Drivers of participation in gypsum treatment of fields as an innovation for water protection

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Abstract:

This paper examines the motivations of participants in a large-scale pilot project that develops a new agri-environmental measure, gypsum treatment of arable fields, to reduce phosphorus loads to the Baltic Sea. We build a general model of crop production that allows for three motivations: profit maximization, utility from agricultural innovation, and stewardship towards the nature. They all are present in the sample, proved by farmer survey and confirmatory factor analysis. Strong profit motivation relates to large gypsum-treated area and perceived easiness of gypsum as a water protection measure, and strong environmental motivation to environmentally friendly cultivation technologies.

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Keywords: agri-environmental policy, Baltic Sea, gypsum application, innovation, water protection

1 Introduction

Nutrient loading deteriorates the ecological state of aquatic ecosystems all over the Europe. While loads from point sources, such as industrial plants and municipal waste water treatment plants, have considerably decreased, progress in agriculture has been negligible. Despite all efforts and policies devoted to agriculture, it remains the biggest source of water pollution, for instance, in the Baltic Sea or the Chesapeake Bay (HELCOM 2007; Iho et al. 2015). The difficulty of reducing agricultural nutrient loads is an outcome of many factors. Agriculture is a nonpoint source polluter, subject to stochastic weather and growing conditions. Conventional economic or regulatory instruments targeting directly loading cannot be applied. Feasible instruments for nonpoint sources are second-best targeting those inputs that may affect loading (Griffin and Bromley 1982; Shortle and Dunn 1986). Furthermore, there are currently no efficient and affordable measures in agriculture to reduce nutrient runoff and leaching from the fields.

New and efficient measures for agricultural nutrient loads are needed. One such new measure is to use gypsum ($CaSO_4 \cdot 2H_2O$) to reduce phosphorus release from fields. Gypsum has been used to improve soils already by ancient Greeks but its use to improve water quality is of recent origin. An early small-scale pilot in Finland showed that gypsum can reduce phosphorus loads to surface waters almost by 50%: more importantly, it reduces both particulate phosphorus (57%) and dissolved reactive phosphorus (27%) loads (Ekholm et al. 2012). When spread on arable fields, gypsum increases ionic strength of soil, creates larger aggregates of soil particles and calcium bridges, which decrease phosphorus release to waterways. These changes improve soil structure, reduce erosion and yet phosphorus remains available for crops. Therefore, previous studies report no yield penalty (e.g. Uusitalo et al. 2010).

Availability of measures is not enough, since introducing new measures requires acceptance among farmers, social acceptance from all other stakeholders, and experimental field work that fits the novel measure to the ordinary cultivation practices. Thus, an innovation phase is needed to root the new measure firmly and efficiently to cultivation. Most importantly, both farmers and other stakeholders must witness that positive impacts really take place in aquatic systems and ascertain that no negative environmental side effects takes place. In case of gypsum, these refer to improved water clarity due to reduced phosphorus release and the lack of any harm to aquatic biota caused by a temporary increase in sulphates in waterways.

This paper builds on a large-scale pilot organized in 2016 to develop the gypsum treatment of fields to reduce phosphorous loads. The aims were to examine logistic feasibility, required cultivation practices and social acceptance of a large-scale of gypsum treatment (http://blogs.helsinki.fi/save-kipsihanke/?lang=en). The pilot consists of 55 participating farmers with 1550 field hectares in the catchment area of the River Savijoki discharging into Archipelago Sea, which suffers from severe nutrient enrichment and eutrophication. We examine the gypsum treatment of fields as an eco-innovation, following the OECD definition of an eco-innovation as an innovation that "results in a reduction of environmental impact, no matter whether or not that effect is intended" (OECD 2010:15). We focus on the motives of farmers to participate in fine tuning the new concept, and narrow our approach closer to the concept of user innovation. The concept has been applied to development of products and services in various domains (see e.g. Stock et al. 2015, von Hippel 1998).

Typical features of innovation in agriculture comprise, in general, innovative changes in products or production processes and novel technologies or farm practices as well as acquisition of knowledge (Läpple et al. 2015), aiming at improving efficiency, skills, and products. Previous literature on user innovations has confirmed various motivations to participate in innovation activity, including benefits derived from the use of the product, skill improvements, learning, fun, and innovation task itself. Furthermore, social conduct may be present in the form of helping others, or improving the own or the industry's reputation. The review of Stock et al. (2015) and the references there-in provide an overview of the applications of user innovation concept over several domains. Regarding co-creation, the extrinsic and intrinsic motivations were evidenced. The extrinsic motivations relate to the compensation received from participation, the expected product-related benefits, and the reciprocation and social recognition. The expected benefits of gypsum treatment of arable fields relate to the positive impact of gypsum on soil structure and nutrients (phosphorous, sulphur) for crops.

In the gypsum pilot, the farmers provide and apply their agronomic know-how to relevant work phases, including delivery and storage of gypsum, internal carriage on the farm, spreading gypsum to fields, and scheduling with other work in fields. In this paper we ask: What are the motives of farmers to participate in the gypsum innovation project? Is it possible to identify different groups among participating farmers by using their announced motives? What can be learnt from the pilot concerning a large-scale extension of the innovation?

While previous empirical literature provides a starting point for the study, we also root our empirical work in a formal analysis of farmers' behavior. We develop a series of models to describe alternative preferences farmers may exhibit, and examine analytically their cultivation choices and conditions to participate in the pilot. Our model allows farmers to have three motivational identities: to be profit maximizers, to derive utility from innovating new cultivation practices or to have stewardship attitudes towards environment. Drawing on the theory we derive behavioral hypotheses and test the presence of the motives with a survey data on a pattern of attitudinal statements with confirmatory factor analysis. The individual scores produced measure the extent of which each farmer exhibits each of three motivations. We use statistical tests to compare the motivational profiles generated in terms of farm and farmer characteristics, land allocated to gypsum treatment, and attitudes and concerns regarding the gypsum pilot.

