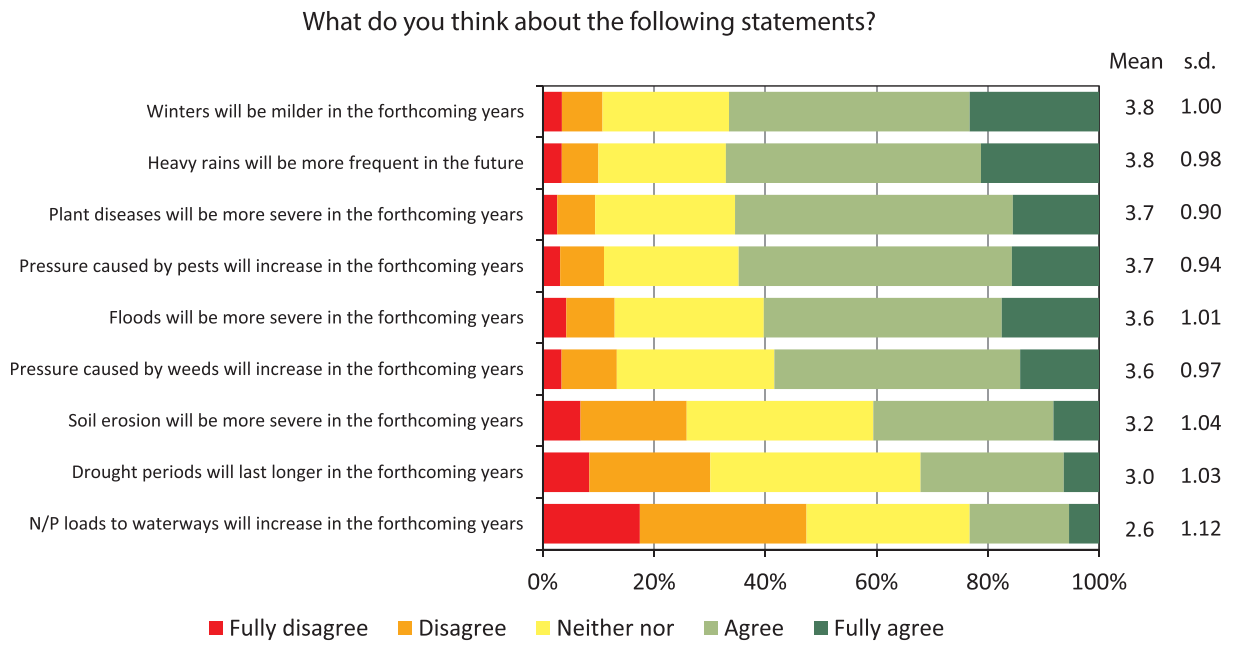

Fig. 1. The distribution of farmers' answers (N = 4399) to the principal question "What do you think about the following statements?" and the mean for each statement with the standard deviation (s.d.).

would increase and 18% of the respondents fully disagreed that the risks for nutrient loads would increase and only 5% fully agreed that this would be probable. Farmers were also uncertain about the risks of longer drought periods in the future, as 30% fully or partly disagreed and another 32% fully or partly agreed.

3.2. Personal experience of risks

Farmers considered increased frequency of damage caused by wild animals and higher annual variation in yields to be the most frequent changes that had occurred in the 2000s as 47% and 42% answered that these had occurred frequently or stated that they occurred all the time, respectively (Figs. 2 and S1). Additionally, a lower yield quality had been experienced but 81% answered that only occasionally, rarely or not at all. Farmers identified increased damage caused by heavy rains and the increased need to control weeds and diseases, but less frequently pests. Increases in the damage caused by either flooding or drought were quite rarely experienced as were increases in winter damage: only some 23%, 11%, and 17%, respectively, answered that flooding, drought and overwintering risks were more frequent or present all the time.

The farmers had already observed that the growing season had become longer and novel crops and cultivars (also those maturing later) had already been taken into cultivation. 32–34% of the respondents stated that they had experienced these changes more frequently or stated that they were already a part of everyday life (Fig. 2). Higher yields and earlier starts for crop growth were experienced at least to be more frequent in some 20% of the answers. However, opportunities related to autumn sowing were utilised only occasionally, rarely or not at all according to 87% of responders. On the other hand, only < 1% of farmers considered plant stands to have matured clearly earlier in the 2000s, while 57% considered that this had happened rarely or not at all.

Reduced populations of pollinators had been observed in the 2000s: 5% answered that they observed this all the time, 23% frequently and only 13% not at all (Figs. 2 and S1). Additionally, populations of farmland nesting birds were reported to be reduced frequently or all the time by 20% of farmers, while again not at all by 24%. The corresponding figures for the loss of soil fauna and microbial flora were 9% and 32%, respectively.

3.3. Views on the importance of different measures

Farmers considered taking care of basic soil conditions, subsurface drainage, and overall drainage systems on the farm and local scale to be particularly important measures. As many as 60%, 53% and 52% considered these aspects to be important, respectively, and only 1% considered them to be unimportant, and 1–2% quite unimportant (Figs. 3 and S2). Increasing organic amendments to the soil were considered important or quite important according to 70% of the farmers, and using autumn sown crops for wintertime ground cover was viewed as important for 55% of them.

Controlling disease pressure by crop sequencing and diversifying crop rotations in general were favoured by farmers as measures more than cultivating early maturing crops or using certified seeds. The first two measures were both considered to be important or quite important by 75% and 76% of farmers, respectively, while the latter two by some 42% (Fig. 3). 60% considered cultivation of

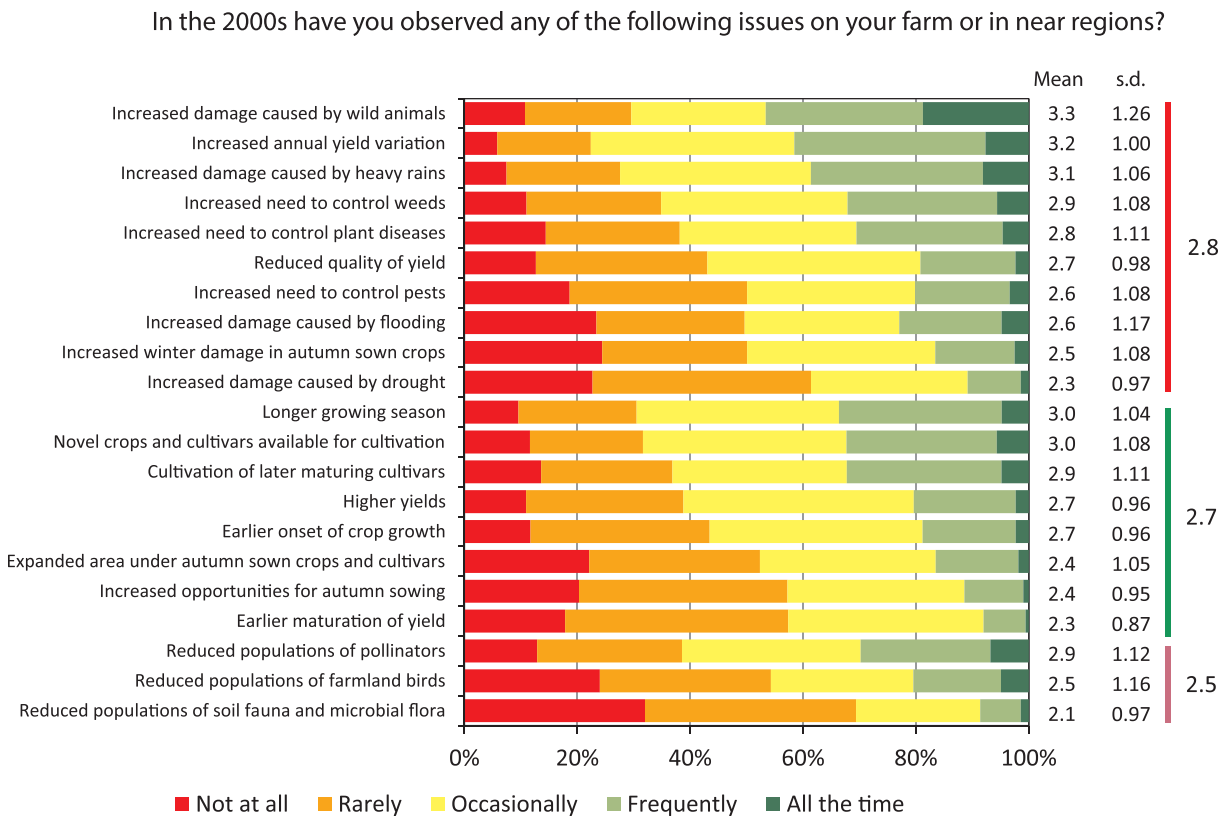

Fig. 2. The distribution, mean and standard deviation (s.d.) of farmers' answers (N = 4400) to the principal question "In the 2000s have you observed any of the following issues in your farm or near regions?" when afterwards grouped as harmful impacts of climate change (red line), opportunities driven by climate change (green) and impacts on biodiversity (purple). Means across each group are shown rightmost. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

novel crops and cultivars to be important or quite important, while 11% considered these to be unimportant or quite unimportant.

