European Review of Agricultural Economics

Manuscript accepted 15th October, 2019

Demand and supply of agricultural ecosystem services: towards benefit-based policy

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Abstract

In order to integrate ecosystem services (ES) in designing agri-environmental policy, we investigated both the demand for, and supply of, ES from agricultural environments in Finland. Using the discrete choice experiment method, we measured citizens' willingness to pay (WTP) for four different ES and analysed farmers' compensation request (WTA) for producing these services. Biodiversity and water quality gathered the highest WTA of farmers, but also highest WTP of citizens. Overall, the average WTA exceeded the WTP for almost all attributes and levels, but 20–27% of farmers were willing to produce the ES with the compensation lower than citizens' WTP.

Keywords: agriculture; benefit-based agri-environmental policy, ecosystem services, choice experiment

JEL classification: Q18, Q51, Q57

1. Introduction

Agricultural production faces versatile and often conflicting expectations. These include considerations related to the production of various ecosystem services (ES), such as food, pollination, landscape and climate services. Policy-makers should be able to integrate these different expectations into acceptable and applicable agri-environmental policy. This task will become increasingly difficult in the future, because in Finland, as in many other European countries, the public sector suffers from a fiscal sustainability gap. This paper explores and provides tools for integrating citizens' and farmers' preferences and values (related to agricultural production) into the design of agri-environmental policies to obtain more environmental benefits with lower costs for taxpayers. One solution to these challenges would be agri-environmental policy based on citizens' and farmers' values and preferences (Burton and Schwarz, 2013; Hasund, 2013; Schroeder et al., 2013)

In the framework of ecosystem services, the primary goal of agriculture is to produce provisioning services, such as food. However, it is commonly recognised that agricultural environments also deliver cultural (such as enjoyment from landscape and recreation), regulating (such as control of climate and diseases), and supporting services (such as nutrient cycles) (de Groot et al., 2002; Gobster et al., 2007; Power, 2010; van Zanten et al., 2014). Some of these services, and possible dis-services, are unintended side effects of the production of provisioning services. The purpose of agri-environmental policy is to develop incentives towards agricultural management that supports a broader range of ecosystem services (Prager et al., 2012; Rey Benayas and Bullock, 2012). To support the efficient design of agri-environmental policies, knowledge of the value of the services provided by agricultural ecosystems is required.

The current agri-environmental policy in the European Union (EU) is designed to encourage farmers to participate in voluntary agri-environmental schemes and to compensate them for the additional costs incurred by the implementation of agri-environmental measures as well as the income foregone due to any loss of profit (for example, reduced production). The current schemes do not demand or ascertain the production of public goods or ES, i.e. farmers are not paid for achieving environmental outcomes but for implementing management practices. For example, farmers are currently compensated for providing water protection zones instead of outcomes of water protection, such as decrease in nutrient run-offs from their farm.

Instead of management oriented policies, new forms of policies in which farmers obtain income from the production of public goods, i.e. environmental outcomes, have been suggested. In some previous studies, these new policy initiatives have relied on environmental and other indicators of scheme success and have been discussed under the term of result-oriented or result-based policy (e.g. Burton and Schwarz, 2013; Herzon et al., 2018). Here, we stress that the design and legitimisation of such policies also requires knowledge of how the various ES are valued by the final beneficiaries, i.e. citizens (ENRD, 2010; van Tongeren, 2008). Emphasis on benefits entails analysing how citizens weight the services and how they perceive their trade-offs, for example, how valuable are possible improvements in landscape compared to improvements in water quality. To underline the information on the values of beneficiaries as an important part of policy design, we use the term of *benefit-based policy*. Benefit-based policy implies that, in policy design, the environmental outcomes are in focus as in results-based policy, but it also emphasises the value of outcome for citizens. Instead, in the traditional cost-based policies, the focus of policy design is in compensations for farmers to cover the cost of environmental management practices. From the farmers' point of view, the question concerning the feasibility of benefit-based policy is whether the compensation corresponding to the production of benefits is enough to motivate them to supply new types of services demanded by citizens.

Previous studies on policies focusing on ES have demonstrated the importance of demand and supply information (Lima Santos et al., 2016). Few studies have empirically contributed to the design of benefit-based policies from both demand and supply perspectives, although such integrated analysis might provide a strong consultation basis in policy-making (e.g. Castro et al., 2014; Huang et al., 2015; Nieto-Romero et al., 2014; Zasada, 2011). Although agricultural ES are often supplied in multiple-service bundles, preferences are usually identified for a single provisioning, regulating or cultural service. Most previous studies have only addressed demand, neglecting the supply side, and have also concentrated on a single or occasionally on a few ecosystem services (Chen et al., 2017). Our paper aims at responding to these limitations by exploring both the supply of, and demand for, a bundle of ES from agriculture.

The overall preferences of citizens and farmers for agri-environmental policy objectives in the form of ES are derived using the discrete choice experiment (CE) method. The CE method reveals citizens' willingness to pay (WTP) for agricultural ES. The same method is used to evaluate the willingness of farmers to provide ecosystem services. In this case, farmers consider the amount of compensation needed, i.e. their willingness to accept (WTA), to produce the environmental outcomes in terms of ES.

This study covers both the demand and supply sides of ecosystem services from agricultural land. First, we measure citizens' WTP for four different ecosystem services from agricultural environments. Second, we analyse farmers' WTA for producing the four services. In both, we apply coordinated CEs in such a way that the results can be used for aggregation to reveal the policy priorities for benefit-based future policies.

2. Previous studies on ecosystem service demand and supply from agri-environments

Agro-ecosystems are human-managed ecosystems that play a crucial role as both a provider and consumer of multiple ES (Swinton et al., 2007; Zhang et al., 2007). They are socio-ecological systems that are multifunctional, including functions for food and fibre provision, and greatly interact with, and depend on, surrounding natural ecosystems (Huang et al., 2015). The provision of goods and services is a direct result of ecosystems influenced by farming activities, where the latter externally modify, improve or degrade the ES provision of agro-ecosystems (Dale and Polasky, 2007; Power, 2010; Zhang et al., 2007), but do not directly provide them.

Agro-ecosystems provide a range of provisioning, regulating and cultural services to human society (Huang et al., 2015; Power, 2010; Swinton et al., 2007), while, due to their strong dependence on natural, unmanaged ecosystems, these systems require other regulating and supporting services to be productive. Given certain management practices, agro-ecosystems may also generate dis-services, i.e. negative effects from farming activities, such as nitrogen leaching and pesticide drift, the loss of habitat or sedimentation of waterways (Zhang et al., 2007).

Integrated approaches suggest that the supply of, and demand for, ES should be analysed together in order to identify supply–demand mismatches that lead to the unsustainable and/or non-efficient management of ecosystems. Several frameworks for the integrated assessment of ES supply and demand are available in literature (Wei et al., 2017). In all these frameworks, supply is measured in biophysical terms defined as "the components of a provided ecosystem based on biophysical properties, ecological functions, and social properties in a particular area and over a given period" (Wei et al., 2017: 16). These frameworks ignore the social and economic part of supply, i.e. how physical supply is affected by the acts and practices of farmers and by policy or market responses.

