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Drivers of farmers' adoption and continuation of climate-smart agricultural practices. A study from northeastern Italy

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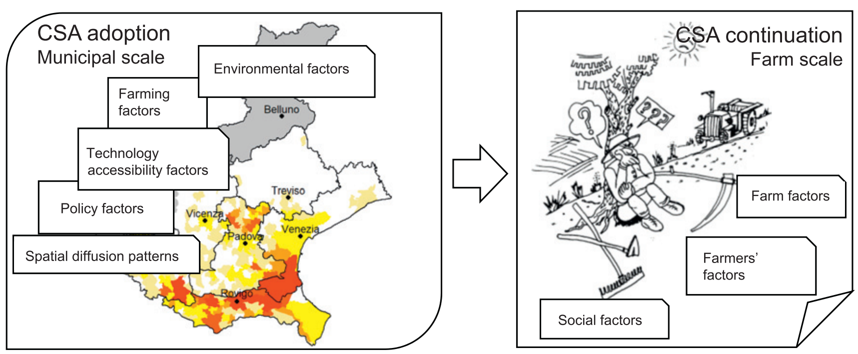
HIGHLIGHTS

- Several non-financial factors affect climate smart agriculture practices adoption
- Continuation of CSA practices assures long-term resilience to climate change
- A farm-level survey explores motivations and attitudes affecting continuation
- Policymakers should leverage social endorsement to nudge adoption and continuation

GRAPHICAL ABSTRACT



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ABSTRACT

The EU rural development policy has addressed challenges related to climate change in agriculture by introducing public voluntary schemes, which financially support the adoption of climate-smart agricultural practices. Several factors, most of which are non-financial ones, drive adoption and continuation of these schemes by farmers. Despite the importance of these factors, only a few studies explore their role in the European context. This paper contributes to filling this gap from a twofold perspective. First, it investigates the role of the farming factors, technology accessibility, environmental features, policy design and social expertise at the territorial level on early adoption. Second, it sheds light on farmers' attitudes and motivations and on social pressure on their decision to continue or discontinue the practices, by surveying a sample of early adopters. Three schemes for the Veneto region rural development programme are considered: no-tillage, fertiliser reduction, and water and fertiliser reduction. The results highlight that non-financial factors should be considered in order to design more effective schemes to prompt farmers to adopt and continue such practices over the long run. The paper also stresses the need to complement financial support with proactive information-based instruments.

1. Introduction

In recent decades, climate change has been widely recognised by scientific communities and policymakers as one of the most critical environmental issues and shown to severely impact the sustainability of many natural processes and human activities (Kerr, 2007; Cook et al.,

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2016). Agriculture is tightly connected to climate factors and therefore is threatened by climate change (Shaffril et al., 2018). For example, changes in rainfall or increases of extreme climatic events, such as droughts, seriously jeopardize yields and harvests. On the other side, agriculture can also mitigate climate change, for example by improving carbon-stocking capacity of soils through appropriate management (Hutchinson et al., 2007; de Araújo Santos et al., 2019; Martinsen et al., 2019).

Challenges related to climate change in agriculture require the adoption of innovative practices capable of increasing resilience and mitigating impacts, while also maintaining farm productivity. This set of practices has been comprehensively labelled by the FAO (2010) as climate-smart agriculture (CSA). CSA includes options for managing nutrients or water in an efficient way, conserving or enhancing soil fertility and aiding farm mechanization (Ogundari and Bolarinwa, 2018). Several of these options are already available to farmers, who can reduce water consumption by innovative water-saving irrigation systems, enhanced water storage and effective water management (Levidow et al., 2014; Tromboni et al., 2014; Bonzanigo et al., 2016). They can also enhance the capacity of agricultural soils to stock carbon by limiting the use of nitrogen fertilisers or abandoning conventional ploughing practices in favour of conservation tillage (Camarotto et al., 2018; Marinello et al., 2017; Pezzuolo et al., 2017; de Oliveira Ferreira et al., 2018).

A wide variety of policy instruments may be used for steering the adoption of CSA practices in agriculture: regulatory instruments based on command and control; economic instruments, such as taxes and public compensations; or information-based instruments, such as labelling and certification. The latter have been beneficially applied to address a broad range of environmental issues (Taylor et al., 2015), when information disclosure to consumers prompts behavioural changes towards the adoption of environmentally friendly practices. Four types of information-based regulation schemes can be identified (Bowen et al., in press) which combine whether i) information disclosure to external stakeholders is mandatory or voluntary; and ii) performance complies with mandatory standards or it is beyond them.

The EU has recently encouraged member states to embed CSA in their Rural Development Programmes through economic instruments. Public compensation is delivered to farmers who voluntarily adopt specific CSA schemes beyond the mandatory levels (European Commission, 2008, 2009, 2013; Long et al., 2016; Schulte Rogier et al., 2016). The extent to which farmers decide to adopt and carry on these schemes over time is crucial to define their success and, given that building resilience to climate change requires time, to ensure the sustainability of agriculture in the long run (Deressa et al., 2009).

Research on farmers' adoption and continuation of voluntary schemes has highlighted that farmers' choices are affected by a wide range of factors, connected to environment, technology, policy design features, structure of the farm, farmers' socioeconomic characteristics, attitudes and motivations and social aspects (Deng et al., 2016; Page and Bellotti, 2015; Luo et al., 2016). In Europe, the role of these factors on the diffusion of these schemes has been widely studied considering their adoption but much less as far as their continuation is concerned. In contrast, adoption and continuation of specific climate smart schemes is less studied, due probably to their more recent introduction. Although farmers are exposed to climate change, decisions on changing their farming practices are not obvious: they may be technically unprepared or reluctant to adopt innovations, or unable to perceive the advantages of the changes in the long term. Their farming structures may not be suitable for the changes, or existing policies not enough well designed or tailored to particular environmental conditions. All these factors may play an important role in CSA accomplishment in a medium-long term perspective, hence, there is an interest to better understand their effect.