The cultivation of nitrogen (N) fixing leguminous crops was the most important measure in the category of management of crop nutrition as 65% of responders considered it to be important or very important (Figs. 3 and S2). The corresponding figure for the increasing use of phosphorus (P) fertilizers was 54%, while for N it was 42%, and for precise and/or split use of fertilizers it was 52%. The use of catch crops to reduce nutrient leaching into waterways was not very popular among the farmers: only 9% considered it to be important and 28% quite important, while 29% considered this to be unimportant or quite unimportant.

In general, maintaining biodiversity on the farm scale was considered to be important (25%) or quite important (41%). However, actual measures such as sparing poorly performing fields as habitats for wildlife fauna and flora, maintaining diverse flora in field edges and leaving patches of forest between or in the middle of field parcels were considered by 48%, 38% and 25% of farmers, respectively, to be either important or quite important (Fig. 3).

Different soil incorporation methods were not considered to be among the most important measures. 34%, 21% and 19% of responders judged reduced tillage, direct drilling and shifting from autumn to spring tillage to be important or quite important practices (Fig. 3). Being prepared to implement irrigation was the most unpopular measure among farmers. As many as 32% considered it to be unimportant, another 32% quite unimportant and only 3% felt it was important.

The farmers' views on measures were dependent on the farm size. On small farms (< 30 ha) taking care of basic soil conditions and drainage systems and increasing organic materials in the soil were considered to be less important than on larger farms (Table 1) opposite to the use of winter crops to provide ground cover, which was more important than on large (50–99 ha) or very large farms (≥100 ha) (Table 1). Regarding changes in nutrient and soil management, the use of catch crops and shifting from autumn to spring tillage were seen as more important measures on smaller than on larger farms, contrary to increases in the use of P and N rates, precise and split fertilizer methods and reduced tillage (Table S3). On small farms diversification of crop rotations and thereby controlling disease pressure as well as the introduction of novel crops were considered to be less important than on larger farms, which felt the opposite about the use of certified seeds (Table S4). Small farms considered any means to increase biodiversity more important than the larger farms did (Table 2).

The cultivation of N-fixing, catch and winter cover crops, shifting from autumn to spring tillage, taking care of basic soil conditions and drainage systems, increasing organic materials in the soil, diversifying crop rotation and also thereby controlling disease pressure, as well as increasing biodiversity by all means was more important for organic than conventional farms. Conventional farms

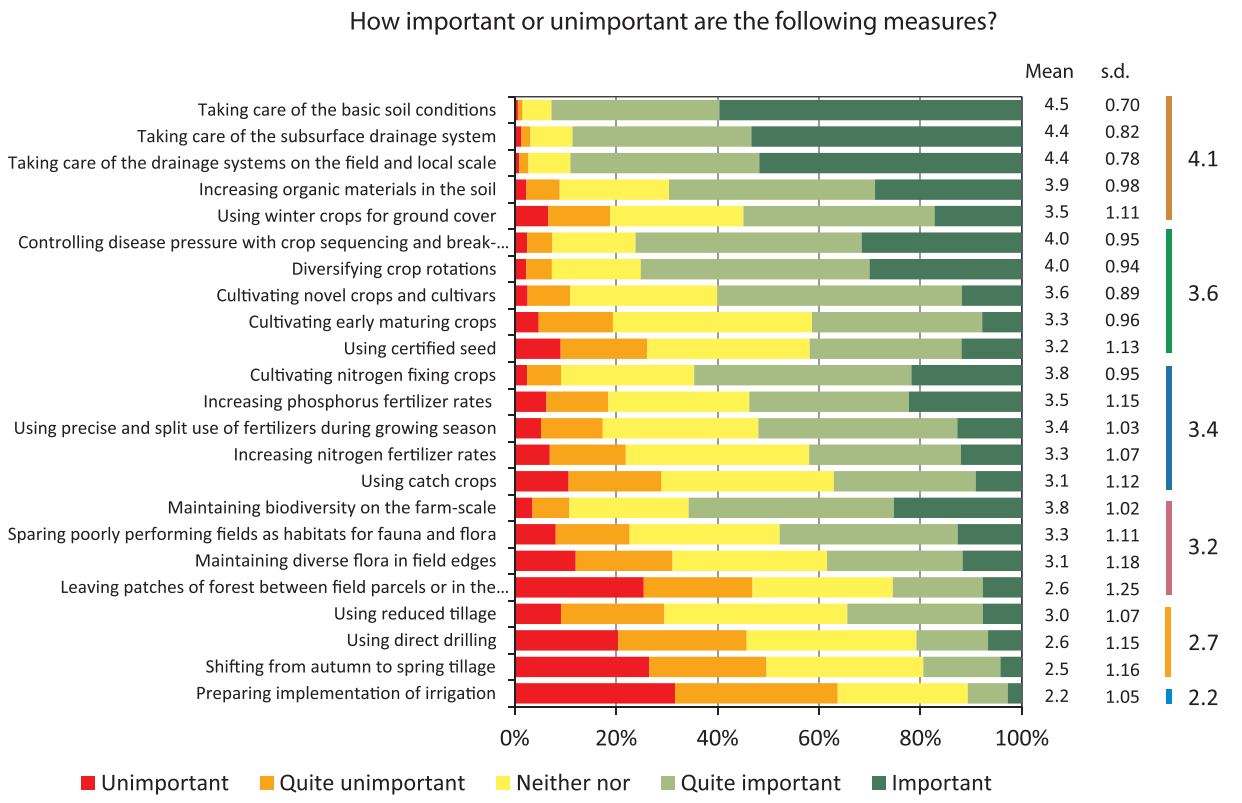

Fig. 3. The distribution, mean and standard deviation (s.d.) of farmers' answers (N = 4400) to the principal question "How important or unimportant are the following measures?" The answers were afterwards grouped according to the farmers' priorities: maintaining and improving soil conditions (brown line), diversifying crop choices and controlling disease pressure (green), managing crop nutrition (blue), sustaining biodiversity (purple), changing soil incorporation methods (orange) and preparing the implementation of irrigation (turquoise). Means across each group are shown rightmost. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

considered that it was important to increase future N and P use rates, use split and precise methods for fertilizing crops as well as direct drilling (Tables 1–2 and S3–S4). Often horse and sheep farms considered measures for taking care of basic soil conditions and drainage systems, increasing N and P use rates, diversifying crop rotations, and thereby controlling disease pressure as well as cultivating novel crops and cultivars less important than other farm types. They had again positive views about generally maintaining biodiversity. Cattle and crop production farms differed in their views on taking care of the basic soil conditions, cultivating N-fixing crops, using reduced tillage, direct drilling and shifting from autumn to spring tillage, introducing novel crops and cultivars and sparing poorly performing fields as habitats for fauna and flora. The views of poultry and pig farms were often similar.

Regarding the age of a farmer often the two youngest age categories ($\leq$30 and 31–50 years) differed from the very old farmers (> 70 years) if any systematic difference was found in the farmers' views. Older farmers, e.g., considered that it was less important to take care of basic soil conditions and drainage systems and control disease pressure through diversified crop sequencing than did farmers in any other age group. Younger farmers again tended to be more open to increasing N and P fertilizer rates and maintaining diverse flora and fauna in field edges and leaving patches of forest between field parcels (Tables 2–3 and S4). Farmers with higher levels of education considered the use of organic materials -as soil amendments to be more important than farmers with basic or unidentified levels of education (Table 1). Furthermore, farmers with a university education were most positive about diversifying crop rotations (Table S4).