Farmers face the trade-off between production of provisioning services, i.e. food and fibre, and the provision of regulating or cultural services to society (Gordon et al., 2010; MEA, 2003; Power, 2010; Rodríguez et al., 2006). Empirical studies that have quantified trade-offs are limited in number (Baldi et al., 2015). In order to govern the trade-offs and to target sustainable practices, it is imperative to better understand the interdependencies between various ES (Baldi et al., 2015) and to account for the views of farmers on aggregated/bundled ES (de Groot et al., 2002; Raudsepp-Hearne et al., 2010).

The demand or the benefit side can be addressed by using non-monetary indicators (e.g. people's perceptions of the importance of ES) and/or by using economic indicators derived from real or hypothetical markets (Martín-López et al., 2012; Turner et al., 2010). Usually, economic valuation of demand aims at revealing the WTP of citizens or beneficiaries in general for certain ES. The supply or cost side is related to farmers' willingness to adopt management practices and farming procedures (e.g. organic farming or extensive management) that can promote ES, such as amenities, as well as soil and water protection (Zasada, 2011). An extensive list of studies have referred to the farmer uptake of voluntary agri-environmental measures and the factors that determine farmers' willingness to implement such measures and consequently to supply ES (Grammatikopoulou, 2016; Siebert et al., 2006). The willingness to supply ES can also be measured in terms of farmers' willingness to accept (WTA) a certain level of payments to adopt specific management practices. The outline of demand and supply will entail the identification (profile, preferences and valuation of ES) of beneficiaries, as well as that of providers, to ensure the socially efficient management of ES, solving the problems of under provision or mismatching of ES (Pagiola et al., 2005).

Stated preference studies including contingent valuation, conjoint analysis, CEs, and contingent ranking (Huang et al., 2015) have been employed in assessing ESS from agro-ecosystems. For agricultural ES, which are often examined in the framework of agri-environmental schemes, CEs can account for the complex characteristics (Bennett and Blamey, 2001; Hanley et al., 2001) of the service in the sense that multiple options and several attributes are considered.

Some studies have aimed at deriving a comprehensive picture of citizens' preferences for agricultural ES. Novikova et al. (2017) applied a CE in Lithuania to explore the preference of residents for the reduction of underground water pollution, preservation of biodiversity and sustenance and improvement of agricultural landscapes at the national scale, which revealed heterogeneity of preferences. A CE and latent class choice modelling were used to examine the demand for a range of agri-environmental services in Thailand from multifunctional agriculture (Sangkapitux et al., 2017). Dupras et al. (2018) applied contingent valuation and CE methods to value the impact of farming practices on landscape aesthetics in Canada. WTP for landscape aesthetics as well as water quality and fish diversity were found to be at a high level. The WTP for enhanced biodiversity of small forest patches in agricultural landscapes was examined in a study by Varela et al. (2018) through a CE.

On the supply side, studies have mainly focused on farmers' perceptions of ES rather than on economic assessment of the compensation required to produce the ES. Bernués et al. (2016), Smith et al. (2014) and Xun et al. (2017) explored farmers' knowledge of ES, interaction among them, perceptions of value, and their relationships with certain practices. An interesting outcome of these studies is that, although farmers place high value on ES, they perceive them to be only moderately manageable. Several studies have employed CE applications in eliciting farmers' choices. Aslam et al. (2017) and Espinosa-Goded et al. (2010) revealed that farmers prefer to remain in a 'business as usual' state, showing a strong aversion to drastic changes in current activities. Some CE studies have concluded that the level of compensation is related to and differentiated according to farmers' current management practices as well as the attributes of the new scheme (e.g. Espinosa-Goded et al., 2010; Vedel et al., 2015; Villanueva et al., 2017). Broch and Vedel (2012), Christensen et al. (2011) and Ruto and Garrod (2009) have highlighted the relationship between the required compensation level and the scheme's flexibility and administrative burdens. Previous literature has also indicated challenges in using WTA measure due to WTP/WTA disparity (Tunçel and Hammitt, 2014). Villanueva et al. (2017) revealed considerable heterogeneity among farmers in their preferences for agri-environmental schemes, which to a large extent could be explained by the specifics of the agricultural system (the type of joint production), but also by farm/farmer characteristics and farmer knowledge and perceptions. Broch et al. (2013) examined the relationship between farmers' willingness to provide ES and the spatial heterogeneity associated with ES demand. WTA deviates in accordance with the ES in question, as revealed by Broch and Vedel (2012) who found that farmers accept a lower level of compensation when the aim is to protect biodiversity and groundwater relative to recreation.

Latacz-Lohmann & Schreiner (2019) used integrated approach and examined consumers' WTP and producers WTA for higher animal welfare standards by using similar CEs for both respondent groups. However, related to ES, the literature still lacks studies that account for both demand and supply and conclude with holistic suggestions for policy-making. One example comes from Finland where both citizen and landowner preferences for one agricultural ecosystem service (landscape improvements) have been examined using a voluntary scheme (Grammatikopoulou et al., 2013). The study concluded with clear suggestions for a locally implemented landscape value trade scheme. Target- or result-based schemes are structured based on the ES framework and on the evidence that ES include values that are measurable and visible in a demand–supply market context. This is one of the rare studies that empirically addresses both parts, i.e. demand and supply, to assist in the design of benefit-based measures. National-level studies are either ongoing or lacking.

3. Methods and data

3.1. Identifying ecosystem services for valuation

We began the selection of agricultural ES for valuation by applying the Common International Classification of Ecosystem Services as a basis (CICES, 2016). CICES is a continuously developing European-wide classification system that can also be used for valuing ES. To select relevant ES provided by agricultural environments from the CICES classification, a literature review and the expert judgement of agricultural economists and ecologists were used. The selected services included food, agro-diversity, bioenergy, pollination, habitats for animal nursery and reproduction, pest control, soil productivity, cultural heritage, the existence of species and ecosystems, the recreation environment, landscape, water quality, and climate change mitigation.

In the valuation of agricultural ES with the CE method, it is not possible to include all of the various services agricultural environments provide. To choose the attributes for the CE from the 13 ES mentioned above, the following steps were performed by the project group:

1. Analysis of the importance of the ES for citizens based on previous survey data (n = 800) (Pouta and Hauru, 2015);
2. Evaluation of the importance of agri-environmental ecosystem services by stakeholders from the administration and NGOs (n = 6);
3. Stakeholder (n = 7) discussion of the relevant ES based on step 2;

4. A summary by researchers (n = 9) of steps 1 to 3 and analysis of market and non-market services, as well as final and intermediate services;
5. Evaluation by valuation experts (n = 10) of the questionnaire and the CE;
6. Attribute selection for the pilot study;
7. Pilot study (n = 202);
8. A decision by researchers on the attributes in the valuation task of the final survey.

