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Forecasting mitigation measures for agricultural greenhouse gas emissions in Finland

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The objective of this paper is to provide insights for researchers and policy makers concerning the impact of specific mitigation measures for greenhouse gas emissions at the farm level. Both quantitative simulations and qualitative expert judgements are used to analyse the impacts of four different mitigation measures for greenhouse gas emissions in Finland. The quantitative effects projected by the farm level modelling can provide the expert panel an opportunity to evaluate the acceptability at the farm level and the effectiveness of these mitigation measures to reduce emissions from agriculture. The results indicate that the potential to reduce emissions from Finnish agriculture is limited with current technology and the cost is high for implementing these measures at the farm level. The possible emissions reduction in Finland from these measures would contribute to less than one tenth of the reduction target for sectors excluded from the Emissions Trading System.

Keywords: quantitative method, qualitative method, greenhouse gas emissions, agriculture, Finland

JEL codes: F53, Q18, Q54

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1. Introduction

Climate change mitigation policies can substantially reduce the risks associated with human-induced global warming. Climate change mitigation consists of actions to limit the magnitude of long-term climate change and generally involves reductions in human induced emissions of greenhouse gases. Mitigation may also be achieved by increasing the capacity of carbon sinks, for example through reforestation or forest management. Other mitigation policies include energy efficiency, for example, through improving the insulation of buildings and decreasing the use of fossil fuels, and switching to low-carbon energy sources such as renewable energy.

The EU has committed to reduce its emissions to 20% below 1990 levels and offered to increase its emissions reduction to 30% by 2020 if other major emitting countries in the developed and developing worlds commit to undertake their fair share of a global emissions reduction effort. Furthermore, the European Commission proposes that the EU set itself a target of reducing emissions to 40% below 1990 levels by 2030 in the climate and energy policy framework for 2030. Thus, this is setting the stage for EU member states to plan and implement climate change mitigation policies to achieve these targets.

The Effort Sharing Decision establishes binding annual greenhouse gas emission targets for EU member states for the period 2013–2020. These targets concern emissions from most sectors not included in the EU Emissions Trading System (EU ETS), such as agriculture, transport, energy to heat buildings and waste. By 2020, Finland is given a reduction target of 16% in emissions (5.84 million tonnes of CO_2 equivalents) from the sectors not included in the EU Emissions Trading System (non-EU-ETS) compared with 2005 levels of emissions. Greenhouse gas emissions from the “EU ETS” sectors and “non-EU-ETS” sectors alongside with the greenhouse gas removals from the land use, land-use change and forestry (LULUCF) sector in Finland are illustrated in Table 1.

Table 1. Finland: Greenhouse gas emissions and removals broken down between emissions trading scheme sources (EU ETS), non-emissions trading scheme sources (non-EU-ETS) and the land use, land-use change and forestry (LULUCF) sector [million tonnes CO_2 eq.].

	2005	2008	2009	2010	2011	2012	2013*
TOTAL (excl. LULUCF sector)	69.6	71.3	67.6	75.9	68.3	62.5	63.2
"EU ETS" emissions [1]	33.1	36.2	34.4	41.3	35.1	29.5	31.5
"non-EU-ETS" emissions [2]	36.5	35.1	33.2	34.6	33.2	33	31.7
LULUCF sector [3]	-29.7	-26.9	-39.4	-26.7	-26.2	-27.9	-20.4
[1] Source: Energy Authority. In 2013, emissions trading were expanded with new sectors.							
[2] Also includes the emissions of domestic civil aviation, although the emissions in question are in the emissions trading scheme of the EU's internal civil aviation.							
[3] The land use, land-use change and forestry (LULUCF) sector does not come under the scope of the emissions trading scheme or the reduction targets under the Effort Sharing Decision.							
* Preliminary data. Due to changes in the global warming potential (GWP) values and reporting guidelines, the figures are not comparable with the previously released figures.							

Source: Statistics Finland (2015)

The Finnish government has published a Climate and Energy Strategy to refine the reduction targets for the "non-EU-ETS" sectors that include the agricultural sector. The agricultural sector is given a national reduction target of 13% (850 000 tonnes of CO_2 equivalents) for greenhouse gas emissions in by 2020 (TEM, 2008). The strategy does not define the exact mitigation measures to be used to reach the target, but forthcoming mitigation policies for greenhouse gas emissions in agriculture for Finland will have a considerable impact on Finnish agricultural production. The bulk of greenhouse gas emissions in 2013 were directly from the energy (57%) and transport (19%) sectors amounting to 76% of total emissions from Finland (Figure 1). Emissions from agriculture were only 10% of the total greenhouse gas emissions from Finland (Statistics Finland, 2015). Therefore, the agriculture sector plays a minor role in the total greenhouse gas emissions in Finland.

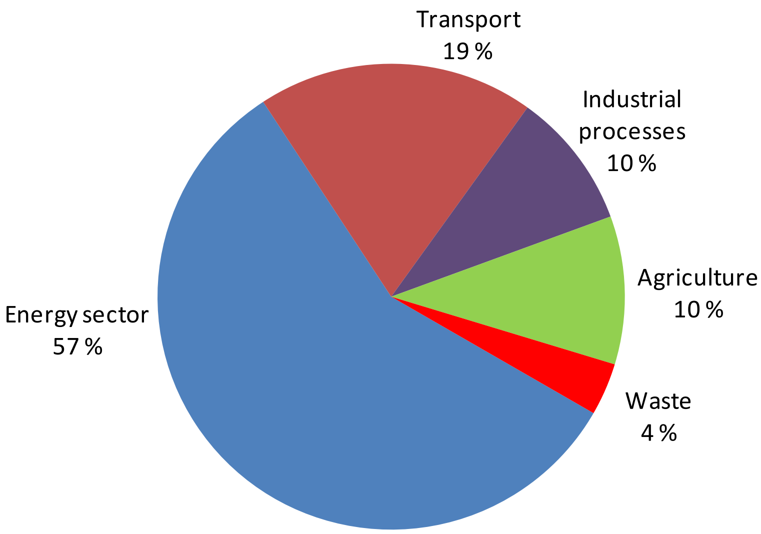

Fig. 1. Greenhouse gas emissions from Finland in 2013 (Statistics Finland, 2015).

The total greenhouse gas emissions from the agricultural sector in Finland have been gradually going down from 7.6 million tonnes of carbon dioxide (CO_2) equivalents in 1990 to 6.5 million tonnes of carbon dioxide (CO_2) equivalents in 2013 (Table 2). This trend is mainly due to the gradual reduction in methane (CH_4) emissions from enteric fermentation and nitrous oxide (N_2O) emissions from agricultural soils in Finland. The reduction in methane emissions is directly linked to the decrease in the number of bovine animals in Finland from 1990 to 2013. In order to further decrease greenhouse gas emissions from the agricultural sector in Finland, there must be measures to decrease in the emissions from enteric fermentation and agricultural soils, which are the largest components of emissions stemming from agricultural production. There is also a need to curb emissions from manure management.

Table 2. Finland: Total greenhouse gas emissions from the agricultural sector [thousand tonnes of CO_2 eq.].

	1990	1995	2000	2005	2010	2013
Enteric fermentation (CH_4)	2580	2273	2241	2183	2222	2181
Manure management (CH_4)	387	408	430	496	494	486
Manure management (N_2O)	284	254	253	253	279	285
Agricultural soils (N_2O)	3756	3584	3298	3341	3428	3337
Total	7630	6907	6551	6541	6671	6487

Source: Statistics Finland (2015)

In this paper, both quantitative and qualitative methods are used to analyse the impacts of different mitigation measures for greenhouse gas emissions from Finnish agriculture. Farm level modelling and the Delphi method are used in to foresee and evaluate the possible ways to reduce greenhouse gas emissions from agricultural production. The farm level modelling will evaluate the quantitative effects of four specific mitigation measures, and the Delphi method with an expert panel will evaluate altogether twenty climate and energy policy measures (general and specific measures for emissions reduction, energy efficiency, & renewable energy) by different qualitative dimensions. The most important dimensions in the expert panel evaluation are farm level acceptability and effectiveness in reducing greenhouse gas emissions. The farm level acceptability is an important dimension because many of the studied measures also increase costs and require changes in the way of production. Also, the effectiveness in reducing greenhouse gas emissions from agriculture varies considerably between the chosen mitigation measures. Therefore, there may be a trade-off between reduced greenhouse gas emissions and increased costs for farms.