The farmer's views on the measures varied depending on region (Figs. 4–7). For example, farmers in the eastern part of the country considered the use of winter ground cover crops to be a more important measure than those in the western regions. Taking care of the drainage system at the field and local scale was more important in the north than in the south and central parts of Finland, while again taking care of subsurface drainage systems was found to be a more important measure in south-west Finland than in east and north Finland. Precise nutrient management was viewed as less important in western coastal and inland regions compared to south-west of the country, where also the increased use of N fertilizers were considered to be important. Views on use of higher P rates were more scattered across the country. Shifting from autumn to spring tillage was seen to be less important for southern than northern parts of the country, in contrast to the use of direct drilling and reduced tillage as well as the introduction of novel crops and cultivars. The use of certified seeds was considered an important measure especially inland and in the north-east parts of the country. Maintaining biodiversity on the farm-scale and leaving patches of forest between fields were more important for farmers in the east of Finland (also in the archipelago) than in western coastal regions. Maintaining diverse flora in field edges was again more important

Table 1
Farmers' views towards maintaining and improving soil conditions depending on farm and farmer characteristics. Means with the same letter do not differ significantly from each other (at $P \leq 0.05$). Triple dots indicate a non-significant difference. The answer choices were: 1 = Unimportant, 2 = Quite unimportant, 3 = Neither important nor unimportant, 4 = Quite important and 5 = Important.

Farm/farmer characteristic*	N	Maintaining and improving soil conditions									
		Taking care of the basic soil conditions		Taking care of the subsurface drainage system		Taking care of the drainage systems at field and local scale		Increasing organic materials in the soil		Using winter crops for ground cover	
Farm size:											
0–29 ha	1841	4.4	a	4.2	a	4.2	a	3.8	a	3.5	a
30–49 ha	910	4.5	b	4.4	b	4.4	b	3.8	a	3.5	ab
50–99 ha	1069	4.6	c	4.5	c	4.5	c	4.0	b	3.4	b
≥100 ha	518	4.7	d	4.6	c	4.6	c	4.1	b	3.3	b
Farming system:											
Organic	657	4.6	a	…	…	4.4	a	4.3	a	4.0	a
Conventional	3743	4.5	b	…	…	4.4	b	3.8	b	3.4	b
Farm type:											
Horse/sheep farm	126	4.3	a	3.9	a	4.0	a	…	…	3.7	a
Cattle farm	1091	4.6	b	4.4	b	4.5	b	…	…	3.5	a
Crop farm	2248	4.5	c	4.4	b	4.4	c	…	…	3.4	a
Pig farm	165	4.6	bc	4.6	c	4.6	b	…	…	3.3	ab
Poultry farm	65	4.7	bc	4.6	bc	4.4	bc	…	…	2.9	b
Age of farmer:											
≤30	137	4.6	ab	4.4	ab	4.4	a	4.0	a	3.4	ab
31–50	1844	4.6	a	4.4	a	4.4	a	4.0	a	3.4	a
51–70	2289	4.5	b	4.4	ab	4.4	a	3.8	b	3.5	b
> 70	129	4.3	c	4.2	b	4.1	b	3.7	b	3.6	ab

*Farmers with a university (mean 4.0, N = 1119) and vocational education (3.9, N = 2871) were more positive about increasing organic materials in the soil than those with unidentified (3.6, N = 84) and basic education (3.3, N = 325).

Table 2
Farmers' views towards increasing biodiversity depending on the farm and farmer characteristics. Means with the same letter do not differ significantly from each other (at $P \leq 0.05$). The alternative answer choices and the number of cases (N) for each farm/farmer characteristic are shown in Table 1.

Farm/farmer characteristic	Increasing biodiversity							
	Maintaining biodiversity on the farm-scale		Sparing poorly performing fields as habitats for fauna and flora		Maintaining diverse flora in field edges		Leaving patches of forest between field parcels or in the middle of them	
Farm size:								
0–29 ha	3.9	a	3.4	a	3.3	a	2.9	a
30–49 ha	3.8	b	3.3	b	3.0	b	2.6	b
50–99 ha	3.6	c	3.2	c	2.9	b	2.4	c
≥100 ha	3.5	d	3.1	c	2.7	c	2.1	d
Farming system:								
Organic	4.3	a	3.5	a	3.6	a	3.1	a
Conventional	3.7	b	3.3	b	3.0	b	2.5	b
Farm type:								
Horse/sheep farm	4.1	a	3.4	a	3.6	a	3.4	a
Cattle farm	3.7	b	3.1	bc	3.0	bc	2.5	b
Crop farm	3.7	b	3.3	a	3.0	b	2.5	b
Pig farm	3.5	bc	3.2	ac	2.8	bc	2.1	c
Poultry farm	3.2	c	2.9	bc	2.6	c	2.1	c
Age of farmer:								
≤30	3.6	ab	3.0	a	2.6	a	2.4	a
31–50	3.7	a	3.3	a	3.0	b	2.5	a
51–70	3.8	b	3.4	b	3.2	c	2.7	b
> 70	3.9	ab	3.3	ab	3.2	bc	2.9	b

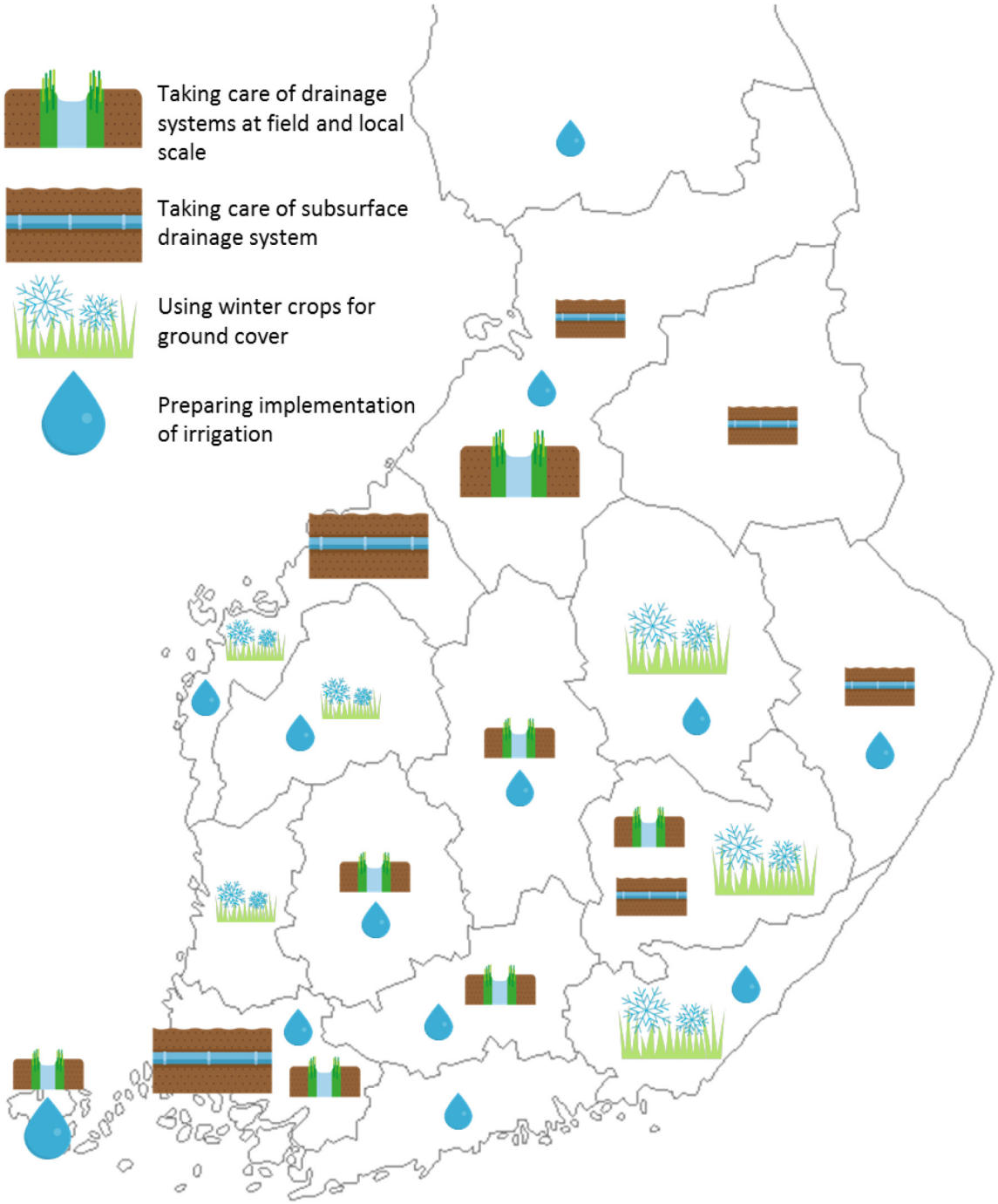

Fig. 4. Some of the most noteworthy differences between the regions in the farmers' views towards maintaining and improving soil conditions and preparing implementation of irrigation. Map shows significant regional differences ($P \leq 0.05$) in views towards different measures. The farmers in regions with a large symbol were more positive about the measure than those shown with the same small symbol.

for the farmers in the south of Finland than in the north-west coastal regions. Corresponding differences between regions concerning the intended actions were quite similar to the views towards adaptation measures.