The paper contributes to this aim by exploring the drivers affecting both adoption and continuation of some CSA practices connected to public voluntary schemes financially supported by the Rural Development Programme of the European Union. The 2007–2014 Rural Development Programme of the Veneto Region (northeastern Italy) is considered, when three CSA schemes were proposed for the first time. First, the paper provides an analysis of the drivers of farmers' choices on the early adoption of CSA-related Rural Development Programme schemes at the municipal scale, investigating the role of factors such as the farming structure, the local environmental features, the technology accessibility, the policy design. The spatial diffusion patterns of CSA innovation are also analysed. These factors are sometimes overlooked by research but may have an important role as triggers or barriers to adoption. Second, the paper analyses the role of factors affecting the farmer's decision to continue or discontinue the schemes after the first five years by subscribing or not a new contract. This is linked to the need of exploring farmers' choices in a longer perspective, considering that climate change adaptation is a long-term process which requires not only that farmers adopt CSA practices, but also that they do not discard them in the short-to-medium run. This analysis highlights the role played by farmers' motivations and attitudes as well as by the social pressure. To this end, individual data need to be considered; hence, a sample field survey of scheme adopters is carried out. The identification of relevant drivers of adoption and continuation is then operationalised in some policy recommendations to steer further diffusion of CSA practices in the region and at a broader scale.

2. Drivers of adoption and continuation of climate-smart agriculture practices

There is a wide and still growing body of literature analysing the factors affecting the adoption of environmental schemes in agriculture, in general. In Europe, this literature has evolved significantly thanks also to the role played by the Rural Development Programmes and their measures in steering farmers' decisions (Long et al., 2016; Schulte Rogier et al., 2016). While earlier works were mainly focused on farmers' socioeconomic and structural factors, more recent research has addressed farmers' attitudes and motivations (Defrancesco et al., 2008; Franks and Emery, 2013; Ma et al., 2012; Price and Leviston, 2014; Ruto and Garrod, 2009; Li et al., 2019), the role of human and social capital, e.g. of farmers' knowledge, information availability, and peers' influence (Klerkx and Leeuwis, 2009; Moschitz et al., 2015; Pascucci et al., 2013; Polman and Slangen, 2008), and the spatial dimension of the diffusion of practices (Bartolini and Vergamini, 2019; Bjørkhaug and Blekesaune, 2013; Boncinelli et al., 2016; Marconi et al., 2015; Raggi et al., 2015; Vergamini et al., 2017; Yang et al., 2015).

Specific literature on the adoption of CSA practices in Europe (and particularly in Southern Europe) is however still limited. A review of the literature has revealed a larger research focus on Asia, Africa and Latin America and on soil- and water-related technologies (Brandt et al., 2017; Khatri-Chhetri et al., 2017; Akrofi-Atitianti et al., 2018; Makate et al., 2019). CSA practices require access to specific technology and a predisposition to innovate; hence, farmers' adoption of such practices may be complex and difficult (Davidson et al., 2019). This may be also due to the imbalance between the long-term climate change benefits to society and the benefits to farmers that might be unperceived or negligible in the short term (Long et al., 2016). In addition, more than with other schemes, environmental features such as soil type and water availability can play a significant role in the case of CSA; however, they have been seldom addressed in the literature (e.g. in Ward et al., 2018). More often the existing studies have shown that financial support through specific policy measures is insufficient for inducing CSA implementation (Reimer et al., 2014; Darragh and Emery, 2018; Inman et al., 2018); rather, non-financial aspects, such as technical and management considerations and policy design factors, may act as barriers: for example, some EU schemes for water conservation in agriculture have failed because of their mismatch with farmers' objectives (Giordano et al., 2015). The positive role of farm size and intensity in increasing innovation adoption has also been highlighted; similarly, farmers' features (e.g. education) and the access to information play a positive role in innovation adoption, while increasing age and employment in off-farm activities hinder it (Läpple et al., 2015). Collins et al. (2016) and Inman et al. (2018) claim the crucial role of advice and information provision.

Continuation literature on CSA practices is even scarcer than adoption literature and has an even stronger focus on developing countries. Similar to adoption literature, however, it has highlighted the multiplicity of factors that affect farmer decisions. For example, a larger farm size, a larger share of family members under employment and environmental factors e.g. steeper slopes increase continuation of cover crops in northern Honduras (Neill and Lee, 2001), while in the case of no-tillage practices in Australia a positive role on continuation is played by higher rainfalls (D'Emden et al., 2006). Financial factors, technology and perception of risk delay the abandonment of soil fertility management practices in Kenya (Marenya and Barrett, 2007). Information provided to farmers through extension services and periodical meetings has also shown essential to ensure continuation for Brazilian (De Souza Filho et al., 1999), Australian (D'Emden et al., 2006), and Finnish farmers (Nyblom et al., 2003).

In the last decades, the whole literature studying adoption and continuation of environmental schemes in agriculture has largely benefitted from the theory of reasoned action and planned behaviour (Ajzen and Fishbein, 2005), that provides a helpful analytical framework to explain behaviours by human beings (Inman et al., 2018). In this context, the theory posits that the behavioural intentions of farmers depend on a range of background factors which include the farm structural and management factors; the farmer socio-demographic and motivational factors; the informational factors; and the social factors (Mettepenningen et al., 2013; Gatto et al., 2019; Deng et al., 2016; Wang et al., 2018). This theory is a reference point for systematising the broad range of factors emerging from the literature on adoption and continuation of voluntary environmental schemes and the more specific one on CSA considered in this paper.

3. The area under analysis and the related policy context

3.1. The characteristics of the study area

The flat and hilly farmed area of the Veneto region, where the considered CSA practices are implemented, covers approximately 730 thousand hectares in 114 thousand farms. Farm structure is characterised by small scale (73% of the holdings manage <5 ha of utilised agricultural area), high rate of part-time (77% of the farmers), and elderly holders (55% are over 60 years, and 3.5% are under 34 years) (ISTAT, 2010). The region is a fertile and intensively farmed area, characterised by arable crops (77% of the utilised agricultural area), including also fodder crops for a large animal production sector. Since the 1980s, the Nitrate Vulnerable Zones have been designated in the flatlands as priority target areas (see Fig. A.1 in the Annex) for regulating the use of fertilisers, which are responsible for eutrophication problems in the waters of the Venice lagoon (Collavini et al., 2005). Hence, reducing the use of fertilisers in agriculture and introducing new conservative agriculture practices represent important objectives of the region's agricultural policies. With regard to water consumption in agriculture, in recent years, the region has experienced severe heat spells connected to climate change and subsequent droughts (Bonzanigo et al., 2016).