The objective of this paper is to provide insights for researchers and policy makers concerning the impact of specific mitigation measures at the farm level. The quantitative effects projected by the farm level modelling can provide the expert panel an opportunity to evaluate the acceptability of specific mitigation measures at the farm level and the effectiveness of these mitigation measures to reduce greenhouse gas emissions from agriculture in Finland. Hence, this paper can contribute to the discussion on future climate policies to be implemented in Finland as well as in the EU and globally.

2. Material and Methods

EU member states have to report their greenhouse gas emissions annually according to a common reporting framework designed by the United Nations Framework Convention on Climate Change (UNFCCC). Following the UNFCCC reporting framework, the inventory for the agricultural sector only includes emissions of methane (CH_4) and nitrous oxide (N_2O). It has to be noted that emissions (and removals) of carbon dioxide (CO_2) from agricultural soils are not accounted for in the "agriculture" sector, but under the category "land use, land use change and forestry" (LULUCF) sector. Likewise, carbon dioxide emissions released by agricultural activities related to fossil fuel use in buildings, equipment and machinery for field operations are assigned to the "energy" sector. Other agriculture-related emissions, like those from the manufacturing of animal feed and fertilizers are included in the "industrial processes" sector (IPCC, 2006). Thus, the overall greenhouse gas emissions that are related to agricultural production and activity are actually greater than those reported under the "agriculture" sector in the UNFCCC official inventories. This paper follows the Common Reporting Format (CRF) of the UNFCCC, where the "agriculture" sector covers only emissions of nitrous oxide and methane because the reduction targets for greenhouse gas emissions are based on this accounting format.

2.1. Farm level modelling of four specific mitigation measures

Alternative farm level models are presented in this paper to evaluate the effects of different mitigation policy measures for reducing greenhouse gas emissions. Different measures also required various data sources and specific farm level data in order to assess the effectiveness of each policy measure. The effects and costs or benefits of implementing the policy measures are mainly undertaken by individual farms. Below are the four specific policy measures:

1) Requiring cattle farms to cultivate perennial grass on organic soils

Cultivation of agricultural land causes emissions of nitrous oxide (N_2O) which are accounted in the agricultural sector. Perennial grass will reduce emissions from organic soils compared to annual crops, such as cereals, due to less frequent tillage of the soil and a longer period of nitrogen uptake from grass compared to cereals. According to Monni et al. (2007), the emission factor of cultivating cereals on organic soils is 11.7 kg N_2O-N/ha per year, while the emission factor of cultivating grass on organic soils is 4.0 kg N_2O-N/ha per year. According to the IPCC (2013) wetlands supplementary guide definition, there are approximately 238 400 hectares[1] of organic soils under cultivation in Finland (year 2009), whereby 60% are cultivated with perennial grass and 40% with annual crops. The emissions of nitrous oxide from agricultural soils accounted for 51% of the green house gas emissions from the agricultural sector (Table 1). Finnish cattle farms cultivate both annual crops, such as feed grains, and perennial grass on their fields. The specific policy measure requiring cattle farms to cultivate only perennial grass on fields with organic soils is modelled at the farm level. Farms have a possibility to allocate their own feed grain production from organic soils to mineral soils and replace the possible lack of feed grains by buying from the market. The data used is retrieved from the annual cultivated areas recorded at the Finnish register for field parcel from the year 2009, according to production lines. The soil type of each field parcel is identified by using the Finnish Soil Database (Lilja et al., 2009). The soil type is divided into two main types: mineral soils and organic soils. Cattle farms accounted for 112 500 hectares organic soils, and 35 870 hectares are cultivated with annual crops. Thus, the effect of allocating these field parcels with organic soils to perennial grass production (instead of feed grains production) can be estimated.

2) Increase rapeseed oil in feedstock for cattle

Ruminants, such as cattle, produce methane (CH_4) in their enteric fermentation. According to the total value of agricultural production, the dairy together with the meat sectors are the most important production lines in Finland. A total of 911 000 cattle produced 34% of the greenhouse gas emissions from the agricultural sector in 2013 (Table 1). Dairy cattle accounted for 56% of the emissions from the cattle population. The specific measure, whereby rapeseed containing oil is added to dairy cow's feedstock to increase fat concentration in the diet for dairy cow, is modelled at the farm level. It is found that increasing fat concentration in cattle's diet reduces methane (CH_4) production from enteric fermentation, however, high fat content in dairy cow's diet will decrease milk yield (e.g. Ramin & Huhtanen, 2013).

[1] The statistics for organic soils presented in this paper is from preliminary data for the Kyoto Protocol's second commitment period. The emissions calculation has changed due to the internationally agreed new methodological and reporting guidelines for greenhouse gas emissions (IPCC, 2013). For example, the published National Inventory Report by Statistics Finland (2014) reported approximately 330 000 hectares as organic soils in 2009, but our data indicated only 238 000 hectares.

3) Storing feed grains without drying

In northern latitudes, grain is usually harvested when the grain moisture is 23% on average because of the short growing season and low temperature. The grain must be dried to 14% moisture for preservation. When this is done for 1000 kilograms of grain, 88.6 kilograms of water has been taken out. Currently, fossil fuel oil is the most commonly used energy source for drying grains, and drying one tonne of grain consumes about 12 kilograms of fuel oil. The energy saving potential resulting from storing feed grains without drying is modelled at the farm level. It is possible to preserve feed grains without drying, for example with air-tight storing. In terms of feeding values, it makes no difference if the grain is preserved wet or dry. In 2012, 786 000 hectares of land were cultivated with feed grains. The yield of feed grains was 2.7 million tonnes (Tike, 2013). From this, 1.6 million tonnes was used directly as feed in farms (Tike, 2012). However, the market for “wet stored” grains is limited, hence this is mostly an on-farm solution. It is assumed that half of the feed grains can be “wet stored” without drying to estimate the reduction of carbon dioxide emissions. It should be noted that carbon dioxide emissions are accounted under the energy sector and not under the agriculture sector, but emissions abatement from not drying the feed grains are overall accounted under non-EU-ETS emissions which include the agriculture sector.

4) Promote the use of selective insemination in cattle breeding

More than 80 % of annual beef production (80 300 tonnes) in Finland is from dairy breeds, and Finnish Ayrshire (Ay) and Holstein-Friesian (Hol) are the two most frequently used breeds. Annual consumption of beef is about 98 200 tonnes, thus beef is imported to satisfy domestic consumption (Niemi 2014). Because of the discrepancy between demand and supply, slaughterhouse pricing favours heavy carcasses. At the same time, consumers generally favour lean meat, whereby carcasses with high fat content rating are penalised. Bulls gain weight more and faster than heifers. In addition to gender, crossbreeding dairy with beef breeds has favourable effects on carcass gain and meat quality compared to pure dairy breeds (Huuskonen et al., 2013). Both the gender and breed of cattle can affect the feed conversion ratio, and thus the feed intake per kilogram of meat produced can be decreased, and therefore reduce methane emissions from beef production. The current replacement rate for dairy cows compels breeding scheme to primarily produce dairy breed cows, and hence there is only limited possibility to increase cross breeding inseminations. Currently, only 6% of inseminations are from beef breeds. Therefore, dairy calf production can be improved through selective insemination by using sex-sorted sperm (Heikkilä & Peippo, 2012). The effect of promoting the use of selective insemination in cattle breeding to improve the efficiency of beef and dairy production is modelled at the farm level to estimate the potential to reduce methane emissions. The estimation is based on the current cattle population and removal rate of dairy cows. When the number of dairy-breed calves is ensured, a larger share of inseminations can be accomplished through cross breeding without compromising the dairy herd. Part of the cross breed inseminations can be made with bull-sorted semen to increase the share of bulls in the meat production. The increase in selective inseminations would boost the possibilities to produce heifer-calves from genetically superior cows.

