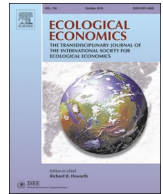




ELSEVIER

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecocon

Analysis

Drivers of Participation in Gypsum Treatment of Fields as an Innovation for Water Protection

Anna-Kaisa Kosenius*, Markku Ollikainen

Department of Economics and Management, FI-00014 University of Helsinki, P.O. Box 27, Finland

ARTICLE INFO

Keywords:

Agri-environmental policy
Baltic Sea
Gypsum application
Innovation
Water protection
Stewardship attitudes

ABSTRACT

This paper examines the motivations of participants in a large-scale pilot project that aims at developing a new agri-environmental measure, gypsum treatment of arable fields, to reduce phosphorus loading in 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 environment by employing farmer survey and confirmatory factor analysis. Strong environmental motivation is associated with small farm size, adoption of environmentally friendly cultivation technologies, and part-time farming. Strong profit motivation is associated with large gypsum-treated areas, perceived ease of gypsum application as a water protection measure, and agricultural education, which associates also with strong innovation motivation.

1. Introduction

Nutrient loading deteriorates the ecological state of aquatic ecosystems. While loading from point sources, such as industrial plants and municipal wastewater treatment plants, has considerably decreased, progress in agriculture has been negligible. Despite all efforts and policies devoted to agriculture, it remains the biggest source of water pollution, e.g. in the Baltic Sea or Chesapeake Bay (HELCOM, 2007; Iho et al., 2015). The difficulty inherent in reducing agricultural nutrient loading is an outcome of many factors. Agriculture is a nonpoint-source polluter, subject to stochastic weather and growing conditions. Conventional economic or regulatory instruments directly targeting 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 for reducing nutrient runoff and leaching from fields.¹

New and efficient measures for reducing agricultural nutrient loading are needed. One such new measure is the use of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) to reduce phosphorus release from fields. Gypsum was

used by the ancient Greeks to improve soil quality but its use in improving water quality is of recent origin. An early small-scale pilot project in Finland showed that gypsum can reduce phosphorus loading in surface waters by almost 50%. More importantly, it reduces both particulate phosphorus (57%) and dissolved reactive phosphorus (27%) loading (Ekholm et al., 2012). When spread on arable fields, gypsum increases the ionic strength of soil and creates larger aggregates of soil particles and calcium bridges that decrease phosphorus release to waterways. These changes improve soil structure and reduce erosion, yet the phosphorus remains available for crops. Therefore, previous studies have reported no yield penalty (e.g. Uusitalo et al., 2010).

Introducing a new technology requires acceptance among farmers, social acceptance from all other stakeholders and experimental field work in an innovation phase that fits the novel measure firmly and efficiently to ordinary cultivation practices. Crucial to acceptance of new conservation measures is that both farmers and other stakeholders observe the positive impacts that actually occur in aquatic systems and ascertain that no negative environmental side effects have occurred (Rogers, 2003; Sattler and Nagel, 2010). In the case of gypsum, these refer to improved water clarity due to reduced phosphorus release and

* Corresponding author.

E-mail address: anna-kaisa.kosenius@helsinki.fi (A.-K. Kosenius).

¹ The main water protection measures currently are reduced use of nitrogen and phosphorus fertilizers, establishing uncultivated and unfertilized buffer strips between fields and waterways, using wintertime plant cover and catch crops. They work quite well in reducing nitrogen runoff but poorly in reducing phosphorus runoff. In particular, they do not reduce dissolved reactive phosphorus (DRP) that is directly available for algae growth. The only exception is reduced phosphorus fertilisation but it impacts only in the long run by reducing the soil phosphorus content, the source of DRP.

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 project that started in 2016 for developing the gypsum treatment of fields to reduce phosphorus loading. The aims are to determine the logistic feasibility, required cultivation practices and social acceptance of large-scale gypsum treatment.² The pilot consists of 53 participating farmers having > 1500 field ha in the catchment area of the Savijoki River which discharges into the Archipelago Sea and suffers from severe eutrophication. We examine the gypsum treatment of fields as an eco-innovation, following the Organisation for Economic Cooperation and Development (OECD) definition of an eco-innovation as one that ‘results in a reduction of environmental impact, no matter whether or not that effect is intended’ (OECD, 2010:15). In the gypsum pilot, the farmers provided and applied their agronomic know-how to relevant work phases, including delivery and storage of gypsum, internal transport on the farm, spreading gypsum on the fields and scheduling other work in the fields. We focus on the motives of farmers for participating in fine-tuning of the new concept and narrow our approach closer to the concept of user innovation. This concept has been applied to development of products and services in various domains (see e.g. von Hippel, 1998; Stock et al., 2015).

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. The review of Stock et al. (2015) and the references therein provide an overview of the applications of the user innovation concept over several domains. Regarding co-creation, extrinsic and intrinsic motivations were evidenced. In a more general context of user innovations, the extrinsic motivations are associated with the compensation received for participation, expected product-related benefits, reciprocation and social recognition. The intrinsic motivations, in turn, relate to skill improvements, learning, fun and the innovation task itself. Furthermore, social conduct may be present in the form of helping others or improving one's own or the industry's reputation. In the specific context of developing the gypsum treatment of arable fields as a water protection measure, the extrinsic motivations refer to the expected benefits associated with the positive impact of gypsum on soil structure and nutrients (phosphorus, sulphur) for crops as well as the compensation payment received from participation. The intrinsic motivations refer to aspects like improvement of one's professional skills and the sector's reputation.

Besides economic and innovation-related motivations, new measure for agricultural water protection may also associate with environmental stewardship attitudes (e.g., Chouinard et al., 2008; Atari et al., 2009). Moreover, extensive literature on farmers' adoption of agri-environmental technologies and participation in agri-environmental schemes aims at associating various factors with the probability of participation, modeling both participants and non-participants (for syntheses, see Siebert et al., 2006; Knowler and Bradshaw, 2007; Baumgart-Getz et al., 2012; Lastra-Bravo et al., 2015). Scientific evidence exists on heterogeneity among farms in what drives the adoption of agri-environmental measures, explained by the characteristics of measures, farms as well as farmers (e.g., Atari et al., 2009; Sattler and Nagel, 2010; Unay-Gailhard and Bojnec, 2015).

The role and features of innovation have been explored more rarely. Barreiro-Hurlé et al. (2010) reported the role of innovation in adopting agri-environmental programs. Their econometric model, focusing on a

measure that requires low intensity of changes in practices, revealed that increase in adoption associated positively with a farmer's positive attitude towards policies that imply changes in farm management. Zabala et al. (2017) explored how motivational the Payments for Ecosystem Services (PES) schemes are for farmers. Based on empirical survey, they identified a proactive self-sufficient innovator and an environmentally conscious farmer whose decisions to plant fodder trees depend less on PES compared to a payment-dependent conservative, that is, a farmer type who emphasises the importance of payments for family's livelihood. Mann (2018), applying a theoretical model and regression analysis, reported a positive association of innovative attitude with participation in payment schemes promoting new farming technologies that contribute to resource-savings and emission-cuts.

This paper brings the innovation aspect to the front of research agenda in a more detailed way by focusing on the developing phase of an environmental innovation and farmers' diverse motivations to participate. While previous empirical literature on development processes in which users have been involved provides a starting point for the study, we also root our empirical work in a formal analysis of farmer behaviour. We develop a series of economic models to describe alternative preferences farmers may exhibit, and examine analytically their cultivation choices and reasons for participating in the pilot. Drawing on the theory, we derive behavioural hypotheses on three motivational identities: to be profit maximisers, to derive utility from innovating new cultivation practices or to have stewardship attitudes towards the environment. We test the presence of the motives in the gypsum pilot context with survey data on the pattern of motivational statements and with confirmatory factor analysis. In the explorative part of the study, we test how farm and farmer characteristics, land allocated to gypsum treatment, and attitudes and concerns regarding the gypsum pilot are associated with each of three motivational identities.