The ES selected for the CE were landscape, the existence of species and ecosystems, water quality due to agriculture, and climate change mitigation. In developing these selected ES into measurable attributes and their levels, the project group of environmental economists, ecologists and agri-environmental policy experts (n = 12) searched for concrete indicators that could be affected by farming practices and consequently targeted with agri-environmental policy. It was important to find reasonable attribute levels for both citizens and farmers separately, while making them as compatible as possible. The selected attributes and their descriptions for both citizens and farmers are presented in Appendix A. The different levels for the attributes are listed in Table 1 where level 0 represents the current state, i.e. the status quo option.

In the farmers' CE, some status quo (level 0 in Table 1) attribute levels were farm-specific. For example, the status quo level for the area of traditional rural biotopes (TRB) was given as the farmers' current TRB area, which had been enquired in a preceding part of the survey. In addition, the reduction of nutrient runoff and current agri-environmental payment were case-specific.

Crop producers and those in animal husbandry had different landscape attributes in the CE. The crop producers' landscape attribute was crop diversity and that of the animal husbandry farmers was the length of the grazing season. The questionnaires were targeted at the groups of farmers based on their main production line which was obtained from the national farmer register, along with the contact information.

Table 1. Attributes of agri-environmental policy programmes and their levels

Ecosystem service		Citizen survey	Farmer survey
Biodiversity	Level 0	Present area (TRB), 0 species protected	Present area of TRB
	Level 1	Area is increased by 30%, 100 species protected	Area increased by 5 ha
	Level 2	Area is increased by 60%, 200 species protected	Area increased by 10 ha
Landscape: Animals	Level 0A	Seldom seen	Cattle, sheep and horses graze for under 3 months
	Level 1A	Often seen during summer	Cattle, sheep and horses graze for over 3 months
	Level 2A	Often seen during summer and the unfrozen season	Cattle, sheep and horses graze for over 6 months
Landscape: Plants	Level 0P	3 species	3 species
	Level 1P	4 species	4 species
	Level 2P	5 species	5 species, of which one is a scenic plant (sunflower, corn etc.)
Climate change mitigation	Level 0	0% decrease in current emissions	At least 20% of the area under cultivation with perennial plants
	Level 1	10% decrease in current emissions	At least 40% of the area under cultivation with perennial plants
	Level 2	30% decrease in current emissions	At least 60% of the area under cultivation with perennial plants
Water quality effects	Level 0	60% of surface waters in good or excellent condition	The estate's current nutrient flow
	Level 1	70% of surface waters in good or excellent condition	70% of the current nutrient flow
	Level 2	80% of surface waters in good or excellent condition	40% of the current nutrient flow
Cost/Agri-environmental payment	Levels	€5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 130, 160, 190, 300, 500 /taxpayer/year, during 2017–2026	€50,100, 200, 350, 550, 800* ha/year during 2021–2027

3.2. Surveys and choice experiments

The citizen survey started with questions about personal relationship with agriculture and then proceeded to questions concerning attitudes towards agri-environmental issues, importance of different agricultural ecosystem services and how well Finnish agriculture has succeeded in producing ecosystem services. Next, citizen survey introduced a new benefit-based agri-environmental policy to the respondents by informing them that, in the hypothetical new programme, farmers would be paid for producing environmental benefits. The survey explained that the new agri-environmental programme would be financed with income tax. Depending on the extent of the programme, the cost to taxpayers would vary, but all taxpayers would participate in financing the programme. Respondents were informed that the current programme also causes expenses to citizens, amounting to approximately 40 euros per individual per year. This cost was based on expert judgement. Consequentiality was enforced by stating that the information from the choice tasks would help decision-makers to revise the agri-environmental programme.

The farmer survey began with socio-demographic questions and background information on the farm. These were followed by questions about current agri-environmental compensation and attitudinal questions concerning agri-environmental schemes as well as current and potential production of ecosystem services on the farm. The survey then suggested that the current agri-environmental scheme, which compensates additional costs and income foregone resulting from applying agri-environmental measures, would be replaced by a benefit-based agri-environmental scheme. The proposed programme would replace all other environment-related compensation currently paid to the farmers. Current agri-environmental scheme has been in place for 20 years and 90% of the farmers are included. There has been a strong public discussion of the in-efficiency of current agri-environmental practices in producing environmental outcomes. Consequentiality, important for incentive compatibility (Vossler et al., 2012), was enforced in the farmer survey by informing about the need to renew the agri-environmental scheme for the next Rural Development Programme period starting in the EU in 2021.

Both surveys informed the respondents about the suggested new agri-environmental scheme and the attributes as well as their levels (Table 1). Following the introduction of the attributes and the new benefit-based programme, the respondents in both citizen and farmer surveys were presented with six choice tasks. Each choice task had three alternatives: the status quo alternative, described as maintaining the current programme, and two alternatives with improvements in the state of ES. The alternatives were described with four ES attributes. Attributes had three different levels: status quo level as well as lower improvement and higher improvement. Status quo levels of different attributes also appeared in non-status quo alternatives. There was also a monetary attribute (cost for citizens and compensation for farmers) associated with each alternative. The status quo alternative was identical across choice tasks. Examples of choice tasks for citizens and farmers are presented in Appendix B.

To allocate the attribute levels to the choice tasks in the both citizen and farmer CE, we used efficient experimental designs. Efficient designs are used to generate parameter estimates with standard errors that are as low as possible and thus to obtain the maximum information from each choice situation (see Rose and Bliemer, 2009). The generation of efficient designs requires the specification of priors for the parameter estimates. In the design of the pilot surveys, we employed zero priors. In the final studies, however, we employed a Bayesian D-efficient design using Ngene (v. 1.0.2), taking 500 Halton draws for the prior parameter distributions, and parameter estimates obtained from the pilot study were used as priors. Bayesian efficient designs take into account the uncertainty related to the parameter priors. In the design of the CE for citizens, we used a Bayesian prior only for the number of cultivated plant species in the landscape and fixed priors for the other attributes. In the design of the farmer survey, we used Bayesian priors for all other attributes except for the bid level.

In total, 36 choice tasks were generated and blocked in 6 subsets, which resulted in six choice tasks per respondent. For the citizens' survey, four versions of the design were created using four different cost scales (€5–300, €5–500, €40–300 and €40–500). The design of the four versions was identical, aside from the varying cost scale. However, in this paper, the effect of differing cost scales is not examined. In the farmer survey, the compensation scale was €50–800. The final designs of the citizen and farmer CEs had D-errors of 0.08829 and 0.057962, respectively.

Our survey design aimed at defining meaningful attribute levels and changes that were reasonable for both respondent groups. We also aimed to avoid vague qualitative descriptions of attribute levels. Although correspondence between samples was sought, the selected levels might have led to differences in the amount of change between citizens and farmers. For most of the attributes, we can conclude that the level of research information available is not comprehensive enough to guarantee the information bases to define the measures on farm level that would lead with certainty to particular environmental outcomes.