2.2. The Delphi method

Delphi technique as a research method has been widely used in futures studies. The users of Delphi technique aim to predict and explore alternative future images, possibilities, their probabilities of occurrence, and their desirability by tapping the expertise of respondents (Linstone & Turoff, 1975). In the method, information is obtained from experts through questionnaires and interviews, after which the information is revised with one or more additional rounds of information gathering. Prior to a new round of answers, the experts are informed of the results of the previous round. This allows individual experts to position themselves in relation to the opinions of the group of experts. Typically, in the Delphi method, opinions tend to converge and the estimates become more consensus-based. The principle of several rounds in Delphi method enhances learning to take place during the process. The participants get the results from previous round and can familiarize themselves with the argumentation that other participants have presented. Therefore, a participant can receive a confirmation for his/her future view or change his/her view on future development based on the arguments that the others have brought to the table or new information received from elsewhere.

The selection of the panel is a critical phase in using methods like the Delphi technique (Kuusi, 1999). In this study, the selection process proceeded as follows. First, the criteria and classification for choosing the experts are prepared according to the research goals. The needed expertise and actors in agricultural field are determined in an expertise matrix (Figure 2). In the matrix, the decisive dimensions are 1) expertise and educational background (agriculture, climate change, renewable energy, economics, social science in general, technological and natural science) and 2) actors in the agricultural field (research and education, agricultural producers, administration, NGO's, agricultural extension, interest groups, food industry and trade). Also, in this phase, the preliminary panellists are listed by the research group. The coordinator of the Delphi questionnaires first contacted the chosen experts by e-mail and then later called to organise a personal interview. The empirical data are gathered between summer 2013 and spring 2014. The questionnaires are sent beforehand by e-mails, which are immediately followed by personal interviews. The second round of questionnaires is conducted online. The first round of questionnaires is sent to 36 experts of whom 29 returned the questionnaires. The expert panel evaluated altogether twenty climate and energy policy measures (Appendix A) by different dimensions: 1) probability of the use, 2) desirability, 3) societal acceptability, 4) farm level acceptability 5) the broadness of implementation, 6) the effectiveness to reduce emissions and 7) the overall importance (e.g. Appendix B). Farm level acceptability is an important dimension because many of the studied measures also increase costs and require changes in production. Therefore, there is a trade-off between reduced green house gas emissions and increased costs for farms. Also, the effectiveness to reduce emissions from agriculture varies considerably between the studied climate policy measures.

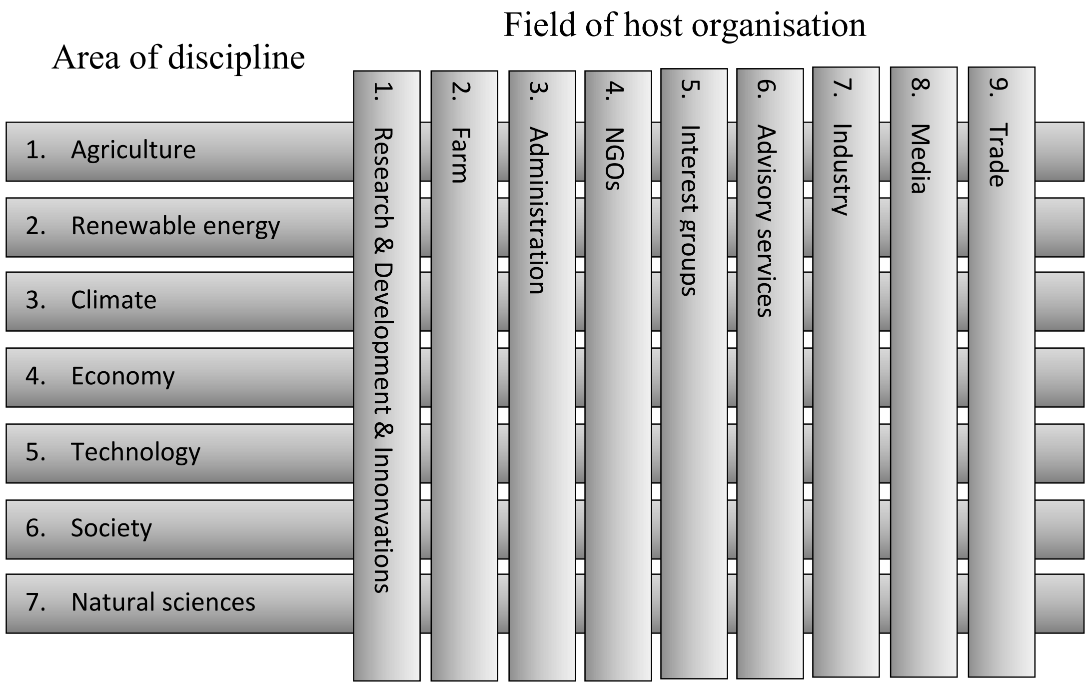

Fig. 2. The expertise matrix for the needed expertise and actors in the agricultural field.

2.3. Combining farm level modelling with the Delphi method

Farm level modelling is used in parallel with the Delphi method to evaluate four specific climate policy measures. There are all together 20 climate and energy policy measures in the Delphi questionnaire, but only four measures in the questionnaire incorporated results from the farm level simulations, therefore providing more information on the effects of a specific policy measure at the farm level. These specific measures are 1) the benefits (decreased emissions) and costs of requiring cattle farms with organic soils to cultivate perennial grass on them, 2) requiring cattle farms to change feeding practice and intensify diet for livestock by increasing rapeseed oil in feeding in order to decrease methane emissions, and 3) storing feed grains without drying, thus avoiding fossil fuel use, and 4) promote selective insemination in cattle breeding in order to produce genetically superior cows and improve weight gains for bulls. The first two specific measures are evaluated in parallel with the general policy measures that have no information on the potential to reduce greenhouse gas emissions, and the last two specific measures are evaluated individually without comparison to any general policy measures.

The process for the first round of the Delphi questionnaire:

1) Farm level modelling to simulate the effects of the four specific climate policy measures.

2) The effects of the four specific climate policy measures are included in the Delphi questionnaire in order to provide more information for the expert panel, while at the same time to instigate expert evaluations of a specific policy measure containing the simulated effects (see an example of the questionnaire in Appendix B).

3) Both the simulated results from the farm level modelling and evaluations from the expert panel are combined to foresee the overall potential and effectiveness of the four specific climate policy measures.

3. Results

3.1. The farm level simulation results

3.1.1. The benefits (decreased emissions) and costs of requiring farms with organic soils to cultivate perennial crops (grass) on them

As a general policy measure by accounting all farms in Finland, annual crops are approximately cultivated on 93 000 hectares of field parcels with organic soils. By changing the cultivated annual crops on organic soils to perennial grass, nitrous oxide emissions would be reduced by 278 000 tonnes of CO_2 equivalents per year. At the same time, the amount of direct carbon dioxide emissions would be reduced by 453 000 tonnes of CO_2 equivalents per year. However, carbon dioxide emissions from agricultural land use are calculated under the land use, land-use change and forestry (LULUCF) sector and not under the scope of any reduction targets for greenhouse gas emissions. Therefore, the reduction in direct carbon dioxide emissions from this general policy measure cannot be accounted in the target to reduce emissions from the agricultural sector. As a result, this general policy measure would not only reduce nitrous oxide emissions in the agricultural sector, but also increase the carbon sink of the LULUCF sector in Finland.

As a specific policy measure by accounting only cattle farms in Finland, annual crops are approximately cultivated on 36 000 hectares of field parcels with organic soils. All Finnish cattle production is based on silage from perennial grass, and there is hardly any maize production or similar annually cultivated rough feed due to low temperatures in Finland. Finnish farms do not have permanent grassland and perennial grass is typically renewed every third or fourth year, and grain is typically used for one year of crop rotation with perennial grass to avoid the widespread of weeds. Grass silage and most of the feed grains are typically produced on-farm. Farms may be able to concentrate the cultivation of the annual/grain crops on mineral soils of the farm and perennial grasses on organic soils as a part of normal silage production. If all cattle farms in Finland would cultivate perennial grass on the organic soils instead of annual crops, it would reduce nitrous oxide (N_2O) emissions by 107 000 tonnes of CO_2 equivalents per year. At the same time, the amount of direct carbon dioxide emissions would be reduced by 175 000 tonnes per year, and this would contribute to the carbon sink of the LULUCF-sector in Finland.