Our study contributes to the literature in two ways. First, we provide a formal approach to the examination of participation in a user innovation, and second, we tailor our results to answer the questions concerning how to motivate farmers to adopt new environmentally friendly innovations. Identifying farmer decision-making styles and related motivations for testing and applying new cultivation techniques aid in planning how to effectively introduce the gypsum treatment to southern Finland, to reduce phosphorus loss to the Baltic Sea.

The rest of the article is structured as follows. Section 2 develops a theoretical model to analyse the theoretical underpinnings of the agricultural producers' use of inputs to produce agricultural market outputs and their private and public motivations for participating in eco-innovation development. Moreover, the section derives the testable behavioural hypotheses and presents the factors associated with participation in agri-environmental programs according to the literature. Section 3 presents the statistical methods and the acquisition and description of the empirical data utilised in Section 4 to test hypotheses on farmer motivations and to explore the associated background and attitudinal characteristics. Section 5 discusses and Section 6 concludes.

2. User Innovation Under Alternative Preferences: Model and Behavioural Hypotheses

We start by extending a theoretical model of crop production beyond the ordinary profit-maximization to facilitate an analysis of multiple farmer motives. We include innovation effort (such as developing gypsum treatment of arable fields) and stewardship attitudes (water quality) in the model to provide a single nicely working expression and a consistent formal analysis of all three motivations. We then derive the behavioural hypotheses on motivations and refer to the relevant literature on the underlying features.

2.1. Setup

Consider a risk-neutral farmer participating in a pilot. Let l denote a

²In addition to logistical issues and social acceptance, the SAVE project examines the efficiency of gypsum treatment to reduce phosphorus loading from fields. It also explores the impacts of gypsum on the quality of arable soils and the impacts of sulphates on aquatic environment. (<http://blogs.helsinki.fi/save-kipsihanke/?lang=en>).

conventional productive input, such as of fertiliser. Denote the expected yield from fertilising 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, both of which may increase crop growth. In addition, gypsum improves the soil structure, promoting cultivation. Suppose that the farmer makes 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 in the soil structure and reduction in phosphorus release. The expected crop yield when gypsum is applied is $Y = f(l, \bar{k}(e))$. Drawing on previous empirical findings (e.g. [Uusitalo et al., 2010](#)), no yield penalty occurs, but sometimes yields may increase. Hence, the participating farmer should expect that $f(l, \bar{k}(e)) \geq f(l)$. We assume conventionally that $f_l > 0$, but that $f_{ll} < 0$. For the innovation effort, we assume that $\bar{k}'(e) > 0$ and $\bar{k}''(e) < 0$. Even though gypsum is applied in a fixed amount, the skills involved in 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 the costs of seeds, machinery, field work time and related costs. Innovation requires 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 net revenue from cultivation is $\pi = pf(l, \bar{k}(e)) - cl - M(e)$, providing the objective function of a profit-maximising farmer.

Turning to alternative objective functions, we first introduce stewardship attitudes towards the environment assuming that the farmer's preferences are linear in revenue, but concave in the environmental attributes (for 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 fertiliser application and gypsum spreading, $z = z(l, \bar{k}(e))$, with $z_l > 0$ and $z_{\bar{k}} < 0$. The preferences of the farmer towards the environment can now be expressed as $u = u(z(l, \bar{k}(e)))$, with $u_z < 0$, indicating that the 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 a clean environment, but is rather associated with improvement in environmentally friendly agricultural practices. As a second option, we allow for a case in which 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, i.e. as $u = u(z(l, \bar{k}(e)), e)$ and assume that $u_e > 0$ and $u_{ee} < 0$.

Finally, to facilitate separating all possible motives, we introduce the dummy variables α_i , ε_i and σ_i , obtaining either a value of 1 or 0, which multiplies the utility function and its arguments. Under these assumptions, we obtain the following quasi-linear objective function containing several possible types of farmers:

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

Choosing the values of the 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 the assumptions made above on the production, utility and cost functions guarantee that the second-order conditions will hold for all farmers' optimisation 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 behavioural hypotheses for the empirical analysis.

2.2.1. Profit-Maximising Farmer

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

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

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

Economic interpretation of (2a) is conventional: the value of the marginal product of the input equals its unit price. By Eq. (2b), the profit-maximising 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 the 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 is dependent only on prices, costs and crop yield.

2.2.2. 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 :

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

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

$$v_l = pf_l - c = 0, \tag{4a}$$

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

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, the innovation effort also provides positive marginal utility from innovating. Consequently, the effort increases relative to the profit-maximising 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 remaining outside the pilot. For the net revenue from crop production, we have $\pi^*(l^{**}, e^{**}) < \pi^*(l^*, e^*)$, indicating that relative to the profit-maximising farmer, an innovating farmer has lower net revenue. Thus, this farmer would require a smaller compensation for participation than the profit-maximising farmer. Moreover, given that the preferences of the innovating farmer impact the cultivation choices, socioeconomic variables, such as education and experience, also count for the participation decisions.

2.2.3. Farmer With Stewardship Attitudes

We next set $\alpha_i = 1$, $\varepsilon_i = 1$ 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:

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

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

$$V_l = pf_l - c - u_z z_l = 0, \quad (6a)$$

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

By Eq. (6a), when choosing the polluting productive input the farmer experiences negative marginal utility from the decreased water quality, due to runoff. Hence, the farmer equates the value of the marginal product with the sum of the input cost and the negative marginal utility. Accounting for the negative environmental impacts decreases the optimal use of fertiliser, relative to the previous cases. The innovation effort produces positive marginal utility from improved water quality. Thus the innovation effort is higher than in the case of the profit-maximising farmer. Comparison with the case of an innovating farmer depends on the size of the marginal utility from innovating, relative to that from improving water quality, thus the outcome of the 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 net 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 the profit-maximising farmer. This happens because environmental preferences, in this case notably, that improve the local state of water are given a certain priority.³

2.3. Behavioural Hypotheses

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

H1. All three motivational types of farmers can be identified among farmers participating in the development of the gypsum treatment.

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

H2a. Only economic variables count towards the participation of a profit-maximising farmer.

Preferences for innovation are important for the innovating farmer. Aspects that play a role for an innovating farmer include ambition to increase his/her own professional competence and possibly willingness to serve the entire agricultural sector, including the local agricultural society. Even though in this case the innovation is also associated with environmental improvement, farmers with innovation motivations see the environment as instrumental for the innovation process itself. We can formulate the hypothesis as follows:

H2b. Innovating farmers promote agricultural production efficiency beyond current technological competence to improve professional

competence and to serve the entire agricultural sector and local agricultural community.

Finally, for the farmer who has stewardship attitudes towards the environment, preferences for the environment are most important. For this farmer, the impact of his/her own contribution and ability to improve the local environment and the social acceptability of agriculture are essential for the motivation to participate in the development process. Environmental motivation gives a further boost for promoting eco-innovation. We also expect that these farmers trade-off agricultural revenue with water protection.

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

2.4. Characterization of Motivations

We characterize economic, innovation, and environmental motivations for participation in developing eco-innovation by identifying the essential empirical variables that associate with each of them. As the scientific literature concerning the development phase of new agri-environmental measures and specifically the gypsum application of fields is rare, we choose the potential explanatory variables from a broader context. In what follows, we list the factors that have been empirically evidenced by probability models to increase participation either in agri-environmental schemes (AES) consisting of a set of measures or in application of a specific agri-environmental measure.