The correspondence of attribute levels was also analysed by ex-post expert judgement. The levels for landscape were found to correspond with each other rather well. However, it was impossible to reliably compare the water quality effects based on existing knowledge, because one cannot directly deduce the ecological condition of waters from a reduction in agricultural nutrient runoff. The ecological status of surface waters is primarily defined based on biological quality factors (phytoplankton, other aquatic plants, fish, and benthos). In addition to biological quality factors, nutrients, water quality and hydromorphological factors are also considered. There was also some uncertainty in the climate change attribute concerning the correspondence of citizens' and farmers' attribute levels. According to the expert knowledge, we can assume that the lower level of climate attribute in the farmer survey corresponded quite well with the citizen survey, but there is considerable uncertainty in the correspondence of the higher level of climate attribute. The uncertainty relates especially to peatland fields, where the carbon balance is very sensitive to different management practices. Another source of uncertainty is the end use of biomass from perennial plants. In the biodiversity attribute, the levels in the citizen survey could have been obtained if those farmers who are currently managing traditional rural biotopes increased their activity. Farmers producing traditional rural biotopes in areas that have not been managed by traditional methods in the past would not automatically lead to significant increases in biodiversity as the natural conditions may not be suitable for creating these ecosystems. Furthermore, there is also uncertainty in the knowledge on how establishing a traditional biotope in a typical field area would enhance the protection of endangered species.

3.3. Data

3.3.1. Citizen data

The survey data of citizens (aged between 18 and 74) were collected using an Internet survey in the spring of 2016. The sample was drawn from the Internet panel of an independent market research company, Taloustutkimus, comprising over 30,000 respondents who have been recruited to the panel using random sampling to represent the population (Taloustutkimus, 2017). A pilot survey (n = 202) was used to test the questionnaire, especially the attributes and levels in the CE. For the final study, a random sample of 8,391 respondents was selected, of whom 2,066 completed the survey, resulting in a response rate of 25%. Comparison of the socio-demographics of the sample with the population indicates that the proportion of females was lower, the respondents were slightly older and more highly educated and the proportion of people with children was a little higher compared with the population based on one-sample z-test (Table 2). However, most of these differences were small.

Table 2. Descriptive statistics (*n* = 2,066)

	Sample	Population* (age 18-74)	z-test p-value
Proportion of females, %	44	50	0.000
Mean age, years	53	48	0.000
Proportion of people with a higher educational level, %	37	24	0.000
Proportion of people with children (<18 years) in the family, %	26	24	0.000
Proportion of people living in Southern Finland, %	52	52	0.928

*Statistics Finland (2015)

3.3.2. Farmer data

The quantitative farmer data were collected in January 2017 using an Internet survey. The sample was drawn from the farm business register of the Agency for Rural Affairs. An e-mail invitation was sent to 5000 farmers. The sample consisted of 3,449 farms with crop production as the main production line and 1,551farms focused on animal husbandry. After two reminders, we received 591 usable responses. The response rates of the crop producers and animal husbandry farmers were 13% and 11%, respectively. The questionnaire was tested before the main study in a pilot survey (*n* = 98, response rate 10%) and in several expert interviews.

Descriptive statistics of the farmer sample are compared with the whole population, i.e. all farmers in Finland, in Table 3. Most of the statistics for the sample are close or equal to the population, and the representativeness of the sample was thus satisfactory.

Table 3. Descriptive statistics of the farmer sample (n = 591) and the whole farmer population of Finland (N = 49,982)

	Sample	Population*
Mean age, years	52	51
Mean acreage of agricultural land, ha	31	54
Organic farming	9%	9%**
Participating in an agri-environmental scheme	89%	88%
Crop production	45%	35%
Other plant production	13%	27%
Greenhouse production	0%	2%
Outdoor production	1%	3%
Milk production	12%	15%
Beef production	4%	6%
Other cattle husbandry	1%	1%
Pig production	3%	1%
Poultry production	1%	1%
Other grazing livestock	5%	5%
Mixed production	9%	4%

* Natural Resources Institute Finland
**Finnish Food Safety Authority, Evira / Finnish Organic Food Association Pro Luomu

3.4. Statistical models

A mixed logit model (MXL) takes into account respondent heterogeneity by allowing parameter values to vary across the respondents according to a pre-specified distribution. MXL is a highly flexible model and enables efficient estimation when there are repeated choices by the same respondents (Revelt and Train, 1998). The MXL model also resolves the problem of the independence of irrelevant alternatives (IIA) as it does not require this assumption.

In the modelling of both the demand for, and supply of, ecosystem services, monetary variables were treated as continuous variables and the other attributes were coded as dummy variables. We also included alternative specific constant for the status quo (ASC SQ), having value 1 when respondent chose the status quo alternative and 0 otherwise. In the estimation, the distributions must be imposed for each of the random parameters. All programme attributes and the alternative specific constant for the status quo were treated as random variables with normal distributions. The cost and compensation parameters were specified as fixed. Specifying cost as a random parameter can cause problems in the estimation of WTP, as WTP is the ratio of the attribute's coefficient to the price coefficient (Hensher, Rose and Greene, 2015). When both coefficients are allowed to vary, the distribution of WTP is quite complex as it is no longer just the scaled distribution of the attribute's coefficient (Train, 2003). Selecting the distribution for the price coefficient is not straight forward and can lead to WTP distributions that do not have defined moments or they can be heavily skewed (Hole and Kolstad, 2012), implying extremely high WTP. This is why we used fixed parameters for cost and compensation, even though assuming that there is no heterogeneity among the respondents in relation to price is somewhat unrealistic.

4. Results

The results of MXL models for both citizens and farmers are presented in Table 4. In the citizen model, most of the ecosystem service parameters were statistically significant and of the expected sign, excluding number of cultivated plant species in the landscape. There were no clear tendencies in the choice of policy alternatives, as the alternative specific constant for the status quo (ASC SQ), i.e. the current programme, was not significant. The cost was significant and negative, meaning that an increase in the cost decreases the utility. Level 2, i.e. greater improvement, was preferred for animals in the landscape, climate regulation and water conditions. However, for biodiversity, level 1 was preferred. Biodiversity (level 1) and water conditions (level 2) had the greatest effects on utility.