The area is part of a wider region in Northern Italy, i.e. the Po Valley, and shares common features with it. The Po Valley is the flat largest and most intensively farmed area in the country, providing 54.8% of the total Italian cereals production, a quarter of which coming from the Veneto region (ISTAT, 2017). Considering that similar environmental problems characterise the whole Po Valley flatlands, Veneto region can be considered representative for such a larger area. However, it should not be forgotten that agricultural policies are region-specific.

3.2. The policy context

The EU Common Agricultural Policy addresses the climate change-related environmental issues in agriculture by means of a complex approach, combining command and control regulations and support mechanisms (Taylor et al., 2019).

Command and control regulations, also known as cross-compliance, set compulsory prescriptions, made increasingly stricter over time, for any farmer. They aim to avoid those agricultural practices that have a severe impact on the environment. From an information-based viewpoint, cross-compliance is classified among the traditional approaches to environmental regulation, as disclosure to external stakeholders is limited to record-keeping, made available for public controls (Bowen et al., in press). Being mandatory, in Italy cross-compliance regulations are not disclosed to consumers through labelling schemes.

Compensation-based public voluntary schemes, instead, define regulations for farming practices which go beyond the cross-compliance mandatory levels. In Italy, detailed prescriptions are defined at the regional scale, to make them better fit to the situation on the ground. These schemes might activate a ‘collective learning process’ (Lange and Gouldson, 2010) among farmers, so contributing to their wider diffusion. Although systematic public control of these schemes prescribes the provision of detailed information for the audit only, proactive information-based mechanisms can be adopted as a tool to increase their efficacy and diffusion (Bowen et al., in press). Indeed, farmers may use these voluntary schemes to disclose trustable information to consumers and to implement product differentiation strategies. This goal may be achieved through public (national or regional) voluntary certification and labelling schemes for agricultural products and foodstuffs (European Commission, 2010), as well as through private self-assurance or certification-based labelling schemes. In the Italian context, most regional public authorities have implemented voluntary labelling systems based on third party certification, which signal to the final consumer the environmentally-friendly farming practices, including those prescribed by the voluntary schemes (e.g. *Qualità Verificata* system in the Veneto Region). These proactive public mechanisms are mostly adopted by fresh fruit and vegetable producers' associations. However, they are integrated also into wider private self-assurance-based labelling schemes managed by large scale retailers. Private labelling schemes for processed food are at their very initial stage and adopted only by some large companies in the pasta industry.

3.3. The schemes under analysis

This paper focuses on three support-based public voluntary CSA schemes, beyond mandatory cross-compliance, newly introduced in the 2007–2014 Veneto Region Rural Development Programme:

i) *No-tillage*, i.e., the adoption of sod seeding techniques on at least 25% of a farm's arable land. This practice has multiple benefits: it improves the soil biological activity, nutrient cycling, water holding capacity and water use efficiency, it avoids soil erosion and increases the stock of soil organic CO_2 (Pittelkow et al., 2015; Ren et al., 2018; Dekemati et al., 2019; Zhang et al., 2019). All arable crops, but horticultural ones, are eligible for this scheme. No-tillage farming systems require technical skills and investments in specific machinery. Only larger farms can afford to invest in sod seeders, while smaller farms usually rely on contractors that deliver no-till operation services.
ii) *Fertiliser reduction*, i.e., optimised distribution of nitrogen fertilisers with a 30% reduction on arable crops, and the use of cover crops. The fertilisers' use has to be recorded in a farming book. Unlike *No-tillage*, this scheme does not require significant

financial investments in technology, but it similarly requires specific technical knowledge.

iii) *Water-fertiliser reduction*, i.e., *Fertiliser reduction* coupled with a 25% reduction of irrigation volumes. While *Fertiliser reduction* covers a wide range of arable crops, *Water-fertiliser reduction* is limited to the two crops with the highest water needs, i.e., maize and tobacco. In addition to keeping records of the use of fertilisers, farmers are required to install flow metres on the irrigation systems, and to adopt a specific software to optimise irrigation on each crop, made available by the public authority for free.

The schemes – targeted only to commercial arable-crop farms, even when part-time managed – are not mutually excludible for each individual farmer. However, *Fertiliser reduction* and *Water-fertiliser reduction* must be applied on different farm plots.

In the 2007–2014 Rural Development Programme, three calls were issued for *No-tillage*, one in 2010 and two in 2011, and two were issued for *Water-fertiliser reduction* and *Fertiliser reduction*, one in 2011 and one in 2013. The schemes were reintroduced in the following 2015–2020 policy round, when one call per scheme has been issued, only recently. Adopters signed their first five-year contracts in the 2007–2014 Rural Development Programme, at the end of which they could decide whether to continue or discontinue with the scheme by subscribing to a new contract.

Per-hectare payments granted by each scheme were crop-specific and aimed at covering the direct and indirect implementation costs. However, these payments were based on average estimates, so implicitly favouring larger farms, with lower average unit costs. In terms of policy targeting, only farmers in flat and hilly areas were eligible, while mountainous farmers were excluded. No geographically differentiated payment tiers were established, while a priority score was assigned to farmers located in the Nitrate Vulnerable Zones. The information provision to farmers was based on traditional approaches by the regional public authority (e.g. meetings organised locally throughout the region), while advice from public extension services has no longer been available since the late 1990s.

Official regional 2007–2014 records show that a limited number of farmers adopted each scheme: 72 farmers for *No-tillage* (2486 ha), 645 farmers for *Fertiliser reduction* (15,102 ha), and 275 farmers for *Water-fertiliser reduction* (7077 ha).[1] The low uptake rate for the schemes (1.1% of the arable crop holdings in the area) is not surprising, given that these farmers are the early adopters for these new schemes. As expected, their average size is larger than the regional average size of farms in the eligible area (6.4 ha): 39.4 ha for *Fertiliser reduction* adopters, 53.5 ha for *Water-fertiliser reduction* adopters and 64.1 ha for *No-tillage* adopters. The spatial distribution of adopters differs among the three schemes (Fig. 1).

4. Empirical strategy

To assess the drivers of adoption and continuation of the schemes, this paper adopts a twofold empirical strategy.

First, it considers the drivers of the early adoption. The analysis moves from the official regional dataset on beneficiaries for the three schemes. This dataset provides individual-level information on the areas under contract and the municipality where the farm is located. Given that no other information on farms is available, a municipality-level analysis is performed, only considering the set of 463 municipalities eligible for the schemes. At such a territorial level, three models are estimated, one for each scheme. Each model counts the total number of beneficiaries who have adopted each scheme (irrespective of the specific call) under the 2007–2014 Rural Development Programme in each municipality as a function of the farming structure, technology accessibility, environmental and policy design factors and spatial diffusion patterns. Data on these factors are available from official regional and national agricultural statistics.