Regarding farm characteristics, participation in agri-environmental programs increases with farm size (Wilson and Hart, 2000; Defrancesco et al., 2008; Ruto and Garrod, 2009; Hynes and Garvey, 2009; Grammatikopoulou et al., 2016; Unay-Gailhard and Bojnec, 2016; Zimmermann and Britz, 2016) with some exceptions (for instance, Pascucci et al., 2013). The effect of farm size may be measure-specific (Vanslebrouck et al., 2002), leaving the general conclusion ambiguous. While Unay-Gailhard and Bojnec (2015) found no statistically significant effect of the share of rented land on participation in agri-environmental schemes, positive association with operating on one's own land has been reported (Defrancesco et al., 2008; Ruto and Garrod, 2009). As to farming type, increase in participation associates with crop production as a main production line (Grammatikopoulou et al., 2016) and less labour or capital intensive farming types (Defrancesco et al., 2008; Pascucci et al., 2013; Unay-Gailhard and Bojnec, 2015).

As for, regarding farmer characteristics, younger farmers are more likely to adopt new technologies (D'Souza et al., 1993; Mann, 2018). The effect of age on participation in agri-environmental schemes is ambiguous (Lastra-Bravo et al., 2015) or statistically insignificant (Atari et al., 2009; Grammatikopoulou et al., 2016). Experience as a farmer increases participation in agri-environmental schemes (Atari et al., 2009; Lastra-Bravo et al., 2015). Most empirical studies report a positive association of education level with implementation of environmental practices (D'Souza et al., 1993; Kilpatrick, 2000; Rogers, 2003; Lastra-Bravo et al., 2015; Grammatikopoulou et al., 2016). Low dependence of household income on farming activity (Defrancesco et al., 2008; Grammatikopoulou et al., 2016; Unay-Gailhard and Bojnec, 2016) or higher annual gross farm income (Atari et al., 2009) increases participation in agri-environmental measures.

The intensity of applying agri-environmental measure depends largely on the characteristics of the measure and relates to farm and location characteristics. For instance, large farm size increases the intensity of participating in nitrate reduction measure (Damianos and Giannakopoulos, 2002) as well as in extension of field margins but less likely in farm beautification measures (Vanslebrouck et al., 2002). The positive effect of farm size and the negative effect of farm growth on the application of biodiversity-enhancing measures is proposed to be

³Note also that setting $\alpha_i = 1$, $\varepsilon_i = 1$ and $\sigma_i = 1$ results in 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.

linked to eligibility criteria, i.e., more suitable areas may exist in larger farms, and to greater benefits accrued to farm in food production than environmental services, respectively (Unay-Gailhard and Bojnec, 2015; ref. Wilson and Hart, 2000 and Mann, 2005).

Finally, attitudes and concerns related to agri-environmental measure matter. The increase in participation associates with previous participation in agri-environmental measures (e.g. Vanslebrouck et al., 2002; Defrancesco et al., 2008; Lastra-Bravo et al., 2015; Unay-Gailhard and Bojnec, 2016), easiness of measure and adequate compensation (Defrancesco et al., 2008; Sattler and Nagel, 2010; Barreiro-Hurlé et al., 2010), perceived environmental benefits (Vanslebrouck et al., 2002; Dupraz et al., 2003; Grammatikopoulou et al., 2016) as well as the perceived private benefits associated with application of the measure (Vanslebrouck et al., 2002; Yu and Belcher, 2011). Moreover, the adoption of best management practices increases with the knowledge of individual farmers on how practices and actions conducted on farm affect the environment (Barreiro-Hurlé et al., 2010; Baumgart-Getz et al., 2012) and with training and skill development associated with the application of the measure (Kilpatrick, 2000; Burton and Schwartz, 2013).

3. Methods and Data

3.1. Farmer Survey

As an empirical setting to test the theory-based hypotheses on motivations for developing eco-innovation and to explore the associated factors serves the 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 nonparticipation being the lack of suitable fields for gypsum treatment.

Targeted to the pilot participants, the survey questionnaire was designed during autumn 2016 in cooperation with farmers and researchers. The project research group developed and elaborated the questions in a 3-week iterative process. During the following four weeks, the survey structure and wording were tested in three rounds of revised questionnaires by selected farmers to ensure respondent comprehension and the shared interpretation of terminology by researchers and respondents. Two farmers participating in the gypsum pilot and two non-participants were interviewed in phone or face-to-face after filling in the web-based survey versions. Additionally, five members of the project steering group and two agricultural economics researchers tested and commented the web-based questionnaire. The details of the questionnaire (attached as Supplementary material) were modified according to the feedback.

The beginning of the questionnaire inquired cultivation practices and the area allocated to gypsum treatment. As for the 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 alternative cultivated crops. These were reported separately on the farm level and gypsum-treated areas, and a detailed map was provided in the questionnaire to help farmers provide the correct answers.

The core of the survey, preceded by a question about the farmers' pre-pilot awareness of gypsum as a measure for water protection, was the set of questions on drivers for participation in the pilot. It was guided, on one hand, by behavioural implications based on theoretical analysis of profit-maximising, innovation and environmental stewardship motivations and, on the other hand, by previous empirical studies on the motivations for participating in user innovation and the co-creation projects. The pattern of 15 motivational statements assessed the importance of alternative motivations for the participation in developing the gypsum concept, following a 7-point Likert scale (Likert, 1932) from 'Not at all important' to 'Very important'.

Next, the questionnaire inquired the farmer's attitudes and concerns regarding the gypsum pilot. The attitudinal statements, assessed with a 7-point Likert scale from 'Totally disagree' to 'Totally agree', covered the acceptability of gypsum as a water protection measure, the reflection of cultivation practices applied on the farm subject to water protection and the perceptions on co-operation. For measuring the extent of economic and agrological concerns regarding the gypsum pilot, the 7-point scale from 'Not at all' to 'A lot' was applied.

In the last section of the survey, the farmer characteristics inquired were age, education and years of experience in the agricultural sector, future plans to continue farming and the percentage of agricultural income out of the household income. The farm characteristics elicited were the main cultivation practices on farm level (autumn ploughing, reduced tillage and no-tillage), farm size, production line and enrolment in the current agri-environmental payment scheme.

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 to acquire as many responses as possible out of the 53 farmers recruited to the pilot to guarantee reliability of the statistical analysis. The invitation to participate in a survey by email and surface mail was followed by a maximum of four reminders by either email or telephone. The data collection resulted in 47 eligible responses, corresponding to 89% of the participants and 92% of the gypsum treatment area (1430 ha out of 1540 ha). Reasonable response rate permitting, we use the term participants to refer to survey respondents in further analysis.

3.2. Statistical Methods

We test the behavioural hypotheses using confirmatory factor analysis. Factor analysis combines the correlated statements into one factor that represents the essence of original statements. The factor structure for a set of variables, such as the number of factors in the analysis, can be pre-defined when validating a model, (confirmatory analysis) or not (exploratory analysis) (Statsoft, 2011). To test the hypothesis H1 on the presence of three participation motives, we carry out Principal component analysis and Varimax rotation with Kaiser normalization with the software package SPSS 24 (IBM Corp., Armonk, NY, USA) to reduce the answers to the 15 original motivational statements to three factors representing the profit-maximization motivation (Profit), innovation motivation (Innovation) and motivation based on stewardship attitudes towards the environment (Environment). The statements are assigned to factors according to the highest factor loads.

We test the internal consistency of the factor analysis results by measuring the Cronbach alphas for the statements assigned to the same factor. The larger values of alphas, the better the variables measure what they are intended to measure, and according to the rule of thumb, the values above 0.7 are acceptable. Additionally, to ensure freedom of the analysis from reliability issues given the sample size of 47 survey respondents, we perform a robustness test of the assignment of statements to three factors. We also re-explore the assignment in the subsamples based on exclusion of one respondent at a time (leave-one-out cross-validation) and compare the results of 47 tests with the original factor extraction. The leave-one-out cross-validation is a common robustness test for predictive models.