Table 4. Demand for, and supply of, agricultural ecosystem services. Mixed logit models in the preference space for citizen and farmer data

		Citizens		Farmers	
		Mean	Standard deviation	Mean	Standard deviation
ASC(SQ)		0.239		0.776**	
		(0.00)		(0.380)	
Cost/Agri-environmental payment		-0.009***		0.005***	
		(0.147)		(0.000)	
Biodiversity	Level 1	0.707***	1.171***	-1.572***	1.757***
		(0.066)	(0.080)	(0.208)	(0.221)
	Level 2	0.368***	2.227***	-2.068***	1.903***
		(0.086)	(0.102)	(0.243)	(0.270)
Landscape: Animals	Level 1	0.411***	0.977***	0.025	1.822***
		(0.071)	0.096	(0.208)	(0.212)
	Level 2	0.587***	1.331***	-0.798***	2.446***
		(0.076)	0.083	(0.232)	(0.276)
Landscape: Plants	Level 1	0.082	0.928***	-	-
		(0.063)	(0.094)		
	Level 2	0.068	1.161***	-	-
		(0.064)	(0.084)		
Climate change mitigation	Level 1	0.297***	1.421***	-0.421**	1.239***
		(0.076)	(0.081)	(0.191)	(0.211)
	Level 2	0.417***	1.689***	-1.141***	1.752***
		(0.079)	(0.094)	(0.222)	(0.232)
Water quality effects	Level 1	0.434***	1.517***	-1.346***	1.769***
		(0.072)	(0.081)	(0.237)	(0.211)
	Level 2	0.719***	0.877***	-1.370***	2.137***
		(0.071)	(0.103)	(0.250)	(0.261)
N		2,066		456	
Log likelihood		-11473.417		-2119.340	
LR chi^2(10)[a](8)[b]		1,723.67		496.25	
Prob<chi		0.000		0.000	

[a] Degrees of freedom in the citizen model
[b] Degrees of freedom in the farmer model

In the farmer model (Table 4), the ASC for the status quo was significant and positive, indicating that the respondents preferred the status quo, not the alternatives with increased ecosystem service production together with a certain amount of compensation. The share of serial non-respondents (i.e. respondents always choosing status quo option) was 22 percent of the farmer respondents. On the other hand, the share of those respondents who did not choose the status quo option in any choice set was 20 percent. Level 1 of the landscape attribute was not statistically significant, but level 2 was. In all other attributes, the lower levels were also statistically significant and the signs of the attributes were negative, as expected. In the biodiversity improvement and climate change mitigation attributes, level 1 was preferred to level 2. This result is in accordance with the expectation that larger changes require higher compensation. In the nutrient flow attribute, the coefficients of the levels 1 and 2 were very close to each other, indicating that the respondents did not react to the differences in the required reduction in nutrient run-off.

The standard deviations for all random parameters were statistically significant in both the citizen and farmer models. This implies that there is heterogeneity between the respondents over the mean parameter estimates (Hensher et al., 2015). For citizens, level 2 of the biodiversity attribute had the largest standard deviation, indicating that preferences for greater improvement of this attribute varied the most among the respondents. However, the standard deviation was lowest for the greater improvement in water quality, whereas this was the attribute that had the highest level of heterogeneity among farmers. Overall, the standard deviations were slightly lower in the citizen model.

The CE for citizens included two landscape attributes, grazing animals in the landscape and diversity of cultivated plants, whereas farmers had either of these two attributes based on their main production line. The farmer model presented in Table 4 is a joint model for crop producers and animal husbandry farmers[1], and the coefficient of the landscape attribute can thus be interpreted as an average of lengthening the grazing season and increasing the number of plant species in cultivation. Crop producers comprised 69% of the respondents, which corresponds well with their share of all Finnish farmers, and thus increasing plant diversity dominates the result.

The citizens' WTP and farmers' WTA for different attributes and their levels were calculated based on the MXL models. The results are presented in Table 5. WTP ranged between 31 and 76 euros per taxpayer per year. WTP was highest for a greater improvement in water quality effects and animals in the landscape, as well as for a lower improvement in biodiversity. Farmers' WTA figures ranged between 81 and 397 euros/hectare/year. The WTA was lowest for the lower

[1] Separate models were estimated for crop and animal husbandry farmers to test if there was a difference in the response to the landscape attribute. The results were very similar: the smaller change (Level1) in attribute level was insignificant, but the larger change (Level 2) had a negative, significant coefficient. We will analyse the heterogeneity of farmers' responses in the CE in detail in the forthcoming paper.

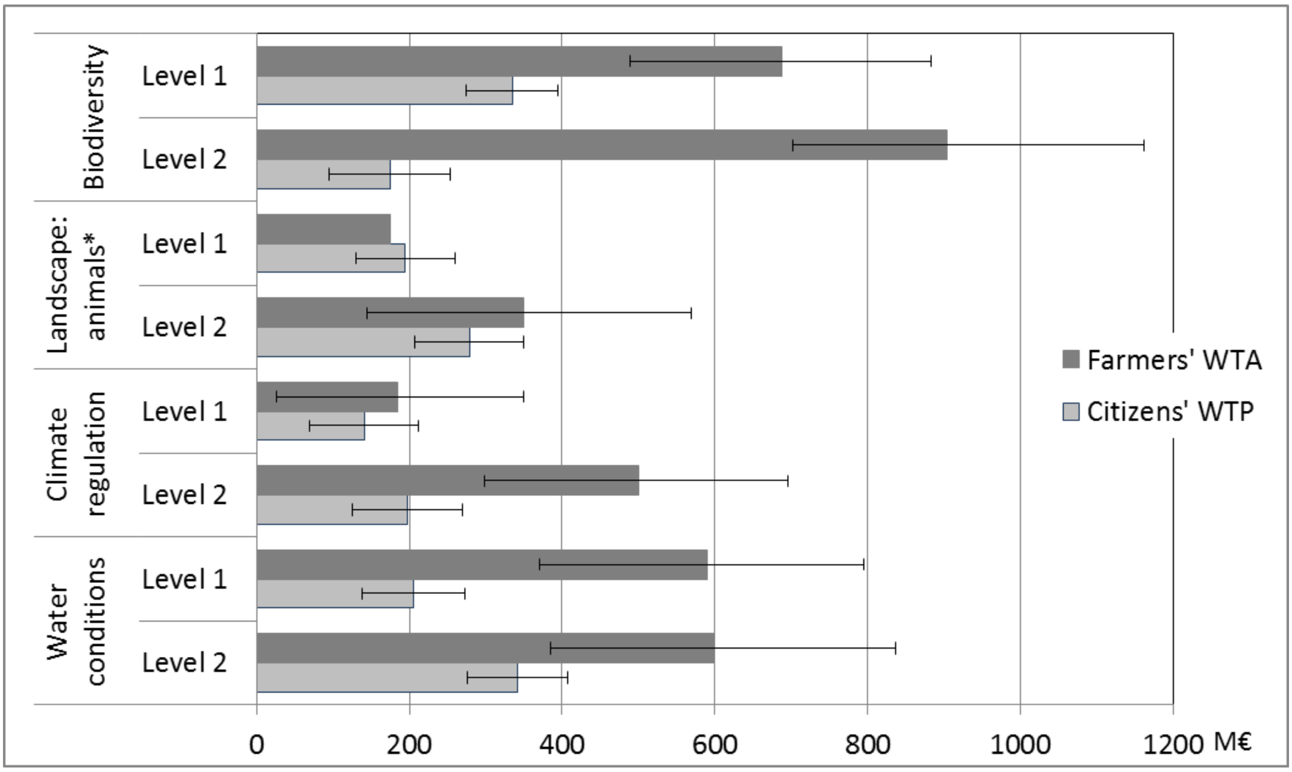
improvement in GHG mitigation, i.e. increasing the area cultivated with perennial plants, and highest for a greater improvement in biodiversity, with a 10-hectare increase in the TRB area.