Second, the paper explores the drivers underlying continuation in the scheme at the individual farmer scale. A questionnaire-based field survey through face-to-face interviews is performed. A random sample of 66 adopters under the 2007–2014 Rural Development Programme (around 7% of the adopters) is selected, stratifying by: i) Nitrate Vulnerable Zone/non-Nitrate Vulnerable Zone priority areas, and ii) farmers who continued/discontinued the scheme in the 2015–2020 Rural Development Programme, by signing a new contract at the end of the first five-year mandatory period. Among the drivers of the choice of either continuing or discontinuing the schemes, the analysis focusses on the role of farmers' motivations and attitudes and on social pressure. A joint model for the three schemes is estimated.

4.1. Modelling the early adoption at the municipality level

Dealing with a count-dependent variable, i.e., the number of farmers who have adopted each scheme by municipality in the eligible area, a Poisson regression is specified as follows:

$$P(Y_i = y_i) = \frac{e^{-\lambda_i}\lambda^{y_i}}{y_i!}, \text{for } y_i = 0, 1, 2, \tag{1}$$

where $\lambda > 0$. The natural log link is defined as follows:

$$\lambda_i = \boldsymbol{\beta}' \boldsymbol{x}_\mathbf{i} \tag{2}$$

The following covariates, grouped according to the type of factors (Table 1 and Table A.1 for their descriptive statistics) are included in the models:

- *Farming factors.* Characteristics of farming at the municipality scale are considered: the share of farms larger than 30 ha. and the share of arable crop area, which is a proxy for the municipality farming specialisation.
- *Technology accessibility factors*. For *No-tillage*, the share of irrigable area is considered as a proxy for soil moisture. The distance between the farm and closest contractor with a sod seeder is also considered as a proxy for the availability of contractors because farmers seldom own this machinery. For *Fertiliser reduction* and *Water-fertiliser reduction*, the share of irrigable area, the shares of the utilised agricultural area with poor-efficiency systems (i.e., surface irrigation), with medium-efficiency systems (i.e., the adoption of sprinklers), and without constraints in water availability (i.e., share of utilised agricultural area having free access to water from in-farm basins, surface water and groundwater) are considered.
- *Environmental factors*. The average yearly rainfall in the municipality in the 2001–2010 period is considered for all three schemes. For *No-tillage* only, the prevailing soil type in the municipality, i.e., sand, clay, and other soil types, is considered, which is expected to impact the outcome of *No-tillage* practices.
- *Policy factors*. The inclusion of municipality in the priority Nitrate Vulnerable Zone and the official urban-rural classification of municipalities in the Veneto Region are considered, according to the classifications adopted by the regional authority.
- *Size control*. Given that the number of potential adopters by municipality might be affected also by the size of the farming

[1] These figures exclude 70 tobacco-specialised farms localised in a well-defined area. All of them have applied for Water-fertiliser reduction, having permanently adopted the same fertiliser and water saving technology. Consequently, their behaviour was uninformative for the aims of this research; hence, they have been not considered in this analysis.

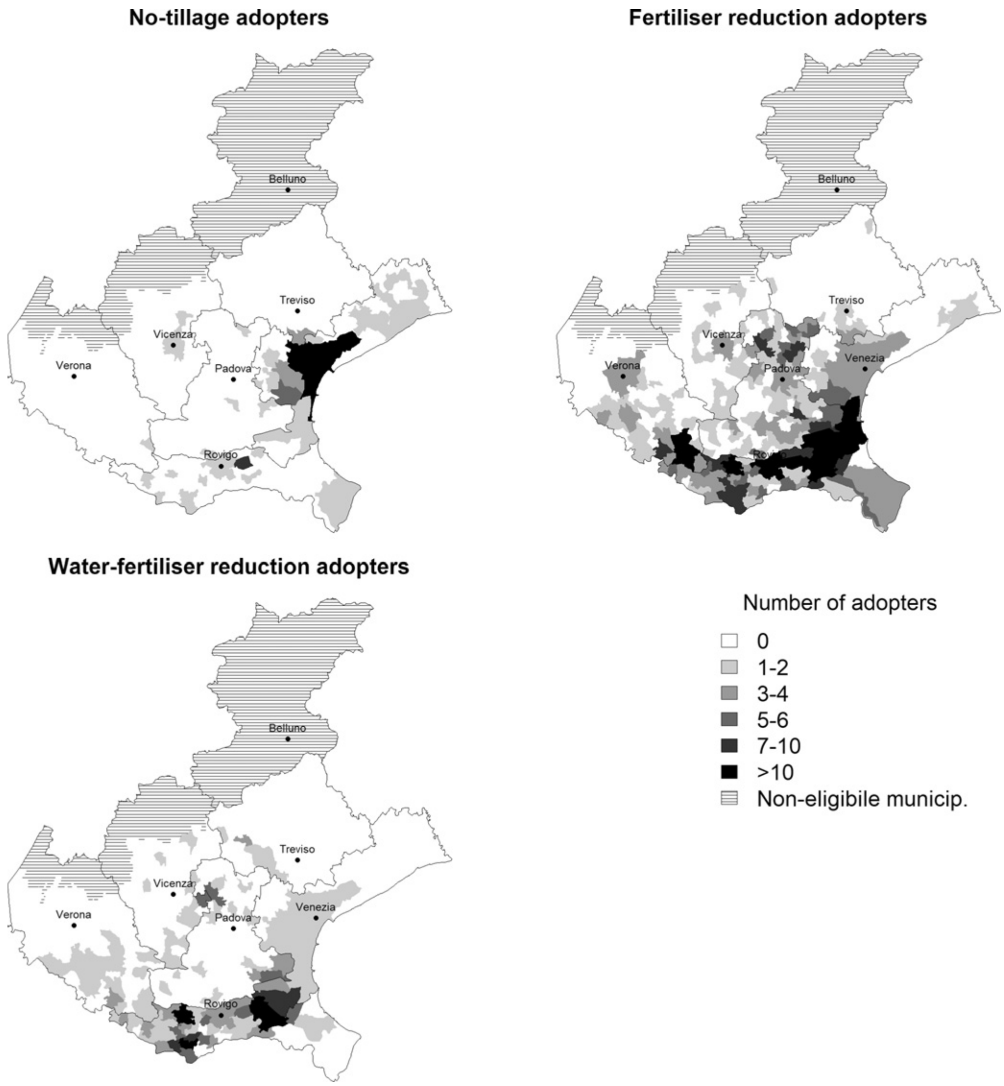

Fig. 1. No-tillage, fertiliser reduction and water-fertiliser reduction adopters, by municipality.

area in each municipality, the utilised agricultural area of the municipality is explicitly introduced as a control variable. This ensures a level playing field in explaining the role of the other factors on the number of adopters by municipality.