3.4. Intended action

In general, there was an association between the importance of a measure for a farmer and the farmer's readiness to implement it (Fig. 8). Only some minor deviations from this quite straightforward trend appeared. For example, 76% of the farmers had already

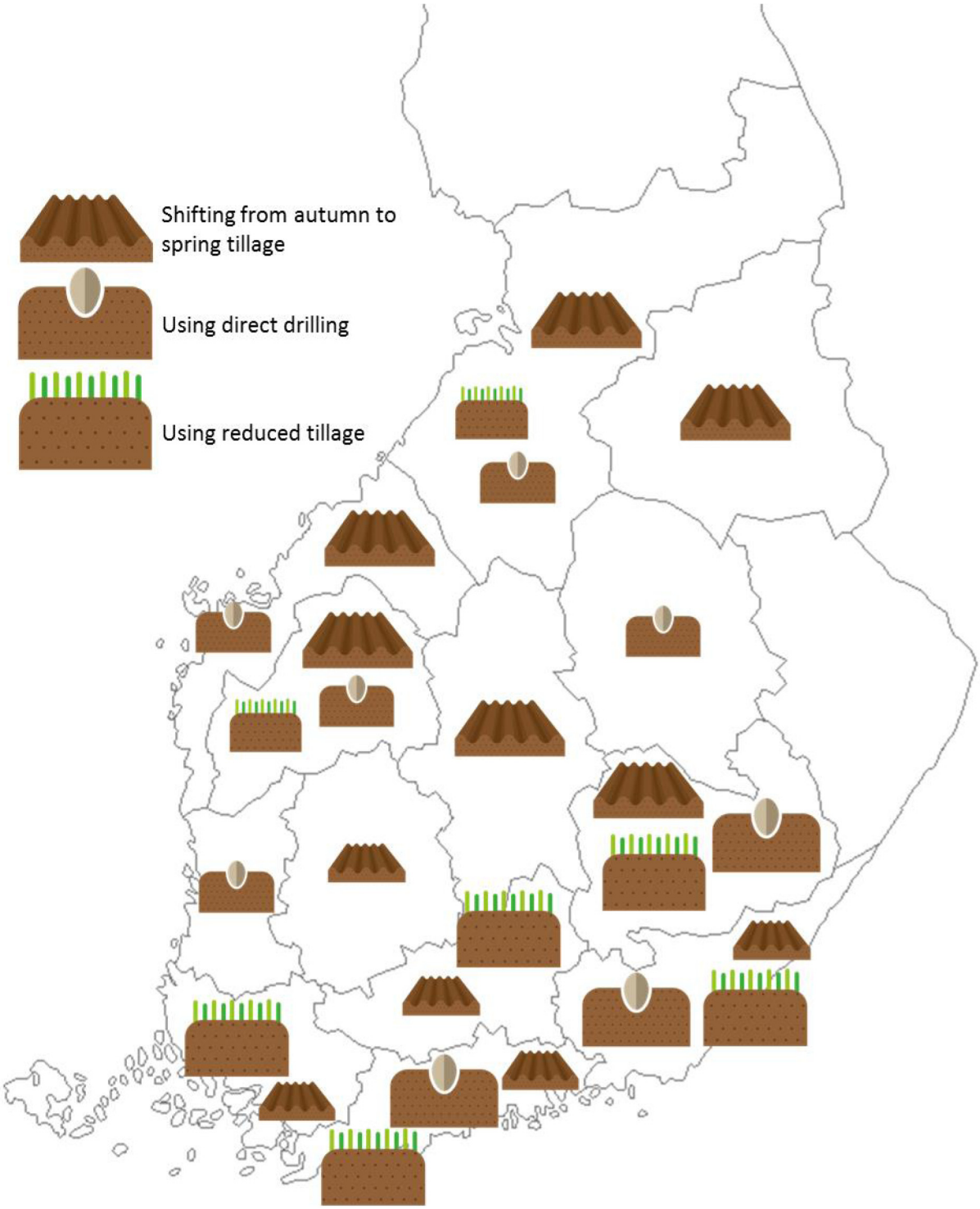

Fig. 5. Some of the most noteworthy differences between the regions in the farmers' views towards changing the soil management. Map shows significant regional differences ($P \leq 0.05$) in views towards different measures. The farmers in regions with a large symbol were more positive about the measure than those shown with the same small symbol.

used and an additional 4% planned to use winter cover crops in their farm the next year (Figs. 9 and S3), but they did not consider it to be as an important measure as some other means to improve or maintain soil conditions. Certified seeds were also used more frequently compared to how useful a measure it was according to the answers given. Additionally, taking measures to maintain

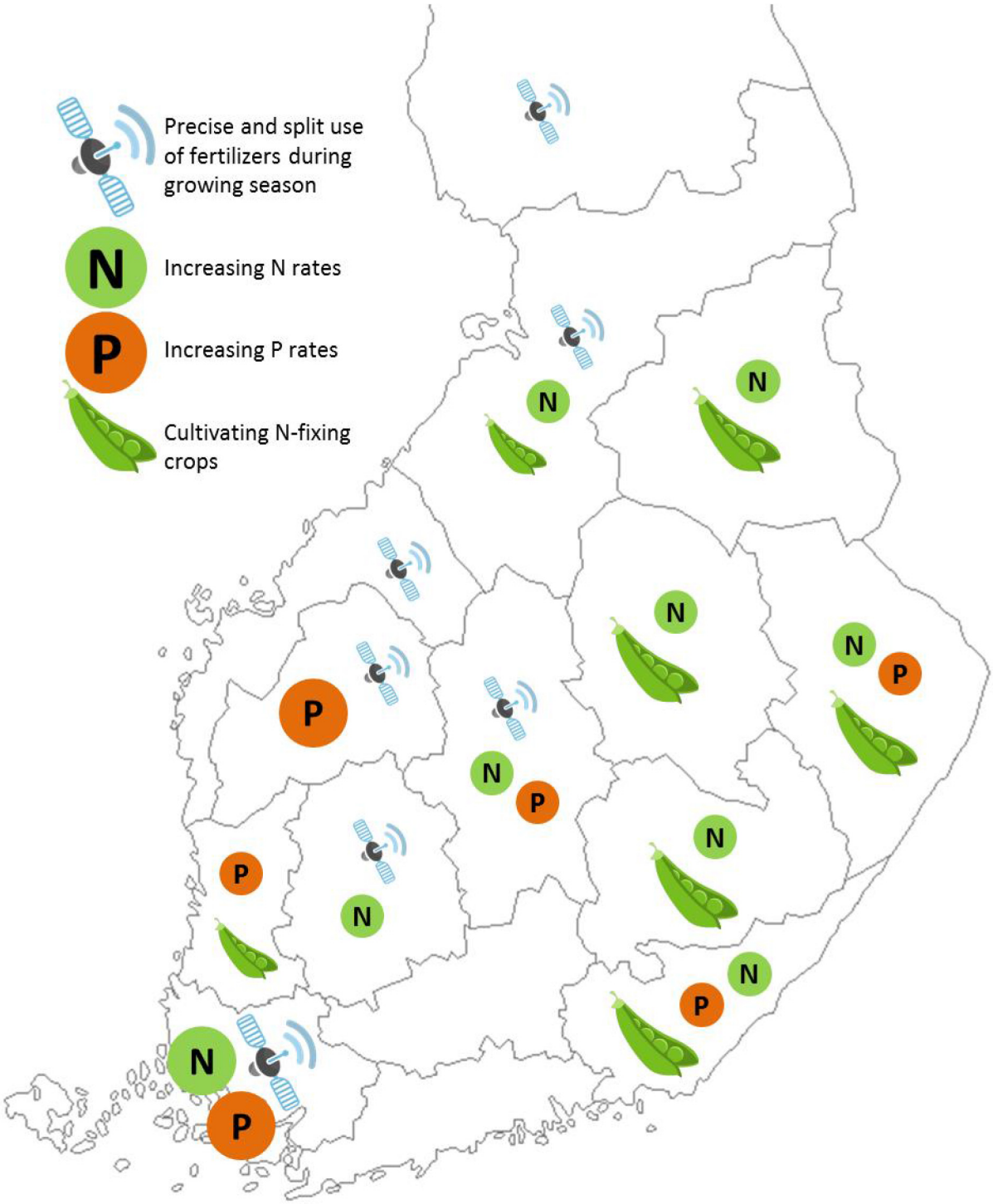

Fig. 6. Some of the most noteworthy differences between the regions in the farmers' views towards changing the nutrient management. Map shows significant regional differences ($P \leq 0.05$) in views towards different measures. The farmers in regions with a large symbol were more positive about the measure than those shown with the same small symbol.