Our study contributes to the literature in two ways. First, we provide a formal approach for the examination of participation in a user innovation, and second, we tailor our results to answer the questions concerning how to incentivize farmers to adopt new environmentally friendly innovations. Identifying farmer decision making styles and related motivations to test and apply a new cultivation technique helps to plan how to effectively spread the gypsum treatment of fields to the southern Finland, to reduce to phosphorous loss to the Baltic Sea.

The rest of the paper is structured as follows. Section 2 develops a theoretical model to analyze theoretical underpinnings of the agricultural producer's use of inputs to produce agricultural market outputs and their private and public motivations to participate in developing an eco-innovation, and derives testable behavioral hypotheses. Section 3 presents the acquisition and description of empirical data utilized in section 4 to identify the motivational profiles, to test hypotheses on farmer motivations, and to explore the characteristics of farmer segments. Section 5 discusses and concludes.

2 A model of user innovation under alternative preferences

We develop a theoretical model of crop production, which facilitates an analysis of multiple farmer motives including innovation (such as developing gypsum treatment of fields) and stewardship attitudes (water quality).

2.1 The set-up

Consider a risk-neutral farmer participating in a pilot. Let l denote a conventional productive input, such as fertilizer input. Denote the expected yield from fertilizing a given field parcel by $Y = f(l)$. When participating in a gypsum pilot the farmer spreads a fixed amount of gypsum (denoted by $\bar{k}$) in the field parcel. Gypsum contains small amounts of phosphorus and sulphur, which both may increase crop growth. In addition, gypsum improves soil structure promoting cultivation. Suppose that the farmer takes an innovation effort (e) to develop the spreading machinery, its use and the best timing of spreading to ensure that gypsum provides the best possible improvement of the soil structure and reduction of phosphorus release. The expected crop yield when gypsum is applied is $Y = f\big(l, \bar{k}(e)\big)$. Drawing on previous empirical findings (e.g. Uusitalo et al. 2010), no yield penalty takes place but sometimes yields may increase. Hence, the participating farmer should expect that $f\big(l, \bar{k}(e)\big) \geq f(l)$. We assume conventionally that $f_l > 0$ but $f_{ll} < 0$. For the innovation effort we assume that $\overline{k'}(e) > 0$ and $\bar{k}''(e) < 0$. Even though gypsum is applied in a fixed amount, the skills of spreading gypsum affect how it impacts yields, thus we have $f_{\bar{k}}\bar{k}'(e) \geq 0$.

Let p denote the crop price, c the price of the input and let the other cultivation cost be $M(e) = K + \varphi(e)$. K is constant per field parcel and denotes costs from seeds, machinery, field work time, and related costs. Innovation takes time and may incur other costs as well. It is denoted by $\varphi(e)$. We assume convex costs in the effort ($M'(e) > 0$ and $M''(e) > 0$). Thus, the revenue from cultivation is $\pi = p\, f\big(l, \bar{k}(e)\big) - cl - M(e)$ providing the objective function of a profit-maximizing farmer.

Turning to alternative objective functions, we first introduce stewardship attitudes towards the nature assuming that the farmer's preferences are linear in revenue but concave in the environmental attributes (for the literature on stewardship motives, see Lichtenberg 2002 and references therein). Here we assume that farmers may value water quality and, therefore, derive utility from reduced nutrient release. Nutrient release (z) from fields is a function of fertilizer application and gypsum spreading, $z = z(l, \bar{k}(e))$ with $z_l > 0$ and $z_{\bar{k}} < 0$. The preferences of the farmer can now be expressed as $u = u\big(z(l, \bar{k}(e))\big)$ with $u_z < 0$ indicating that marginal utility from nutrient release is negative. Note that even though a farmer may value water quality, this valuation does not equal the social valuation of clean environment but is rather connected to improvement of environmental-friendly agricultural practices. As a second option, we allow for a case, where the farmer derives utility from innovation beyond ordinary direct economic profits or other extrinsic drivers. Thus, we let the innovation effort enter the utility function as a separate argument: as $u = u\left(z\left(l, \bar{k}(e)\right), e\right)$ and assume that $u_e > 0$ and $u_{ee} < 0$.

Finally, in order to facilitate separating all possible motives, we introduce dummy variables α_i, ε_i, and σ_i, obtaining either value of 1 or zero; they multiply the utility function and its arguments. Under these assumptions we obtain the following quasi-linear objective function containing several possible types of farmers.

$$V = pf\left(l, \bar{k}(e)\right) - cl - M(e) + \alpha_i u\left(\varepsilon_i z\left(l, \bar{k}(e)\right); \sigma_i e\right) \tag{1}$$

Choosing the values of dummy variables allows us to identify the farmers' key motives for participation in the development of environmental innovation and to examine how their preferences show up in their choices. Note also that assumptions made above on production and utility and cost functions guarantee that the second-order conditions will hold for all farmers' optimization problems and will be omitted in what follows.

2.2 Participation and production choice of farmers with differing motives

Consider now a farmer deciding whether or not to participate in the gypsum pilot. Assume that the compensation payment, A, covers all costs of gypsum application. To make the participation decision, the farmer must compare the value of his/her objective function under participation to that under no participation. The compensation requirement, choice of inputs and the maximum values of the objective function serve as the source of behavioral hypotheses for the empirical analysis.