– *Spatial diffusion patterns*. A last set of covariates deals with the chance of diffusion patterns affecting the adoption of CSA innovative practices. The presence of certain types of innovative spatial diffusion patterns among peers may act through two different channels: within the same municipality, and across neighbouring municipalities. In the former case, the number of beneficiaries of other agri-environmental schemes in the previous 2000–2006 Rural Development Programme is a proxy of a pre-existing experience in attracting and using Rural Development Programme agri-environmental funds in the same municipality. In the latter case, innovative spatial diffusion patterns occur across neighbouring municipalities. To model them, two different spatially-lagged covariates are introduced: the spatial lag of the number of agri-environmental scheme beneficiaries in 2000–2006, and the spatial lag of the utilised agricultural area of the municipality. In particular, the spatial lag of the number of 2000–2006 beneficiaries tests the same aforementioned effect considering the neighbouring areas. The spatial lag of the utilised agricultural area of the municipality tests the presence/absence of large agricultural areas in the surroundings, which could also be a trigger for CSA adoption.[2]

4.2. Modelling the continuation at the farm level

To estimate the role played by the drivers on the decision to continue or discontinue with any scheme at the end of the first contract, a logit model is estimated:

$$\ln\left(\frac{P_i}{1-P_i}\right) = \boldsymbol{x}^{\mathbf{i}'}\boldsymbol{\beta} + \varepsilon_i \tag{3}$$

[2] Formally, the introduction of spatially-lagged variables returns, for any i^{th} municipality, the average value of the same variable under consideration as observed in the neighbourhood. These values are computed according to a *n* x *n* row-standardised spatial weights matrix (W), based on a first-order queen contiguity matrix (Anselin, 1988). Contiguity means that two spatial units share a common border of non-zero length. This matrix is adopted here, as there are no islands in the region. In particular, the generic element w_{ij} of **W** is defined as follows: $w_{ij} = \frac{w^*_{ij}}{\sum_{j=1}^{463} w^*_{ij}}$ where w^*_{ij} is equal to 1 when i ≠ j and j∈N(i), while it is equal to 0 when i = j or when i ≠ j and $j \notin N(i)$. Here, N(i) represents the set of neighbours of the i^{th} region when dealing with the set of 463 municipalities in Veneto under consideration here. It is worth noticing that other spatial econometrics models (to exhaustively accommodate for spatial issues) cannot be properly modelled in the case of Poisson distributions (Diggle, 1983; Griffith, 2006; Glaser, 2017).

Table 1
Model covariates (data at municipality level).

Name	Meaning	Unit	No-tillage	Fertiliser reduction	Water-fertiliser reduction
Farming factors					
Holdings_30 ha	Share of agricultural holdings with 30 ha and more	%	x		
Arable crop	Share of arable crops area out of the total utilised agricultural area (proxy of farming specialisation)	%	x	x	x
Technology accessibility factors					
Irrigable	Share of irrigable area out of the total	%	x	x	x
Irrigation_poor	Areas with surface irrigation out of the total irrigated area	%		x	x
Irrigation_medium	Areas with sprinkler irrigation systems out of the total irrigated area	%		x	x
Irrigation_no_constr	Areas facing no water constraints out of the total irrigated area	%		x	x
Distance	Distance to the closest No-tillage contractor	10 km	x		
Environmental factors					
Rainfall	Average yearly rainfall (years 2001–2010)	10^2 mm	x	x	x
Soil type	Prevailing type of soil	Sandy (baseline) Clayey Other	x		
Policy factors					
Nitrate Vulnerable Zones	Municipality falls into a Nitrate Vulnerable Zone area	1 = Yes 0 = No	x	x	x
Rural	Classification of the municipality as urban or rural	1 = Rural 0 = Urban	x	x	x
Size control					
UAA_municip	Utilised agricultural area at the municipality level, proxy of its agricultural size	km^2	x	x	x
Spatial diffusion patterns					
Benef_00_06	Share of other agri-environmental schemes beneficiaries in the 2000–2006 Rural Development Programme	%	x	x	x
Benef_00_06_lag	Spatial lag of Benef_00_06	%	x	x	x
UAA_municip_lag	Spatial lag of UAA_municip	km^2	x	x	x

where $\boldsymbol{x^i}$ considers the effect of covariates on the log-odds of continuing or discontinuing for farm *i* under the 2015–2020 Rural Development Programme.[3]

In line with the theory of reasoned action and planned behaviour, the following covariates have been used in the model (Table 2):

- *Farm factors*. The farm size in hectares and the share of income the household derives from farming activities with respect to the total household income;
- *Farmers' factors*. These encompass a group of socio-demographic characteristics of farmers that include the number of years into education, the number of children as a proxy of the bequest value the farmer attributes to the farm, and a covariate expressing whether the commercial farmer is either full-time or part-time. A group of attitudinal/motivational factors are considered also: i) the environmentally friendly attitude of the farmer, measured through a single item on a 5-point Likert scale; ii) his/her orientation to risk, expressed as the average of farmer's ratings of a set of seven statements – adapted from Läpple (2012) – each of them measured on a 5-point Likert scale; iii) the farmer's attitude towards the introduction of innovation in the farm, expressed by the actual behaviour regarding the prompt adoption of innovations (dummy variable);
- *Social factors*. The farmer's perception of peers' judgement on his/her own participation in the schemes is considered as a proxy of social pressure, triggering adoption.

[3] Given the scheduling of the RDP call waves for the schemes, the decision to continue by subscribing a new contract was possible for all the early adopters in the only 2015–2020 RDP call that was available at the moment of the analysis. Thus, we model the decision to continue or not for farmers who were already in the scheme only for one period.

5. Results and discussion

5.1. Early adoption at the municipality level

Table 3 presents the three model estimates for the early adoption at municipality level.