3.1.2. Requiring cattle farms to change feeding practice and intensify diet for livestock by increasing rapeseed oil in feeding in order to decrease methane emissions

As a general policy measure, changes in livestock feeding could reduce greenhouse gas emissions through enteric fermentation. Nutrition research in animal science has focused on finding methods to reduce methane emissions. On average, cattle lose 6 % of their ingested energy as methane. This causes inefficiency to the animal feeding because part of the valuable energy is lost. The other concern is related to the role of methane in global warming (Johnson & Johnson, 1995). In ruminant feeding, diet quality is highly related to forage quality resulting from cultivation and harvest techniques, and timing of the harvest. It can also be affected by dietary supplements, such as dietary oils, probiotics or enzymes (Eckard et al., 2010).

As a specific policy measure, adding 0.5 kg of rapeseed oil in dairy cow's diet is evaluated. The utilised model is based on published empirical data derived from relationships between feed composition, feed intake (Huhtanen et al., 2007, 2008, 2010), associative effects in digestion (Huhtanen et al., 2009), and milk production responses (Huhtanen & Nousiainen, 2012). The model optimizes the feed ratio based on least-cost ratio on given prices by taking into account the potential and actual milk yield of the cow. In the baseline, the diet consists of grass silage (D-value 670 g kg^{-1}), equal mixture of barley and oats, and rapeseed meal. The simulation is made for an average cow (weight 660 kg) on her 150th lactation date with production level of 32.1 kg energy corrected milk (ECM) per day. In the scenario, crushed (oil-containing) rapeseed partially replaces cereals and rapeseed meal in the normal dairy cow's diet so that the fat content increases by 0.5 kg, while the ECM production is kept constant. The methane emissions per ECM litre are reduced by 8 % from 13.6 to 12.5 g per kg ECM. However, the cost of the daily diet would increase by 7 %, as observed by the price average of feed grains from years 2010 – 2013 (Luke, 2015). Thus, the cost for methane emissions reduction would be €268 per tonne of CO_2 equivalents. If this diet is applied to all dairy cows in Finland, the total abatement in methane emissions would roughly be 60 000 tonnes of CO_2 equivalents per year. However, the additional cost for the dairy farmers in Finland would roughly amount to over €16 million per year. In reality, this scenario would be impossible on large scale in Finland due to a lack of availability in rapeseeds and the exorbitant cost in relation to the abatement in methane emissions.

3.1.3. Storing feed grains without drying, thus avoiding fossil fuel use

As a specific policy measure, storing feed grains without drying could contribute to the abatement of greenhouse gas emissions through the avoidance of energy used to dry the grains. In Finland, grain is usually harvested when the grain moisture is 23 % on average; this is because of the short growing season. The grain must be dried to 14 % moisture for preservation. The drying process requires a lot of energy, usually from fossil fuel oil. The consumption of oil (fossil fuels) for drying feed-grains will cause 57 400 tonnes of CO_2 equivalents emissions annually (Kässi et al., 2014).

In 2012, 60% of the grain production in Finland is used directly as fodder in livestock farms. It is possible to preserve feed grains without drying with air-tight storing. The majority of feed grains are used for cattle (568 000 tonnes) and pigs (939 000 tonnes). Preservation must be done at the farm where the feed is consumed because the moist grains go bad quickly when taken out from the silo (where the grain is stored air-tight). Therefore, the possibilities for trading and transporting the moist grain are limited. It is estimated that half of the feed grains for cattle and pigs could be stored without drying. The potential of reducing fuel oil use for drying feed grains is 21.2 million litres, and thus the potential cost saving is €21.7 million per year with the average price of €1.02/litre for fuel oil from year 2010 to 2013. The emissions reduction would be 28 650 tonnes of CO_2 equivalents per year. The reduction in emissions from this policy measure would be accounted under the energy sector and not under the agricultural sector. The energy sector has the largest greenhouse gas emissions (48.4 million tonnes of CO_2 equivalents in 2013) in Finland.

3.1.4. Promote selective insemination in cattle breeding in order to produce genetically superior cows and improve weight gains for bulls

As a specific policy measure, promoting selective insemination in cattle breeding could reduce greenhouse gas emissions by advancing efficiency and yield gains in cattle farms. In 2013, there are 283 000 dairy cows in Finland. For replacement of cows, there is a need to produce 119 000 heifer-calves annually. With unsorted semen, 51 male to 49 female calves are expected, while female semen-sorting results 10 male and 90 female calves and male semen-sorting results 85 male and 15 female calves. Kässi and Niskanen (2014) estimated that the share of cross breed inseminations could be increased from current 6 % to 27.5 % by increasing the use of selective inseminations for dairy cows in Finland. Selective inseminations would improve the feed conversion ratio and reduce the gross feed energy (GE) needed by 50.3 TJ even though the overall yield of beef production would increase by 1 100 tonnes. However, the total decrease in methane emissions would be minimal by only 1 250 tonnes of CO_2 equivalents per year, but the emissions would decrease by 3 % per kg of beef production in Finland. It should be noted that the total value of beef production in Finland would increase by €10 million due to yield and quality improvements in beef production.

The main problem with this policy measure is the extra cost for implementation. The cost for selective inseminations will occur at the dairy farms, but the benefits of higher yields are mainly accrued to the farms specialised in beef production because the offspring from the cross breeds will grow faster with better meat quality. The dairy farms will eventually benefit from genetic improvement in the dairy herd, but the cost is entirely shouldered by the dairy farms. There should be a way to share the cost and benefits of this policy measure in order to make this policy measure more attractive to the dairy farmers and encourage widespread implementation for selective inseminations in cattle breeding. The higher uptake of this policy measure in the cattle population will further improve the abatement in greenhouse gas emissions from both beef and dairy production through genetically superior cattle.

3.2. The results from the Delphi method

The effects of four specific climate policy measures are simulated at the farm level to be included in the Delphi questionnaire in order to provide more information for the expert panel. Two of the specific policy measures have corresponding general climate policy measures. In the Delphi questionnaire, two questions are asked in parallel: first, the expert panel is presented with a general climate policy measure then followed by a specific mitigation measure with the simulated effects at the farm level. The first question deals with the general climate policy measure requiring all farms to cultivate perennial grass on organic soils and followed by the specific mitigation measure on requiring only cattle farms to cultivate perennial grass on organic soils together with the simulated effects. The second question deals with the general climate policy measure requiring livestock farms to change their feeding practice and followed by the specific mitigation measure on increasing rapeseed oil in cattle feeding together with the simulated effects. The third and the fourth questions concerning "storing feed grains without drying" and "promoting selective inseminations in cattle breeding" do not have counterpart questions with general climate policy measures, but the expert panel is given the simulated effects of these measures for deeper evaluation.

3.2.1. General versus specific mitigation measure: Requiring perennial grass cultivation in all farms with organic soil versus requiring only cattle farms to cultivate perennial grass on organic soils

The general measure concerns all farms that possess organic soil fields, whereas the specific measure concerns only cattle farms with organic soils. The overall importance is almost similar in both the general and specific measures with the same range of consensus (Figure 3). The desirability of requiring perennial grass cultivation in all farms with organic soil fields is slightly higher than its counterpart question: requiring only cattle farms to cultivate perennial grass on organic soils. More information through the simulated effects of the specific policy measure did not have an impact on the desirability of the measure. This can be explained by the overall view for this specific measure. The respondents did not see it appropriate to intervene in the way entrepreneurs manage their business. It is noteworthy that some of the respondents did not support any sanctions for non compliance, and thus, the specific measure is undesirable by nature. The probability of the use between these two measures differs more than their desirability. This can be explained by the respondents' views that the specific measure restricts especially the cattle farms to run their business.