Table 5. Willingness-to-pay (€/year) and willingness-to-accept (€/ha/year) estimates from MXL models (95% confidence intervals*)

Ecosystem service		Citizens' WTP (€/year)	Farmers' WTA (€/ha/year)
Biodiversity	Level 1	75.71 (61.07–89.55)	302.24 (214.96–387.71)
	Level 2	39.38 (21.28–55.45)	396.93 (307.88–510.04)
Landscape: Animals	Level 1	44.04 (28.90–58.30)	-
	Level 2	62.87 (49.00–78.76)	153.46 (63.97–249.68)
Landscape: Plants	Level 1	-	-
	Level 2	-	-
Climate change mitigation	Level 1	31.81 (15.38–47.66)	80.88 (11.35–153.37)
	Level 2	44.66 (28.75–60.47)	219.43 (130.99–305.24)
Water quality effects	Level 1	46.43 (31.60–61.68)	258.74 (162.99–348.91)
	Level 2	76.98 (62.53–91.29)	263.42 (168.57–367.01)

*Calculated with the Krinsky and Robb method

As the WTP and WTA estimates were not directly comparable (WTP was for taxpayer per year but WTA was for farmer per hectare), we aggregated the total WTP and WTA estimates (Figure 1). For the aggregation of citizens' WTP, we used the Finnish population over 18 years (4,431,392 in 2016). The aggregated WTP for different ecosystem services ranged from 141 million euros to 341 million euros. For the aggregation of farmers' WTA, the total area enrolled in the current agri-environmental scheme (2,278,500 hectares) was used. The marginal, per hectare WTA figures were multiplied by this number to produce the aggregated WTA per year for certain attributes. Total area enrolled in current scheme was used for aggregation, as it was the best and most justified estimate. However, it is possible that by using benefit-based policy, the environmental benefits could be obtained from a smaller area and therefore at lower cost as the measures would be undertaken where they actually are beneficial.



* In the survey of citizens, the landscape was divided into two attributes, whereas in the farmer study, livestock producers had an attribute concerning the grazing period and crop producers concerning the number of different plants cultivated in one season.

Figure 1. Aggregated WTP and WTA and 95% confidence intervals for different attributes.

Figure 1 presents the aggregated WTP and WTA for each attribute and level. The high demand for biodiversity, in particular on the lower level, faces a high demand for compensation from the farmers' side. Citizens' WTP for biodiversity does not follow the monotonicity assumption, as the WTP for level 1 is higher than for level 2. This could be due to the fact that some of the respondents may have considered 60% increase in TRB area as too large and been concerned about the area left for food production. However, as the current area of TRB is only 1% of the total area of agricultural lands, the area would remain low even with the higher increase.

The compensation request for water quality benefits is about two or three times as much as the citizens' willingness to pay. WTPs and WTAs for climate regulation on a lower level, as well as landscape benefits from grazing animals, approach each other. In the landscape attribute, the citizens' aggregated WTP for a lower level even exceeds the farmers' compensation demand. It should be noted, however, that the farmers' WTA for the lower level landscape attribute was linearly interpolated from the larger level change as the lower level landscape attribute was not statistically significant in the farmer model. In this case, we perceive that this method produces an acceptable, conservative estimate for WTA for a lower landscape change.

Figure 2 presents the aggregated WTP and WTA for three scenarios. The first scenario sets all the attributes on their lower level. It reveals that the aggregated compensation request of farmers is about twice as high as the aggregated WTP of citizens. The WTP of citizens increases only slightly for the scenario that raises all the attributes to their highest level. Instead, farmers perceive the burden of increased service provision, showing an approximately 50% higher demand for compensation than in the lower level scenario. The scenario with the highest net benefits was formulated by selecting those attribute levels in which the difference between the aggregated WTA and WTP was as low as possible. This means the lowest level for other attributes except water conservation. For this scenario, the costs also exceeded the benefits. The comparison of aggregated WTP and WTA suggests that none of the scenarios should be implemented as such.

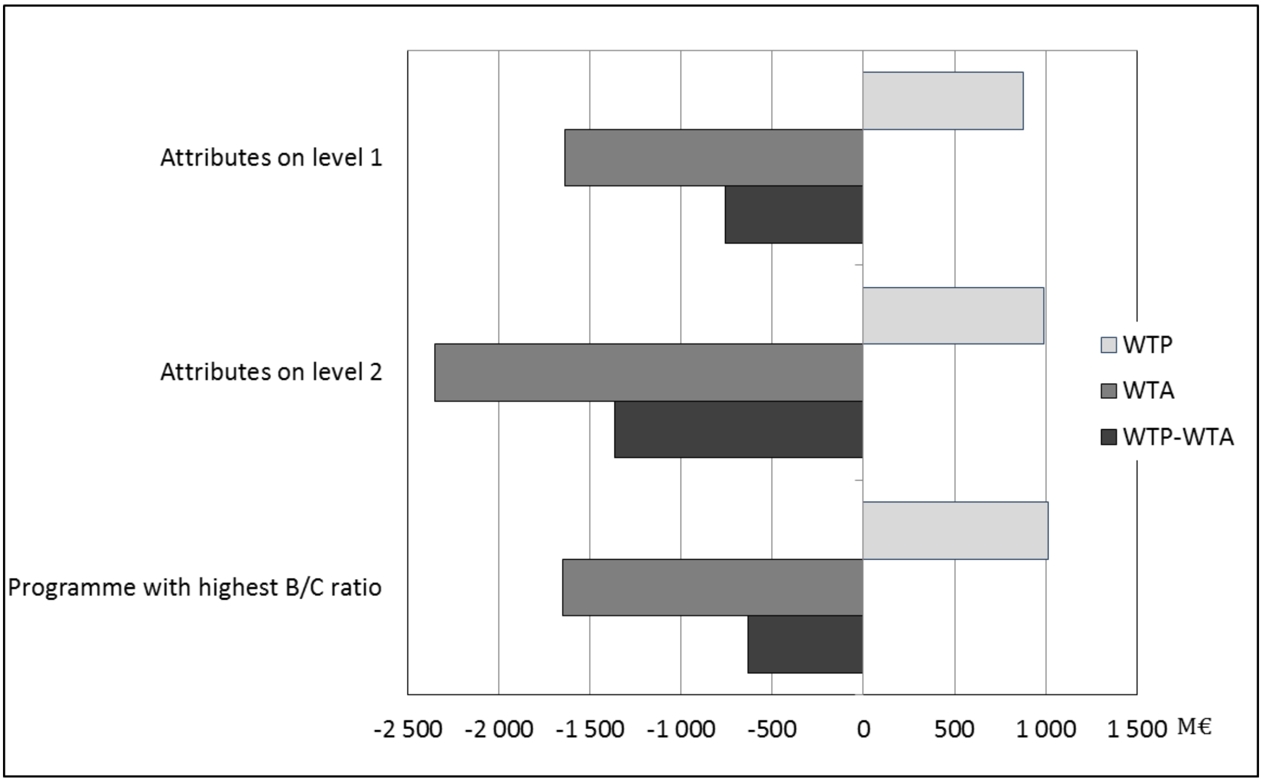


Figure 2. Scenario comparisons based on annual aggregated WTP and WTA estimates.