Profit maximizing farmer

We start working on equation (1) by setting $\alpha_i = 0$. The last term vanishes yielding the case of a profit maximizing farmer. The farmer chooses the use of inputs (fertilizer and innovation effort) so as to maximize the profits from crop production: $\pi = p\, f\big(l, \bar{k}(e)\big) - cl - M(e)$. The first-order conditions are given by

$$\pi_l = pf_l - c = 0 \tag{2a}$$

$$\pi_e = pf_{\bar{k}}\bar{k}'(e) - \varphi'(e) = 0 \qquad (2b)$$

Economic interpretation of (2a) is conventional: the value of marginal product of the input equal its unit price. By equation (2b) the profit maximizing farmer increases his/her innovation effort up to the point where the marginal increase in yield equals the marginal cost of the effort. Plugging the optimal values of the productive input and innovation effort (denoted by $l*$ and $e*$) to the profit function gives the indirect profit function, which indicates the maximum profits under exogenous variables. Let π^0 denote farmer's profit when not participating in the innovation pilot. Then, the minimum compensation required for the participation is defined by $\pi^*(l^*, e^*) + A \geq \pi^0$, that is, the compensation must make profits at least equal to those when not participating in the innovation pilot. This compensation requirement depends only on prices, costs and crop yield.

Innovating farmer

We set next $\alpha_i = 1$, $\varepsilon_i = 0$ and $\sigma_i = 1$ to produce the objective function of an innovating farmer who derives utility from innovation beyond profits but does not have preferences towards the environment. For notational convenience, we denote the target function of this farmer by small v.

$$v = pf\left(l, \bar{k}(e)\right) - cl - M(e) + u(e). \qquad (3)$$

The farmer chooses l and e so as to maximize the quasi-linear utility function:

$$v_l = pf_l - c = 0 \qquad (4a)$$

$$v_e = pf_{\bar{k}}\bar{k}'(e) - \varphi'(e) + u'(e) = 0 \qquad (4b)$$

The first-order condition of the productive input is qualitatively the same as before but the choice of innovation effort is different. In addition to marginal revenue, innovation effort provides also positive marginal utility from innovating. Consequently, the effort increases relative to the profit maximizing case. Let $l**$ and $e**$ denote the optimal levels of inputs. Plugging them back to the objective function defines the indirect utility function, again, indicating its maximum value subject to exogenous variables. The innovating farmer participates in the pilot if $v^*(l^{**}, e^{**}) + A \geq v^0$, where v^0 denotes utility when staying outside the pilot. For the revenue from crop production we have that $\pi^*(l^{**}, e^{**}) < \pi^*(l^*, e^*)$ indicating that relative to the profit maximizing farmer, an innovative farmer has lower revenue. Thus, this farmer would require a smaller compensation for participation than profit maximizing farmer. Moreover, given that the preferences of the innovating farmer impact cultivation choices, also socio-economic variables, such as education and experience, count for the participation decisions.

Farmer with stewardship attitudes

We set next $\alpha_i = 1$, $\varepsilon_i = 1$ and $\sigma_i = 0$ to produce an objective function for a farmer who has stewardship attitudes towards the environment. The quasi-linear target function of the farmer is

$$V = pf\left(l, \bar{k}(e)\right) cl - M(e) + u(z(l, k(e))). \qquad (5)$$

The choice of inputs produces the following first-order conditions for the optimum:

$$V_l = pf_l - c - u_z z_l = 0 \tag{6a}$$

$$V_e = pf_{\bar{k}}\bar{k}'(e) - \varphi'(e) - u_z z_{\bar{k}}\bar{k}'(e) = 0 \tag{6b}$$

By equation (6a), when choosing the polluting productive input farmer experiences negative marginal utility from decreased water quality due to runoff. Hence, the farmer equates the value of the marginal product to the sum of the input cost and the negative marginal utility. Accounting for the negative environmental impacts decreases the optimal use of fertilizer relative to previous cases. Innovation effort produces positive marginal utility especially from improved water quality, thus innovation effort is higher than in the case of profit maximizing farmer. Comparison to the case of an innovative farmer depends on the size of the marginal utility from innovating relative to that from improving water quality, thus, the outcome of comparison is ambiguous. Denoting the optimal choice of inputs by triple stars, the participation condition can be expressed as $V^*(l^{***}, e^{***}) + A \geq V^0$. In terms of revenue from cultivation, we have $\pi^*(l^{***}, e^{***}) < \pi^*(l^*, e^*)$. Thus, a farmer with stewardship attitudes would require a smaller compensation for participation than profit maximizing farmer. This happens because environmental preferences, in this case notably, improving local state of water is given certain priority. .[1]

3 Empirical testing

3.1 Behavioral hypotheses

The choices of three farmer types of the theoretical setting provide identifiable hypotheses for the empirical examination of participants of the gypsum pilot. The first hypothesis and the basic condition for all further analysis is the following:

H1a. *All three motivational types of farmers can be identified among farmers participating in the development of the gypsum treatment and can be used to group the respondents*.

The second set of hypotheses relates to motivational variables of the farmers' participation. The analytical model suggests pivotal differences between farmers. Farmers maximizing profits are keen to economic variables, such as the size of compensation, costs of spreading, and possible impacts of an introduction of a new agri-environmental measure on existing subsidies. They do not care of environmental issues or the innovation beyond economic benefits. Participation in the eco-innovation pilot is rational on economic grounds. Thus, we can state:

H2a. *Only economic variables count for the participation of a profit maximizing farmer*.

In contrast to H2a, preferences on innovation count for the innovating farmer. Aspects that play a role for an innovating farmer include an ambition to increase own professional competence and possibly willingness to serve the whole agricultural sector, including the local agricultural society. Even though in this case the innovation relates also to the environmental improvement, farmers with

[1] Note also that by setting $\alpha_i = 1, \varepsilon_i = 1$ and $\sigma_i = 1$ produces an objective function of a farmer who exhibits both stewardship attitudes towards nature and derives utility from innovation beyond its monetary benefits. Our analysis comprises, however, these aspects, and there is no need to elaborate this case further.

innovation motivations see the environment instrumental for the innovation process itself. Beside the motivation to participate in innovation, the ability to develop new agricultural practices needs sufficient skills. Regarding their personal characteristics, innovating farmers have education and experience, both/either in terms of age or years in agricultural sector. Thus, we expect education, experience in field work, and potentially age to be connected to innovation motivation to participate. We can formulate the hypothesis as follows:

H2b: *Innovating farmers promote the agricultural production efficiency beyond current technological competence to improve professional competence and to serve the whole agricultural sector and local agricultural community*.