For *No-tillage*, the model suggests that the number of adopters by municipality is positively affected by the farming factors: in particular, the municipality specialisation in arable crops triggers *No-tillage* adoption due to the policy design constraints (only some arable crops are admitted to the scheme). In contrast to Ward et al. (2018), a higher share of large-size farms does not significantly increase the number of *No-tillage* adopters. This result may suggest that neither the need to invest in expensive no-tillage machineries nor the lack of managerial skills connected to no-tillage – issues typically overcome by large farms – act as barriers for adoption in this case. Among the technology accessibility factors, the share of irrigable area has a negative effect. In line with Ren et al. (2018), this result confirms that farmers who do not have access to irrigation are more inclined to adopt *No-tillage*, because this practice improves the water and moisture retention capacity of soils and helps balancing the lack of irrigation. Among the environmental factors, rainfall is not significant, in contrast with D'Emden et al. (2006). Conversely, the type of soil matters: in line with Giller et al. (2011), a larger number of adopters is associated with clayey rather than sandy soils. Indeed, *No-tillage* on clayey soils delivers higher cost savings when compared to traditional tillage practices (Børresen, 1999; Känkänen et al., 2011). With regard to policy factors, those municipalities located in Nitrate Vulnerable Zones show a larger number of adopters. A similar result is found by Boncinelli et al. (2016) and by Defrancesco et al. (2018), when considering other schemes. The number of early adopters is larger in the urban rather than in the rural municipalities. This unexpected result is explained by the specific context under analysis: 17% of *No-tillage* adopters are located in

Table 2
Model covariates (data at farm level).

Name	Meaning	Levels	Statistic	Value
Farm factors				
F_Size	Farm size (hectares)		Mean[a]	70.58 (29.29)
F_Income	Share of household income from farming		Mean[a]	44.64 (23.44)
Farmer factors				
Socio-demographic characteristics				
Year_Edu	Number of years of education of the farmer		Mean[a]	12.73 (4.26)
Child	Number of children, proxy of the farm's bequest value		Mean[a]	1.14 (1.11)
Full_Time	Full-time farmer	1 = Yes 0 = No	%	84.85
Attitudes and motivations				
Envir_Att	Importance of adopting environmentally friendly practices in the farmer's opinion[b]		Mean[a]	4.76 (0.56)
Risk_Att	Risk-orientation of the farmer[c]		Mean[a]	3.84 (0.46)
Inno_Att	Actual behaviour of the farmer towards innovation adoption	1 = Farmer who promptly adopts innovative farming practices 0 = Otherwise	%	56.06
Social factors				
Soc_Pressure	Farmer perception of peers' judgement towards his/her agri-environmental schemes participation	1 = Positive 0 = Otherwise	%	62.12

[a] Standard deviation in parentheses.
[b] Statement was measured on a 5-point Likert scale ranging from 'very low' (1) to 'very high' (5).
[c] Average of farmer's ratings of a set of seven statements, each measured on a 5-point Likert scale ranging from 'strongly disagree' (1) to 'strongly agree' (5).

Table 3
Model estimates for early adoption of each scheme at the municipality level (n = 463).

Variable	No-tillage			Fertiliser reduction			Water-fertiliser reduction		
	β		Exp(β)	β		Exp(β)	β		Exp(β)
Constant	−3.81	**	0.02	−0.15		0.86	−2.85	***	0.06
Farming factors									
Holdings_30 ha	0.03		1.03						
Arable crop	0.02	**	1.02	0.03	***	1.03	0.03	***	1.03
Technology accessibility factors									
Irrigabile	−0.02	**	0.99	0.00		1.00	0.00		1.00
Irrigation_poor				−0.02	***	0.98	−0.02	***	0.98
Irrigation_medium				0.00		1.00	0.00		1.00
Irrigation_no_constr				0.00		1.00	0.00	**	1.00
Distance	−0.15		0.86						
Environmental factors									
Rainfall	0.01		1.01	−0.22	***	0.80	−0.22	***	0.81
Soil type (baseline: sands)									
Clay	1.33	***	3.80						
Other	−1.25		0.29						
Policy factors									
Nitrate vulnerable zones (baseline. no)									
Yes	0.71	*	2.03	0.53	***	1.70	0.43	***	1.54
Rural (baseline: Urban)									
Rural	−0.85	**	0.43	0.01		1.01	1.17	***	3.23
Size control									
UAA_municip	0.02	***	1.02	0.02	***	1.02	0.01	***	1.02
Spatial diffusion patterns									
Beneficiaries_00_06	−0.01		0.99	0.01		1.01	0.02	*	1.02
Beneficiaries_00_06_lag	−0.07		0.93	0.05	**	1.06	0.11	***	1.11
UAA_municip_lag	0.02		1.02	0.00		1.00	0.01	*	1.01
log-likelihood (fitted model)	−169.16			−644.23			−366.54		
Nagelkerke pseudo R2	0.47			0.88			0.74		
Over-dispersion	No			Yes			No		

Notes: When overdispersion occurs, a quasi-Poisson model has been estimated.
*** $p < 0.01$.
** $p < 0.05$.
* $p < 0.1$.

the Venice municipality, which is classified as urban, although it includes a wide agricultural area. Spatial diffusion patterns are not significant, showing that pre-existing experience of the farmers in other agri-environmental schemes within the municipality and in the neighbouring ones does not trigger *No-tillage* adoption. This finding could be connected with the specific technical requirements of this new scheme.

In the case of *Fertiliser reduction* and *Water-fertiliser reduction*, the share of arable crops positively affects the number of adopters. As for *No-tillage*, this is due to the constraints imposed by the policy design. Technology accessibility, namely, irrigation issues, is a key driver, with a few differences between the two schemes. Although poor-efficiency irrigation systems negatively affect the number of adopters of both schemes, the number of *Water-fertiliser reduction* adopters is also significantly reduced by the lack of constraints of water availability, in line with Alcon et al. (2011). Rainfall negatively affects the number of both *Water-fertiliser reduction* and *Fertiliser reduction* adopters. Indeed, when the amount of rainfall is lower, farmers are more prone to adopt CSA practices that optimise both water uses (Khatri-Chhetri et al., 2017) and fertilisation (Roy et al., 2006). Regarding policy factors, Nitrate Vulnerable Zone plays a positive role for both schemes, while the urban/rural classification of municipalities is significant and positive only for *Water-fertiliser reduction*. For both schemes, spatial diffusion patterns matter, and, in the case of *Water-fertiliser reduction* they act through multiple channels.