In addition to factor loadings, the analysis produces farmer-specific individual scores. They indicate the strength of each farmer exhibiting each of three motivations relative to all other farmers in the sample. We convert positive values, indicating a relatively strong motivation, into 1 and negative scores, indicating a relatively weak motivation, into 0. This dichotomous variable facilitates a comparison of the group of farmers with relatively strong motivation to the group of farmers with relatively weak motivation using a simple one-by-one analysis of variables. Cross tabulation and Fisher's exact test, comparing whether the relative shares of values measured with dichotomous variables are similar in two populations, is applicable for small samples. It provides an

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

	Sample	County
	(n = 47)	(n = 4536)
	Mean	Mean
Farm characteristics		
Total field area of farm (ha, mean)	112.4	53.1
Percentage of field area leased (%)	30.4	32.0
Crop production (%)	85.1	na
Participation in agri-environmental payment scheme (%)	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 (%)	6.4	8.2
Age group 35–49 years (%)	34.0	33.8
Age group 50–64 years (%)	44.7	46.0
Age group > 65 years (%)	14.9	12.0
Experience in agriculture (yrs, mean)	27.6	na
Agricultural education: none (%)	25.5	na
Plans to continue farming at least 6 yrs. (%)	73.2	na
Percentage of agricultural income: > 75% (%)	25.5	na
Percentage of agricultural income: 50–74% (%)	27.7	na
Percentage of agricultural income: 25–49% (%)	14.9	na
Percentage of agricultural income: < 25% (%)	31.9	na
Percentage of agricultural income in household income (%)	na	30.6

na = not applicable.

appropriate tool for the comparison of distributions of dichotomous attitudinal variables, that is, the extent of agreement in terms of proportion of agreeing respondents and of categorical background variables. The nonparametric Mann-Whitney *U* test is used for continuous background variables. Moreover, for internal validity of results, we explore whether the use of field area and cultivation practices associate differently with profit-maximization, innovation and environmental stewardship motivations.

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 (Southwest Finland) (OSF Official Statistics of Finland, 2015) to assess how well the results can be generalised to the larger population. When the variables lacked information on the county level, the sample statistics were compared with the country statistics.

In terms of the total field area, the participating farms are, on average, larger (112.4 ha) than farms in the county of Varsinais-Suomi (53.1 ha). The sample-average percentage of field area leased 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 ha to 985 ha and the percentage of fields leased from 0% to 91%. The most common production line is crop production (85.1%) and the number of cultivated crops ranges from 1 to 12. The majority of farms (89.6%) participate in the Finnish agri-environmental payment scheme, corresponding reasonably well to the Finnish average of 86% (Finnish agricultural and food sector, 2017). The most common cultivation practice is ploughing for half of the farms, followed by reduced tillage (40.0%) and no-tillage (10.0%).

The age of the 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 the agricultural sector is 27.6 years. One fourth of the participants (25.5%) report no agricultural education, and none has a university degree in agriculture. The majority of participants (73.2%) plan to continue farming for at least the next 6 years. In comparison to a nationwide survey on the future plans of Finnish

farmers (n = 4417) in which 46.5% of the interviewees reported plans to continue for at least 6 years (Kallinen et al., 2016), the sample exhibits farms with higher short-term future probability of continuing farming activities. Approximately one fourth of the respondents report that agricultural income covers at least 75% of the household income, thus representing 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 farm income formation report much smaller average percentages of agricultural income out of household income in the county of Varsinais-Suomi (30.6%) and in Finland (34.6%) (OSF, 2015).

4. Farmers' Preferences and Motivations for Participating in Developing Eco-Innovation

4.1. Land Allocation, Perceptions and Concerns Regarding Gypsum Treatment

Table 2 presents the survey results regarding land allocation for the gypsum treatment, cultivation methods and previous knowledge on gypsum, reported in the upper part of the table. While every farm with parcels located in the study area in the Savijoki River catchment was invited to participate in the gypsum pilot, their potential to supply fields for the gypsum treatment vary for two reasons. First, only those field parcels that are located in the pilot area were, in principle, eligible for gypsum treatment. On average, this is 57.6% of the farm's field area, ranging from 2% to 100%. Second, the parcels located in the pilot area were, in practice, eligible for gypsum treatment, provided that they had valid agronomic conditions, that is, a cation equilibrium (based on the ratios of selected minerals) of soil favourable for the use of gypsum.

Of the hectares eligible for the gypsum treatment, the average percentage assigned by farm is 73.7%. The average gypsum treatment area per farm is 30.0 ha, ranging from 3.4 ha to 304.4 ha. As for the 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%) with no-tillage. More than every second participant (64.6%) knew about the role of gypsum as a water protection measure prior to the invitation phase of the gypsum pilot.

The lower part of Table 2 is devoted to results concerning attitudes on easiness of gypsum treatment and perceptions on environmental effects, on social acceptance among stakeholders, on private benefits as well as issues related to knowledge and training while developing a new agri-environmental measure.⁴ Every second participant (57.4%) accepts the statement suggesting that the gypsum treatment of fields is a less complicated method for water protection. Moreover, almost two thirds (63.8%) of the participants require more experience in the use of gypsum before they find its use reliable in water protection.

The promise of the gypsum treatment as a new environmental measure is reflected by wide confidence in the ability of gypsum to reduce phosphorus loading, being questioned by only every fifth participant (19.1%). Furthermore, only 17% express concern for the negative effects of gypsum on nature.

The majority of pilot participants believe that the local people are in favour of the gypsum treatment (72.3%), while only roughly every fourth participant (27.7%) question other farmers' willingness to adopt gypsum treatment as part of the agri-environmental payment scheme. These figures suggest a rather wide potential for the social acceptability of the gypsum concept among stakeholders.

Three out of five participants (59.6%) express no concerns about the impacts of gypsum on the productivity or condition of the soil; farmers

⁴ The statements in Table 2 is not in the same order of as they were in the questionnaire (available as Supplementary material).

Table 2
Descriptives of participation in gypsum treatment and related attitudes (n = 47).

Gypsum-treated field area and previous knowledge	
Percentage of field area in Savijoki catchment	57.6%
Percentage of gypsum-treatment area in field area in Savijoki catchment	73.7%
Gypsum treatment area (ha, mean)	30.0
Percentage of gypsum-treated area in field area	42.3%
Cultivation method in gypsum-treated area: ploughed	51.5%
Cultivation method in gypsum-treated area: reduced tillage	36.5%
Cultivation method in gypsum-treated area: no-tillage	11.9%
Previous knowledge on gypsum: know someone, heard, read	64.6%
Attitudinal statements ^a	
I think gypsum treatment is a less complicated method for water conservation.	57.4%
I need more experience in gypsum treatment as a conservation method before being able to use it reliably.	63.8%
I don't believe gypsum treatment reduces nutrient loading significantly.	19.1%
I am concerned about the effects of gypsum on nature.	17.0%
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 payment scheme.	27.7%
I am not concerned about the impacts of gypsum on productivity and condition of my fields.	59.6%
I often try new agricultural methods.	38.3%
I feel it rewarding to share my ideas.	38.3%
I'm proud of participating in this experiment.	40.4%
I have advised 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 on how to use gypsum.	36.2%
In my perception, my agricultural methods impact water system and the Baltic Sea.	57.4%
Concerns regarding the gypsum pilot ^b	
Costs that won't be covered	68.1%
Funding for traditional conservation measures decreases	63.8%
Gypsum hardens the soil	51.1%
Smaller yield because of gypsum	48.9%

^a 7-point Likert scale ranged from 'Totally disagree' to 'Totally agree', the share of 'Agree' refers to 3 most agreeing categories.