Finally, for the farmer who has stewardship attitudes towards nature, preferences for environment count. For this farmer, the impact of own contribution and ability to improve the local environment and the social acceptability of agriculture are essential as the motivation to participate in the development process. Environmental motivation gives a further boost for promoting eco-innovation. Also we expect that these farmers have a keen interest on water protection issues and give less emphasis on revenues.

H2c: *Farmers with stewardship attitudes towards nature focus on the impact of own contribution on the environment, promoting environmentally friendly technologies, and improving the reputation of agricultural sector.*

3.2 Farmer survey

As an empirical setting to test the hypotheses serves a large-scale pilot project in which gypsum is spread on fields located in the catchment area of the river flowing into the sea. The invitation process to participate in the pilot included several rounds of phone calls targeted to all farmers who own fields in the study area and an information event for potential participants. As a result, 60% of active farmers in the area took part in the pilot, the major reason for non-participation being the lack of suitable fields for gypsum treatment. Targeted to the pilot participants, the survey questionnaire was designed during autumn 2016 in co-operation with experts in agricultural sector. The survey structure and wording were tested during several rounds by selected farmers (both pilot participants and non-participants) in order to ensure the respondent comprehension and the shared interpretation of terminology by researchers and respondents. Based on feedback, the details were modified. The questionnaire is available from the authors by request.

The core of the survey was the set of drivers for participation in the pilot presented to the respondents. It was guided, on one hand, by the behavioral implications based on theoretical analysis on profit-maximizing, innovation, and environmental stewardship motivations, and, on the other hand, by previous empirical studies on the motivations to participate in user innovation and co-creation projects. The pattern of 15 motivational statements to be assessed subject to their importance for participating in developing the gypsum concept follow a 7-point Likert scale (Likert 1932) from “Not at all important” to “Very important”.

The questionnaire also inquired cultivation practices performed in the catchment area and the farmer’s perceptions and characteristics. As to cultivation practices, the respondents were asked to report the areas under alternative cultivation technologies, such as ploughing, reduced tillage, and no-tillage, and the field areas addressed to cultivated crops. These were reported separately on the farm level, for the catchment area, and for the gypsum treated area, and a detailed map was provided in the questionnaire to help farmers to provide correct answers. The attitudinal statements, to be assessed with a 7-point Likert scale from “Totally disagree” to “Totally agree”, covered the acceptability of gypsum as a water protection measure and the reflection of cultivation practices applied on the farm subject to water protection. For the concerns regarding the gypsum pilot, the scale from “Not at all” to “A lot” was applied. The inquired respondent characteristics were age, education, and years of experience in agricultural sector as well as the pre-pilot awareness of the gypsum as a measure for water protection, the enrollment to the current agri-environmental scheme, the plans to continue farming in the future, and the share of agricultural income out of the household income.

The data were collected with a mixed-mode survey conducted between December 2016 and February 2017. Multiple formats (on-line platform, mail surveys, and phone interviews) were applied in order to acquire as many responses as possible out of the 53 farmers recruited to the pilot, to guarantee the reliability of the statistical analysis. The invitation to participate in a survey by email and mail was followed by the maximum of four reminders by either email of telephone. The data collection resulted in 47 eligible responses, corresponding to 88.7% of the participants and 91.6% of the gypsum treatment area (1430 out of 1540 hectares). Permitted by a reasonable response rate we refer by the term participants to survey respondents in further analysis.

3.3 Data

Table 1 describes the survey data (n=47) on pilot participants and the corresponding information available for the county of Varsinais-Suomi (Statistics Finland 2015) to assess the generalizability of the results to the larger population. Concerning variables for which information on the county level are lacking, the sample statistics is compared to the country statistics.

In terms of the total field area, the participating farms are, on average, larger (112.4 hectares) than farms in the county of Varsinais-Suomi (53.1 hectares). The sample-average share of leased field area per farm out of the total field area (30.1%) corresponds to that of the county-average (32.0%). The total field area of participating farms ranges from 8.4 to 985 hectares and the share of leased field from 0 to 91%. The most common production line is crop production (85.1%) and the amount of cultivated crops ranges from 1 to 12. The majority of farms (89.6%) participate in the Finnish Agri-Environmental Programme, corresponding reasonably well to the Finnish average of 86% (Finnish agricultural and… 2017). The most common cultivation practice is ploughing for a half of the farms, followed by reduced tillage (40.0%) and no-tillage (10.0%).

The age of participants is on average 52.0 years, representing well the average age of farmers in the county (51 years). The average length of experience in agricultural sector is 27.6 years. One fourth of participants (25.5%) report no agricultural education, and none has a university degree in agriculture. A majority of participants (73.2%) plan to continue farming at least for the next 6 years. Compared to a nationwide survey on the future plans of Finnish farmers (n=4417) in which 46.5% of interviewees reported plans to continue for at least six years (TNSGallup 2016), the sample exhibits the farms with higher probability to continue farming activities in short-term future. Around one fourth of respondents report that agricultural income covers at least 75% of the household income, thus representing the full-time farmers. Moreover, for more than every second farmer (53.2%), agricultural income covers at least 50% of household income. The official statistics on the farm income formation report much smaller average shares of agricultural income out of household income in the county of Varsinais-Suomi (30.6%) and in Finland (34.6%) (OSF 2015).

Table 1. Descriptive statistics of the sample and the county of Varsinais-Suomi.