To analyse if a share of the farmers would be willing to provide the services with the compensation level corresponding to the citizen aggregated WTP, Figure 3 presents farmers' individual-level WTA estimates for the highest net benefit scenario. The estimates were calculated with individual-level coefficients. The figure also presents the aggregated WTP of citizens divided by the number of hectares in the agri-environmental scheme to make them comparable with the WTA per hectare in monetary terms. The aggregated WTP per hectare for the scenario with the highest net benefits was 444.6 euros. About 27% of the farmers were willing to produce ecosystem services for this compensation per hectare. In policy planning, it would be important to focus on these farmers who would be willing to produce the requested services with the lowest compensation demand.

Figure 3 also shows individual-level WTP estimates for citizens by presenting the share of respondents willing to accept a certain payment level. Instead of presenting traditional demand and supply curves and market balance, it explores how well farmers' WTA and citizens' WTP for a policy programme match. The WTA and WTP measures are equal (600€/ha) for a 37% share of citizens and farmers. However, even though a larger share of farmers would be willing to supply ecosystem services for this amount of compensation, it would not be legitimate from the citizens' point of view, as the scheme would be paid with taxes and less than half of the citizens are willing to pay this much.

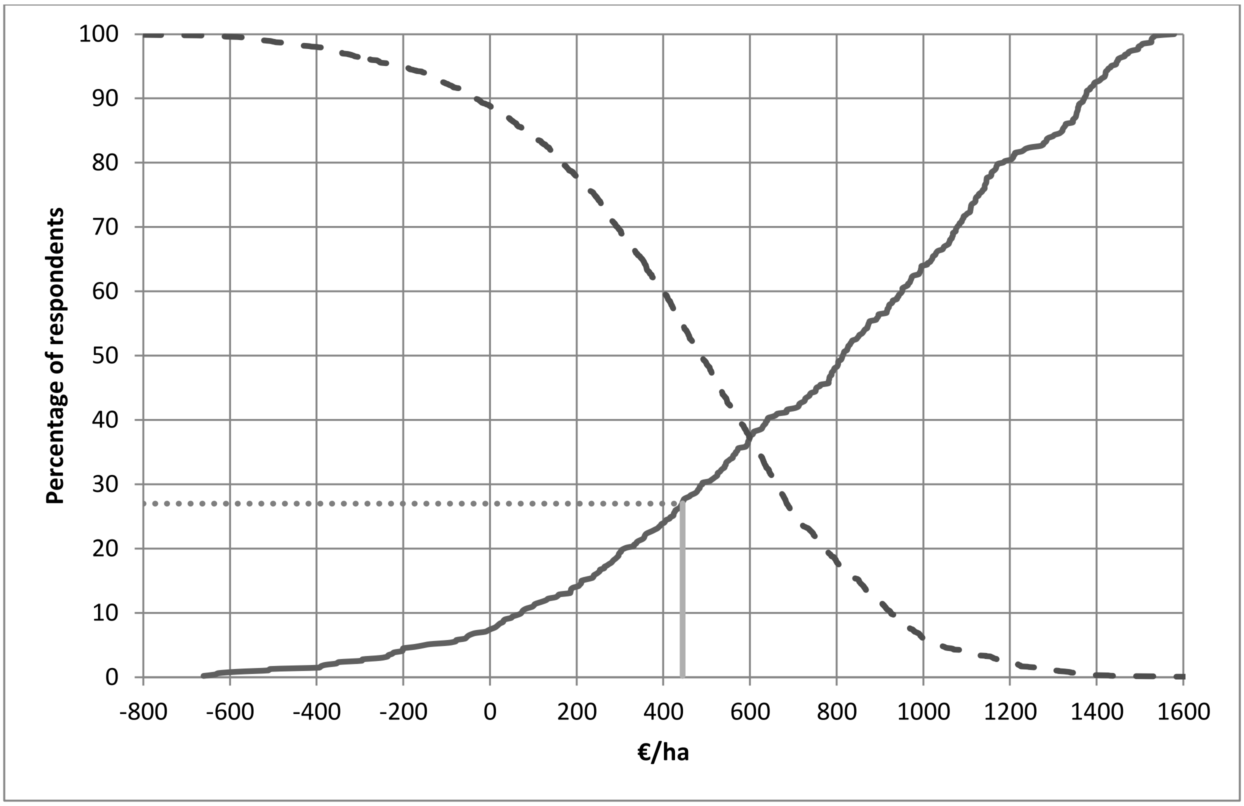


Figure 3. Distributions of the farmers' individual-level WTA measures (black curve), citizens' individual-level WTP measures (dashed curve), citizens' mean aggregated WTP (grey line) and the percentage of farmers with a lower WTA than this mean WTP (dotted line).

5. Discussion and conclusion

This study examined the demand for, and supply of, agricultural ecosystem services on a national level in Finland. We used MXL models to analyse citizens' WTP for four agricultural ecosystem services and farmers' requested compensation (WTA) for producing them. The study revealed that there is a clear demand for higher levels of ecosystem services produced by agriculture. The demand was highest for better water quality and a more diverse landscape. On the supply side, farmers preferred the status quo, i.e. the current programme. This was reflected in high WTA values, indicating that farmers require greater amounts of compensation in order to improve the production of ecosystem services. However, it is promising that the ecosystem services with the highest requested compensation were also those with highest citizens' WTP. Overall, the comparison between annual aggregated WTP and WTA estimates revealed that the costs of the programme exceeded the benefits in all scenarios. However, a proportion of farmers, i.e. 20–27%, depending on the details of the programme, were willing to produce the ecosystem services for the compensation that the citizens were willing to pay.

The results presented here are the first national results on the supply of, and demand for, key ecosystem services from agri-environment. If we reflect them with a local case study from Finland concerning landscape attributes in agricultural environments (Grammatikopoulou et al., 2013), we observe considerable differences. In Grammatikopoulou et al. (2013) citizens' WTP for landscape attributes exceeded the actual costs caused by the provision of landscape attributes, but we did not observe the same tendency here when WTP was compared with the compensation demand i.e. WTA. This implies that there is a need to evaluate the farmers' WTA in relation to the actual costs of providing the services. However, we obtained similar results in that farmers were most willing to provide other services than those that were most demanded by citizens.