Summing up, environmental and technology accessibility factors play a crucial role in stimulating adoption of any beyond-compliance schemes as far as they affect farm profitability (Alcon et al., 2011; Corbeels et al., 2014): this is the case of soil type for *No-tillage* adoption and of water availability for *Fertiliser reduction* and *Water-fertiliser reduction* adoption. Indeed, when water is a limiting factor, its shadow price increases (Hayami and Ruttan, 1985), inducing the adoption of more efficient water and fertilisers saving technologies. Moreover, the existence of spatial diffusion patterns suggests the role of social expertise (Lange and Gouldson, 2010; Moschitz et al., 2015) in triggering early adoption, especially through networks and relations among farmers (Collins et al., 2016; Inman et al., 2018). Well-consolidated experience (as already outlined by Ward et al., 2018) in participating in other schemes in the past 2000–2006 Rural Development Programme (both in the municipality and across its neighbours) facilitates a greater adoption in the 2007–2014 Rural Development Programme. The strength of this effect varies according to the specific technical features of the schemes. Indeed, while *No-tillage* implementation is more constrained by technical barriers, *Fertiliser reduction* and *Water-fertiliser reduction* require managerial skills, which can more effectively capitalize on past experiences in other agri-environmental schemes.

5.2. Continuation at the farm level

Table 4 reports the model estimates of the farmers' continuation choice by subscribing or not a new contract at the end of the first one (60.6% and 39.4%, respectively). Among the farm factors, only the share of off-farm income sources triggers the continuation as shown by the negative sign of the coefficient of the share of household income from farming. This finding is consistent with the adoption literature, which contends that off-farm income could effectively mitigate the risk of innovative practices, acting as a safety net (Clarke et al., 2018; Mozzato et al., 2018).

Regarding the socio-demographic farmer factors, being a full-time rather than a part-time farmer acts as a catalyst for continuation because CSA practices require adequate expertise and an active presence in the farm. This finding is consistent with that of Bartolini et al. (2013), Morgan et al. (2015), and Pierpaoli et al. (2013). In addition, Teshome et al. (2016) found that a larger number of persons involved in full-time farming is positively related to maintaining CSA practices. The number of children, which is used as a proxy of the bequest value attributed by the farmer to her/his farm, positively affects continuation (Lynch and Lovell, 2003; Tosakana et al., 2010; Vanslembrouck et al., 2002).

Farmers' attitude towards promptly adopting innovation triggers continuation. This finding is consistent with the adoption literature (Haghjou et al., 2014; Giovanopoulou et al., 2011; Greiner et al., 2009; Barnes et al., 2019; Etriya et al., 2018). Similarly, the risk orientation of the farmer has a positive effect, as shown by the literature on adoption (Baidu-Forson, 1999; Greiner et al., 2009; Kallas et al., 2010) and on continuation (Läpple, 2010; Goswami and Choudhury, 2015). Consistent with other literature findings, both on adoption (Grammatikopoulou et al., 2014; Han et al., 2018) and continuation (Gatto et al., 2019), the opinion of the farmer about adopting environmentally friendly practices is not statistically significant in explaining continuation.

Finally, the results highlight the role played by social factors on the continuation choice, showing the positive effect of peers' opinions about the farmer's participation in the schemes. This result aligns with other findings (Barnes et al., 2019; Deng et al., 2016; Gatto et al., 2019; Kallas et al., 2010; Läpple, 2010; Ward et al., 2018).

Table 4
Model estimates for farmers' decision to continue with the adopted scheme (n = 66).

Variables	β (S.E.)	Exp(β)
Constant	−13.11 (5.00)***	
Farm factors		
F_Size	0.00 (0.00)	1.00
F_Income	−0.08 (0.03)***	0.92
Farmer factors		
Socio-demographic characteristics		
Year_Edu	−0.06 (0.11)	0.94
Child	1.14 (0.43)***	3.12
Full_Time	4.89 (1.68)***	132.57
Attitudes and motivations		
Envir_Att	−0.32 (0.73)	0.72
Risk_Att	2.99 (1.21)**	19.98
Inno_Att	2.39 (1.14)**	10.87
Social factors		
Soc_Pressure	2.23 (0.95)**	9.31
Log L	−24.52	
Nagelkerke pseudo R^2	0.61	

Note: Standard errors are reported in parentheses.
* p < 0.1.
*** p < 0.01.
** p < 0.05.

Summing up, the results show that non-financial motivations are crucial not only for adoption but also for continuation. In particular, farmers' attitudes towards risk and innovation are more important than environmental attitudes, as also found by Morgan et al. (2015). The continuation is also affected by the social pressure, which originates from the farmers' desire to meet the values shared by the community of peers (Pierpaoli et al., 2013; Barnes et al., 2019). However, it should be highlighted that this analysis focusses on early adopters: according to Murphy et al. (2014), their motivations and attitudes may be different than those of the followers.

6. Conclusions and policy implications

With a study in the Veneto region of Italy, the paper has added a new case to the scarce Southern European literature on farmers' adoption and, above all, continuation of CSA voluntary and financially supported schemes. It has contributed also to cast light on some of the most important drivers affecting the uptake and maintenance of beyond-compliance practices that can help to mitigate the impacts of climate change in agriculture. This is important for the sustainability of agriculture in the long run.

The study has some limitations that need to be acknowledged. Due to the novelty of CSA-related schemes in the Rural Development Programme, only the behaviours of a specific group of farmers, i.e., the early adopters, could be analysed. In fact, attitudes and motivations of late adopters – who must be involved in the schemes to increase the overall uptake rates – may be different from those of early adopters. In addition, further analyses should consider continuation in a longer time-span, namely taking more than just one period. Given the scheduling of the available call waves, the analysis was limited in this. Other shortcomings relate to the specific geographical context considered and the small number of CSA practices analysed. Hence, the current results should be tested in other contexts and with a larger set of climate change mitigation practices. As in similar empirical works, caution should also be exercised in interpreting the results on the spatial diffusion patterns of social expertise, which could also be driven by other unobserved features.

The study provides some policy recommendations, aiming at increasing the uptake rate and persistence over time of CSA schemes, through: i) improving the design of financially supported voluntary schemes and the related tools of information provision to farmers; and ii) complementing them with proactive information-based regulations.