	Sample (n=47)			County (n=4536)
	Min	Max	Mean	Mean
Farm characteristics				
Total field area of farm (mean, hectares)			112.4	53.1
Share of leased field area (%)			30.4 %	32.0 %
Crop production (%)	na	na	85.1 %	na
Participation in agri-environmental programme (%)	na	na	89.6 %	na
Main cultivation practice: autumn ploughing			50.0 %	na
Main cultivation practice: reduced tillage			40.0 %	na
Main cultivation practice: no-tillage			10.0 %	na
Farmer characteristics				
Age (yrs, mean)			52.0	51
Age group < 35 years (%)	na	na	6.4 %	8.2 %
Age group 35-49 years (%)	na	na	34.0 %	33.8 %
Age group 50-64 years (%)	na	na	44.7 %	46.0 %
Age group > 65 years (%)	na	na	14.9 %	12.0 %
Experience in agriculture (yrs, mean)			27.6	na
Agricultural education: none (%)	na	na	25.5 %	na
Plans to continue farming at least 6 yrs (%)	na	na	73.2 %	na
Share of agricultural income: >75% (%)	na	na	25.5 %	na
Share of agricultural income: 50-74% (%)	na	na	27.7 %	na
Share of agricultural income: 25-49% (%)	na	na	14.9 %	na
Share of agricultural income: < 25% (%)	na	na	31.9 %	na
Share of agricultural income of household income (%)	na	na	na	30.6 %

4 Farmers' preferences and motivations to participate in developing eco-innovation

4.1 Extraction of motivational factors

Rooted in theoretical analysis of farmer behavior in section 2.2, the confirmatory factor analysis tests the hypothesis H1 on the presence of three motives among the pilot participants. The answers to the fifteen original statements are reduced to three factors representing the profit-maximization motivation (Profit), innovation motivation (Innovation), and motivation based on stewardship attitudes towards environment (Environment). The Principal Components Analysis and Varimax Rotation with Kaiser normalization is carried out with software package SPSS 24. All three factors imply eigen values larger than one and explain 68.3% of all variation. To ease the interpretation of results and the assessment of validity of factors in relation to theoretical expectations, table 2 reports the factor loadings larger than 0.3. The statements are assigned to the factor for which they have the highest loading.

Table 2. Behavioral factors extracted from 15 motivational statements.

	Factors		
Original motivational statements	**Profit**	**Innovation**	**Environment**
I also get the sulphur fertilization to my fields.	**,835**		
I believe that I benefit from the gypsum's impact on soil condition.	**,831**		
I feel it my duty to participate in the gypsum pilot.	**,603**		,369
I get a monetary compensation from the work related to gypsum pilot.	**,578**	,321	-,321
I want to impact on how the gypsum spreading is implemented in the future.		**,804**	
I want to act as a forerunner in testing a new methodology.		**,701**	,376
I want to share my expertise and experiences as a farmer.	,394	**,682**	
Gypsum pilot is a welcomed change to my work as a farmer.	,489	**,587**	
Experience from gypsum pilot improves my agronomic skills.	,506	**,514**	,323
Gypsum pilot can reduce nutrient load into local water bodies.			**,883**
Gypsum pilot gives a possibility to support the protection of the Baltic Sea.			**,819**
I'm curious about the impacts of gypsum treatment.		,457	**,707**
I want to improve environmental reputation of Finnish agricultural sector.		,517	**,693**
By testing a new technology, I want to strenghten the Finnish agricultural sector.	,419	,360	**,649**
I want to support research of new water protection measures.		,486	**,584**

To the first behavioral factor (Profit) are assigned the statements reflecting the direct and indirect benefits of gypsum treatment of fields. The statements that load highest to this factor relate to the contribution of gypsum to sulphur fertilization and improvement of soil structure, followed by the perception that participating in the development of new agricultural practices is one’s professional duty. Interestingly, the sense of duty also loads relatively highly to the factor that reflects stewardship attitude towards nature (Environment). While the monetary compensation paid to participants for work related to spreading gypsum loads highest to the Profit motivation, it loads relatively highly to the Innovation motivation, and negatively to the Environment motivation.

The highest loading to the second factor (Innovation), comes from the statement concerning the farmer’s willingness to impact, by developing gypsum treatment and equipment, on the way the gypsum treatment of fields will be organized in the future. The next highest loadings to the Innovation motivation relate to willingness to be a forerunner of a new cultivation technology and to sharing one’s expertise and experience. Moreover, experiencing the gypsum pilot as a welcomed change to the everyday work and valuing the experience obtained as a way to improve one’s professional skills load highest to the Innovation motivation. The statement related to the future implementation of the gypsum treatment of fields is the only one that loads solely to the Innovation motivation. The statements reflecting one’s professional identity as a farmer (as an active member in the farmer society, openness to new activities in everyday work, and professional development) load also relatively highly to Profit factor. Although being a forerunner and improving one’s skills loads highest to Innovation, it connects relatively highly also to the Environment motivation.

Regarding the third factor (Environment), the statements with the highest loading relate to the contribution of the gypsum treatment to the quality improvement of local waters and the Baltic Sea. It makes sense that these water-related statements are connected solely to the Environment motivation. The curiosity for the impacts of gypsum loads highest to this factor but also relatively highly to the Innovation factor together with the willingness to improve the environmental reputation of agriculture and to support the research of new water protection measures. The statement concerning strengthening the Finnish agricultural sector by participating in the gypsum pilot loads relatively highly to all three factors (highest to the Environment motivation), reflecting the importance of innovations for profit maximization and reducing environmental effects.

The confirmatory factor analysis of the assignment of motivational statements to three behavioral factors confirms the theoretical expectation on the presence of three motivations in the sample of participants of the gypsum pilot. The interpretation of factors makes sense in terms of pre-determined motivation statements, following the theoretical expectations and thus confirming the hypotheses H2a-H2c presented in section 2.3.