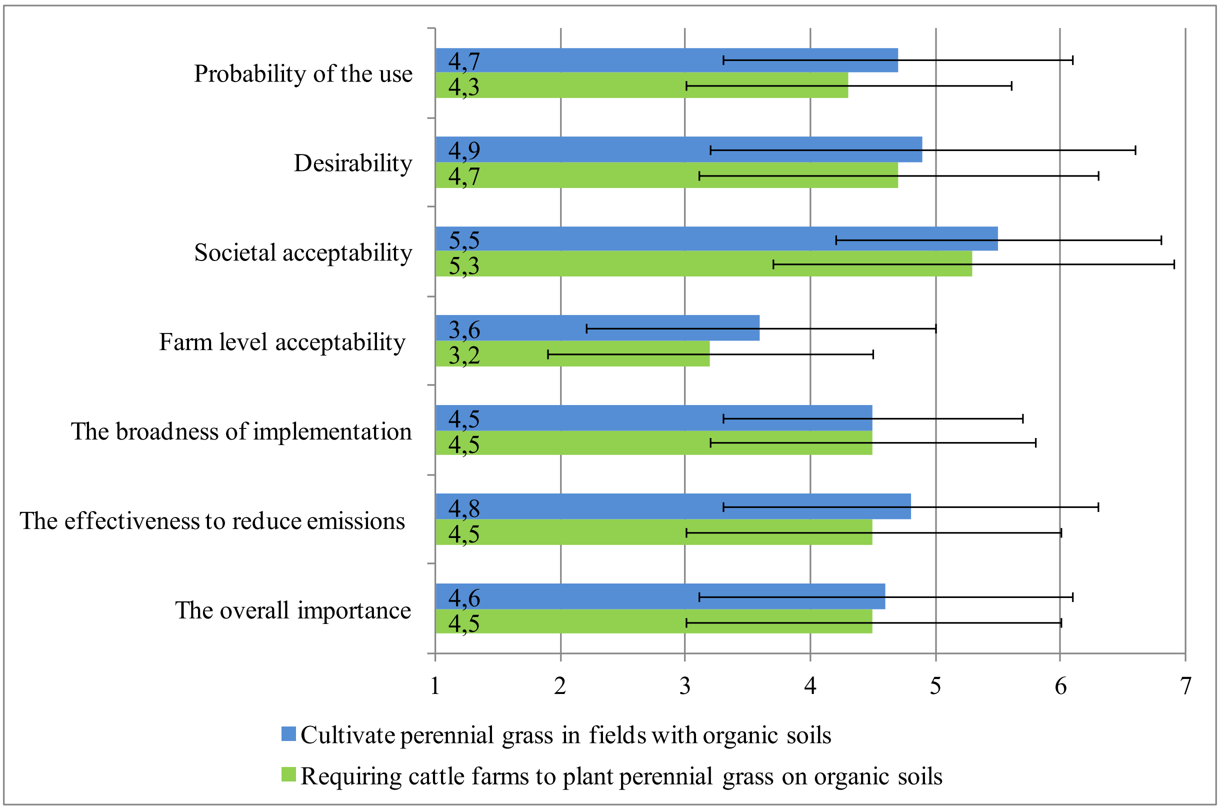

Fig. 3. General versus specific policy measures: Cultivate perennial grass on organic soils.

Farm level acceptability is a higher in the general measure compared to the specific measure. The respondents consider that farmers could transfer their production from organic soils to other soils if the farms have different soil types. Most of the cattle farms are located in areas where a lot of organic soils exist. Farms which have only organic soils in cultivation are more concerned by the specific measure: how this kind of cattle farms can procure their concentrated feeds if they cannot cultivate them in their own fields. If they need to buy them, how expensive it would be and from where they should buy. Another concern is the implementation of crop rotation on the organic soils. Perennial grass cultivation in the organic soil fields is seen more acceptable in societal dimension for the general measure compared to the specific measure. This is because the specific measure focuses only on cattle farms, and therefore it is not a fair policy measure. The broadness of implementation is seen similar in both measures. The respondents predict that these measures could be enforced by the EU in the future. The general measure is seen to be more effective in reducing greenhouse gas emissions compared to the specific measure. This can be explained by the additional information provided: in all farms (general measure), 93 050 hectares of organic soils are cultivated by annual (grain) crops that can be replaced by perennial grass, but only 35 870 hectares are possessed by cattle farms (specific measure). By factoring in the additional information, the respondents get the picture that it would be more effective to target all farms with organic soils rather than focusing only on cattle farms with organic soils.

3.2.2. General versus specific mitigation measure: Changes in livestock feeding versus increase rapeseed oil in cattle feeding

The overall importance is similar for the general and specific mitigation measures, but there is more consensus for the general measure (Figure 4). The desirability in changing livestock feeding is much higher than in its counterpart question: increase rapeseed oil in cattle feeding. More information provided for the specific mitigation measure reduced the desirability for this specific measure. This can be explained by the deeper understanding provided by the simulated effects of the specific mitigation measure. It is noteworthy that the respondents answered that adding fat in the feed for dairy cows is non physiological for the feeding behaviour of the species. This specific mitigation measure is undesirable because fat does not belong to the diet of ruminants, and therefore part of the respondents would not accept it. Moreover, some of the respondents indicated that changes in livestock feeding may involve also other animals besides cattle, and changes in feeding can be accomplished in various ways. The respondents estimated a much higher societal acceptance for changing livestock feeding as a general measure, but not just by adding fat in the feedstock for cattle. Farm level acceptability was the same in both general and specific measures, though the standard deviation is 33% bigger in the specific measure compared to the general measure. This can be explained by the high costs of adding rapeseed oil to feed and the increased need for rapeseed cultivation in Finland (crop yields for rapeseed vary a lot between years).

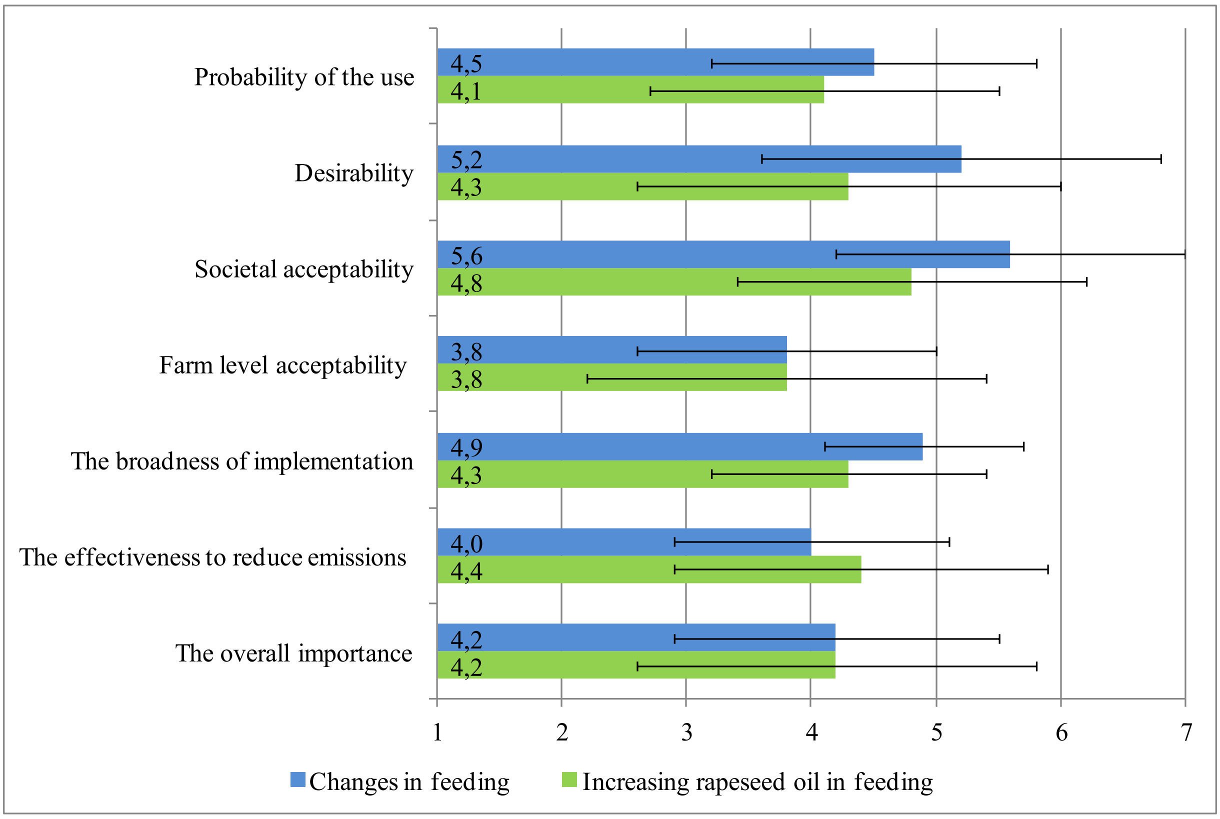

Fig. 4. General versus specific policy measures: Changes in cattle feeding.