There is also a possibility that farmer takes into account his or her own benefit from the public good while making choices. From our survey attributes, a farmer would be most likely to derive utility from the changes in landscape and traditional rural biotopes, i.e. the attributes that have very local effects. Instead, water quality and climate effects spreading to wide spatial area, are more complex and are also related to choices of the other farmers in the area as well as other agents further away. Our focus group discussions with farmers showed that their own interest was mainly in improving the growth potential of soil. Due to high WTA values obtained, it is rather unlikely that farmers would have deducted their own utility from the WTA. However, the farmers own utility from different ecosystem services on their own lands is an interesting future research topic.

High WTA values for farmers are partly driven by the difficulties in providing biodiversity services. In this study, the focus of biodiversity services was on traditional rural biotopes, which are hotspots of biological diversity and threatened species. The high compensation request related to these highlights the importance of finding new and more easily manageable solutions for providing biodiversity on agricultural land. The WTA estimates could be slightly increased by non-participation in the policy due to protest behaviour. The possible protest respondents were not excluded from the analysis because of the difficulty in ensuring the protest status of any respondent group, despite the typical attitude questions included in the survey. The serial participation and non-participation may also imply problematic behaviour from the modelling point of view if these respondents have decided to choose the status quo or one of the proposed policy alternatives despite the actual attribute levels. However, the shares of serial non-participation and serial participation were almost equal and are assumed to cancel out most of each other's impact on the WTA estimates.

Due to the study questions and design, we used both WTP and WTA measures, although an empirical divergence is often observed between WTA and WTP while measuring the same environmental change and the WTA approach is possibly problematic due to incentive compatibility issues (Lloyd-Smith and Adamowicz, 2018). WTA estimates have typically been higher in cases with less familiarity of the environmental good (Tunçel and Hammitt, 2014). In our case, farmers were also unfamiliar with the new type of benefit-based measures. In farmer decision-making, there was considerable uncertainty about the methods that would produce the given attribute levels. This probably caused farmers to support the status quo alternative in many choice sets and consequently led to high WTA estimates. It is also possible that in this application of a PES scheme, in which farmers are asked to give up production possibilities, i.e. private good, there exists strategic behaviour and some respondents have overstated their WTA (Lloyd-Smith and Adamowicz, 2018). Earlier choice experiment studies on landowners' WTA for ecosystem services have concluded that strategic behaviour is possible (Vedel et al., 2015). Nevertheless, we consider that the general recommendation to use WTA in cases where it is institutionally feasible (Johnston et al., 2016) is applicable here, although we cannot rule out strategic behaviour and fully guarantee incentive compatibility. We recommend future research looking for solutions for this issue in the case of CE.

If agri-environmental policies are moving towards benefit-based direction, there is a need to find policies that balance the demand for, and supply of, different ecosystem services. As our results demonstrated that citizens' WTP does not cover the compensation need of farmers if WTP and WTA are examined on average level, the results do not encourage the policy towards large scale provision of ecosystem services as such. However, the public support for the supply of ecosystem services could be targeted for the quarter of farmers that are willing to supply these services for compensation that is equal to or lower than citizens' WTP. Targeting the policy to these farmers might decrease the total area under AES scheme, but could still compete with the current policy or even outperform it with regards to environmental outcomes if farmers with good prerequisites for ecosystem service production are found. However, significant uncertainties related to a benefit-based policy and the information requirements of farmers related to choosing methods that produce particular environmental outcomes need to be resolved before changing the policy regime.

The results of this study could also be useful in developing the current policy scheme based on compensating the costs, by focusing on the ecosystem services having the greatest demand. Compensation based on the additional costs and income losses resulting from agri-environmental measures, however, may not lead to the most efficient outcome in terms of the overall supply of the desired ecosystem services. In this sense, payments based on observed and measured environmental benefits are more likely to lead to improved cost-effectiveness and efficiency. However, the implementation of a benefit-based policy scheme would require a fundamental shift in policy structures.

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Appendix A.

Attributes of agri-environmental policy programmes in choice experiment

Table summarises how different attributes were described to the two different respondent groups (citizens and farmers) in the survey.

Ecosystem service	**Attribute for citizens** Attribute description	**Attribute for farmers** Attribute description
Biodiversity	**Traditional rural biotopes and endangered species** Mowed or grazed semi-natural grasslands (meadows, leas, pastures) can provide a habitat for several endangered species.	**Traditional rural biotopes (TRB)** TRBs are biotopes shaped by traditional land use (e.g. meadows and pastures). Mowed or grazed TRBs can provide a habitat for several endangered species.
Landscape	**Typical agricultural landscape** Grazing animals and crops grown in open fields affect the diversity of the landscape.	**Diverse agricultural landscape** **Crop producers:** Diversity of crops increases the recreational value of the agricultural landscape. **Animal husbandry farmers:** A higher number of grazing animals increases the recreational value of the agricultural landscape.
Climate change mitigation	**Climate effects** A decrease from current emissions. Agricultural greenhouse gas emissions contribute to climate change. The greenhouse gas emissions can be reduced by various cultivation practices and capturing greenhouse gases.	**Climate change mitigation** Agricultural greenhouse gas emissions contribute to climate change. Greenhouse gas emissions can be reduced by increasing the acreage of perennial plants.
Water quality due to agriculture	**Water quality effects** Proportion of surface waters in a good or excellent state. About half of the nutrient runoff to waters comes from fields. This is affected by the amount of fertilizers used, cultivation practices, and annual weather conditions.	**Nutrient flow** The amount of nutrient runoff depends, for instance, on the fertilizers used. Nutrient runoff can be monitored from ditches with an indicator that would be installed without cost for farmers.

Appendix B.

Example of the choice set for citizens

	Current programme	**Alternative X**	**Alternative Y**
Traditional rural biotopes and endangered species	Present area, 0 species protected	Area is increased by 60%, 200 species protected	Area is increased by 30%, 100 species protected
Typical agricultural landscape			
• Grazing animals	Seldom seen	Often seen during summer	Often seen during summer
• Plants in cultivation	3 species	5 species	4 species
Climate effects Decrease from current emissions	0%	0%	30%
Water quality effects Proportion of surface waters in good or excellent condition	60%	80%	60%
Cost/taxpayer/year, during 2017–2026	€40	€70	€130
My choice	○	○	○

Example of the choice set for animal husbandry farmers

	Current programme	**Alternative X**	**Alternative Y**
Grazing season	Cattle, sheep and horses graze for under 3 months	Cattle, sheep and horses graze for over 3 months	Cattle, sheep and horses graze for over 6 months
Climate effects Share of the perennial plants from the arable area.	At least 20% of the area under cultivation with perennial plants	At least 40% of the area under cultivation with perennial plants	At least 60% of the area under cultivation with perennial plants
Water quality effects Reducing the amount of nutrient runoff with the measures chosen by the farmer. Measurement from the main drain.	Your farm's current nutrient flow	Nutrient flow decreased to 70%	Your farm's current nutrient flow
Traditional rural biotopes	Current area	Area is increased by 10 hectares	Area is increased by 5 hectares
Agri-environmental payment, €/ha/year, during 2021–2027	Your current agri-environmental payment per ha	€100	€350
My choice	○	○	○