^b 7-point scale for concerns ranged from 'Not at all' to 'A lot', the percentage of 'Concerned' refers to 3 most concerned categories.

clearly are well aware of the use of gypsum as a soil amendment measure. Approximately one third (38.3%) expresses openness towards new technologies or sharing one's ideas. Importantly, more often (40.4%) the farmers declare their feeling of pride in participating in the development of gypsum treatment of arable fields.

Approximately every third participant (31.9%) had advised other farmers or received useful information from them (38.3%) during the pilot. While this measures cooperation among innovation developers, some knowledge acquisition during the pilot project is shown by that every third participant (36.2%) declare self-assessed confidence in one's skills in gypsum treatment of fields. Finally, more than half of the respondents (57.4%) acknowledge that their agricultural methods impact the aquatic system and the Baltic Sea. As to concerns regarding the gypsum pilot, on average, the pilot participants are more often concerned with the cost-related issues than the effects of gypsum on soil and yield.

4.2. Extraction of Motivational Factors

Table 3 presents the results of confirmatory factor analysis. The statements are assigned to the factor for which they show the highest loading. All three factors imply eigenvalues larger than 1 and explain 68.3% of all variation. Cronbach's alphas, measuring internal consistency of statements assigned to each factor, are 0.725, 0.845 and 0.915 for Profit, Innovation and Environment motivations, respectively, indicating adequate reliability. To ease interpretation of the results and assessment of the validity of factors in relation to theoretical expectations, Table 3 highlights factor loadings larger than 0.3 that are elaborated in detail.

The statements reflecting the direct and indirect benefits of gypsum

treatment of fields are assigned to the first behavioural factor (Profit). The statements that load highest to this factor are associated with the contribution of gypsum to sulphur fertilisation and improvement in soil structure, followed by the perception that participating in the development of new agricultural practices is one's professional duty. Interestingly, this sense of duty also loads relatively highly to the factor that reflects stewardship attitudes towards the environment (Environment). While the monetary compensation paid to participants for work related to spreading gypsum loads highest in the Profit motivation, it also 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, the way the future gypsum treatment of fields will be organised. The next highest loadings in the Innovation motivation are associated with willingness to be the forerunner of new cultivation technologies and to sharing one's expertise and experience. Moreover, experiencing the gypsum pilot as a welcome change from the daily routine 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 load solely 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 the daily routine and professional development) also load relatively highly to Profit factor. Although being a forerunner and improving one's skills loads highest to Innovation, the statements are also highly associated with the Environment motivation.

Regarding the third factor (Environment), the statements with the highest loading are associated with the contribution of the gypsum

Table 3
Behavioural factors extracted from 15 motivational statements.

Original motivational statements	Factors		
	Profit	Innovation	Environment
I also get sulphur fertilisation to my fields.	0.835	−0.021	0.269
I believe that I benefit from the gypsum's impact on soil condition.	0.831	0.081	0.206
I feel it my duty to participate in the gypsum pilot.	0.603	0.162	0.369
I earn monetary compensation for work related to the gypsum pilot.	0.578	0.321	−0.321
I want to impact how future gypsum spreading will be implemented.	−0.017	0.804	0.214
I want to act as a forerunner in testing a new methodology.	0.095	0.701	0.376
I want to share my expertise and experiences as a farmer.	0.394	0.682	0.147
The gypsum pilot is a welcome change to my work as a farmer.	0.489	0.587	0.242
Experience in the gypsum pilot improves my agronomic skills.	0.506	0.514	0.323
The gypsum pilot can reduce nutrient loading into local bodies of water.	0.274	0.140	0.883
The gypsum pilot enables support for protection of the Baltic Sea.	0.239	0.172	0.819
I'm curious about the impacts of gypsum treatment.	0.183	0.457	0.707
I want to improve the environmental reputation of the Finnish agricultural sector.	0.062	0.517	0.693
By testing a new technology, I want to strengthen the Finnish agricultural sector.	0.419	0.360	0.649
I want to support research on new water protection measures.	0.032	0.486	0.584

treatment to the quality improvement of local waters and the Baltic Sea. It makes sense that these water-related statements are associated solely with the Environment motivation. The curiosity for the impacts of gypsum loads highest to this factor, but also relatively highly to the Innovation factor. Even though the willingness to improve the environmental reputation of agriculture and to support research in new water protection measures loaded highest to Innovation factor, it loads relatively highly also to Environment factor. The statement concerning strengthening of 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.

Confirmatory factor analysis of the assignment of motivational statements to three behavioural factors supports the theoretical expectation of the presence of three motivations in the sample of participants in the gypsum pilot (H1). The interpretation of the factors makes sense in terms of the predetermined motivation statements, thus supporting the hypotheses H2a–H2c presented in Section 2.3.

Regarding the re-exploration of the assignment of statements to extracted factors according to the highest factor loads, the comparison of original factor extraction in Table 3 with factor loadings from 47 subsamples suggests the following. The majority of subsamples (60%) replicated the results of original factor analysis. In 16 subsamples (34%), the statement ‘The experience from the gypsum pilot improved my agronomic skills’ shifted from Innovation to Profit. In four subsamples (9%), the statement ‘I want to support research on new water protection measures’ shifted from Environment to Innovation, two of these in combination with the most common shift above. Three re-explorations were subject to changes that were hardly interpretable from the viewpoint of supporting the theoretical model. Convinced by the numbers of successful replications of original factor extraction and of shifts that make sense, we conclude that the result is robust enough for further analysis.

4.3. Exploration of Motivations

To provide insight on factors associated with the three motivations and for developing a plan to persuade farmers with differing characteristics and motivations to use gypsum, we perform statistical tests to explore the dependencies between the background and attitudinal variables (in Tables 1 and 2) and the strengths of three motivations for participating in the gypsum pilot (Table 3). The strengths of motivations are measured with three dichotomous variables (*Pro*, *Inn*, *Env*) for each of the 47 farmers in our sample. *Pro* equals 1 if the farmer has a

strong profit motivation, zero otherwise, and similarly, *Inn* equals 1 for a strong innovation motivation and *Env* for a strong environmental stewardship motivation, zero otherwise.

Table 4 shows for all three motivations statistically significant differences in shifting from weak to strong motivation with respect to farmer and farm characteristics, gypsum-treated field area, attitudes and concerns. To begin with statistically insignificant factors explored but excluded from Table 4, farmers with strong motivation and farmers with weak motivation, for all motivations, were similar with respect to years of experience as a farmer, plans to continue farming, ploughing or reduced tillage as cultivation method in gypsum-treated area, previous knowledge on gypsum, concern on effect of gypsum on nature, perception of participation of other farmers in gypsum treatment of fields, and concerns on the reduction in funding for traditional conservation measures and in yields.

From Table 4, the farmers with strong profit motivation participate more often in the Finnish agri-environmental payment scheme, are younger and more often have agricultural education than farmers with weak profit motivation. While the latter also applies to farmers with strong (in comparison to weak) innovation motivation, agricultural education plays no role in the strength of environmental motivation. Farmers with strong environmental motivation for testing the gypsum treatment of fields have smaller total field area, smaller percentages of leased field area and are less often fulltime farmers and more often crop producers than farmers with weak environmental motivation.

We find that farmers with strong profit motivation to develop gypsum treatment of fields have larger percentages of farm fields and gypsum-treated areas in the catchment area. In contrast, farmers with strong innovation motivation have smaller percentages of their field area in the catchment area and of the gypsum treatment area out of the total field area, in comparison to participants with weak innovation motivation. Relative to farmers with weak environmental motivation, farmers with strong environmental motivation more often cultivated the gypsum-treated area with no-till technology and have larger percentages of field area in the catchment area, resembling that of farmers having strong profit motivation for participating in the gypsum pilot.