Given the sample size of 47, we performed a robustness test of the assignment of statements to these extracted factors. In order to ensure the analysis free from reliability issues, the re-exploration of the assignment of the statements to factors based on the highest factor loads was based on random exclusion of one respondent at a time. The results of 12 random tests were compared to the original factor extraction presented in table 2. In one case, 7 out of 15 statements were re-assigned resulting in hardly interpretative motivational factors. Three cases were subject to the shift of one statement between motivational factors. In more detail, the statement “I want to support research of new water protection measures” shifted from Environment to Innovation in one case and “The experience from gypsum pilot improves my agronomic skills” shifted from Innovation to Profit in two cases. Both shifts make interpretable sense. Since two thirds of random tests resulted in identical result with the original factor extraction, we conclude that the result is robust enough for further analysis of the appearance of motivations in the sample.

4.2 Land allocation, perceptions and concerns regarding gypsum treatment

Table 3 presents the survey results regarding the land allocation to the gypsum treatment and the related attitudes and concerns. While every farm with parcels located in the study area in the catchment of the River Savijoki was invited in the gypsum pilot, their potential to supply fields to the gypsum treatment vary due to two conditions. First, only those parcels of the farms that are located in the pilot area are in principle eligible for gypsum treatment. On average, this is 57.6% of the farm’s field area, ranging from 2 to 100 percentages. Second, the parcels located in the pilot area are in practice eligible for gypsum treatment provided that they have valid agronomic conditions, that is, a cation equilibrium (based on the ratios of selected minerals) of soil favorable for the use of gypsum. Out of the hectares eligible for the gypsum treatment, the average share assigned by farm is 73.7%. Measured in hectares, the average gypsum treatment area per farm is 30.0, ranging from 3.4 to 304.4. As to cultivation methods applied in the gypsum treatment area, every second (51.5%) participant report that the gypsum treated area was ploughed after treatment in autumn 2016, while every third (36.5%) farmer cultivated the area with reduced tillage, and every tenth (11.9%) farmer with no-tillage.

More than every second participant (64.6%) reports knowledge about the role of gypsum as water protection measure prior the invitation phase of the gypsum pilot. The majority of pilot participants believe that the local people sympathize the gypsum treatment (72.3%) and only roughly every fourth participant (27.7%) is suspicious about other farmers’ willingness to adopt the gypsum treatment as part of the agri-environmental support scheme. These figures suggest rather large potential for the social acceptability of the gypsum concept among stakeholders. Surprisingly, only every second participant (57.4%) accepts the statement suggesting that the gypsum treatment of fields is an easy method for water protection. Moreover, almost two thirds (63.8%) of participants require more experience on the use of gypsum before they find its use reliable in water protection. For all technical uncertainties present during the first year of pilot, a promise of the gypsum treatment as a new environmental measure is reflected by large confidence both in the ability of gypsum to reduce phosphorous load, being questioned by only every fifth participant (19.1%). Furthermore, only 17 % express concern for negative effects of gypsum on nature. Three out of five participants (59.6%) express no concerns about the impacts of gypsum on the productivity or condition of soil; farmers obviously are well aware of the use of gypsum as a soil amendment measure

Table 3. Descriptives of participation in gypsum treatment and related attitudes (n=47)

Gypsum treated field area	
Share field area in Savijoki catchment	57.6 %
Share gypsum area of field area in Savijoki catchment	73.7 %
Gypsum treatment area (mean, hectares)	30.0
Share gypsum area of field area	42.3 %
Cultivation method in gypsum area: ploughed	51.5 %
Cultivation method in gypsum area: reduced tillage	36.5 %
Cultivation method in gypsum area: no-tillage	11.9 %
Attitudinal statements	**Agreement**
Previous knowledge on gypsum: know someone, heard, read (%)	64.6 %
In my opinion, local people have a positive attitude towards gypsum treatment.	72.3 %
I don't believe that farmers elsewhere in Finland would use gypsum treatment as part of Finnish agri-environmental scheme.	27.7 %
I think gypsum treatment is an easy method for water conservation.	57.4 %
I don't believe gypsum treatment reduces nutrient loading signicantly.	19.1 %
I need more experience in gypsum treatment as a conservation method before being able to use it reliably.	63.8 %
I am worried about the effects of gypsum on nature.	17.0 %
I am not worried about the impacts of gypsum on productivity and condition of my fields.	59.6 %
In my perception, my agricultural methods impact water system and the Baltic Sea.	57.4 %
I often try new agricultural methods.	38.3 %
I feel rewarding to share my ideas.	38.3 %
I have adviced other farmers concerning the spreading of gypsum or in other pilot stages.	31.9 %
I have received useful information from other farmers about their experiences on spreading gypsum.	38.3 %
I would be able to advice other farmers how to use gypsum.	36.2 %
I'm proud of participating in this experiment.	40.4 %
Concerns regarding gypsum pilot	
Concerns: costs that won't be covered	68.1 %
Concerns: funding for traditional conservation measures decreases	63.8 %
Concerns: gypsum hardens the soil	51.1 %
Concerns: smaller yield because of gypsum	48.9 %

The scale for attitudes ranged from "Totally disagree" to "Totally agree". The scale for concerns ranged from "Not at all" to " A lot". The shares reflect the agreement with statements by showing the summed proportion of three upmost categories out of seven.

More than a half of respondents (57.4%) acknowledge that their agricultural methods impact water system and the Baltic Sea, and around one third (38.3%) expresses openness towards new technologies or sharing one's ideas. Around every third participant had advised (31.9%) other farmers or received useful information from them (38.3%) during the pilot. While this measures co-operation of innovation developers, a measure of knowledge acquisition during the pilot project expresses that every third participant (36.2%) declare self-assessed confidence in one's skills on gypsum treatment of fields. Importantly, more than a half (40.4%) of farmers declare feeling proud of participating. On average, the pilot participants are more often concerned on the cost related issues than effects of gypsum on soil and yield.