The general measure is considered to be broader for implementation compared to the specific mitigation measure. The respondents have indicated that the costs of production must be optimized more in the future and changes in livestock feeding could be one way to do so. However, adding rapeseed oil to feed would considerably increase the cost of production. It is worth mentioning that some of the respondents have envisaged changes in livestock feeding that would improve the overall feeding system for livestock and not just to reduce greenhouse gas emissions. The specific measure is considered to be only effective in reducing greenhouse gas emissions. The farm level simulations provided additional information on how costly is the specific measure compared to the possible decrease in emissions, and the respondents think it is unnatural to add oil to the diet of ruminants, in addition to the increase in costs.

3.2.3. Specific mitigation measure: Storing feed grain without drying

This specific measure (Figure 5) has the highest score for overall importance among the four specific measures and is rank sixth among the 20 climate and energy measures rated by the respondents in the Delphi questionnaire (Appendix A). Also, the desirability in storing feed grain without drying is highest among the four specific measures. The reason is because this specific measure is straightforward and easy to implement. Furthermore, avoiding the use of fossil fuels can be seen acceptable both at the farm level and also for society. The probability of using this measure, however, is lower than the desirability in storing feed grain without drying, thus the lower level of acceptance at the farm level. The broadness of implementation is considered by the respondents as highly plausible because this specific measure allows extensive agricultural production. Also, this measure is considered to be effective in reducing green house gas emissions due to the potential of reducing the usage of fossil fuels in addition to cost savings by avoiding the process of drying the feed grains.

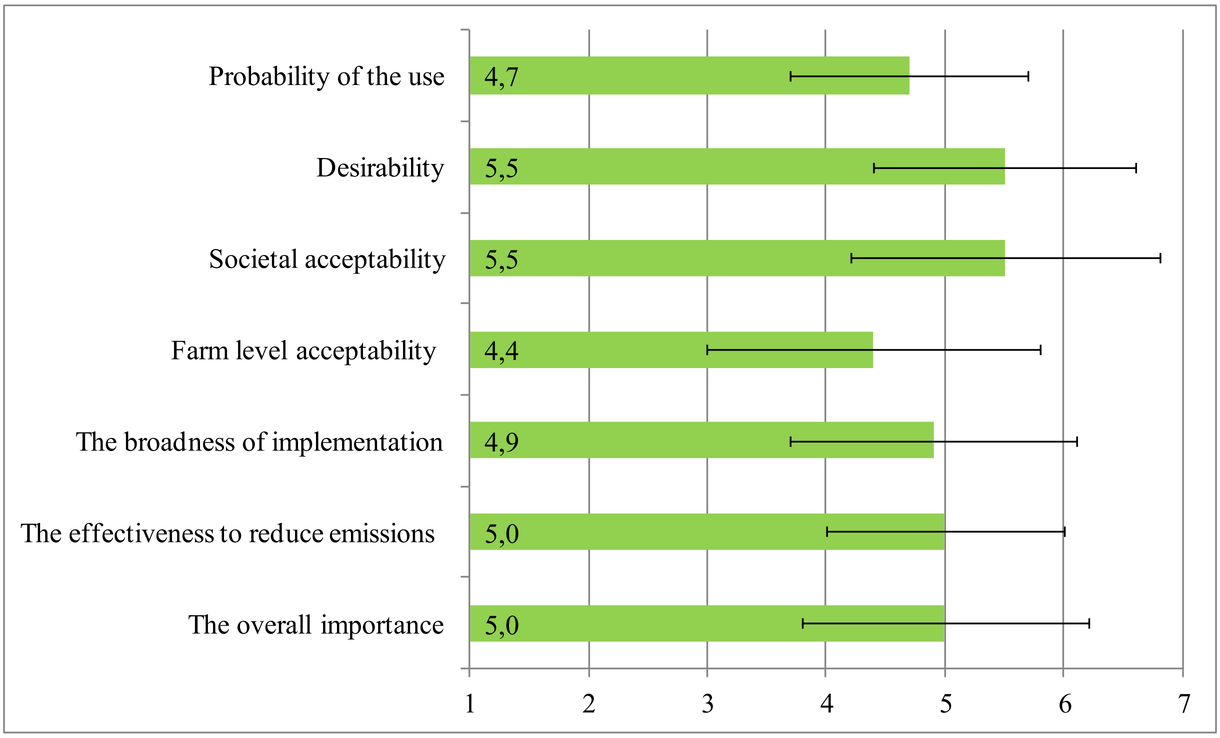

Fig. 5. Specific policy measure: Storing feed grain without drying.

3.2.4. Specific mitigation measure: Promote selective insemination in cattle breeding

This specific measure (Figure 6) has the highest score for the probability of usage among the four specific measures. Furthermore, the desirability for this specific measure is high along with acceptability at the farm level. However, the score for overall importance is low because the ability to reduce greenhouse gas emissions with this specific measure is minimal. More information provided by the simulated effects reduced the score for the overall importance and effectiveness of this specific measure. The score for societal acceptability is low because the respondents are divided between the ethics of artificial insemination, animal welfare and preservation of genetic diversity with the technological advancement for cattle breeding. Also, the cost and benefits of this specific measure are not equally shared among the different production lines (dairy versus beef producers). Otherwise, the broadness of implementation for this specific measure has the same score with "storing grains without drying" and is considered by the respondents as highly plausible to be implemented on farms in the future.

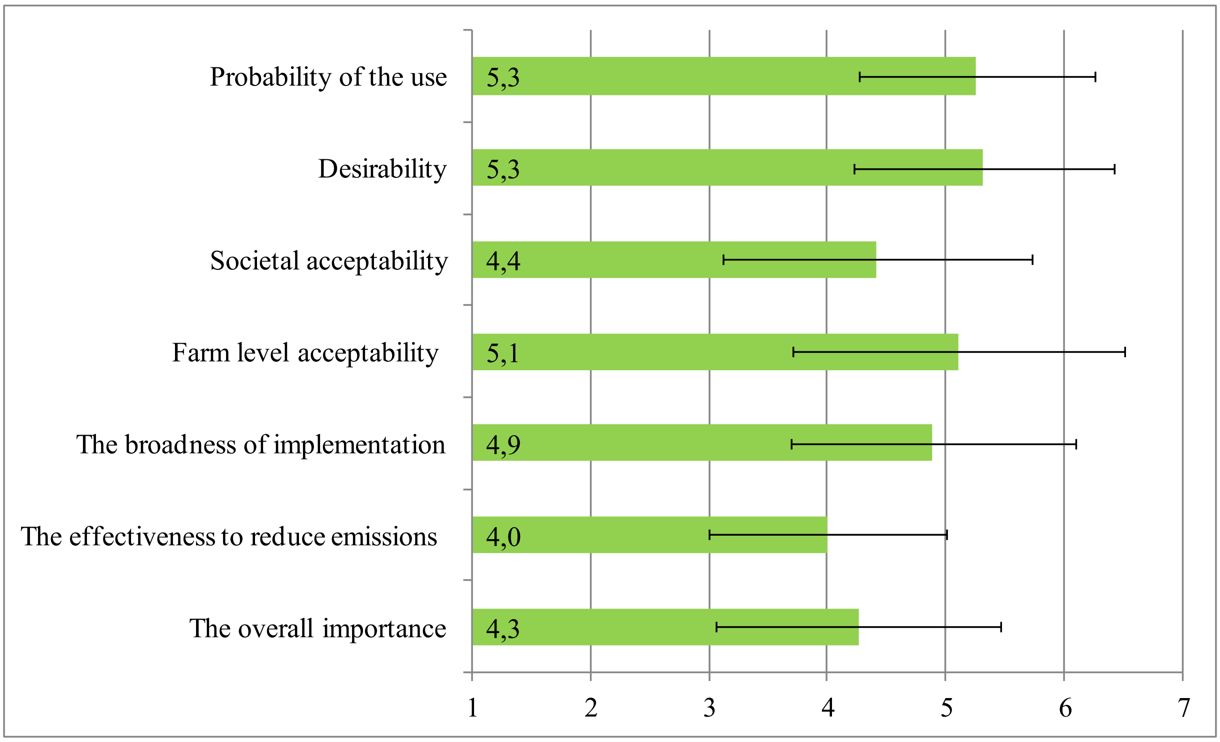

Fig. 6. Specific policy measure: Promote the use of selective insemination in cattle breeding.