diverse flora in field edges was implemented on 51% of farms though it was not considered to be as an important measure as maintaining biodiversity on the farm scale and sparing poorly fields as habitats for fauna and flora (Fig. 3). Examples of strong correlations between farmers' views, self-reported and intended actions included: taking care of basic soil conditions (77% already in use), taking care of drainage systems (62–68%), controlling diseases with crop sequencing (59%), diversifying crop rotations (52%),

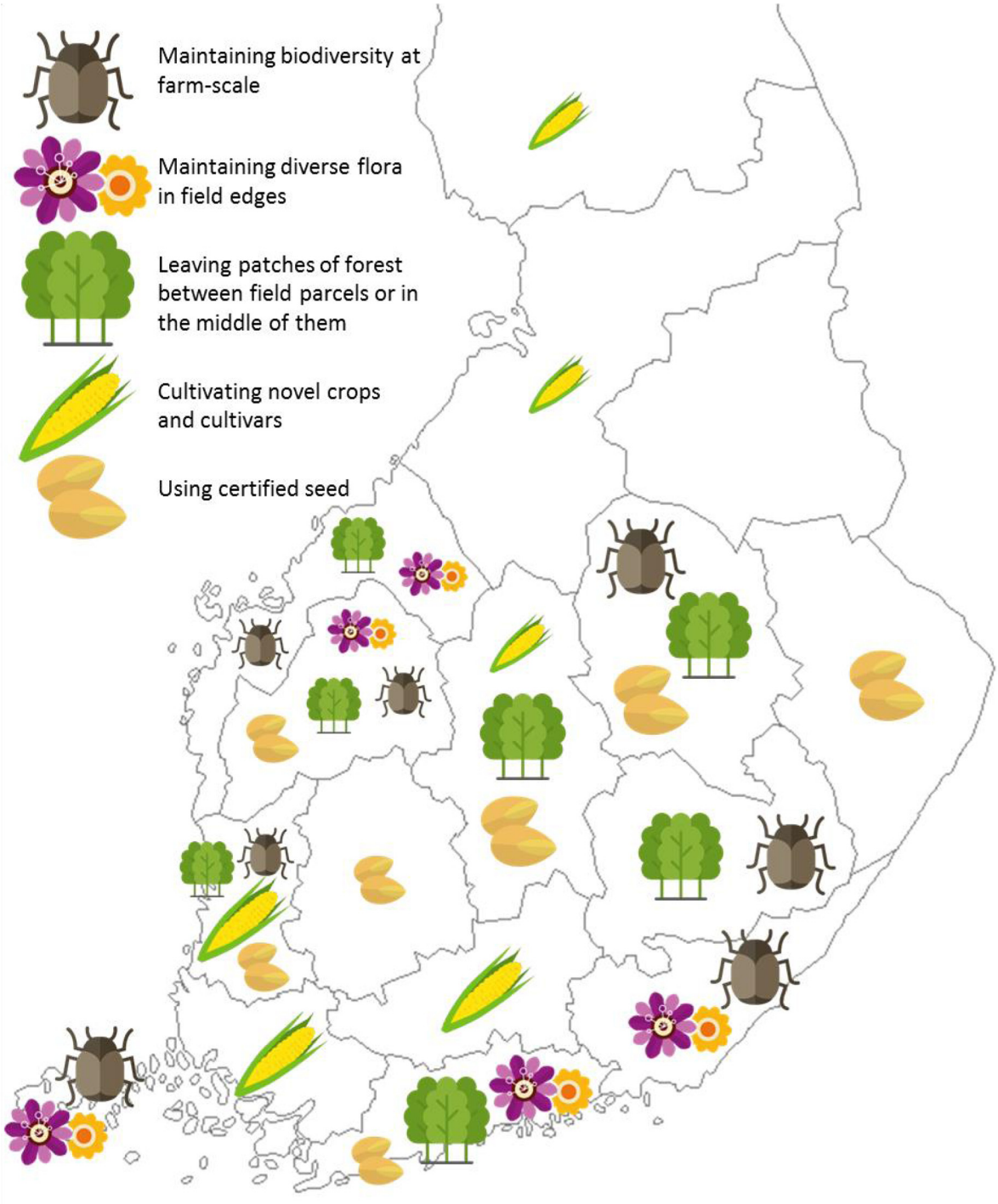

Fig. 7. Some of the most noteworthy differences between the regions in the farmers' views towards introducing novel crops and cultivars as well as increasing biodiversity. Map shows significant regional differences ($P \leq 0.05$) in views towards different measures. The farmers in regions with a large symbol were more positive about the measure than those shown with the same small symbol.

using N fixing crops (48%) and maintaining biodiversity on the farm-scale (57%). On the other hand, 78% of farmers were not at all ready to make any preparations for the future use of irrigation, which they did not appreciate as a measure. 71%, 61% and 62% of farmers did not see any need for the near future use of direct drilling, switching from autumn to spring tillage or leaving patches of forest in the middle of field parcels, respectively, which they did not consider as important measures either.

Farmers have already implemented many of the measures to maintain or improve soil conditions, but less frequently on small

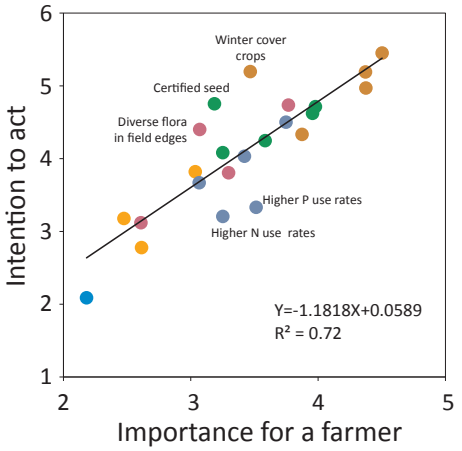

Fig. 8. The association between the importance of a statement for a farmer and the intentions to act. The most divergent statements from the trend are highlighted.

Table 3
Farmers' intentions to change the nutrient and soil management depending on the farm and farmer characteristics. Means with the same letter do not differ significantly from each other (at $P \leq 0.05$). Triple dots indicate non-significant difference. The number of cases (N) for each farm/farmer characteristic is shown in Table 1. The answer choices were: 1 = Does not concern my farm, 2 = I'm not going to implement, 3 = I will but earliest after 6 years, 4 = I will within the next 2–5 years, 5 = I will on next growing season and 6 = Implemented already.

Farm/farmer characteristic*	Changing nutrient management										Changing soil management					
	Cultivating N fixing crops		Increasing P fertilizer rates		Precise and split use of fertilizers during growing season		Increasing N fertilizer rates		Using catch crops		Reduced tillage		Direct drilling		Shifting from autumn to spring tillage	
Farm size:																
0–29 ha	4.3	a	2.9	a	3.7	a	2.8	a	3.4	a	3.4	a	2.5	a	3.4	a
30–49 ha	4.5	b	3.4	b	4.0	b	3.2	b	3.7	b	3.8	b	2.7	a	3.2	ab
50–99 ha	4.8	c	3.7	c	4.3	c	3.6	c	3.9	b	4.3	c	3.0	b	3.1	b
≥100 ha	4.9	c	4.0	d	4.8	d	3.9	d	4.2	c	4.5	c	3.3	c	2.8	c
Farming system:																
Organic	5.6	a	2.5	a	2.7	a	2.5	a	4.6	a	3.5	a	2.2	a	3.9	a
Conventional	4.3	b	3.5	b	4.3	b	3.3	b	3.5	b	3.9	b	2.9	b	3.1	b
Farm type:																
Horse/sheep farm	3.9	a	2.3	a	3.1	a	2.3	a	2.8	a	3.4	a	2.7	ab	3.2	ab
Cattle farm	4.8	b	3.4	b	4.1	bc	3.2	b	3.6	b	3.4	a	2.6	a	3.5	a
Crop farm	4.5	c	3.5	b	4.1	b	3.3	b	3.8	b	4.1	b	2.9	b	3.1	b
Pig farm	4.6	bc	3.8	b	4.5	c	3.8	c	3.8	b	4.7	c	2.9	ab	2.9	b
Poultry farm	4.3	abc	3.8	b	4.3	bc	4.1	c	3.3	ab	4.8	bc	3.2	ab	2.7	b
Age of farmer:																
≤30	4.9	a	3.6	a	4.2	ab	3.6	a	4.2	a	4.0	ab	…	…	3.3	ab
31–50	4.7	a	3.5	a	4.1	a	3.4	a	3.9	a	3.9	a	…	…	3.3	a
51–70	4.4	b	3.2	b	4.0	b	3.1	b	3.5	b	3.7	b	…	…	3.1	b
> 70	3.9	c	3.2	ab	3.6	b	3.0	b	3.2	b	3.6	ab	…	…	2.9	ab