The strength of motivations relates statistically significantly to attitudinal variation among the participants. Perceived easiness of gypsum treatment as a method for water conservation associates positively with strong profit and environmental motivations. Also related the usefulness of measure in water protection, farmers with strong environmental motivation more often demand additional experience in gypsum treatment before being able to use it reliably, in comparison to farmers with weak environmental motivation. As to perceived

Table 4
Factors associated with strength of three motivations to participate.

	Profit	Innovation	Environment
Farm characteristics			
Total field area of farm (ha)			–
Percentage of field area leased			– –
Crop production (%)			++
Participation in agri-environmental payment scheme (%)	+		
Farmer characteristics			
Age (yrs, mean)	–		
Agricultural education (%)	+++	++	
Fulltime farmer: percentage of agricultural income > 75% (%)			– – –
Gypsum treated field area			
Percentage of field area in Savijoki River catchment	+	– –	++
Percentage of gypsum-treatment area in field area in Savijoki River catchment	++		
Gypsum treatment area (ha)	++		
Percentage of gypsum-treated area in field area	++	– –	
Cultivation method in gypsum-treated area: no-tillage			+
Attitudinal statements			
I think gypsum treatment is a less complicated method for water conservation.	+++		+
I need more experience in gypsum treatment as a conservation method before being able to use it reliably.			+++
I don't believe gypsum treatment reduces nutrient loading significantly.			– – –
In my opinion, local people have a positive attitude towards gypsum treatment.	++		
I am not concerned about the impacts of gypsum on productivity and condition of my fields.	+++		
I often try new agricultural methods.		+++	
I feel rewarding to share my ideas.		+++	
I'm proud of participating in this experiment.	+++	++	+++
I have advised 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 on how to use gypsum.	++	++	+
In my perception, my agricultural methods impact water system and the Baltic Sea.		+++	++
Concerns regarding the gypsum pilot			
Costs that won't be covered		+	
Gypsum hardens the soil	–		

+++ / – – – significant at 0.01 level, ++ / – – at 0.05 level, + / – at 0.1 level.

environmental benefits of gypsum, farmers with strong environmental motivation are more often confident in the ability of gypsum to reduce phosphorous.

The perceived social acceptance of the measure is reflected by agreement with statement suggesting that local people have positive attitudes towards gypsum application to fields. It is positively correlated with strong profit motivation. Moreover, farmers with strong profit motivation are more often less concerned with the effect of gypsum treatment on the productivity and condition of their fields, which is natural, since they obtain maximum net revenue from cultivation.

Reflecting the essential nature of innovating behaviour, strong innovation motivation associates with the keenness to try new agricultural methods and the rewarding feeling of sharing one's ideas. Common for all three motivations is the positive correlation of being proud of participation in the pilot project with strong motivation.

Farmers with strong innovation motivation have advised other farmers in the stages of the gypsum pilot more often than farmers with weak innovation motivation. As for knowledge sharing, farmers with strong profit or innovation motivation more often received useful information from their colleagues' experiences in spreading gypsum. The strong and weak extents of all motivations differ in a statistically significant manner with respect to the stated ability to advise other farmers in the use of gypsum.

Farmers who exhibit 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 weak innovation or environmental motivation. As to the concerns of gypsum treatment of fields, farmers with strong innovation motivation are more often very concerned that only part of the costs induced by the gypsum pilot would actually be covered, in comparison to those with weak innovation motivation.

5. Discussion

Our examination of the gypsum treatment of fields as an eco-innovation for agricultural water protection utilised the empirical survey from the pilot project. Introducing the user innovation setting (Stock et al., 2015) into agri-environmental context makes 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 organised precisely according to this fashion and in the spirit of co-development: farmers' experience was used in all stages of the pilot. This novel feature makes investigation of farmers' motives to participate a unique contribution to scientific literature on agri-environmental policy.

Unlike in most respective studies, we rooted our analysis on a consistent economic theory. Previous analyses have applied qualitative research methods (for instance, Zabala et al., 2017) or empirical data and statistical methods (for instance, Wilson and Hart, 2000; Zimmermann and Britz, 2016). Moreover, when applying a micro-economic framework, attitudinal constructs concerning innovation or environmental stewardship have been introduced as variables in econometric models on participation decision (for instance, Vanslebrouck et al., 2002; Barreiro-Hurlé et al., 2010). Our theoretical analysis provides a procedure to formally model all farmer motivations, and the inclusion of innovation effort in the economic crop production model is our genuine contribution.

Our confirmatory factor analysis was conducted following the empirical procedure of user innovation research. The analysis shows support to our hypotheses that farmers' motivations to participate in an innovation project cover profit, innovation and environmental stewardship motivations. The presence of innovation motivation is the most novel feature in the literature focusing on agri-environmental issues. Closest to our analysis of three motivations is Zabala et al. (2017) who

identified a group of self-sufficient pioneers as initial adopters of new agricultural practices. Moreover, their sample of smallholders consisted of groups of environmentally-conscious followers and payment-dependent conservatives. Confronting economic and non-economic motives for participation in agri-environmental programs has been a common research approach. In contrast, our empirical analysis assumes that the presence of different motivations does not imply that they are mutually conflicting. Every farmer in the sample may exhibit each of three motivations to either strong or weak extent.

Some caution is, however, needed when interpreting the empirical results. Our analysis does not capture the stability of preferences and attitudes over time. It describes the motivations related to the decision to participate in the pilot project studied, as usually is the case when exploring user innovation motivations specific to the case or domain (Stock et al., 2015). Examining the presence of the three motives in the whole farmer population is an interesting topic for future research.⁵

Our key finding – the importance of innovation motivation in environmental protection – has potential policy implications. When promoting environmental protection in agriculture, authorities should also appeal to the set of farmers who have a strong innovation motivation in order to increase participation and to foster gradual improvement of measures applied for environmental protection. Furthermore, the presence of three motives suggests shifting towards conservation programs that are based on co-creation with respect to measures used.

In addition to motivation revelation, the second main contribution of our paper relates to the examination of the strength of farmers' motivations and their correlation with farmer characteristics and the field areas. By making binary comparison between strong and weak motivation within each of the three motivations, we were able to clarify statistically how motivations are related to attitudes and how farm and farmer characteristics associate with strong motivations. Naturally, many statistically significant background variables associated with strong motivations are in line with the previous findings on adoption of agri-environmental practices or participation in agri-environmental payment schemes (e.g. Lastra-Bravo et al., 2015).

Farmers with innovation motivation turned out to be keen on participating in innovative projects. They find participation as an inspiring opportunity to improve their skills and promote the competence and reputation of the whole profession. This showed up, for instance, in agreement with statements about frequent testing of new agricultural methods and about sharing the experiences, reflecting a proactive professional attitude. Farmers with strong innovation motivation had smaller percentages of their field area devoted to gypsum treatment reflecting the fact that some farms had only some field parcels in the pilot area. Despite this, their interest in innovation activities made them to participate.

Our findings concerning farmers with environmental motivation are in line with previous studies. These farmers understand that their technologies and practices affect water quality, they are interested in the environmental effect of their activities and they apply environmentally friendly practices, such as no-tillage. In our sample these farmers were mostly part-time crop producers with relatively small farms size and small land areas in the pilot. Attitudes associated with strong environmental motivation indicate need for more experience in gypsum spreading before its reliable use in water conservation and confidence on environmental benefits of gypsum. Thus, the information on the visibility of intended effects in adjacent waters (Sattler and Nagel, 2010) might be crucial to convince environmentally-motivated farmers to apply gypsum.

Farmers with profit maximization motives had the largest farms and land areas in the pilot. Thus, they were crucial in the pilot aiming at gathering experiences on the gypsum application, just as their participation is crucial in any agri-environmental program, in order to have

the expected environmental effect. Strong profit motivation was associated with young age, agricultural education and current enrolment in the agri-environmental scheme. This is in line with Mann (2018) who reported the association of young age with the tendency to participate in agri-environmental programs.