4. Climate Policy Discussions

The EU's climate and energy package, agreed in December 2008, lays down legislation to meet the bloc's binding goal to reduce greenhouse gas emissions by 20% from 1990 levels by year 2020. In October 2014, EU leaders committed to reduce greenhouse gas emissions by at least 40% by year 2030 as the global community is engaging in negotiations to agree on a new climate treaty which will come into effect and be implemented after year 2020 to replace the Kyoto Protocol[2]. This ambitious EU target would try to convince big polluters such as China

[2] The Kyoto Protocol to the United Nations Framework Convention on Climate Change was adopted in Kyoto, Japan, in December 1997 and entered into force on 16 February 2005. The Kyoto Protocol sets a specific time period – known as the first commitment period – for Annex I Parties to achieve their emission reduction and limitation commitments, commencing in 2008 and ending in 2012 (UNFCCC, 2008). The Doha Amendment is an amendment to the Kyoto Protocol that was adopted on 8 December 2012 in Doha, Qatar and establishes the second commitment period of the Kyoto Protocol, which began in 2013 and will end in 2020.

and the United States to agree in Paris on a global and legally binding agreement for greenhouse gas emissions in December 2015. A global climate policy is only meaningful when big polluters are actively involved in reducing emissions because the total green house gas emissions in a year from Finland in 2010 was emitted in just 4 minutes by China (Table 3).

Table 3. Greenhouse gas emissions in Finland compared to China in 2010.

Emissions from China in one second*	340	tonnes of CO_2 equivalents
Emissions from China compared to the total emissions from Finland in a year (2010)*	4	minutes
Emissions from China compared to one year emissions from Finnish agriculture (2010)	13* (20**)	seconds

* Source: World Bank, 2014 (http://wdi.worldbank.org/table/3.9)

** Source: Statistics Finland, 2015. Greenhouse gas emissions in Finland: Data tables. (http://www.stat.fi/til/khki/tau_en.html)

In the second commitment period of the Kyoto Protocol (2013-2020), the countries that have binding commitments to reduce greenhouse gas emissions in the world are mainly the 28 member states of the EU. Under the Kyoto Protocol, the sectors that are under reduction commitments are energy, industrial processes, solvent & other product use, agriculture, and waste. However, the land use, land-use change and forestry (LULUCF) sector does not have any binding or reduction commitments. The Kyoto Protocol restricts the accounting of the LULUCF sector to net emissions and removals from specific activities that are defined under Article 3, paragraphs 3[3] and 4[4], of the Kyoto Protocol (UNFCCC, 2008). Instead of emissions, the total carbon sink from the LULUCF sector in Finland in 2013 is 20.4 million tonnes of carbon dioxide equivalents (Table 1). The LULUCF sector in Finland has been a net sink

[3] Article 3, paragraph 3, covers direct, human-induced, afforestation, reforestation and deforestation activities. Accounting of these is mandatory: each Annex I Party must report on and account for emissions and removals in the commitment period on lands on which these activities have occurred (UNFCCC, 2008).

[4] Article 3, paragraph 4, activities are restricted to forest land management, cropland management, grazing land management and/or revegetation. Accounting of these activities is optional, which means that each Party must choose whether to account for emissions and removals from each activity during the commitment period (UNFCCC, 2008).

during the whole period 1990-2012 as the removals in the sector exceeded the emissions, whereby most of the removals in the LULUCF sector came from tree biomass growth (Statistics Finland, 2014). However, the total carbon sink contributed by Finland is not reflected in the target to reduce greenhouse gas emissions from Finland. It should be noted that, in 2013, the total emissions from the agriculture sector (Table 2) is less than one third of the carbon sink of the LULUCF sector in Finland. Moreover, the agriculture and forestry sectors in Finland are very much interlinked, and it is common that farmers are also owners of forest land. Therefore, the total carbon sink contributed by the LULUCF sector should be pursued by policy and decision makers in future climate policy negotiations because climate change mitigation may also be achieved by increasing the capacity of carbon sinks.

5. Conclusions

The objective of this paper is to provide insights for researchers and policy makers concerning the impact of mitigation measures for greenhouse gas emissions at the farm level. The evaluation by quantitative and qualitative methods of the four mitigation measures indicate that three of the measures are viable climate policy measures with further research at the farm level in order to improve the feasibility of these measures. The policy measures can be tested at the farm level through pilot projects before implementation on a wide scale.

Increasing rapeseed oil in feeding cattle in order to decrease methane emissions is not a feasible measure. The farm level simulations have indicated that this specific measure is very costly compared to the possible decrease in methane emissions. The estimated cost for emissions reduction would be €268 per tonne of CO_2 equivalents, which is more than double the cost (€122.5 per tonne of CO_2 equivalents) estimated by Pérez Domínguez & Britz (2010) for the abatement of agricultural greenhouse gas emissions in Finland. Furthermore, the respondents from the Delphi questionnaire think it is unnatural to add oil to the diet of ruminants, and also animal science research has proven dietary supplements of oil lowered the yields of milk due to an adverse effect on intake (Bayat et al., 2015). Thus, this specific measure not only may cost the dairy farmers roughly over €16 million per year, but also may decrease animal welfare.

Requiring perennial grass cultivation on fields with organic soils is the only measure examined in this paper with a significant effect on the abatement of greenhouse gas emissions. However, it is considered unfair by the respondents of the Delphi questionnaire if only cattle farms are targeted under this measure. Therefore, voluntary participation in this measure can be considered because binding commitments fit poorly to agricultural production due to rapid changes in the market environment and increased volatility of the agricultural markets. Therefore, further research should demonstrate that this specific measure is saving costs instead of increasing production costs at the farm level besides reducing greenhouse gas emissions.

Storing feed grain without drying is a potential measure, but this policy measure contributes explicitly to emissions reduction in the energy sector and not the agriculture sector. Moreover, this measure requires investments at the farm level to implement this technology. However, there will be cost savings after the initial investments because of the potential to reduce the usage of fuel oil to dry feed grains (21.2 billion litres). Investment subsidies for this specific measure may help to spread the use of this measure due to the potential of reducing both greenhouse gas emissions and production costs at the farm level. Farms who already have the technology and machinery to make silage from hay can also harvest the grains in a similar way, thus the feedstock is fed in a similar way like silage and no new investment is needed.

Promoting the use of selective insemination for cattle breeding is cost efficient, but the potential to reduce emissions is minimal. Currently, the costs of this measure will occur in the dairy farms producing the calves and the benefit is mainly reaped by the beef production farms, thus resulting marginal use of this specific measure. Further research should indicate a method to divide the cost and benefits of this specific measure equally among the different production lines (dairy versus beef producers) in order to convince farmers to implement this measure at the farm level.

The potential to reduce greenhouse gas emissions from the agricultural sector in Finland is limited with current technology and the cost is high for implementing mitigation measures at the farm level. All the four policy measures examined in this paper would contribute to emissions abatement under sectors not included in the EU Emissions Trading System (non-EU-ETS). By 2020, Finland is given an emission reduction target of 16% (5.84 million tonnes of CO_2 equivalents) from the non-EU-ETS sectors compared with 2005 levels of emissions. The total possible emissions reduction from the four policy measures would be 367 900 tonnes of CO_2 equivalents, which is less than one tenth of the target. Moreover, adding oil to feedstock to reduce emissions is not a feasible measure because the implementation cost is very high for dairy farmers in Finland compared to the minimal abatement in methane emissions and animal welfare issues. Also, all farms in Finland are not able to cultivate perennial grass on organic soils because only cattle farms are able to use the grass as feedstock. This measure would significantly reduce grain production in Finland. Therefore, the cost in reducing greenhouse gas emissions in the agricultural sector should not be much higher than the cost for reducing emissions in the other sectors: energy, transport, industrial processes, and waste. As a result, only 136 900 tonnes of CO_2 equivalents reduction in emissions could be possible in a cost efficient way out of the four policy measures. Comparing to the national emissions reduction target of 13% (850 000 tonnes of CO_2 equivalents) for the agricultural sector in Finland, only 108 250 tonnes of CO2 equivalents reduction in emissions can be achieved in a cost efficient way from two measures out the four examined policy measures. Therefore, these two measures can contribute to roughly one tenth of the national emissions target for agriculture.