*Farmers with a university education were more active in cultivating N fixing crops (mean 4.7) and using catch crops (3.9) than those with a basic (4.2 and 3.5, respectively) or vocational education (4.4 and 3.6, respectively). Farmers with a basic education were more reluctant to increase the N fertilizer rates (2.9) and reduced tillage (3.6) than farmers with a university (3.2 and 3.9, respectively) and vocational education (3.2 and 3.8, respectively).

farms (Table S5). Such differences between farm sizes also holds for the measures to change nutrient and soil management practices (Table 3) as well as the introduction of novel crops and cultivars (Table 4), which were more at the stage of planning than realization. The only exceptions were that small farms planned to shift from autumn to spring tillage a bit earlier than larger farms and furthermore, small and very large farms were least interested towards using certified seed. Means to increase biodiversity were dependent on farm size: smaller farms favoured maintenance of diverse flora in field edges and leaving patches of forest between field parcels but not sparing poorly performing fields as habitats for fauna and flora (Table S6). Organic farms were more advanced than

Table 4
Farmers' intentions to introduce novel crops and cultivars depending on the farm and farmer characteristics. Means with the same letter do not differ significantly from each other (at $P \leq 0.05$). Triple dots indicate a non-significant difference. The number of cases (N) for each farm/farmer characteristic is shown in Table 1 and alternative answer choices in Table 3.

Farm/farmer characteristic	Introducing novel crops and cultivars									
	Controlling disease pressure with crop sequencing and break-crops		Diversifying crop rotations		Cultivating novel crops and cultivars		Cultivating early maturing crops		Using certified seeds	
Farm size:										
0–29 ha	4.3	a	4.2	a	3.7	a	3.7	a	4.6	c
30–49 ha	4.9	b	4.8	b	4.4	b	4.3	b	4.9	ab
50–99 ha	5.1	bc	5.0	bc	4.7	c	4.4	b	5.0	a
≥100 ha	5.2	c	5.2	c	5.0	d	4.5	b	4.7	bc
Farming system:										
Organic	5.1	a	5.1	a	…	…	3.8	a	4.9	a
Conventional	4.6	b	4.5	b	…	…	4.1	b	4.7	b
Farm type:										
Horse/sheep farm	3.3	a	3.4	a	3.1	a	2.7	a	4.5	a
Cattle farm	4.7	b	4.6	b	4.2	b	4.2	b	5.1	b
Crop farm	5.0	c	4.9	c	4.5	c	4.3	b	4.7	a
Pig farm	5.1	c	4.9	bc	4.7	c	4.2	b	4.7	a
Poultry farm	5.1	bc	5.0	bc	4.5	bc	4.4	b	4.7	ab
Age of farmer:										
≤30	5.0	ab	4.9	ab	4.7	a	4.4	a	4.7	ab
31–50	4.9	a	4.8	a	4.5	a	4.2	a	4.9	a
51–70	4.6	bc	4.5	bc	4.1	b	4.0	b	4.7	b
> 70	4.2	c	4.3	c	3.9	b	3.9	ab	4.4	b
Education::										
Unidentified	4.6	ab	4.4	ab	4.0	ab	…	…	4.4	ab
Basic	4.2	a	4.4	a	3.6	a	…	…	4.4	a
Vocational	4.7	b	4.6	b	4.2	b	…	…	4.8	b
University	4.9	b	4.7	b	4.5	c	…	…	4.9	b

conventional farms in implementing or planning the implementation of measures such as increasing organic soil amendments, cultivating N-fixing, winter cover and catch crops, shifting from autumn to spring tillage, diversifying crop rotations and thereby controlling disease pressure, using certified seeds and increasing biodiversity (except for sparing poorly performing fields as habitats for fauna and flora). Organic farmers were more reluctant than conventional farmers to increase the rates of N and P fertilizers or apply precise farming and split fertilizers, or use reduced tillage, direct drilling and early maturing cultivars.

Horse and sheep farms differed mostly from the other farm types in their implementation plans especially by being more late or reluctant to change their nutrient management practices or to take care of their drainage systems (Tables 3 and S5). Cattle and crop farms again differed in their plans to implement changes in soil management, but not in maintaining and improving soil conditions (except that cattle farms planned to increase organic materials in the soil earlier than crop farms). Crop, pig and poultry farms did not differ in their plans to introduce novel crops and cultivars – horse and sheep farms were, however, usually the least active (Table 4).

The age of a farmer did not often have a very systematic impact on the implementation or timing of different measures. Often older farmers differed from younger ones in quite the same way as they did when they were asked how important each of the measures was. Farmers with a higher education were more active than others in taking care of subsurface drainage systems, cultivating N-fixing and novel crops as well as maintaining biodiversity on the farm scale and encouraging diverse flora in field edges (Tables 3–4 and S5–S6). They also planned to increase N fertilizer rates and use reduced tillage in the forthcoming years more actively.

4. Discussion

Climate change shapes natural conditions, alters risk positions and impacts essential preconditions for agriculture globally. The pace of change is fast at high-latitude regions such as in Finland (Ruosteenoja et al., 2016a). Farmers consider climate change to be both a threat and an opportunity for agriculture in Finland in quite equal shares, however, with the highest share (44%) having no clear view (Sorvali and Kaseva, 2020). Hence, it is possible that the recorded high variation in the farmers' views on measures is attributable to the uncertainty of the future changes caused by climate change (Sorvali and Kaseva, 2020).

4.1. Ready or not to act?

Farmers considered many of the listed measures to be important rather than unimportant (Fig. 3). However, the number and diversity of possible measures, their prioritization and differences in timing of their implementation depending on the region may