With regard to the former issue, to date, low uptake rates and even lower continuation rates are still observed among early adopters. This leads to consider that, although financial support does help in lifting the cost barriers, there are other non-financial aspects driving farmers' choices. These may act as major barriers or triggers to the adoption or continuation of innovations that impact the overall farming activity, as is commonly observed with CSA. Policymakers would have to consider such non-financial aspects if they wanted to steer extensive and persistent implementation of CSA practices, the only way to assure effective resilience to climate change in the long-term. To this end, the results of this analysis help in drawing recommendations in terms of policy targeting, financial support, and – last but not least – the provision of information and advice to farmers.

The results indicate that the present system of targeting is not sufficient to stimulate voluntary CSA uptake, but needs to be integrated with a wider range of instruments taking into account also environmental and technology accessibility factors, which affect the CSA profitability at the farm level. To this end, the analysis seems to point to the introduction of differentiated payment tiers that could be effectively fine-tuned to the situation on the ground, e.g., considering conditions of water availability, irrigation accessibility and type of soil where the practices are to be implemented.

When defining the financial incentives, policymakers ought also to be aware that the next Rural Development Programme waves will need to capture late adopters mostly among small-scale and risk-adverse farmers. The new payments should take this element into account in order to meet the higher opportunity cost that affects the participation of these types of farmers. The current low uptake and continuation rates might suggest that the present financial support covers the CSA implementation costs only for a limited number of large scale farms, which also benefit from off-farm income as a risk safety net.

In order to enhance the diffusion of CSA practices, also the provision of an accurate advice to the farmers is crucial, given that in the Veneto region – as well as across Southern Europe – a large share of the farms is part-time managed. Part-time farmers could lack the required expertise to adopt CSA practices impacting on the overall farming system. This issue has been probably overlooked by policymakers in the current policy. The information provision tools should be enhanced too, by integrating a top-down approach with a horizontal one triggering the development of networks among farmers to share information (collective learning process). Moreover, social pressure by peers may also activate positive behaviours. Policymakers should leverage social endorsement as a way to nudge adoption and continuation.

Proactive information-based regulations could effectively complement financially supported voluntary CSA schemes in the medium run, by means of certifications and labelling instruments, either public or private. Both approaches are product differentiation tools, letting farmers to get a price premium that could integrate the public compensation. However, several conditions are necessary to get it, including also a new role for public authorities. From the supply side, value creation through information-based proactive regulation requires an appropriate organisation of the whole supply chain. It is not a case that, so far, certifications and labelling instruments have been more easily adopted where a limited number of agents is involved, e.g. in the fresh fruit and vegetable supply chains, rather than in the case of long supply chains, such as the dairy products' and the processed meat's ones. From the demand side, the price premium is achieved only if the consumers are aware of climate-change related environmental issues and only if trustable information on the nexus between CSA practices and climate change mitigation is disclosed. To this end, a proactive cooperation among private and public actors is essential at least to increase the consumers' awareness on the environmental impact of CSA practices.

Author contributions

All authors participated in the initial research design; Edi Defrancesco and Francesco Pagliacci addressed the methodological issues; Daniele Mozzato carried out the sample survey; and Edi Defrancesco, Paola Gatto and Francesco Pagliacci analysed the results and wrote the paper.

Declaration of competing interest

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

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Appendix A. Annex

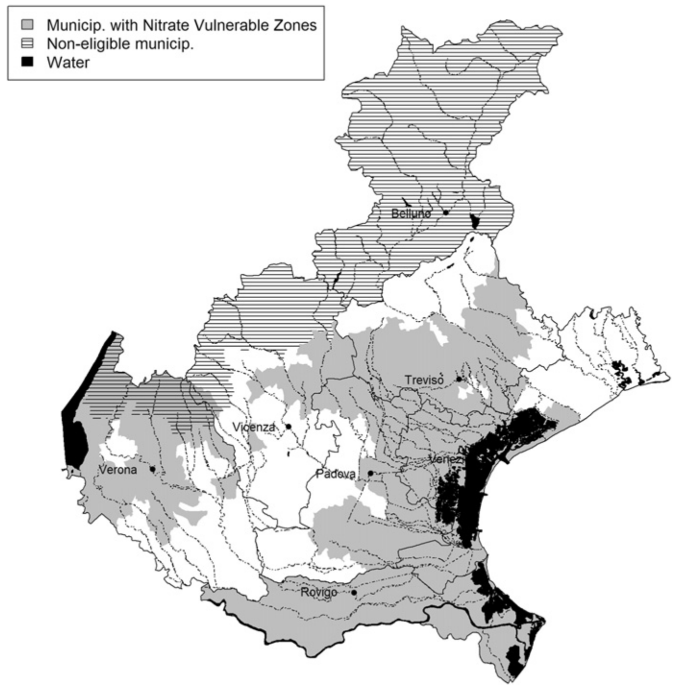

Fig. A.1. Municipalities with nitrate vulnerable zones.

Table A.1
Adoption model: descriptive statistics for the covariates.

Name	Source	Specification	Mean	Standard deviation
Farming factors				
Holdings_30 ha	ISTAT (2010)	%	4.42	5.08
Arable crop	ISTAT (2010)	%	53.78	27.02
Technology accessibility factors				
Irrigable	ISTAT (2010)	%	51.09	28.40
Irrigation_poor	ISTAT (2010)	%	19.89	26.58
Irrigation_medium	ISTAT (2010)	%	65.79	29.58
Irrigation_no_constr	ISTAT (2010)	%	44.67	35.18
Distance	Authors' elaboration	10 km	2.19	1.64
Environmental factors				
Rainfall	Authors' elaboration on Arpav data	10^2 mm	10.29	2.43
Soil type	Authors' elaboration on Veneto Region data	Sandy	28.5%	
		Clayey	35.6%	
		Other	35.9%	
Policy factors				
Nitrate Vulnerable Zones	Veneto Region classification	1 = Yes	54.0%	
		0 = No	46.0%	
Rural	Veneto Region classification	1 = Rural	27.0%	
		0 = Urban	73.0%	
Size control				
UAA_municip	Istat (2010)	km^2	15.78	14.42
Spatial diffusion patterns				
Benef_00_06	Authors' elaboration on regional official data	%	5.04	7.18
Benef_00_06_lag	Authors' elaboration on regional official data	%	5.22	5.06
UAA_municip_lag	Authors' elaboration on ISTAT (2010) data	km^2	18.28	10.45

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