Looking at the global perspective, the total emissions in 2010 from agriculture in Finland was emitted in 13 seconds in China (Table 3). Therefore, the target to reduce greenhouse gas emissions from agriculture in Finland looks trivial and insignificant compared to the major polluters of the world, especially if the costs are high. China, the United States and India accounted for 45% of global greenhouse gas emissions in 2010 (World Bank, 2014). If the LULUCF sector is taken into account, Indonesia would be the third largest polluter in the world due to the destruction of wetlands and rainforests. The emissions from the EU were about 10% of global greenhouse gas emissions. Due to emission leakage, binding targets for the EU do not necessarily lead to emission reductions at the global level. If agricultural production declines in the EU and no corresponding decreases in EU consumption, part of the EU production decrease will be replaced by imports; this can cause emission leakage that may considerably downsize the net effect on the effort to reduce global greenhouse gas emissions (Van Doorslaer et al., 2015). Outsourcing production may even cause higher emissions compared to production in the EU, for example renewable energy such as biofuels from palm oil imports from Indonesia. The question is: how effective is the global climate policy, if the largest polluters are not committed to reduce greenhouse gas emissions? Another question is: how expensive and costly are the mitigation policies? Currently, mainly the EU member countries have binding commitments for greenhouse gas emissions, but the rest of the world are still not committed to a binding international agreement.

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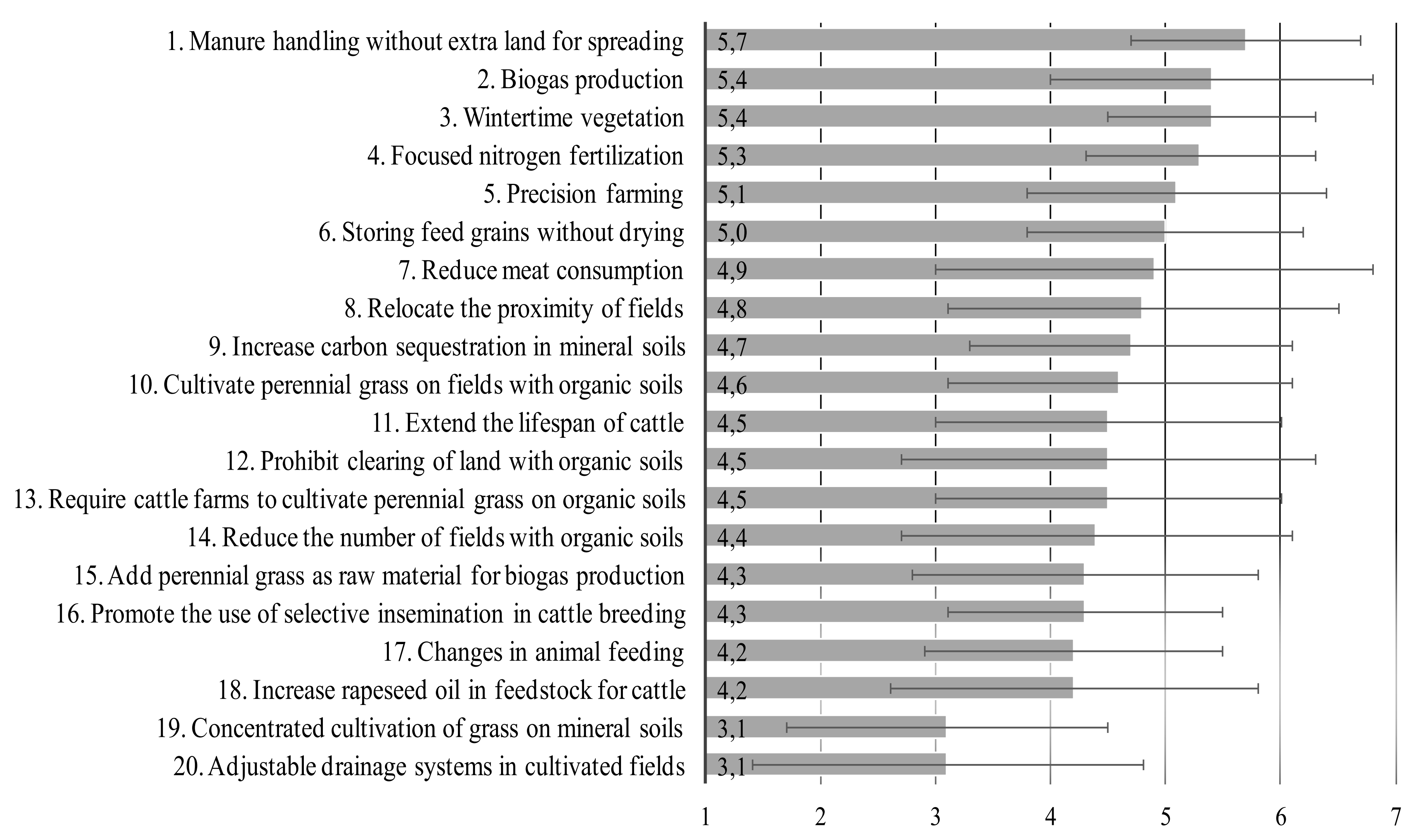
Appendix A: The 20 climate and energy policy measures evaluated by the Delphi questionnaire according to overall importance



Appendix B: The questionnaire format for the specific climate policy measure

Policy Measure: Requiring only cattle farms to cultivate perennial grass on organic soils

Perennial grasses reduce the GHG-emissions of the organic soils. According the WRB-classification (The World Reference Base for Soil Resources), there were approximately 238,400 hectares of organic soils under cultivation in Finland in year 2009, of which 60% were cultivated by perennial grass and 40% by annual or grain crops[5]. Cattle farms had 112 500 hectares organic soils and 35 870 hectares of it was cultivated by grain crops. If the cattle farms would cultivate perennial grass on that 35 870 hectare, it would reduce N_2O emissions by 107 000 tonnes of CO_2 equivalents per year. Emission reductions would represent 1.65% share of the total agricultural emissions in 2013. At the same time, the amount of the direct CO_2 emissions, which is accounted under the LULUCF-sector, would be reduced by 175 000 tonnes per year. Possible costs of implementing this measure, for example, would originate from the need of supplementary sow and increased plant protection costs caused by renewal of perennial grass without grain in the crop rotation. Cattle farms need to replace the yield of the reduced grain cultivation area with bought grain or, when possible, by concentrating the cultivation of the grain crops to the mineral soils of the farm. In this case, the cost would originate from increased transaction costs, e.g. logistics.

Your opinion on the implementation of this measure in the future	**Probability**								**Desirability**								**Societal acceptability**								**Farm level acceptability**						
	1	2	3	4	5	6	7		1	2	3	4	5	6	7		1	2	3	4	5	6	7		1	2	3	4	5	6	7
	O	O	O	O	O	O	O		O	O	O	O	O	O	O		O	O	O	O	O	O	O		O	O	O	O	O	O	O
	small			…			great		small			…			great		small			…			great		small			…			great

Your opinion on the implementation of this measure in the future	**The broadness of implementation**								**The effectiveness to reduce emissions**								**The overall importance**						
	1	2	3	4	5	6	7		1	2	3	4	5	6	7		1	2	3	4	5	6	7
	O	O	O	O	O	O	O		O	O	O	O	O	O	O		O	O	O	O	O	O	O
	small			…			great		small			…			great		small			…			great

[5] When the Delphi questionnaire was constructed, Statistics Finland (2014) reported 330 000 ha of organic soils, of which 44% with perennial grass and 56% with annual crops (cereals). Thus, the effects stated in the original questionnaire are different from the results presented in this paper because the calculations for greenhouse gas emissions have changed due to the internationally agreed new methodological and reporting guidelines for greenhouse gas emissions (IPCC, 2013).