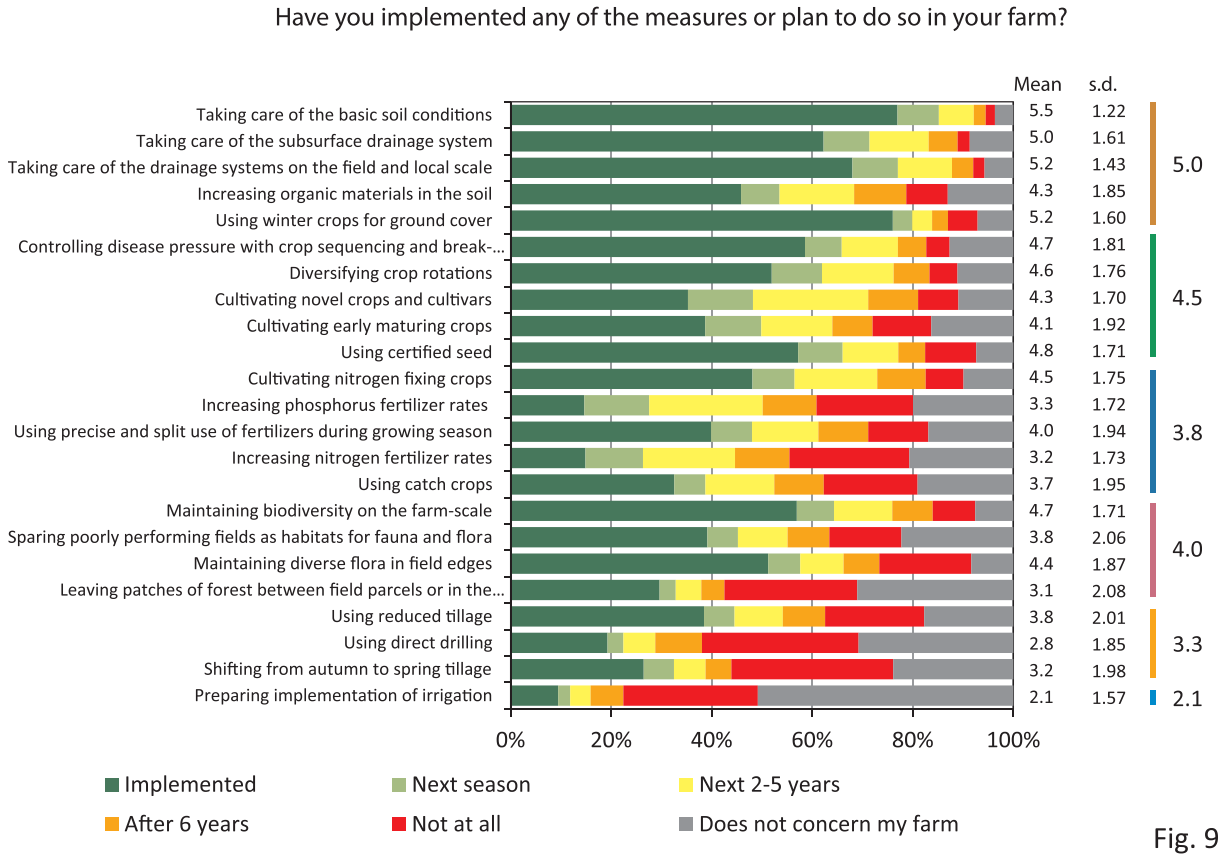

Fig. 9. The distribution of farmers' answers (N = 4400) to the principal question "Have you implemented any of the measures or plan to do so in your farm?" when grouped as for Fig. 3. The means across each group are shown rightmost.

challenge farmers and lead to confusion concerning how and when to act, especially in the context of adaptation to climate change (Sorvali and Kaseva, 2020). Furthermore, currently the economic situation for farmers to invest even for basic inputs is very challenging (Scherer et al., 2018). Also the opposite reasoning to adapt, i.e., "to benefit from or survive despite future changes", may further challenge farmers, as may the difference between the measures (investments) in their payback period. Importance of a measure also varies depending on region (Figs. 4–7). According to Haden et al. (2012) farmers' general awareness and experiences shape their views, and thereby, they may steer the actual behaviour towards transition.

4.1.1. Maintaining and improving soil conditions

Most farmers were aware and agreed that in the forthcoming years winters will get milder, heavy precipitation events will become more frequent and flooding risks will be higher (Fig. 1), as projected for the high latitudes of Europe (Lehtonen et al., 2014; Peltonen-Sainio et al., 2018). They were, however, more uncertain whether problems with soil erosion would increase. Increases in flooding risks were quite rarely experienced by farmers, though occasionally in heavy rains (Fig. 2). This may be partly attributable to the geographical polarization of flooding risks in Finland. Nonetheless, soil conditions and functionality are at risk in the future (Heikkinen et al., 2013). For example, compacted soils have already caused problems for root penetration (Peltonen-Sainio et al., 2011a), which may be further reinforced by monotonous cereal sequencing (Peltonen-Sainio and Jauhiainen, 2019). Soil degradation may contribute to stagnant yield trends (Peltonen-Sainio et al., 2015c).

Farmers considered that taking care of basic soil conditions, especially subsurface drainage and overall drainage systems on the farm and local scale were the most important farming practices (Fig. 3). Small farms were in general more reluctant than larger farms towards such measures. Furthermore, regional differences affected farmers' intentions. More than two thirds of the total drained area (ca. 2 million ha) is on subsurface drainage, while some 300,000 ha is not drained (Anon, 2002). The golden age for draining the land was from the 1960s to the 1990s, followed by a collapse. Renovation loans for ageing drainage systems have cumulated, mainly driven by the high share of leased land with short-term contracts and a general reluctance to make investments in farms in an economically challenging situation (Pouta et al., 2012). The intention of farmers to act instantly (Fig. 9) looks promising, because a high share of drainage systems need maintenance (www.salaojakeskus.fi). However, it may be that the renovation actions concern only a modest share of field parcels on farms.

Various short- and long-term measures (green-fallow, less intensive perennial systems, cover and nurse crops) are currently being

implemented by farmers to take care of basic soil conditions. More than half of the farmers considered winter cover to be an important or quite important measure (Fig. 3), and this was also in use by 80% of the respondents (Fig. 9). They had not, however, registered any expansion of winter sown crops *per se* or better opportunities for their sowing (Fig. 2). This implies that winter cover is provided by non-productive cover crops, as the area under winter cereals and rapeseed is in total < 5% of the agricultural land in Finland (www.statluke.fi).

Contrary to measures (Singh et al., 2015) which may boost gradually reduced soil carbon content (Heikkinen et al., 2013) and functionality in long run, increasing the organic amendments to the soil is a robust measure. Some 70% of farmers considered it to be an important or quite important measure (Fig. 3), and again more than 60% of them had near future implementation plans if they had not yet done so (Fig. 9) in some field parcels. Farmers with a higher education were more positive about using organic amendments. On the other hand, reduced tillage, direct drilling and shifting towards spring tillage were among the least popular measures. Reduced tillage has positive long-term impacts on soil conditions (Singh et al., 2015), and these soil management methods have stabilized to quite a constant field area since their implementation (Peltonen-Sainio et al., 2015c).

4.1.2. Nutrient and water management

Farmers considered that cultivation of N-fixing crops was the most important measure among those related to crop nutrition (Fig. 3). This was important or quite important according to 65% of the respondents. Farmers' views were strongly associated with a readiness to use N-fixing crops. However, change in a single practice often requires changes in others to make a system functional and sustainable. Hence, autumn sown crops or other catch crops should be favoured in future production systems (Peltonen-Sainio et al., 2018) to benefit from the fixed N as an ecosystem service for subsequent crops in rotation and to avoid nutrients leaching into waterways (Valkama et al., 2015), as autumn and winter precipitation is projected to increase (Lehtonen et al., 2014). Using catch crops was not yet very popular among the farmers as < 40% of them thought it was important or quite important (Fig. 3). This may be attributable to the finding that only ca. 20% of farmers agreed that nutrient loads in waterways would increase in the future (Fig. 1). Furthermore, the farmers' experiences so far did not necessarily encourage the use of autumn sown crops, as > 90% of farmers had experienced better opportunities only occasionally, if at all, for autumn sowing (Fig. 2). The area under winter crops tends to vary substantially depending on the success of sowing (Peltonen-Sainio et al., 2011b).

The farmers considered future increases in P fertilizer rates to be more important than that of N rates (Fig. 3). However, < 30% of farmers were ready to act within the next season (Fig. 9). Young farmers especially were more in favour of increasing nutrient use. Organic and small farms were reluctant to use higher fertilizer rates. Current agricultural policies have limitations for nutrient use and hence, higher use rates are impossible if a farm participates in the Agri-Environment Scheme and have not underused fertilizers so far (Peltonen-Sainio et al., 2015c). Farmers have not yet experienced any systematic increase in yield trends in the 2000s (Fig. 2), which could have explained their views on higher fertilizer need. However, variation in yields was one of the most frequently experienced changes during the 2000s, which challenges the appropriate use of fertilizers. Half of the farmers considered the precise and/or split use of fertilizers to be quite important or important measures and these were in use by 40% of farmers (Fig. 9). Precision farming requires investments in special machinery and technology. Split fertilizer use is again often impractical, as the time difference between sowing and additional fertilizer application is short (Peltonen, 1995). This may, however, be a more attractive fertilization practice in the future with earlier sowing (Kaukoranta and Hakala, 2008) and longer reproductive phases of crops. The farmers did not identify such changes during the 2000s, which is likely to be attributable to the fact that the advance in the sowing time is evident when comparing the 2000s to the three preceding decades (Peltonen-Sainio and Jauhiainen, 2014).

Although the majority of the farmers agreed that the winters would get milder, and that heavy rains and flooding risks will become more frequent, and that pressure (and hence the risk of yield losses) caused by pests, disease and weeds will be higher in the future, a minority of them considered that soil erosion and nutrient loads in waterways would increase. This is surprising, as current peaks for nutrient leaching and erosion have coincided with heavy rains, flooding and mild winter conditions (Puustinen et al., 2007). Therefore, wintertime ground cover, considered by more than half of the farmers to be important and also quite largely implemented (80%), would be a potential means to reduce current and future risks for nutrient loads in waterways. However, often the soil cover is provided only by stubble, while true crop cover is especially effective in mitigating erosion and nutrient loads (Puustinen et al., 2007).