The farmers with strong profit motivation share professional ambition with innovational farmers: developing own skills by sharing ideas is important. Not surprisingly, they also perceived gypsum treatment as an easy new technology to conserve adjacent waters. For these farmers, covering costs and not having yield losses together with a possibility of having some private benefits were important for participation (see, Yu and Belcher, 2011). We conclude that for any program to be successful in having large participation, invitation of farmers with profit maximization motive is of importance and thus, economic incentives must be set right.

Farmers valued highly the approach of user innovation adopted in the pilot. Indeed, 40% of farmers indicate they are proud of participating in the development of the gypsum treatment concept. This statement expressing pride correlates strongly with all three motivations examined, that is, promoting environmental sustainability and the reputation of the agricultural sector, improving its economic performance and enhancing one's professional skills. Another attitudinal construct common for all three motivations reflects knowledge-gathering or skill improvement during the gypsum pilot. Strongly motivated participants assess that they are able to advise other farmers on how to use gypsum and spread their experience. This finding also supports the possibilities for large-scale spreading of gypsum together with the experience gathered from the pilot that the measure fits smoothly to the everyday activities of farms (see Sattler and Nagel, 2010). Moreover, in our analysis, the association of strong innovation and strong environmental motivations with the perception of the impact of one's agricultural methods on the adjacent water system implies that a key motivation for creating knowledge by developing eco-innovation is the belief in one's capability to make choices that affect the environment.

As final remark, the survey-based self-reported assessments used in the analysis are subject to the common method bias and systematic measurement error. In order to reduce these biases and to enhance internal validity, we followed the recommendations of Podsakoff et al. (2012). In the questionnaire, we paid attention to question order, and all questions related to gypsum pilot were placed in the beginning followed by attitudinal and background questions. In designing the set of attitudinal statements, the proximity effect was eliminated by separating the items aiming at measuring the same construct. In the cover letter of the survey, we enhanced the motivation to answer properly by enhancing the desire for self-expression: we underlined that we need and value their opinion on this issue. Moreover, all pilot participants were bound by the contract to respond to surveys administered during the pilot, increasing their commitment to the issue and providing reliable answers.

6. Conclusions

We examined the gypsum treatment of fields as an eco-innovation for agricultural water protection, utilising the empirical survey of farmers from a large pilot project. Drawing on economic modeling we examined the presence of three theory-driven motivations, namely maximising profit, deriving utility from developing new cultivation practices or having stewardship attitudes towards the environment, with confirmatory factor analysis and explored the associated background and attitudinal factors.

The paper contributes to understanding the introduction and the development of new agri-environmental technologies. The formal analysis of monetary and non-monetary motivations of this paper is directly applicable to other contexts. Our empirical analysis confirms that the water-quality benefits created, the professional competence and the private benefits associated with gypsum treatment of fields

⁵ We thank an anonymous reviewer for pointing out these issues.

perform as motivations in the studied sample of farmers. To generalize with caution, most farmers will find good grounds for their participation in water protection. While environmentally conscious farmers are driven by the awareness on the impact of their activities in relatively small farms, especially relatively young farmers having allocated relatively large areas to the gypsum treatment express a more profit-minded orientation to the use of gypsum.

Many of our findings are in line with current scientific knowledge on economic and non-economic predictors for the probability to accept or adopt new agri-environmental practices or to participate in agri-environmental payment schemes or programs. Compared to many other measures, gypsum treatment of fields is an exceptional measure in that it invites for many types of farms due to the variety of benefits it provides.

Suitability of gypsum for a broad set of farmers encourages the use of gypsum as a large-scale measure to reduce phosphorus loading. As an investment in sustainable food production, gypsum treatment of fields provides an excellent example of how to internalise the promotion of environmental benefits in economic activities and how to provide farmers an opportunity to develop economic performance and environmental sustainability of agriculture.

From a broader angle, testing if all three motivations could be found among all farmers is an interesting future topic for future research and it will contribute to improved designing of agri-environmental programs for agriculture.

Acknowledgement

The work presented is part of the BONUS GO4BALTIC project: <http://projects.au.dk/go4baltic/>. The BONUS GO4BALTIC project is supported by BONUS (Art 185), funded jointly by the EU and national funding institutions in Denmark (the Innovation Fund Denmark), Estonia (Estonian Research Council ETAG), Finland (Academy of Finland), Poland (National Centre for Research and Development) and Sweden (Swedish Research Council Formas). The work has also received funding from Stockholm University Baltic Sea Centre – project Baltic Eye. The authors acknowledge also funding from the Baltic Sea project of Ålandsbanken. The research assistance of Venla Ala-Harja in data collection is gratefully acknowledged. In addition, the authors wish to thank Petri Ekholm, Eliisa Punttila and Samuli Puroila in the pilot project on the gypsum treatment of fields (the project SAVE) for discussions and co-operation.

Appendix A. Supplementary Data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.ecolecon.2018.12.002>.

References

Atari, D., Yiridoe, E., Smale, S., Duinker, P.N., 2009. What motivates farmers to participate in the Nova Scotia environmental farm plan program? Evidence and environmental policy implications. *J. Environ. Manag.* 90, 1269–1279. <https://doi.org/10.1016/j.jenvman.2008.07.006>.

Barreiro-Hurlé, J., Espinosa-Goded, M., Dupraz, P., 2010. Does intensity of change matter? Factors affecting adoption of agri-environmental schemes in Spain. *J. Environ. Plan. Manag.* 53 (7), 891–905. <https://doi.org/10.1080/09640568.2010.490058>.

Baumgart-Getz, A., Stalker Prokopy, L., Floress, K., 2012. Why farmers adopt best management practice in the United States: a meta-analysis of the adoption literature. *J. Environ. Manag.* 96, 17–25. <https://doi.org/10.1016/j.jenvman.2011.10.006>.

Burton, R., Schwartz, G., 2013. Result-oriented agri-environmental schemes in Europe and their potential for promoting behavioural change. *Land Use Policy* 30, 628–641. <https://doi.org/10.1016/j.landusepol.2012.05.002>.

Chouinard, H.H., Paterson, T., Wandschneider, R.P., Ohl, M.A., 2008. Will farmers trade profits for stewardship? Heterogeneous motivations for farm practice selection. *Land Econ.* 84 (1), 66–82.

Damianos, D., Giannakopoulos, N., 2002. Farmers' participation in agri-environmental schemes in Greece. *Br. Food J.* 104 (3), 261–273. <https://doi.org/10.1108/00070700210425705>.

Defrancesco, E., Gatto, P., Runge, F., Trestini, S., 2008. Factors affecting farmers' participation in agri-environmental schemes: a Northern Italian perspective. *J. Agric. Econ.* 59 (1), 114–131.

D'Souza, G., Cyphers, D., Phipps, T., 1993. Factors affecting the adoption of sustainable agricultural practices. *J. Agric. Resour. Econ.* 22, 159–165. <https://doi.org/10.1017/S1068280500004743>.

Dupraz, P., Vermersch, D., Henry de Frahan, B., Delvaux, L., 2003. The environmental supply of farm households. A flexible willingness to accept model. *Environ. Resour. Econ.* 25 (2), 171–189.

Ekholm, P., Valkama, P., Jaakkola, E., Kiirikki, M., Lahti, K., Pietola, L., 2012. Gypsum amendment of soils reduces phosphorus losses in an agricultural catchment. *Agric. Food Sci.* 21, 279–291.

Finnish agricultural and food sector 2016/2017, 2017. In: Niemi, J., Väre, M. (Eds.), *Natural Resources Institute* 2017.