4.3 Exploration of motivations

To provide insight for developing a strategy to persuade farmers with different characteristics to use gypsum, we perform statistical tests to explore the dependencies between the strengths of three motivations to participate in the gypsum pilot (table 2) and the background variables (in tables 1 and 3). Farmer-specific factor scores, one for each farmer for each motivation (profit-maximization, innovation, and environment), reflect the strength of motivations exhibited by the farmer, relative to all other farmers in the sample. Negative values indicate a relatively weak motivation and positive values indicate a relatively strong motivation. Converting positive scores into one and negative scores into zero produces a dichotomous variable which facilitates a statistical comparison of farmers with relatively strong and relatively weak motivations. The cross tabulation and the Fisher's exact test was used for categorical background variables and the non-parametric Mann-Whitney U-test for continuous background variables in SPSS 24. Table 4 collects, for all three motivations, statistically significant differences when shifting from a weak to a strong motivation with respect to farmer and farm characteristics, gypsum treated field area, and attitudes and concerns on gypsum treatment of fields.

First, the farmers with a strong profit motivation are younger, participate more often in the Finnish agri-environmental scheme, and have more often agricultural education than farmers with a weak profit motivation. While the latter applies also to farmers with a strong innovation motivation, in comparison to a weak innovation motivation, quite surprising is that agricultural education plays no role for the strength of environmental motivation. Instead, farmers with a strong environmental motivation for testing the gypsum treatment of fields have smaller shares of leased field area and are less often fulltime farmers and more often crop producers.

Second, the strongly profit-motivated farmers have larger shares of farm's field and gypsum treated area in the catchment area. In contrast, the farmers with a strong innovation motivation have a smaller share of their field area in the catchment area and of the gypsum treatment area out of the total field area, in comparison to the participants with a weak innovation motivation. Finally, in comparison to farmers with a weak environmental motivation, participants with a strong environmental motivation more often cultivate the gypsum treated area with no-till technology and have a larger share of field area in the catchment area, resembling, with respect to the latter, farmers having a strong profit motivation to participate in the gypsum pilot.

Third, the strength of motivations relates statistically significantly to attitudinal variation among the participants. Compared to farmers with a weak profit motivation, participants with a strong profit motivation more often report the perceptions that local people have positive attitude towards gypsum application to fields and that gypsum treatment is an easy method for water conservation. The participants with a strong environmental motivation are more often confident with the ability of gypsum in reducing nutrients but demand more often additional experience in the gypsum treatment before being able to use it reliably.

Fourth, the farmers who exhibit a strong innovation or environmental motivation agree more often with the statement that their agricultural methods impact the adjacent water system in comparison to farmers having a weak innovation or environmental motivation. In addition to this indication for the importance of eco-innovation, the agreement with a set of statements, described below, is statistically significantly correlated with strong innovation motivation. These statements include the keenness to try new agricultural methods, the feeling of sharing one's ideas rewarding, and having advised other farmers in the stages of the gypsum pilot. As for knowledge sharing, the farmers with a strong profit or innovation motivation have received more often useful information from their colleagues' experiences on spreading gypsum. Two statements, regarding which the strong and weak extents of all motivations differ statistically significantly from each other, include the ability to advice other farmers in the use of gypsum and being proud of participation in the pilot project.

Fifth, regarding the concerns on gypsum treatment of fields, farmers with a strong innovation motivation are more often very concerned on that only part of costs induced by the gypsum pilot will actually be covered, in comparison to those with a weak innovation motivation. This may relate especially to the costs of innovation effort, which typically is an invisible item. Farmers with a strong profit motivation are more often less concerned on the effect of gypsum treatment on the productivity and condition of their fields, which is natural as they maximize revenue from cultivation.

Table 4. Predictors of appearance of motivations to participate.

	Profit	Innovation	Environment
Farm characteristics			
Total field area (ha)			-
Share of leased field area			--
Crop production (%)			++
Participation in agri-environmental programme (%)	+		
Farmer characteristics			
Age (yrs, mean)	-		
Agricultural education (%)	+++	++	
Fulltime farmer: share of agricultural income >75% (%)			---
Gypsum treated field area			
Share field area in Savijoki catchment	+	--	++
Share gypsum area of field area in Savijoki catchment	++		
Gypsum area (ha)	++		
Share gypsum area of field area	++	--	
Cultivation method: no-tillage			+
Attitudinal statements			
In my opinion, local people have a positive attitude towards gypsum treatment.	++		
I think gypsum treatment is an easy method for water conservation.	+++		+
I don't believe gypsum treatment reduces nutrient loading signicantly.			---
I need more experience in gypsum treatment as a conservation method before being able to use it reliably.			+++
In my perception, my agricultural methods impact water system and the Baltic Sea.		+++	++
I often try new agricultural methods.		+++	
I feel rewarding to share my ideas.		+++	
I have adviced other farmers concerning the spreading of gypsum or in other pilot stages.		++	
I have received useful information from other farmers about their experiences on spreading gypsum.	++	+	
I would be able to advice other farmers how to use gypsum.	++	++	+
I'm proud of participating in this experiment.	+++	++	+++
Concerns regarding gypsum pilot			
Concerns: costs that won't be covered		+	
Concerns: gypsum hardens soil	-		
I am not worried about the impacts of gypsum on productivity and condition of my fields.	+++		