Early summer drought that currently limits crop growth and nutrient uptake (Peltonen-Sainio et al., 2016), may be a growing risk (Ylhäisi et al., 2010). In the case of a possible increase in drought events in the future, high residual N (Peltonen-Sainio and Jauhiainen, 2010) may be increasingly prone to leaching. Future projections for changes in precipitation during the summer are highly uncertain (Lehtonen et al., 2014). Farmers were uncertain about having higher drought risks in the future. Farmers neither appreciated irrigation as an important measure nor considered virtually any implementation (Figs. 3, 8 and 9). Finnish farmers are not familiar with irrigation (Peltonen-Sainio et al., 2015b), even though early summer drought results in yield losses (Peltonen-Sainio et al., 2016). Farmers have no ready-to-go technologies available on farms (Peltonen-Sainio et al., 2015a), and future investments are not likely to be considered economically feasible. However, water reserves in Finland are abundant and available for irrigation as one third of Finnish field parcels are located next to waterways (Peltonen-Sainio et al., 2015b).

4.1.3. Novel crops and increased diversity to cover crop protection risks

Controlling disease pressure by crop sequencing and in general diversifying crop rotations were favoured by farmers (Fig. 3). According to the farmer survey, disease and weed pressure is expected to become higher in the future and increased needs for crop protection have already been experienced (Fig. 1-2). These views agree with the changes anticipated by researchers (Hakala et al., 2011; Hyvönen et al., 2012). Higher numbers of fungicide treatments per growing season to control potato late blight (*Phytophthora*

infestans) is one example of an already documented shift towards higher dependence on chemical control, though higher infestation only partly originates from changes in climatic conditions (Lehsten et al., 2017). Controlling disease pressure with crop sequencing was more favoured by farmers than the use of certified seeds (i.e. seeds with a healthy and viability certificate). Certified seeds were used more frequently compared to how useful it was for farmers to manage the risks. Certified seed is especially popular in animal farms due to logistic advantages (Peltonen-Sainio and Rajala, 2014).

The spatial and temporal diversification of cropping systems may help to cope with emerging crop protection risks (Lin, 2011), as a high potential for diversification exists in Finland, where monocultural 5-year rotations are common for cereals, potatoes and sugar beet (Peltonen-Sainio and Jauhiainen, 2019). In the future, novel crops may be introduced (Olesen et al., 2012) due to the longer growing season (Ruosteenoja et al., 2016b). Farmers considered cultivation of novel crops and cultivars to be an important measure. They had also experienced that novel, often later maturing crops have been taken into cultivation. Spring wheat (*Triticum aestivum* L.), oilseed rape (*Brassica napus* L.) replacing turnip rape (*B. rapa* L.), faba beans (*Vicia faba* L.) and even maize (*Zea mays* L.) to some extent are examples of crops with expanded land areas.

Some farmers registered a decline in the populations of pollinators during the 2000s (Fig. 2), which highlights the concerns regarding ecosystem functioning including current and future pollination services (Van Dooren, 2016). Farmers have also observed declines in populations of farmland birds, but not soil fauna and flora. The latter are of course harder to record. However, increases in damage caused by wild animals were the most well recorded change. In the 2000 s, flocks of birds in the fields have increased including, e.g., whooper swans (*Gynus gynus*), Canada geese (*Branta canadensis*) and cranes (*Grus grus*) (https://www.ruokavirasto.fi). Even though farmers considered maintaining biodiversity on the farm scale to be important, actual specific measures such as sparing poorly performing fields as habitats for wildlife fauna and flora, maintaining diverse flora in field edges and especially leaving patches of forest between or in the middle of field parcels were less important or even irrelevant to them (Fig. 3). Organic farms and those farmers with a university education were most in favour of diversifying measures.

4.2. Readiness dependent on investment needs coupled with policy incentives?

The farmers' views towards suggested measures and their intention to implement them varied largely, but in general measures that were important for farmers were often implemented or they were in the near future pipeline (Fig. 8). Our survey does not reveal the scale of the implementation as such, i.e., it may range from only one field parcel to farm-scale implementation. Nonetheless, many of the current policy incentives seem to have elements that either support or at least do not hinder adaptation to future changes and risks. Contradictions between the views and intentions may again indicate the aspects for future encouragement of farmers either by developing policy instruments or sharpening the implementation of research outcomes to shape farmers' views to encourage changes towards more sustainable, resilient and climate- and recourse-smart primary production.

An example of a potential need for further encouragement towards change is winter-time ground cover, which is needed to cope with increasing risks to basic soil conditions, erosion and nutrient leaching into waterways caused by heavy rains (Lehtonen et al., 2014, Puustinen et al., 2007). Nowadays soil cover is mainly provided by stubble, which is an inefficient means to reduce the risks compared to true crop cover (Puustinen et al., 2007). In the future, there is not only a need, but there will also be better opportunities for successful growth of cover crops (Peltonen-Sainio et al., 2018). Hence, policy incentives could encourage farmers to expand areas under yield producing overwintering crops (as they have high risks of winter damage *per se*), non-productive catch crops or other cover crops (Valkama et al., 2015). Aiming at true soil cover is likely to be a cost-efficient means to reduce the environmental footprint of high-latitude agriculture. Need for true soil cover is even further emphasized, as farmers showed interest in increasing the use of N-fixing crops with high residual-N available in the soil (Stenberg et al., 2012).

Since the 1990s, the draining of fields has collapsed and renovation loans for drainage systems have cumulated (Anon, 2002). The farmers' intentions to act instantly are encouraging. However, a high share of drainage systems needs urgent maintenance. Thereby, true renovation actions likely concern only a modest share of field parcels on a farm. Maintaining and improving soil conditions to sustain resource efficiency, high yields and sustainability also in the long-term, require prompt and large-scale renovation actions. This is challenging for farmers in current economic conditions (Scherer et al., 2018) and may need some incentives for investments. The basic soil conditions and functioning of drainage systems have implications for the environmental footprint of farms (Turtola and Paajanen, 1995). However, subsurface draining of open ditches has an adverse impact on biodiversity (Riho et al., 2013) and hence, keeping them as open ditches is recommended if the field parcels are not targeted for food production.

Farmers feel more connected to nature than other rural residents (Kohler et al., 2014). Finnish farmers were interested in maintaining biodiversity on the farm scale in general, though not as clearly when some specific means for implementation were suggested. They considered that leaving patches of forest between or in the middle of field parcels was the least important measure. However, often measures breaking very uniform landscapes, such as nature managed fields or other semi-natural grasslands between field parcels are among the most efficient means to support biodiversity in areas of intensive farming (Herzon et al., 2011; Mäkeläinen et al., 2019). Hence, such land use optimization activities that allocate poorly performing fields to extensification (Peltonen-Sainio et al., 2019) could be potential targets for policy support.

Farmers were uncertain about the risks of longer drought periods in the future, and they did not appreciate irrigation as an important measure. Hence, they were not at all ready to make preparations for the future use of irrigation. The growing season right before the survey (2017) was exceptionally rainy, challenged many farming operations and caused crop failures, which may have influenced the farmers' perspectives. On the other hand, right after the survey, the growing season was exceptionally dry and warm. Hence, our follow-up survey will include statements on views concerning the need for irrigation as such strong views were opposite to the outcomes of research considering the need for future changes in water management (Peltonen-Sainio et al., 2015a). Nonetheless,

it is likely that some investment support is needed as farmers lack virtually any irrigation technology (Peltonen-Sainio et al., 2015b).

5. Conclusion

Farmers have observed many weather-related changes which impact crop production in high-latitude conditions. They also envisage a need to change their practices in managing crops, soil conditions and farming systems. If a farmer considers a measure to be important, he/she has usually implemented it already or has near future intentions to do so. However, this survey highlighted some mismatches between science-based understanding and the farmers' understanding and observations on changes in the growing conditions and production risks, and also concerning measures needed in the future. The most evident examples of these sorts of mismatches were: risks caused by changing winter conditions concerning soil functionality, erosion and nutrient leaching *vs.* farmers' intentions to implement true winter time soil cover (crop stands *vs.* stubble); farmers intentions to maintain biodiversity on a farm-scale *vs.* intentions to use specific diversification measures; and last but not least, farmers' thorough disinterest in irrigation. Hence, with this survey hot spots were identified that may call for consideration of more efficient means of knowledge sharing concerning future changes and means to cope with them, in addition to providing means of encouragement to change the management of crops, soil and farming systems, and supporting investments with tailored policy instruments. This is important not only because the economic situation is challenging for farmers and many of the measures do not solely impact crop productivity *per se*, but also aim to decline the environmental footprint of agriculture.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.crm.2019.100205.

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