Grammatikopoulou, I., Pouta, E., Myyrä, S., 2016. Exploring the determinants for adopting water conservation measures. What is the tendency of landowners when the resource is already at risk? *J. Environ. Plan. Manag.* 59 (6), 993–1014. <https://doi.org/10.1080/09640568.2015.1050551>.

Griffin, R.C., Bromley, D.W., 1982. Agricultural runoff as a nonpoint externality: a theoretical development. *Am. J. Agric. Econ.* 64 (3), 547–552.

Helcom, 2007. Baltic Sea Action Plan. Helcom Ministerial Declaration. Baltic Marine Environment Protection Commission, Krakow, Poland (15 November 2007).

Hynes, S., Garvey, E., 2009. Modelling farmers' participation in an agri-environmental scheme using panel data: an application to the rural environment protection scheme in Ireland. *J. Agric. Econ.* 60 (3), 546–562.

Iho, A., Ribaudo, M., Hyytiäinen, K., 2015. Water protection in the Baltic Sea and the Chesapeake Bay: institutions, policies and efficiency. *Mar. Pollut. Bull.* 93 (1–2), 81–93.

Kallinen, A., Pirttijärvi, R., Saarnivaara, P., Heikkilä, E., 2016. Maatilojen kehitysnäkymät 2022 (engl. Finnish farms: Outlook for development 2022). Suomen Gallup Elintarviketieto Oy Downloaded from: http://www.gallupnet.fi/maatila/Maatilojen_kehitysnakymat_2022.pdf (June 1, 2016).

Kilpatrick, S., 2000. Education and training: impacts on farm management practice. *J. Agric. Educ. Ext.* 7 (2), 105–116. <https://doi.org/10.1080/13892240008438811>.

Knowler, D., Bradshaw, N., 2007. Farmers' adoption of conservation agriculture: a review and synthesis of recent research. *Food Policy* 32, 25–48. <https://doi.org/10.1016/j.foodpol.2006.01.003>.

Läpple, D., Renwick, A., Thorne, F., 2015. Measuring and understanding the drivers of agricultural innovation: evidence from Ireland. *Food Policy* 51, 1–8.

Lastra-Bravo, X.B., Hubbard, C., Garrod, G., Tolon-Becerra, A., 2015. What drivers farmers' participation in EU agri-environmental schemes? Results from a qualitative meta-analysis. *Environ. Sci. Pol.* 54, 1–9. <https://doi.org/10.1016/j.envsci.2015.06.002>.

Lichtenberg, E., 2002. Agriculture and the environment. In: Gardner, B., Rausser, G. (Eds.), *Handbook of Agricultural Economics. Agriculture and Its External Linkages*, vol. 2A. pp. 1249–1313 (Amsterdam: North Holland).

Likert, R., 1932. A technique for the measurement of attitudes. *Arch. Psychol.* 22, 5–55.

Mann, S., 2005. Farm size growth and participation in agri-environmental schemes: a configurational frequency analysis of the Swiss case. *J. Agric. Econ.* 56 (3), 373–384.

Mann, S., 2018. Conservation by innovation: what are the triggers for participation among Swiss farmers? *Ecol. Econ.* 146, 10–16. <https://doi.org/10.1016/j.ecolecon.2017.09.013>.

OECD, 2010. *Eco-Innovation in Industry: Enabling Green Growth*. OECD Publishing, Paris.

OSF, 2015. Official Statistics of Finland (OSF): statistics on the finances of agricultural and forestry enterprises [e-publication]. ISSN = 2489-320X. 2015 Statistics Finland, Helsinki [referred: 5.6.2017]. Access method: http://www.stat.fi/til/mmtal/2015/mmtal_2015_2017-03-21_tie_001_en.html.

Pasucci, S., de-Magistris, T., Dries, L., Adinolfi, F., Capitanio, F., 2013. Participation of Italian farmers in rural development policy. *Eur. Rev. Agric. Econ.* 40 (4), 605–631. <https://doi.org/10.1093/erae/jbt005>.

Podsakoff, P.M., MacKenzie, S.B., Podsakoff, N.P., 2012. Sources of method bias in social science research and recommendations on how to control it. *Annu. Rev. Psychol.* 63, 539–569.

Rogers, E.M., 2003. *Diffusion of Innovation*, Fifth ed. Free Press, New York.

Ruto, E., Garrod, G., 2009. Investigating farmers' preferences for the design of agri-environmental schemes: a choice experiment approach. *J. Environ. Plan. Manag.* 52 (5), 631–647. <https://doi.org/10.1080/09640560902958172>.

Sattler, C., Nagel, U.J., 2010. Factors affecting farmers' acceptance of conservation measures – a case study from north-eastern Germany. *Land Use Policy* 27, 70–77. <https://doi.org/10.1016/j.landusepol.2008.02.002>.

Shortle, J.S., Dunn, J.W., 1986. The relative efficiency of agricultural source water pollution control policies. *Am. J. Agric. Econ.* 68 (3), 668–677.

Siebert, R., Toogood, M., Knierim, A., 2006. Factors affecting European farmers' participation in biodiversity policies. *Sociol. Rural.* 46 (4), 318–340.

Statsoft, Inc., 2011. *Electronic statistics textbook*. Statsoft, Tulsa, OK Downloaded from: <http://www.statsoft.com/textbook>.

Stock, R.M., Oliveira, P., von Hippel, E., 2015. Impacts of hedonic and utilitarian user motives on the innovativeness of user-developed solutions. *J. Prod. Innov. Manag.* 32 (3), 389–403.

Unay-Gailhard, I., Bojnec, S., 2015. Farm size and participation in agri-environmental measures: farm level evidence from Slovenia. *Land Use Policy* 46, 273–282. <https://doi.org/10.1016/j.landusepol.2015.03.002>.

Unay-Gailhard, I., Bojnec, S., 2016. Sustainable participation behavior in agri-environmental measures. *J. Clean. Prod.* 138, 47–58. <https://doi.org/10.1016/j.jclepro.2015.09.003>.

- Uusitalo, R., Ylivainio, K., Nylund, P., Pietola, L., Turtola, E., 2010. Rainfall simulations of Jokioinen clay soils amended with gypsum to decrease soil losses and associated P transfer. In: Turtola, E., Ekholm, P., Chardon, W. (Eds.), *Novel Methods for Reducing Agricultural Nutrient Loading and Eutrophication: Meeting of Cost 869*, 14–16 June, Jokioinen, Finland. MTT Tiede, vol. 10. pp. 56.
- Vanslebrouck, I., Van huylbroeck, G., Verbeke, W., 2002. Determinants of the willingness of Belgian farmers to participate in agri-environmental measures. *J. Agric. Econ.* 53 (3), 489–511.
- von Hippel, E., 1998. Economics of product development by users: the impact of “sticky” local information. *Manag. Sci.* 44, 629–644.
- Wilson, G.A., Hart, K., 2000. Financial imperative or conservation concern? EU farmers' motivations for participation in voluntary agri-environmental schemes. *Environ. Plan. A* 32 (12), 2161–2185. <https://doi.org/10.1068/a3311>.
- Yu, J., Belcher, K., 2011. An economic analysis of landowners' willingness to adopt wetland and riparian conservation management. *Can. J. Agric. Econ.* 59 (2), 207–222. <https://doi.org/10.1111/j.1744-7976.2011.01219.x>.
- Zabala, A., Pascual, U., García-Barrios, L., 2017. Payments for pioneers? Revisiting the role of external rewards for sustainable innovation under heterogeneous motivations. *Ecol. Econ.* 135, 234–245. <https://doi.org/10.1016/j.ecolecon.2017.01.011>.
- Zimmermann, A., Britz, W., 2016. European farms' participation in agri-environmental measures. *Land Use Policy* 50, 214–228. <https://doi.org/10.1016/j.landusepol.2015.09.019>.