+++/--- significant at 0.01 level, ++/-- at 0.05 level, +/- at 0.1 level

5 Discussion and conclusions

This paper examined the gypsum treatment of fields as an eco-innovation for agricultural water protection, utilizing the empirical survey of farmers from the pilot project, containing the total of 1550 hectares of arable fields. We developed a series of crop production models that describe alternative preferences of farmers to participate in developing and fine tuning gypsum treatment of fields as a water protection measure. We resorted to confirmatory factor analysis to examine the presence of three theory-driven motivations, namely, to maximize profit, to derive utility from developing new cultivation practices, or to have the stewardship attitudes towards environment. The empirical analysis validated the theoretical model. We then compared the group of farmers with relatively strong motivations to the group of farmers with weaker motivations using a simple one-by-one analysis of variables. Fisher’s exact test, applicable for small samples, provided as an appropriate tool for the comparison of distributions of dichotomous attitudinal variables, that is, the extent of agreement in terms of proportion of agreeing respondents. Based on findings, we elaborated a strategy to persuade farmers to apply new agricultural technology for water protection. The combination of theoretical qualitative analysis and empirical confirmatory factor analysis provides a novel approach in agricultural economics to study the farmers’ motivations to test and develop new technologies.

Our work contributes to understanding the introduction of a new technology providing environmental innovation. The user innovation setting makes the farmers active developers of agri-environmental measures, and gives the agricultural extension a role to inspire or provoke interest in new ways to perform one's profession. The pilot was organized precisely according to this fashion and in the spirit of co-development, where farmers' experience was used in all stages of the pilot. In the sample this shows up especially in the fact that more than 40% of farmers indicated to be proud of participating in the development of gypsum treatment concept. Furthermore, the agreement with the statement about feeling proud to be involved in the development project correlates strongly to all three studied motivations, that is, promoting environmental sustainability of agricultural sector and its reputation, and improving its economic performance and one's professional skills.

Our key findings can be condensed as follows. Farmers find gypsum treatment of fields beneficial because of multiple reasons: the water quality benefits created, the monetary compensation for participating in spreading the gypsum, and the improvement of soil structure and agricultural productivity as well as their professional competence. This is a promising news for the plans to use gypsum as a large-scale measure to reduce phosphorus loading: most farmers will find good individual grounds for their participation in water protection. The strength of motivations relates statistically significantly to attitudinal variation in the sample. For instance, compared to participants with a weak profit motivation, participants with a strong profit motivation more often report the perceptions that local people have positive attitude towards gypsum application to fields. A new technology offers an easy way to conserve adjacent waters, perceived especially by the farmers to whom profit-related issues matter in decision making, while the farmers with a strong environmental motivation call for more experience in the gypsum treatment before using gypsum reliably. The connection of strong innovation and strong environmental motivations to the perception of the impact of one's agricultural methods on the adjacent water system implies that the belief in one's capability to make choices that affect the environment is a key motivation to develop an environmental innovation.

Besides attitudes that are invisible in the population, the field areas and farmer characteristics provide more generalizable information for planning the large-scale spreading of gypsum. The farmers with a strong profit motivation have larger gypsum treatment potential and they allocate larger areas to the gypsum treatment. This implies that a strong profit motivation, involving private benefits of gypsum, may possibly lead to larger areas of gypsum application per farm. In contrast, the farmers with a strong innovation motivation have a smaller share of their field area of the gypsum treatment out of the total field area. This reflects the fact that, in the sample, some farms had only parts of their farms in the catchment area. But the interest to innovation activities made those farmers to take part in the development of new technology.

The closer exploration of variables and their correlations to farmers' motivations may serve as advice on which aspects to emphasize when bringing gypsum to a part of agri-environmental policies and persuading farmers to use it. Part-time crop producers who have relatively small farms may get inspired by the environmental motivation, i.e., the ideas of sustainable agricultural production and reduced eutrophication of adjacent waters. These farmers are currently applying environmentally friendly practices and understand that their technologies and practices affect the waters. In these small farms the area suitable for gypsum treatment is moderate. For larger farms who have large areas of suitable fields in the catchment area, the key issues are the private benefits from applying gypsum, such as improved soil structure and sulphur fertilization, and monetary compensation. Even for the farmers with minor areas of field in the catchment area, the novelty of gypsum treatment of field may serve an opportunity to develop one's professional skills.

The promise of gypsum treatment of fields as a new agri-environmental measure lies in its suitability to various types of farms and in its ability to provide a variety of benefits and to appeal to multiple motivations. Environmental programs that accrue private benefits or minimize the private costs have a greater probability of adoption by farmers, as noted, for instance, by Yu and Belcher (2011). Regarding motivations, however, further aspects must be highlighted. First, the presence of different motivations does not imply that they conflict with each other. As for the relative strength of motivations we found that even a weak motivation proves strong enough to generate participation in the pilot project. Modelling participants and non-participants in one could provide additional information for the prediction of the future application of new cultivation practices. Second, as the survey was conducted right after gypsum spreading, the farmers' opinions can be interpreted to provide tentative support for the potential for a gypsum treatment as a new agri-environmental measure. Recall, however, that roughly two thirds required for more experience on gypsum before its reliable use and every second participant state that gypsum is an easy method for water protection. Inspecting the opinions after one year's learning from actual observations on yield and water quality could reveal the development of the social acceptability of gypsum treatment over time.

Besides inspiring further analysis, this study provides valuable new information on the identification of farmer types and on the motivations tied with the decision to test a new cultivation technique. Indeed, the farmers are keen on developing the economic performance and environmental sustainability of agriculture, which needs strong economic, social, and environmental ground. The gypsum treatment of fields, considered as an investment to sustainable food production, provides an excellent example on how to internalize the promotion of environmental benefits to economic activities. The combined theoretical and empirical approach applied in the study can be recommended for analysis of user innovations in agricultural and other sectors, where the agents respond to environmental challenges. Further analysis aiming at predicting farmers' behavior and intended use of gypsum in the future is appealing from the viewpoint of estimating the future potential of the gypsum concept in the Baltic Sea area to reduce to phosphorous loss to the sea.

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